Sustainable Interaction with Digital Technologies – Fostering Pro-environmental Behavior and Maintaining Mental Health

DISSERTATION

to obtain the doctoral degree of Economic Sciences (Dr. oec.)

Faculty of Business, Economics and Social Sciences

University of Hohenheim

Institute of Marketing & Management

submitted by

Michelle Berger (M.Sc.)

from Ehringshausen

2023

Date of Disputation: April 05, 2023

Supervisor and First Reviewer:	Prof. Dr. Henner Gimpel
Second Reviewer:	Prof. Dr. Nils Urbach
Exam Chairperson:	Prof. Dr. Bernd Ebersberger
Dean of Faculty:	Prof. Dr. Jörg Schiller

An dieser Stelle möchte ich mich bei allen Personen bedanken, die mich auf dem Weg zu meiner Promotion unterstützt und begleitet haben.

Besonders danken möchte ich meinem Doktorvater, Henner. Durch die vielen, konstruktiven Diskussionen und die gute Zusammenarbeit konnte ich viel lernen und mich persönlich weiterentwickeln. Vielen Dank für deine Hilfestellungen, dein Verständnis und deine Zuverlässigkeit.

Ein weiterer Dank geht an meine (akademischen) Mentor:innen an der Frankfurt School und der DZ BANK, die seit Beginn meines Bachelorstudiums an mich geglaubt und mich bei meinem Weg unterstützt haben. Danke Prof. Roßbach, dass Sie mein Interesse an einer Promotion geweckt und mir stets Mut zugesprochen haben.

Ebenso möchte ich mich bei allen Kolleg:innen und Koautor:innen bedanken, mit denen auch die mühsamsten Bereiche der Forschung erträglich waren. Vielen Dank für die tolle Zusammenarbeit, die gemeinsam überwundenen Rückschläge und die schönen Erfolgsmomente. Ich bin dankbar für die tollen Freundschaften, die sich entwickelt haben.

Danke an alle Freunde, die mich sowohl vor Ort als auch aus der Ferne immer durch liebe Nachrichten, Postkarten, Telefonate oder Spaziergänge, unterstützt und motiviert haben. Danke fürs Zuhören, Mitfiebern, Aufmuntern und vor allem fürs Mitfreuen.

Danke an meine wundervolle Familie. Ihr habt mir den Weg zur Promotion durch euren Glauben an mich und eure Erziehung überhaupt erst ermöglicht. Danke, dass ihr mich immer bedingungslos unterstützt, für mich da seid, und es immer schafft, mich zum Lachen zu bringen, auch wenn die Promotion mich hin und wieder die gute Laune gekostet hat.

Danke Bastian für deine liebevolle Unterstützung, die wertvollen wissenschaftlichen Diskussionen und deine Hilfe. Danke, dass Du immer an meiner Seite warst und genau wusstest, was ich in der jeweiligen Situation brauchte.

Danke.

Abstract

Human-induced environmental deterioration increasingly affects millions of people and causes tremendous economic costs. Therefore, one of the most essential challenges of the twenty-first century is to realize sustainability in everyday behavior. Daily, partly unconscious decisions, for example in contexts such as mobility, food, or heating, influence environmental sustainability. Such everyday choices are increasingly shifted toward digital environments, as digital technologies are ubiquitous in a wide variety of everyday contexts. This yields the great potential to positively influence the users' behavior toward more environmental sustainability when interacting with digital technologies, for example, through the use of digital nudging. Digital nudging refers to the use of user-interface design elements, named digital nudging elements (DNEs) like "default rules" or "framing", that aim to predictably influence the users' choice. But besides these benefits, research indicates that interacting with digital technologies can lead to a specific form of stress, also known as technostress, that can cause adverse health outcomes. Individuals increasingly suffer from – or are at risk of – mental health issues like depression or burnout. Apart from serious health consequences for the individual, mental health issues can also lead to striking impacts on economic costs. This demonstrates that it is essential to ensure a sustainable interaction with digital technologies that is both environmentally friendly and healthy, especially for the mind. Next to the aim of *fostering pro-environmental behavior* of the user, it is also of high importance to *maintain mental health* when interacting with digital technologies.

Addressing individuals' interaction with digital technologies requires a broad understanding from all perspectives. The Human-Computer-Interaction (HCI) framework represents a guiding structure for studying the interaction of humans with digital technologies. The framework describes the interaction in terms of the *context/task*-, *technology*-, and *human*-specific perspectives, which lead to different outcomes. It, thus, represents a comprehensive approach to structure the domain and to classify research along the different perspectives. Along with the guiding structure of the HCI framework, the seven research articles included in this dissertation aim to contribute to sustainable interaction with digital technologies. The focus is on two outcomes resulting from the interaction: First, *fostering pro-environmental behavior* and, second, *maintaining mental health*. This dissertation relies on the collection, analysis, and interpretation of both qualitative and quantitative data. Throughout the research articles, data is obtained from structured literature reviews, a Delphi study, focus group workshops, online surveys, and field experiments. The data is analyzed with qualitative research methods such

as the structured analysis of scientific literature (e.g., Grounded Theory) as well as statistical methods such as exploratory factor analyses, regression analyses, cluster analyses, and analyses related to the Kano model and the Latent Growth model.

After an introductory first chapter, Chapter 2 focuses on the outcome of *fostering pro-environmental behavior* when interacting with digital technologies using digital nudging. Chapter 2.1 contributes to a deeper understanding of the effectiveness of DNEs in different behavioral contexts (HCI perspective *context*) that influence the individuals' pro-environmental behavior (e.g., e-commerce shopping behavior). Therefore, it conducts a structured literature review followed by a framework development, offering a comprehensive overview of the effectiveness of various DNEs in different behavioral contexts. Chapters 2.2 and 2.3 zoom in on two of the behavioral contexts described in Chapter 2.1 to investigate and test the design and effectiveness of specific DNEs in an e-commerce shop and a smart home app (HCI perspective *technology*) through online experiments. Chapter 2.2 finds that the DNE "default rules" is effective among all surveyed customers and the DNE "simplification" among environmentally conscious customers. Chapter 2.3 switches to the context of energy consumption in private households and tests the effectiveness of the DNEs "default rules" and "framing" in a smart home app to foster energy conservation behavior. It finds a large effect for "framing" and a medium effect for both DNEs when combined. Chapter 2.4 focuses on the well-researched and effective DNE "feedback" to promote energy conservation behavior. While prior research concentrated on the effectiveness of different "feedback nudge features" (FNFs) (e.g., different update frequencies), Chapter 2.4 investigates the influence of 25 identified FNFs on user satisfaction in a smart home app through a card sorting approach followed by an online survey based on the Kano model (HCI perspective *human*). The chapter identifies "must-be" FNFs, whose omission leads to user dissatisfaction and thereby sheds light on the importance of not only focusing on features that are efficient in promoting pro-environmental behavior.

Chapter 3 puts focuses on the outcome of *maintaining mental health* when interacting with digital technologies, thus avoiding technostress. Chapter 3.1 concentrates on the role of the organization in preventing technostress among their employees (HCI perspective *context*). It introduces and characterizes 24 primary and secondary technostress prevention measures and determines the relevance of primary prevention measures in reducing different sources of technostress (technostress creators) based on a Delphi study. Out of the 24 technostress prevention measures, two specific measures ("adopt a stress-sensitive digital workplace design" and "use gamification") are addressed in Chapters 3.2 and 3.3. Through a large-scale online survey, Chapter 3.2 derives an understanding of the characteristic profiles of technologies

used at the digital workplace, their interplay, and how they influence technostress (HCI perspective *technology*). Chapter 3.3 focuses on the individual's appraisal (HCI perspective *human*) of a demanding situation when interacting with digital technologies. The appraisal is decisive for determining whether the given situation leads to positive or negative outcomes concerning technostress. After conducting an online experiment, Chapter 3.3 finds that the integration of gamification elements (e.g., points or levels) in digital technologies can reduce the individual's threat appraisal.

Lastly, Chapter 4 discusses the results of the seven included research articles and provides an outlook for future research. In summary, this dissertation aims to provide research and practice with new insights into creating a sustainable interaction with digital technologies to *foster pro-environmental behavior* and *maintain mental health*.

Zusammenfassung

Die vom Menschen verursachte Umweltzerstörung hat zunehmend negative Auswirkungen auf unzählige Menschen und führt zu enormen wirtschaftlichen Schäden. Daher ist die nachhaltige Gestaltung des Lebens eine der zentralen Herausforderung des einundzwanzigsten Jahrhunderts. Alltägliche, teils unterbewusste Entscheidungen, wie beispielsweise im Bereich der Mobilität, der Ernährung oder des Heizens, haben Einfluss auf die ökologische Nachhaltigkeit. Diese Entscheidungen werden durch die Allgegenwärtigkeit digitaler Technologien zunehmend in digitalen Umgebungen getroffen. Dies birgt das Potenzial, die Entscheidungen und somit das Verhalten der Nutzer:innen bei der Interaktion mit digitalen Technologien, beispielsweise durch Digital Nudging, positiv in Richtung ökologischer Nachhaltigkeit zu beeinflussen. Digital Nudging bezeichnet dabei die Verwendung von Designelementen in Benutzeroberflächen, sogenannte Digital Nudging Elements (DNEs), wie beispielsweise „Default Rules“ oder „Framing“, die darauf abzielen, die Wahl vorhersehbar zu beeinflussen. Doch neben diesen Vorteilen zeigt die Forschung, dass die Interaktion mit digitalen Technologien eine spezifische Form von Stress, bekannt unter dem Begriff Technostress, auslösen kann, die zu negativen gesundheitlichen Folgen führen kann. Immer mehr Menschen leiden unter psychischen Krankheiten wie Depressionen oder Burnout oder sind akut gefährdet, diese zu entwickeln. Neben den schwerwiegenden gesundheitlichen Folgen verursachen psychische Krankheiten ebenso hohe Kosten für die Gesellschaft. Das zeigt, dass eine nachhaltige Interaktion mit digitalen Technologien sowohl umweltfreundlich als auch gesund, insbesondere für die Psyche, sein sollte. Demnach ist neben dem Ziel ein *umweltfreundliches Verhalten* zu fördern, auch die Aufrechterhaltung der *psychischen Gesundheit* bei der Interaktion mit digitalen Technologien von großer Bedeutung.

Das erfordert zunächst ein umfassendes Verständnis für die Problematik und muss deshalb aus allen relevanten Perspektiven betrachtet werden. Das Human-Computer-Interaction (HCI) Framework stellt eine Struktur für die Untersuchung der Interaktion von Menschen mit digitalen Technologien bereit. Es beschreibt die Interaktion aus einer *aufgaben-/kontext-*, *technologie-*, und *menschenspezifischen* Perspektive. Die Interaktion führt zu unterschiedlichen Ergebnissen. Das Framework stellt einen ganzheitlichen Ansatz zur Strukturierung und Klassifizierung der Forschung entlang der drei verschiedenen Perspektiven dar. Orientiert an dieser Struktur zielen die sieben Forschungsartikel dieser Dissertation darauf ab, einen Beitrag zur nachhaltigen Interaktion mit digitalen Technologien zu leisten. Dabei liegt der Fokus auf den

beiden Ergebnissen der *Förderung des umweltfreundlichen Verhaltens* und der *Aufrechterhaltung der psychischen Gesundheit*. Die vorliegende Dissertation stützt sich auf die Erhebung, Analyse und Interpretation von sowohl qualitativen als auch quantitativen Daten. In den enthaltenen Forschungsartikeln werden Daten aus strukturierten Literaturrecherchen, einer Delphi-Studie, Fokusgruppen-Workshops, Online-Umfragen und Online-Experimenten gewonnen. Die Daten werden mit qualitativen Forschungsmethoden wie der strukturierten Literaturanalyse (z.B. Grounded Theory) sowie mit statistischen Methoden wie der explorativen Faktorenanalyse, der Regressionsanalyse, der Clusteranalyse und Methoden basierend auf dem Kano-Modell und dem Latent-Growth-Modell ausgewertet.

Nach dem einleitenden ersten Kapitel fokussiert Kapitel 2 die *Förderung eines umweltfreundlichen Verhaltens* bei der Interaktion mit digitalen Technologien durch die Verwendung von Digital Nudging. Durch eine strukturierte Literaturanalyse und der anschließenden Entwicklung eines Frameworks trägt Kapitel 2.1 zu einem tieferen Verständnis und einem Überblick der Effektivität von DNEs in verschiedenen Verhaltenskontexten (HCI Perspektive *Kontext*), die umweltfreundliches Verhalten bestimmen (z.B. Einkaufsverhalten), bei. In den Kapiteln 2.2 und 2.3 werden zwei der in Kapitel 2.1 betrachteten Kontexte vertieft und sowohl das Design als auch die Effektivität spezifischer DNEs in einem E-Commerce-Shop (Kapitel 2.2) und einer Smart Home App (Kapitel 2.3) in Online-Experimenten untersucht (HCI Perspektive *Technologie*). Kapitel 2.2 zeigt bei allen befragten Kund:innen einen positiven Effekt bei „Default Rules“ und bei umweltbewussten Kund:innen bei „Simplification“. Kapitel 2.3 adressiert den Energieverbrauch in privaten Haushalten und testet die Wirksamkeit von „Default Rules“ und „Framing“ in einer Smart-Home-App zur Förderung von energiesparendem Verhalten. Das Ergebnis zeigt einen starken Effekt für „Framing“, aber auch einen mittleren Effekt für die Kombination beider DNEs. Kapitel 2.4 konzentriert sich das gut erforschte und wirksame DNE „Feedback“ zur Förderung von energiesparendem Verhalten. Während sich bisherige Forschung auf die Effektivität verschiedener „Feedback Nudge Features“ (FNFs) konzentriert (z.B. unterschiedliche Aktualisierungsfrequenzen), wird in Kapitel 2.4 der Einfluss von 25 identifizierten FNFs auf die Nutzerzufriedenheit mit Hilfe eines Card Sortings und einer Online-Befragung basierend auf dem Kano Modell untersucht (HCI Perspektive *Mensch*). Das Kapitel identifiziert „must-be“ FNFs, deren Fehlen zu Unzufriedenheit bei den Nutzer:innen führt und verdeutlicht damit, wie wichtig es ist, sich nicht ausschließlich auf FNFs zu konzentrieren, die nachweislich umweltfreundliches Verhalten fördern.

In Kapitel 3 liegt der Schwerpunkt auf dem Ziel der *Aufrechterhaltung der psychischen Gesundheit* und somit der Vermeidung von Technostress. Kapitel 3.1 konzentriert sich auf die

Rolle der Organisation bei der Prävention von Technostress bei Mitarbeiter:innen (HCI Perspektive *Kontext*). Basierend auf einer Delphi-Studie werden 24 primäre und sekundäre Technostress-Präventionsmaßnahmen vorgestellt und charakterisiert, sowie deren Relevanz zur Vermeidung von Technostress eingeschätzt. Von den 24 Maßnahmen werden zwei spezifische Maßnahmen („Gestaltung eines stresssensiblen digitalen Arbeitsplatzes" und „Einsatz von Gamification“) in Kapitel 3.2 und 3.3 behandelt. Kapitel 3.2 trägt durch eine groß angelegte Umfrage zu einem Verständnis für die Charakteristika der am digitalen Arbeitsplatz eingesetzten Technologien und deren Einfluss auf Technostress bei (HCI Perspektive *Technologie*). Kapitel 3.3 konzentriert sich auf das Individuum und dessen Wahrnehmung einer potenziellen Technostress-Situation bei der Interaktion mit digitalen Technologien (HCI Perspektive *Mensch*). Diese Wahrnehmung (herausfordernd oder bedrohend) ist entscheidend dafür, ob eine gegebene Situation zu positiven oder negativen Auswirkungen in Bezug auf Technostress führt. Durch ein Online-Experiment zeigt sich, dass die Integration von Gamification-Elementen (z.B. ein spielerisches Punkte- oder Levelsystem) in digitalen Technologien die bedrohende Wahrnehmung der gegebenen Situation des Einzelnen reduzieren kann.

Abschließend werden die Ergebnisse der sieben Forschungsartikel in Kapitel 4 diskutiert und ein Ausblick auf Ansätze für weiterführende Forschungsarbeiten gegeben. Zusammenfassend zielt diese Dissertation darauf ab, Forschung und Praxis mit neuen Erkenntnissen zu einer nachhaltigen Interaktion von Menschen mit digitalen Technologien zu bereichern, die sowohl *umweltfreundliches Verhalten fördert* als auch die *psychische Gesundheit aufrechterhält* und somit zu den aktuellen Nachhaltigkeitsbemühungen beiträgt.

Content Overview

Table of Contents

List of Figures

List of Tables

1 Introduction[1]

1.1 Motivation

Greenhouse gas continues to rise (Global Carbon Project, 2021), and the consumption of natural resources significantly exceeds the amount that nature can regenerate (FootPrint Network, 2022). This human-induced environmental deterioration results in dramatic consequences, some of which are already becoming visible today (e.g., floods or heat waves) (CRED, 2022; IPCC). In 2021 alone, natural hazards worldwide not only cost approximately 252.1 billion US dollars but also dramatically affected and killed millions of people (CRED, 2022). Individuals contribute to environmental sustainability and consequently to this development with – partly unconscious – behavior in various daily contexts. Using the example of Europe, Ivanova et al. (2016) state that the consumption areas of housing (especially heating systems), mobility (especially automobile use and air travel), and food (especially meat and dairy) cause around 60% of total greenhouse gas emissions and between 50% and 80% of total resource use. It is therefore one of the most essential challenges of the twenty-first century to realize sustainability in everyday life by making decisions that are more beneficial to environmental sustainability.

Increasingly such daily decisions are shifted toward digital environments (Hagberg et al., 2016; Wassan et al., 2021). Examples include e-commerce shopping or managing a heating system via digital control systems (Li et al., 2021). Digital technologies are ubiquitous in a wide variety of everyday contexts and thus can be an effective tool to influence individuals' behavior toward environmentally friendly due to their remarkable ubiquity in daily life (Melville, 2010; Oinas-Kukkonen, 2013). Digital technologies include devices like smartphones or tablets but also applications (Zuppo, 2012). While non-beneficial daily choices negatively impact the environment to a large extent, environmentally sustainable products and services exist for all contexts and provide individuals with a choice. Therefore, engaging individuals in pro-environmental behavior is crucial (Watson et al., 2013). By actively improving the interaction with users, Information Systems (IS) research offers a high potential to positively influence users' behavior by supporting that digitally made decisions favor environmentally sustainable options.

[1] Since a cumulative dissertation consists of individual research articles, this chapter (Introduction) as well as the last chapter (General Discussion and Conclusion) partly comprise content taken from the research articles included in this dissertation. To improve the readability of the text, I omit the standard labeling of these citations.

On the downside of the increased and promising users' interaction with digital technologies, prior research indicates that it may cause stress, known as technostress, leading to potentially negative reactions in individuals (Tarafdar et al., 2019). Interacting with digital technologies places diverse demands on the individual, for example through non-availability or high amount of information (Ayyagari et al., 2011). These IS-enabled demands can trigger the technostress process, which can potentially lead to adverse outcomes like mental health issues. These issues like burnout or depression are constantly threatening and are already affecting individuals' health to great extent, thus must be avoided (Abramson, 2022; World Health Organization, 2021). Aside from their striking impacts on individuals' lives, mental health issues additionally entail direct and indirect economic costs, including preventive or remedial healthcare services (direct costs), as well as reduced labor supply and output (indirect costs) (European Commission, 2020; World Health Organization, 2021). It is thus also important to ensure that individuals interact with digital technologies sustainably in terms of their mental health. Depending on the situation and the individual, the goal is either to *maintain* the healthy status quo when interacting with digital technologies or to *improve* the decreased status quo of mental health due to the interaction with digital technologies. The dissertation includes both mentioned aspects and uses the term *maintaining mental health*.

To sum up, because of the remarkable influence of digital technologies on daily lives, improving individuals' interactions with digital technologies can positively affect individuals' behavior toward environmental sustainability, thus addressing human-induced environmental deterioration. But as it is important to not only focus on environmental sustainability but social sustainability, including the individuals' health, as well (United Nations, 2015), it is crucial to maintain individuals' mental health when interacting with digital technologies, thus avoiding the emergence and negative effects of technostress.

1.2 Sustainable Interaction with Digital Technologies

The interaction of humans with digital technologies has been researched under the term "Human-Computer-Interaction (HCI)" (Zhang & Li, 2005). The HCI distinguishes the three perspectives of *technology* and *humans* interacting with each other to complete a given *task* (in a given *context*), resulting in outcomes. Zhang and Li (2005) developed a framework to study HCI, displaying the three perspectives producing outcomes (Figure 1.2-1).

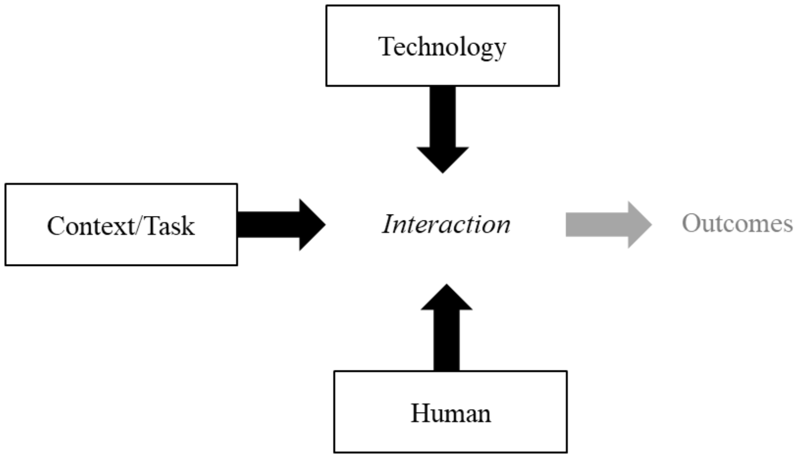

Figure 1.2-1 Framework of Human-Computer Interaction based on Zhang and Li (2005)

The framework represents a holistic approach to structure and to classify research along different *context/task*-, *technology*-, and *human*-specific perspectives. The three perspectives exhibit specific characteristics that shape the interaction and must be considered in detail to guarantee sustainable outcomes when interacting with digital technologies (Zhang & Li, 2005). The *technology* component is broadly defined and comprises hardware and software (Zhang & Li, 2005). Questions from the technology perspective include, for example, the influence of interface design on behavior, performance, or productivity. From the *human* perspective, HCI research analyzes human factors such as perception and cognition, for example, the humans' perception of specific situations when working with digital technologies, or their satisfaction with specific features. Lastly, the *context/task*-related perspective is relevant, as "nothing happens in a vacuum" (Zhang & Li, 2005, p. 232). In this dissertation, this perspective refers to the broader *context*, in which specific *tasks* are completed (e.g., the task of shopping for groceries is summarized as the context of "e-commerce" or more specifically "food"). Therefore, this perspective is referred to as the *context*-specific HCI perspective in this dissertation.

Along with this guiding structure, the seven research articles included in this dissertation aim at contributing to the sustainable interaction with digital technologies in terms of both pro-environmental and mental health (Figure 1.2-1).

1.2.1 Pro-environmental Behavior and Interaction with Digital Technologies

In various daily contexts, individuals can make small choices in favor of pro-environmental behavior to counteract the ongoing human-induced environmental deterioration. With ever-increasing digitalization, these daily choices are shifted toward a digital world. Humans interact with digital technologies in different contexts that influence their environmental behavior. Examples include shopping in e-commerce shops or using a smart home app to control the lights or heating (Kroll et al., 2019; Roozen et al., 2021). Influencing users' behavior and choices when interacting with digital technologies seems promising due to their rising presence in our daily lives. For instance, when interacting with a smart home app, its design and functionality can influence the individual's energy conservation behavior, leading to a more pro-environmental behavior in terms of energy conservation (Corbett, 2013; Kroll et al., 2019). Within these apps, the use of *behavioral interventions* can positively influence the users' behavior. Similarly, in online e-commerce shopping – the design and function of the e-commerce shop that includes behavioral interventions can influence the product choice, potentially leading to a more pro-environmental shopping cart (Demarque et al., 2015; Lehner et al., 2016).

Behavioral interventions using different *nudging elements* (NEs) applied in the physical environment have been well-researched within the last decades (Hummel & Maedche, 2019). Nudging describes ways to predictably impact individuals' behaviors by altering the environment in which decisions are made without restricting the freedom of choice or raising the cost of alternatives in terms of effort, time, and other factors (Hansen & Jespersen, 2013; Hausmann & Welch, 2010; Thaler & Sunstein, 2009). Examples of nudging elements include "default rules" (e.g., preselecting the most favorable option) or "simplification" (e.g., using labels to simplify complex information) (Lehner et al., 2016). Weinmann et al. (2016) extended the concept of nudging by focusing on the digital environment. People can act differently in an analog environment due to the information richness in digital environments, leading to a lower concentration of reading time on digital screens (Liu, 2005). The use of digital nudging elements (DNEs) is a crucial design element for positively influencing individuals' choices made in a digital environment (Weinmann et al., 2016). To sum up, (D)NEs are meant to support better decision-making, which makes them suitable for encouraging pro-environmental behavior (Lehner et al., 2016).

Numerous scientific works have investigated the effectiveness of specific DNEs in a wide range of consumption and behavior contexts (e.g., energy, food, or mobility) (Cappa et al., 2020; Lembcke et al., 2019). These household-related consumption areas cause large amounts of greenhouse gas emissions, leading to tremendous environmental adverse effects; hence these areas are relevant for addressing environmental sustainability (Ivanova et al., 2016). However, while the ongoing digitalization provides manifold opportunities to implement

DNEs to promote pro-environmental behavior, designing digital technologies that effectively leverage DNEs in specific contexts is still a challenge. The DNEs' effectiveness varies in different behavioral *contexts* (e.g., saving energy vs. buying sustainable products). Also, the *design* of the DNEs (HCI perspective *technology*) requires a precise analysis of the respective context and the individual user groups. Lastly, *user preferences* (HCI perspective *human*) must be considered to encourage continued use of the digital technology in which the DNE is implemented. Therefore, *context*-, *technology*-, and *human*-specific (Figure 1.2-1) analysis are necessary to guarantee their successful implementation, hence enabling pro-environmental behavior when interacting with digital technologies.

1.2.2 Mental Health and Interaction with Digital Technologies

One main goal of social sustainability lies in the assurance of healthy lives and the promotion of well-being for all (United Nations, 2015). This goal is threatened by an increasing number of mental health issues (Abramson, 2022; World Health Organization, 2021), that can also be caused by individuals' interaction with digital technologies. While on the one hand, digital technologies offer huge potential for individual's well-being and mental health and have long been part of our private and professional life, their use can also lead to adverse psychological effects like increased psychological exhaustion and therefore decrease the individuals' mental health (Tarafdar et al., 2019). This process is also known as *technostress* (Tarafdar et al., 2019). Tarafdar et al. (2019) describe technostress as the "stress process activated due to the use of [digital technologies]" (p. 8). This process can be triggered by *IS-enabled demands*, which are "objective demands that are enabled by [digital technologies] and [may] stress individuals" (Galluch et al., 2015, p. 3). These can also include attributes or features of a specific digital technology, for example, "pace of change" or "push notifications" (Ayyagari et al., 2011). The individual exposed to these demands next appraises if the demand demonstrates a threat or a disturbing factor (Benlian, 2020; Tarafdar et al., 2019). Further, research findings support that users may also perceive demands as a challenge providing opportunities for personal growth and empowerment when successfully overcome (Benlian, 2020; Le Fevre et al., 2003). The cognitive appraisal, therefore, offers an explanation of different reactions in objectively identical situations (Krohne, 2001).

If these IS-enabled demands are appraised as damaging, they may threaten the individual, indicating *technostress creators* (i.e., stressors responsible for technostress) (Tarafdar et al., 2019). Technostress creators are "conditions or factors that can create stress because of [digital technology] use" (Tarafdar et al., 2015, p. 106) and "are appraised by the individual as damaging" (Tarafdar et al., 2019, p. 9). When confronted with a technostress creator, a user can experience a multifaceted technostress response. In the long-term, the experienced technostress response can lead to serious *adverse technostress outcomes*, especially when the technostress response is intense and long-lasting or frequently repeated. These include societal, economic, and personal consequences as severe health impairments like burnout, depression, or exhaustion – as well as adverse organizational outcomes like decreased productivity, lower levels of job satisfaction, and less organizational commitment (Maier et al., 2015; Ragu-Nathan et al., 2008; Srivastava et al., 2015). While previous research has focused on the negative side of IS use and its implications, recent literature shows that IS-enabled demands can also have positive effects that may primarily result from *challenge appraisals* rather than *threat appraisals* (Tarafdar et al., 2019). Depending on the appraisal of the demands, previous research indicates that interacting with digital technologies can lead to both desirable (e.g., satisfaction, higher productivity) and adverse (e.g., poor health, strain) outcomes (Gimpel et al., 2019).

Since many causes of technostress stem from using digital technologies in work-related settings, organizations face the moral and legal responsibility to improve employees' health by preventing work-related technostress. Next to addressing the emergence of technostress from a *context-specific* perspective (i.e., the organization), the *design of the digital technologies* at a digital workplace should avoid the possible occurrence of technostress (HCI perspective *technology*). Last, however, it depends on the *perception of the individual* whether a given demand is perceived as threatening, which requires a deeper understanding of how the perception can be influenced (HCI perspective *human*). Overall, *context*-, *technology*-, and *human*-centric analysis are important to prevent and mitigate severe outcomes of technostress, and thereby promote mental health when interacting with digital technologies.

1.3 Aim and Outline of this Dissertation

There is a need to promote sustainable interaction with digital technologies to foster pro-environmental behavior and maintain mental health. Addressing the users' sustainable interaction with digital technologies requires a thorough understanding of the contextual, technological, and individual perspectives (Zhang & Li, 2005). Therefore, this dissertation focuses on the three perspectives of *context*, *technology*, and *humans*, and applies the HCI framework of Zhang and Li (2005) as a guiding structure. Thereby, the dissertation aims at creating a deeper understanding of selected aspects of the sustainable interaction with digital technologies to *foster pro-environmental behavior* on the one hand and mitigate threats associated with the use of digital technologies (technostress) on the other hand, hence *maintaining mental health*. To reach this goal, this dissertation relies on the collection, analysis, and interpretation of both qualitative and quantitative data. Throughout the research articles, data is obtained from structured literature reviews, a Delphi study, focus group workshops, online surveys, and field experiments. The data is analyzed with qualitative research methods such as the structured analysis of scientific literature (e.g., Grounded Theory) as well as statistical methods such as exploratory factor analyses, regression analyses, cluster analyses, and analyses related to the Kano model and the Latent Growth model.

Figure 1.3-1 presents the outline of the dissertation, starting with the introduction in Chapter 1. Chapter 2 analyses the three HCI perspectives of context, technology, and human, focusing on *fostering pro-environmental behavior* as an outcome (see the inner cycle in Figure 1.3-1). Next, Chapter 3 focuses on the social aspect of sustainable interaction, thus investigating the three mentioned HCI perspectives with a focus on *maintaining mental health* when interacting with digital technologies (see the outer cycle in Figure 1.3-1). Lastly, Chapter 4 discusses the results, provides an outlook for future research, and concludes thoughts on this dissertation.

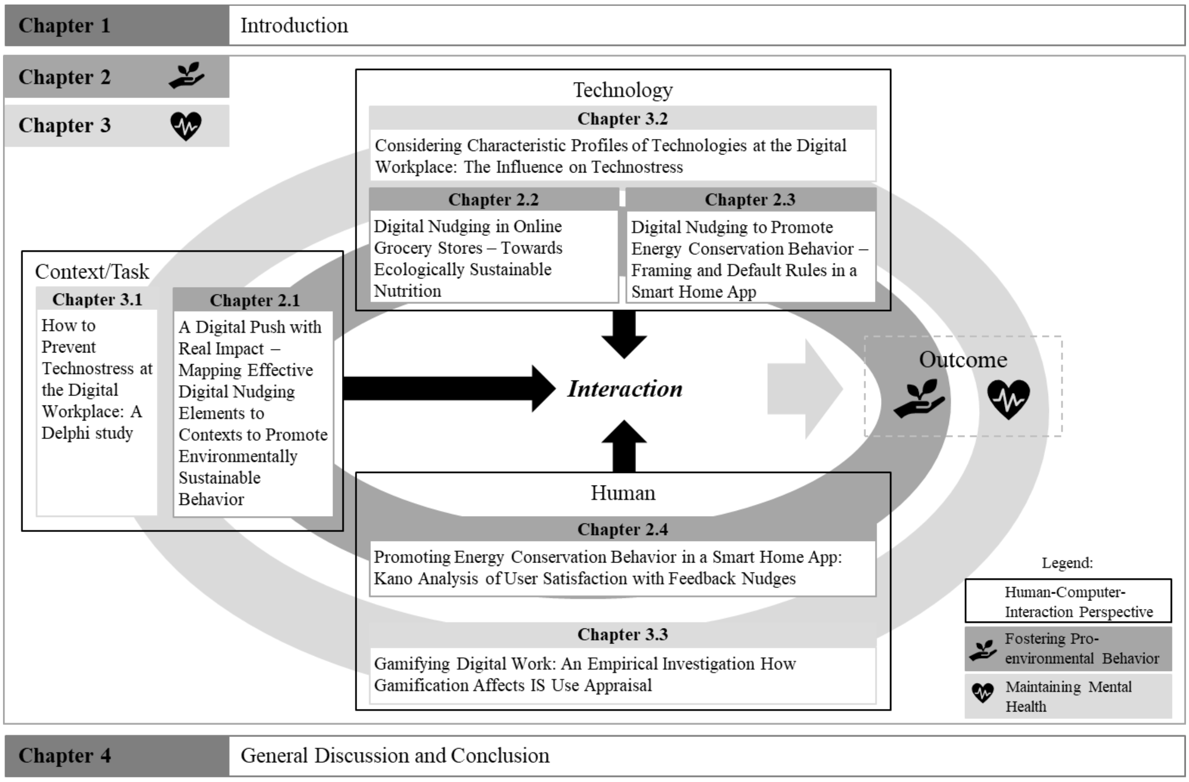

Figure 1.3-1 Structure of this dissertation, focusing on two sustainability-related outcomes when interacting with digital technologies, and Human-Computer-Interaction dimensions in the focus of the included research articles

Table 1.3-1 and Table 1.3-2 give an overview of the included research articles. Table 1.3-1 includes research articles focusing on pro-environmental behavior (Chapters 2.1, 2.2, 2.3, and 2.4) and Table 1.3-2 displays the research articles focusing on mental health (Chapters 3.1, 3.2, and 3.3). The tables provide details regarding the current publication status, objectives, method, data, co-authors, and which articles were written as the lead author. In the following sub-chapters, Chapter 2 and Chapter 3 of this dissertation will be introduced upon which the aims and research questions (RQ) of each of the articles will be outlined in more detail.

Chapter # ***(HCI perspective)***	**Title of the research article** ***Current publication status***	**Objective**	**Method and data**	**Co-authors**
Chapter 2: Fostering Pro-Environmental Behavior when Interacting with Digital Technologies				
Chapter 2.1* *(Context)*	A Digital Push with Real Impact – Mapping Effective Digital Nudging Elements to Contexts to Promote Environmentally Sustainable Behavior *Published in Journal of Cleaner Production (2022), 380(1), 134716, DOI: 10.1016/j.jclepro.2022.134716.*	Providing an IS design perspective, structure, and meta-inferences of the existing knowledge on the effectiveness of digital nudging elements to promote pro-environmental behavior in different behavioral contexts	Structured literature review, and framework development based on Grounded Theory	Theresa Lange, Bastian Stahl
Chapter 2.2 *(Technology)*	Digital Nudging in Online Grocery Stores – Towards Ecologically Sustainable Nutrition *Published in the proceedings of the 41st International Conference on Information Systems (ICIS), a remote conference due to COVID-19, 2020.*	Analyze and compare the effect of the digital nudging elements "default rules", "simplification", and "social norms" on environmentally sustainable grocery shopping behavior regarding customer groups	Online field experiment, comparative (non-) parametric tests, regression analysis, and cluster analysis	Niclas Nüske, Chiara Müller
Chapter 2.3 *(Technology)*	Digital Nudging to Promote Energy Conservation Behavior – Framing and Default Rules in a Smart Home App *Published in the proceedings of the 30th European Conference on Information Systems (ECIS) in Timisoara, Romania, 2022.*	Analyze and compare the effect of the digital nudging elements "default rules" and "framing" on energy conservation behavior in a smart home app	Online field experiment, comparative (non-) parametric tests, and regression analysis	Elias Greinacher, Linda Wolf
Chapter 2.4 *(Human)*	Promoting Energy Conservation Behavior in a Smart Home App: Kano Analysis of User Satisfaction with Feedback Nudges *Published in the proceedings of the 43rd International Conference on Information Systems (ICIS) in Copenhagen, Denmark, 2022.*	Derive a list of features of the nudging element "feedback" to promote energy conservation behavior from literature and analyze the effect of the hypothetical implementation of the features on user satisfaction in smart home apps	Structured literature review, card sorting, online survey, and analysis based on the Kano model	Henner Gimpel, Feline Schnaak, Linda Wolf

* Please note that in these research articles, I was the lead author.

Table 1.3-1 Overview of the research articles of Chapter 2 in this dissertation

Chapter # ***(HCI perspective)***	**Title of the research article** ***Current publication status***	**Objective**	**Method and data**	**Co-authors**
Chapter 3: Maintaining Mental Health when Interacting with Digital Technologies				
Chapter 3.1* *(Context)*	How to Prevent Technostress at the Digital Workplace: A Delphi Study *Working paper*	Develop theoretical and practicable knowledge of relevant prevention measures an organization can introduce to target technostress among their employees	Structured literature review, focus group workshops, and qualitative and quantitative contributions from a Delphi study	Ricarda Schäfer, Marco Schmidt, Christian Regal, Henner Gimpel
Chapter 3.2 *(Technology)*	Considering Characteristic Profiles of Technologies at the Digital Workplace: The Influence on Technostress *Published in the proceedings of the 41st International Conference on Information Systems (ICIS), a remote conference due to COVID-19, 2020.*	Analyze digital workplace by developing characteristic profiles of technologies, and investigating their influence on technostress creators	Literature review, focus groups, quantitative large-scale online survey, structural equation modeling	Julia Becker, Henner Gimpel, Julia Lanzl, Christian Regal
Chapter 3.3 *(Human)*	Gamifying Digital Work: An Empirical Investigation How Gamification Affects IS Use Appraisal *Will be published in the proceedings of the 56th Hawaii International Conference on System Sciences (HICSS), in Lāhainā, USA, 2023.*	Investigate how gamification supports challenge appraisal and reduces threat appraisal of IS-enabled demands when interacting with digital technologies	Literature review, online field experiment, analysis based on the Latent Growth Model	Carolin Jung, Manfred Schoch

* Please note that in this research article, I was the lead author.

Table 1.3-2 Overview of the research articles of Chapter 3 in this dissertation

1.3.1 Fostering Pro-environmental Behavior when Interacting with Digital Technologies (Chapter 2)

Chapter 2 of this dissertation deals with the outcome of fostering pro-environmental behavior when interacting with digital technologies using DNEs. The chapter comprises four research articles that cover the HCI perspective *context* by analyzing DNEs applied in different behavioral contexts (Chapter 2.1, research article 1), the HCI perspective *technology* concerning the design and effectiveness of implemented DNE in online grocery stores (Chapter 2.2, research article 2), and a smart home app (Chapter 2.3, research article 3). Lastly, the HCI perspective *human* is analyzed in terms of users' satisfaction with specific nudging features (Chapter 2.4, research article 4).

Research on digital nudging to promote pro-environmental behavior appears to be highly fragmented, a mosaic in which single blocks are contributed from the domains involved. This leaf IS designers without guidance on which DNE to choose for a specific task in a behavior context that has an impact on the pro-environmental behavior of individuals (e.g., energy, food, mobility). While valuable process guidelines to implement DNEs exist (Weinmann et al., 2016), there is a lack of thematic guidance. Designers of those systems must determine the type of choice the individual faces, whether binary (e.g., yes/no), discrete (e.g., choosing one of several products), or continuous (e.g., regulating the room temperature) choices (Schneider et al., 2018). Second, designers must focus on the respective context in which the task is fulfilled and then identify effective DNE configurations (e.g., strong vs. weak social norms (Demarque et al., 2015)) or even combinations of several DNEs. An overarching perspective and structure of the existing knowledge are needed to derive meta-inferences of context-specific DNEs designs and configurations and to shed light on blind spots. To fill this research gap, Chapter 2.1 answers the following research question (RQ):

RQ 2.1-1: *In which contexts can digital nudging elements effectively promote environmentally sustainable behavior?*

Answering this research question is valuable in that it provides an IS design perspective that matches DNEs to context decision types and indicates the effectiveness of their combination. To answer the question, Chapter 2.1 conducts a structured literature review following the guidelines of Wolfswinkel et al. (2013). Elements of Grounded Theory (Glaser & Strauss, 2017) are used to examine the existing body of 56 identified research articles and develop a framework. The framework of Chapter 2.1 offers an overview that aggregates the variety of behavior contexts, decision types, DNEs, and their effectiveness to promote pro-environmental behavior. Its core structure is a matrix mapping a context with DNE types to studies investigating their effectiveness. Regarding the HCI framework, the article, thus, analyses the potential of DNEs to promote pro-environmental behavior implemented in a digital technology with which a user interacts in a specific behavioral *context* that influences the pro-environmental behavior.

Chapters 2.2 and 2.3 present two specific matrix fields of the framework developed in Chapter 2.1, which each focus on one specific context (i.e., food in Chapter 2.2 and energy in Chapter 2.3) and test the effectiveness of specific DNEs. Chapter 2.2 focuses on the interaction of users with online grocery stores and specifically the design and effectiveness of DNEs in the e-commerce shop (HCI perspective *technology*). Humans' food consumption, including its production and transportation, has tremendous negative effects on the environment in terms of land depletion, exhaustion of natural resources, and global greenhouse gas emissions (Noleppa, 2012; Poore & Nemecek, 2018). It is not sufficient to rely on the proactivity of food producers to turn to more conscious and pro-environmental practices, pressure from the demand side must be increased to accelerate changes (Mont et al., 2014). But consumers often struggle when it comes to choosing more sustainable groceries, as food choices are highly impulsive and the amount of information and the number of choices is overwhelming (Hoek et al., 2017; van't Riet et al., 2011). These factors make food choices prone to nudging. Chapter 2.2, therefore, explores the potential of DNE to promote pro-environmental food choices in online grocery stores. More specifically, it asks the following research questions:

RQ 2.2-1: *Which of the digital nudging elements "default rules", "simplification", and "social norms" are effective in online food shopping contexts regarding the promotion of ecologically sustainable food choices?*

RQ 2.2-2: *Do the digital nudging elements differ in their influence on different consumer groups?*

To answer the first question, Chapter 2.2 derives an exemplary implementation of the three DNEs based on insights from previous literature that mainly focused on physical nudging. A fictitious online grocery store serves as the setting for an online field experiment that gathers information about the purchase behavior of about 300 participants. The effects of the three DNEs on pro-environmental grocery choices and variations due to individual differences are investigated using parametric and non-parametric comparative tests, as well as regression and cluster analyses. To sum up, Chapter 2.2 focuses on the design of three DNEs in an online grocery store and analyzes the DNEs' effectiveness regarding different consumer groups to promote pro-environmental grocery shopping behavior.

Chapter 2.3 focuses on the context of energy consumption in private households, which account for about 29% of the total energy consumption (taking Germany as an example), and thus needs to be reduced to counteract climate change (Federal Environmental Agency of Germany [UBA], 2019). While energy efficiency has steadily increased due to technological advances in the last decades, these improvements are frequently accompanied by an increase in energy demand, reducing the actual savings (Federal Ministry for Economic Affairs & Energy [BMWi], 2020). Therefore, the simple existence of innovative technologies like smart homes is not enough to reduce energy consumption at home; consumer behavior plays an equally important role in using the technologies effectively. Thereby, behavioral interventions like digital nudging bear the great potential of influencing users' decisions. While prior research analyzed DNEs like "social norms" and "feedback" to encourage energy-conservation behavior, "framing" (i.e., simplifying complex information, e.g., by using labels or icons such as green leaves) and "default rules" (i.e., changing the default, e.g., to pre-select the most sustainable option) received little attention in prior research in this context so far. These DNEs show already encouraging results in other sustainability-related contexts (Schrills et al., 2020), however, research also shows that the effectiveness of DNEs highly depends on the underlying context (see Chapter 2.1). Therefore, Chapter 3.3 aims to answer the following research question:

RQ 2.3-1: *Do the digital nudging elements "framing" and "default rules" promote energy conservation behavior of individuals in mobile smart home apps?*

To answer this research question, this article analyzes data from 231 surveyed participants by applying parametric and nonparametric statistics and analyses. To sum up, Chapter 2.3 focuses on the effectiveness of the two specified DNEs as well as their combination to promote pro-environmental behavior in terms of energy conservation.

Lastly, Chapter 2.4 builds on Chapters 2.1 and 2.3 by remaining in the context of smart home technologies (as in Chapter 2.3) and focusing on the well-researched and effective DNE "feedback" in improving energy conservation behavior (pointed out in the framework in Chapter 2.1). When investigating the DNE "feedback" to foster energy-conservation behavior, prior research studied different DNE configurations: for example, investigating different types of update frequencies (real-time vs. weekly) or different types of energy consumption measurement (e.g., kWh, costs, environmental impact). While promising insights into the effectiveness of specific feedback nudge features (FNFs) like update frequency already exist, the investigation of users' preferences concerning feedback nudges is missing (Fleury et al., 2018; Gu et al., 2019). This lack of knowledge is central, as user satisfaction influences their continued app usage, a precondition for achieving positive effects enabled by that app usage (here: lower energy consumption in the long run) (Bhattacherjee, 2001; Gu et al., 2019; Thong et al., 2006). While it is confirmed that user satisfaction contributes to continued use (e.g., Bhattacherjee, 2001), it is not analyzed how FNFs in a smart home app must be designed to achieve this satisfaction. Chapter 2.4, therefore, explores the research question:

RQ 2.4-1: *How do potential smart home app users evaluate a broad set of feedback nudge features designed for nudging towards energy conservation behavior?*

To answer the research question, the chapter first performs a structured literature review and a card sorting procedure with IS researchers to derive a set and overview of FNFs in smart home apps. Furthermore, the article examines the effect of the hypothetical implementation of these FNFs on customer satisfaction. Then, the analysis of the Kano method (Kano, 1984; Matzler et al., 1996) is applied to the data of 188 surveyed participants. Chapter 2.4, therefore, takes an individual *human perspective* on the DNE feedback applied in a smart home app by integrating the perspective on user satisfaction with the specific nudging features.

1.3.2 Maintaining Mental Health when Interacting with Digital Technologies (Chapter 3)

In Chapter 3, the focus changes from pro-environmental behavior when interacting with digital technologies to the preservation of mental health by avoiding technostress. It includes three research articles that deal with the avoidance of technostress in professional life. Starting with the HCI perspective *context*, Chapter 3.1 (research article 5) derives 24 prevention measures the employer can introduce to prevent technostress among their employees. Chapters 3.2 (research article 6) and 3.3 (research article 7) zoom in on two of the proposed prevention measures in Chapter 3.1, namely "adopt a stress-sensitive digital workplace design" (Chapter 3.2) and "use gamification (Chapter 3.3). Chapter 3.2 focuses on the *technology* perspective by analyzing the impact of digital technology characteristics on the occurrence of technostress. Lastly, the HCI perspective *human* is analyzed in terms of the user's perception of a demanding situation when interacting with digital technologies and how the perception can be influenced through the use of gamification (Chapter 3.3).

Chapter 3.1 focuses on the prevention of technostress in the business *context* from the perspective of the employer. Organizations face moral and legal responsibility and economic pressure to prevent employees' excessive technostress. As technostress develops over time, it is important to prevent it throughout the stages of its emergence instead of reacting only after adverse outcomes occur. Chapter 3.1, therefore, aims to answer the following RQ:

RQ 3.1-1: *What are relevant technostress prevention measures an organization can introduce?*

RQ 3.2-2: *How can the technostress prevention measures be characterized in terms of (1) their basic approach to preventive technostress management, (2) their applicability, and (3) their relevance in targeting technostress creators?*

By contextualizing the Theory of Preventive Stress Management to technostress, Chapter 3.1 synthesizes and advances existing knowledge on avoiding technostress, hence offering an alternative view by adding a time perspective through the implementation of primary, secondary, and tertiary prevention. Based on qualitative and quantitative contributions from a Delphi study, Chapter 3.1 introduces a comprehensive set of 24 characterized primary and secondary technostress prevention measures an organization can introduce.

Chapters 3.2 and 3.3 both analyze two specific primary technostress prevention measures identified in Chapter 3.1, namely "adopt a stress-sensitive digital workplace design" (see measure 2 in Chapter 3.1) in Chapter 3.2 and "use gamification" (see measure 5 in Chapter 3.1) in Chapter 3.3. Chapter 3.2 focuses on the HCI perspective *technology* by analyzing the digital workplace to maintain mental health when interacting with digital technologies. Digital workplaces are characterized by the set of digital technologies provided to execute one's work effectively where the design of the digital workplace is key to the worker's productivity (Köffer, 2015; Williams & Schubert, 2018; Yalina, 2019). Ayyagari et al. (2011) emphasized the question of which role the different characteristics of digital technologies (functional and non-functional features) play in terms of technostress. This knowledge is valuable as it can assist developers and designers of workplaces to prevent technostress. Therefore, Chapter 3.2 strives to derive an understanding of the characteristic profiles of technologies used at the digital workplace, their interplay, and how they influence technostress. By applying a mixed-methods approach, Chapter 3.2 deals with the following three research questions:

RQ 3.2-1: *Which characteristics of digital technologies with relation to technostress exist?*

RQ 3.2-2: *How does the characteristic profile of specific digital technologies look like?*

RQ 3.2-3: *What is the influence of characteristic profiles of digital technologies used at the workplace on technostress?*

The research article first conceptualizes the relevant characteristics of digital technologies based on extant literature and qualitative research. To evaluate the characteristics quantitatively, existing item scales are collected and where necessary, new multi-item scales are developed and tested for reliability. Then, in a large-scale survey with both exploratory and confirmatory factor analyses, the scales are further validated. Based on survey data, Chapter 3.2 analyses the influence of characteristic profiles of multiple specific digital technologies used at the respondent's workplace on technostress using structural equation modeling.

Lastly, Chapter 3.3 focuses on the individual's appraisal (HCI perspective *human*) of a demanding situation when working with digital technologies. The appraisal is decisive for determining whether the given situation leads to positive or negative outcomes. Designing IS in a way that gives users the impression that they can successfully deal with IS-enabled demands is considered a possible approach to positively influence the individual's cognitive appraisal towards challenging and away from threatening (Johnson & Wiles, 2003; Tarafdar et al., 2019). A promising approach could be the integration and application of gamification, as these elements can motivate users, for example, by giving them feedback about their performance (Tarafdar et al., 2019; Zichermann & Cunningham, 2011). Chapter 3.3 addresses one specific technostress prevention measure of Chapter 3.1, namely "use gamification" (see measure 5 in Chapter 3.1), and aims to answer the following research question:

RQ 3.3-1: *Does the influence of gamification on cognitive appraisal reduce threat appraisal and support challenge appraisal of an IS-enabled demand?*

To reach this goal, an environment where users must process an unknown number of work tasks in a fictional digital assessment system under time urgency is simulated. Such situations can create both challenge and threat appraisals (Benlian, 2020). For the intervention group in the online experience, gamification elements in the form of a point system, notifications, progress bars, and badges are integrated. Participants filled out surveys assessing their perceived threat appraisal and challenge appraisal throughout the experiment. The data collected at different points in time during the experiment is analyzed with analyses of the Latent Growth Model focusing on the influence of gamification on the reduction of threat appraisal and increase of challenge appraisal.

1.4 References

Abramson, A. (2022). Burnout and stress are everywhere. *Monitor on Psychology*, *53*(1), 72. https://www.apa.org/monitor/2022/01/special-burnout-stress

Ayyagari, R., Grover, V., & Purvis, R. (2011). Technostress: Technological antecedents and implications. *MIS Quarterly*, *35*(4), 831. https://doi.org/10.2307/41409963

Benlian, A. (2020). A daily field investigation of technology-driven spillovers from work to home. *MIS Quarterly*, *44*(3), 1259–1300. https://doi.org/10.25300/MISQ/2020/14911

Berger, M., Müller, C., & Nüske, N. (2020). Digital nudging in online grocery stores – Towards ecologically sustainable nutrition. In *Proceedings of the 41st International Conference on Information Systems (ICIS)*.

Bhattacherjee, A. (2001). Understanding information systems continuance: An expectation-confirmation model. *MIS Quarterly*, *25*(3), 351–370.

Cappa, F., Rosso, F., Giustiniano, L., & Porfiri, M. (2020). Nudging and citizen science: The effectiveness of feedback in energy-demand management. *Journal of Environmental Management*, *269*. https://doi.org/10.101/j.jenvman.2020.110759

Corbett, J. (2013). Using information systems to improve energy efficiency: Do smart meters make a difference? *Information Systems Frontiers*, *15*(5), 747–760.

CRED. (2022). *2021 Disasters in Numbers*. https://cred.be/sites/default/files/2021_EMDAT_report.pdf

Demarque, C., Charalambides, L., Hilton, D. J., & Waroquier, L. (2015). Nudging sustainable consumption: The use of descriptive norms to promote a minority behavior in a realistic online shopping environment. *Journal of Environmental Psychology*, *43*, 166–174. https://doi.org/10.1016/j.jenvp.2015.06.008

Eason, K. D. (1991). Ergonomic perspectives on advances in human-computer interaction. *Ergonomics*, *34*(6), 721–741. https://doi.org/10.1080/00140139108967347

European Commission. (2020). *Cost of Non-Communicable Diseases in the EU*. https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/cost-non-communicable-diseases-eu_en

Federal Environmental Agency of Germany. (2019). *Auswertungstabellen zur Energiebilanz der Bundesrepublik Deutschland 1990 bis 2019, Stand 09/2020.*

Federal Ministry for Economic Affairs, & Energy. (2020). *Energieeffizienz in Zahlen 2020*. www.bmwi.de

Fleury, S., Jamet, É., Michinov, E., Michinov, N., & Erhel, S. (2018). A priori acceptability of various types of digital display feedback on electricity consumption. *Le Travail Humain*, *81*(3), 247–267. https://doi.org/10.3917/th.813.0247

FootPrint Network. (2022). *Country Overshoot Days 2022*. https://www.overshootday.org/newsroom/country-overshoot-days/

Galluch, P. S., Grover, V., & Thatcher, J. B. (2015). Interrupting the workplace: Examining stressors in an information technology context. *Journal of the Association for Information Systems*, *16*(1), 1–47. https://doi.org/10.17705/1jais.00387

Gimpel, H., Lanzl, J., Regal, C., Urbach, N., Wischniewski, S., Tegtmeier, P., Kreilos, M., Kühlmann, T., Becker, J., Eimecke, J., & Derra, N. D. (2019). *Gesund digital arbeiten?!* Projektgruppe Wirtschaftsinformatik des Fraunhofer FIT. https://doi.org/10.24406/fit-n-562039

Glaser, B. G., & Strauss, A. L. (2017). *The discovery of grounded theory: Strategies for qualitative research*. Routledge. https://doi.org/10.4324/9780203793206

Global Carbon Project. (2021). *Entwicklung des weltweiten CO2-Ausstoßes in den Jahren 1995 bis 2020 (in Millionen Tonnen)*. https://de.statista.com/statistik/daten/studie/208750/umfrage/weltweiter-co2-ausstoss/

Gu, W., Bao, P., Hao, W., & Kim, J. (2019). Empirical examination of intention to continue to use smart home services. *Sustainability*, *11*(19), 1–12. https://doi.org/10.3390/su11195213

Hagberg, J., Sundstrom, M., & Egels-Zandén, N. (2016). The digitalization of retailing: an exploratory framework. *International Journal of Retail & Distribution Management*, *44*(7), 694–712. https://doi.org/10.1108/IJRDM-09-2015-0140

Hansen, P., & Jespersen, A. (2013). Nudge and the manipulation of choice: A framework for the responsible use of the nudge approach to behaviour change in public policy. *European Journal of Risk Regulation*, *1*, 3–28.

Hausmann, D., & Welch, B. (2010). Debate: To nudge or not to nudge. *The Journal of Political Philosophy*, *18*(1), 123–136. https://doi.org/10.1111/j.1467-9760.2009.00351.x

Hoek, A. C., Pearson, D., James, S. W., Lawrence, M. A., & Friel, S. (2017). Shrinking the food-print: Food behaviours: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly. *Appetite*, *108*, 117–131. https://doi.org/10.1016/j.appet.2016.09.030

Hummel, D., & Maedche, A. (2019). How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. *Journal of Behavioral and Experimental Economics, 80,* 47–58. https://doi.org/10.1016/j.socec.2019.03.005

IPCC. Summary for policymakers. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*

Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., & Hertwich, E. G. (2016). Environmental impact assessment of household consumption. *Journal of Industrial Ecology*, *20*(3), 526–536. https://doi.org/10.1111/jiec.12371

Johnson, D., & Wiles, J. (2003). Effective affective user interface design in games. *Ergonomics*, *46*(13-14), 1332–1345. https://doi.org/10.1080/00140130310001610865

Kano, N. (1984). Attractive quality and must-be quality. *Hinshitsu (Quality, the Journal of Japanese Society for Quality Control)*, *14,* 39–48.

Köffer, S. (2015). Designing the digital workplace of the future - What scholars recommend to practitioners. In *Proceedings of the 36th International Conference on Information Systems (ICIS).*

Krohne, H. W. (2001). Stress and coping theories. In *International Encyclopedia of the Social & Behavioral Sciences* (pp. 15163–15170). Elsevier. https://doi.org/10.1016/B0-08-043076-7/03817-1

Kroll, T., Paukstadt, U., Kreidermann, K., & Mirbabaie, M. (2019). Nudging people to save energy in smart homes with social norms and self-commitment. In *Proceedings of the 27th European Conference on Information Systems.*

Le Fevre, M., Matheny, J., & Kolt, G. S. (2003). Eustress, distress, and interpretation in occupational stress. *Journal of Managerial Psychology, 18*(7), 726–744. https://doi.org/10.1108/02683940310502412

Lehner, M., Mont, O., & Heiskanen, E. (2016). Nudging – A promising tool for sustainable consumption behaviour? *Journal of Cleaner Production*, *134*, 166–177. https://doi.org/10.1016/j.jclepro.2015.11.086

Lembcke, T.-B., Engelbrecht, N., Brendel, A. B., Herrenkind, B., & Kolbe, L. M. (2019). Towards a unified understanding of digital nudging by addressing its analog roots. In *Proceedings of the 23rd Pacific Asia Conference 2019.*

Li, T., Fooks, J. R., Messer, K. D., & Ferraro, P. J. (2021). A field experiment to estimate the effects of anchoring and framing on residents' willingness to purchase water run-off management technologies. *Resource and Energy Economics*(63), 101107. https://doi.org/10.1016/j.reseneeco.2019.07.001

Liu, Z. (2005). Reading behavior in the digital environment. *Journal of Documentation*, *61*(6), 700–712. https://doi.org/10.1108/00220410510632040

Maier, C., Laumer, S., Weinert, C., & Weitzel, T. (2015). The effects of technostress and switching stress on discontinued use of social networking services: A study of face-book use. *Information Systems Journal*, *25*(3), 275–308. https://doi.org/10.1111/isj.12068

Matzler, K., Hinterhuber, H. H., Bailom, F., & Sauerwein, E. (1996). How to delight your customers. *Journal of Product & Brand Management*, *5*(2), 6–18.

Melville, N. P. (2010). Information systems innovation for environmental sustainability. *Management Information Systems Quarterly*, *34*, 1–21.

Mont, O., Lehner, M., & Heiskanen, E. (2014). *Nudging - A tool for sustainable behaviour?* The Swedish Environmental Protection Agency.

Noleppa, S. (2012). *Climate change on your plate*. Berlin. WWF Germany. https://mo-bil.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Climate_change_on_your_plate.pdf

Oinas-Kukkonen, H. (2013). A foundation for the study of behavior change support systems. *Personal and Ubiquitous Computing*, *17*(6), 1223–1235.

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/sci-ence.aaq0216

Ragu-Nathan, T. S., Tarafdar, M., Ragu-Nathan, B. S., & Tu, Q. (2008). The consequences of technostress for end users in organizations: Conceptual development and empiri-cal validation. *Information Systems Journal*, *19*(4), 417–433.

Roozen, I., Raedts, M., & Meijburg, L. (2021). Do verbal and visual nudges influence con-sumers' choice for sustainable fashion? *Journal of Global Fashion Marketing*, *12*(4), 327–342. https://doi.org/10.1080/20932685.2021.1930096

Schneider, C., Weinmann, M., & vom Brocke, J. (2018). Digital nudging. *Communications of the ACM*, *61*(7), 67–73. https://doi.org/10.1145/3213765

Schrills, T., Zoubir, M., Stahl, J., Drozniak, K., & Franke, T. (2020). Good boy here or bad boy far away? effects of digital nudging on booking decisions in car sharing. In *Proceedings of the 17th International Conference EPCE* (pp. 398–411).

Srivastava, S. C., Chandra, S., & Shirish, A. (2015). Technostress creators and job outcomes: Theorising the moderating influence of personality traits. *Information Systems Journal*, *25*(4), 355–401. https://doi.org/10.1111/isj.12067

Tarafdar, M., Cooper, C. L., & Stich, J.-F. (2019). The technostress trifecta-techno eustress, techno distress and design: Theoretical directions and an agenda for research. *Information Systems Journal*, *29*(1), 6–42.

Tarafdar, M., Pullins, E. B., & Ragu-Nathan, T. S. (2015). Technostress: negative effect on performance and possible mitigations. *Information Systems Journal*, *25*(2), 103–132.

Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: Improving Decisions about Health, Wealth, and Happiness* (Rev. and expanded ed., with a new afterword and a new chapter). Penguin.

Thong, J. Y., Hong, S.-J., & Tam, K. Y. (2006). The effects of post-adoption beliefs on the expectation-confirmation model for information technology continuance. *International Journal of Human-Computer Studies*, *64*(9), 799–810. https://doi.org/10.1016/j.ijhcs.2006.05.001

United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

van’t Riet, J., Sijtsema, S. J., Dagevos, H., & Bruijn, G.-J. de (2011). The importance of habits in eating behaviour. An overview and recommendations for future research. *Appetite*, *57*(3), 585–596.

Wassan, S., Gulati, K., Ghosh, A., shafi rafiqi, I., Mammani, B. S., Tabbassum, S., & Khaja Mohiddin, M. (2021). Impact of digitalization on retailers and its future trends. *Materials Today: Proceedings.* Advance online publication. https://doi.org/10.1016/j.matpr.2021.06.238

Watson, D., Fernández, J. A., Wittmer, D., & Pedersen, O. G. (2013). *Environmental pressures from European consumption and production. A study in integrated environmental and economic analysis*. Publications Office of the European Union. https://www.osti.gov/etdeweb/biblio/22079106

Weinmann, M., Schneider, C., & vom Brocke, J. (2016). Digital nudging. *Business & Information Systems Engineering*, *58*(6), 433–436. https://doi.org/10.1007/s12599-016-0453-1

Williams, S. P., & Schubert, P. (2018). Designs for the digital workplace. *Procedia Computer Science*, *138*, 478–485. https://doi.org/10.1016/j.procs.2018.10.066

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems*, *22*(1), 45–55. https://doi.org/10.1057/ejis.2011.51

World Health Organization. (2021). *Depression*. https://www.who.int/news-room/fact-sheets/detail/depression

Yalina, N. (2019). Digital workplace implementation to promote gender equality. In *Proceedings of the International Conference on Research and Academic Community Services (ICRACOS 2019)*. https://doi.org/10.2991/icracos-19.2020.1

Zhang, P., & Li, L. (2005). The intellectual development of Human-Computer Interaction research: A critical assessment of the MIS literature (1990-2002). *Journal of the Association for Information Systems*, *6*(11), 227–292. https://doi.org/10.17705/1jais.00070

Zichermann, G., & Cunningham, C. (2011). Gamification by design: Implementing game mechanics in web and mobile apps. *O´Reilly Media, Inc*.

Zuppo, C. M. (2012). Defining ICT in a boundaryless world: The development of a working hierarchy. *International Journal of Managing Information Technology*, *4*(3), 13.

2 Fostering Pro-environmental Behavior when Interacting with Digital Technologies

2.1 A Digital Push with Real Impact – Mapping Effective Digital Nudging Elements to Contexts to Promote Environmentally Sustainable Behavior

Abstract: The ongoing environmental deterioration is mainly human-induced. In various daily contexts, individuals can make small choices in favor of environmentally sustainable behavior to counteract this effect. With ever-increasing digitalization, these decisions are shifted toward a digital world. Digital nudging presents a promising approach to foster environmentally sustainable behavior without restricting the freedom of choice. However, research on digital nudging appears to be highly fragmented, leaving information systems designers without guidance on which nudging elements to choose in a specific context. By conducting a structured literature review followed by a framework development, this paper provides an information systems design perspective that matches digital nudging elements on context decision types and indicates the effectiveness of their combination. Thus, the provided framework is of practical use for designing effective digital nudging elements. Moreover, it contributes to research by identifying meta-inferences of the current status quo and offering impulses for future research.

Keywords: Digital nudging, environmental sustainability, structured literature review, consumer behavior

Authors: Michelle Berger[2], Theresa Lange, Bastian Stahl

Status: This article is published in the Journal of Cleaner Production (2022), 380(1), 134716, DOI: 10.1016/j.jclepro.2022.134716

[2] Please note that in this research article, I was the lead author.

2.1.1 Introduction

In recent decades, climate change has caused severe impacts worldwide. As indicated by the Intergovernmental Panel on Climate Change (IPCC), anthropogenic global warming and environmental deterioration are continuously increasing and therefore threatening the basis of our very existence (IPCC, 2021). Aside from technology improvements regarding efficiency, small everyday choices and decisions in consumer behavior provide a central opportunity in climate change (Calculli et al., 2021).

Using the example of Europe, Ivanova et al. (2016) state that the consumption areas of housing (especially heating systems), mobility (especially automobile use and air travel), and food (especially meat and dairy) cause around 60% of global greenhouse gas emissions and between 50% and 80% of total resource use. However, environmentally sustainable products and services exist for all contexts and provide users with a choice. Different types of food, for example, have different effects on the environment (Clark & Tilman, 2017; Scarborough et al., 2014) and also environmentally friendly household products or special search engines that cause fewer adverse effects on the environment (Rennings, 2000).

Therefore, engaging consumers in environmentally friendly practices is crucial (Watson et al., 2013). But instead of restricting the number of available options by fiscal measures, rules, or regulations, nudging can support consumers in decision-making by modifying the environment in which the decision is made (Thaler & Sunstein, 2009). Examples for nudging elements include default rules (e.g., pre-selecting the most favorable option) or simplification (e.g., using labels to simplify complex information) (Lehner et al., 2016). While nudging in analog decision contexts has been well-researched within the last decades (Hummel & Maedche, 2019), digitalization has massively impacted our everyday life and increasingly shifted relevant consumers' choices toward digital environments (Hagberg et al., 2016; Wassan et al., 2021). Thus, product choices are made digitally, like buying food via e-commerce (Berger et al., 2020). Also, other decisions affecting environmentally sustainable behavior (ESB) are increasingly shifted toward digital environments, such as managing a heating system via digital control systems (Li et al., 2021). As illustrated by these examples, Information Systems (IS) become a central place for choosing environmentally sustainable products and services as consumers can help reduce environmental impacts. To take advantage of this momentum from IS, a new area in the research field of information systems (IS) emerged, called Green IS (Dedrick, 2010; vom Brocke et al., 2013). Thus, Green IS refers to the "use of information systems to achieve environmental objectives" (Dedrick, 2010, p. 173). Especially for Green

IS, digital nudging offers one possibility to change consumption patterns to a more environmentally friendly product choice.

Hence, Weinmann et al. (2016) extended the concept of nudging by focusing on the digital environment. People can act differently from an analog environment due to information richness in digital environments, leading to a lower concentration of reading time on digital screens (Liu, 2005). The use of digital nudging elements (DNEs) is a crucial design element for positively influencing individuals' choices made in a digital environment (Weinmann et al., 2016). Numerous scientific works have investigated the effectiveness of DNEs in a wide range of consumption and behavior contexts (e.g., energy, food, or mobility) (Cappa et al., 2020; Lembcke et al., 2019). These household-related consumption areas cause roughly 60% of global CO2 emissions and 50-80% of total resource use, leading to tremendous environmental adverse effects (Ivanova et al., 2016). The diversity of the research field is further demonstrated by the fact that a large number of different DNEs (e.g., default rules, feedback, or social norms) exist, which are intended to lead users to more sustainable decisions through different psychological and sociological effects.

However, while the ongoing digitalization provides manifold opportunities to implement DNEs to promote environmentally sustainable behavior (ESB), designing IS that effectively leverage DNEs in specific contexts (e.g., saving energy) is still a challenge: While valuable processual guidelines to implement DNEs exist (Schneider et al., 2018; Weinmann et al., 2016) there is a lack of thematic guidance. Designers of those systems must disentangle the type of choice (e.g., binary decisions with a digital desired behavior) in their respective context and then identify effective DNE configurations or even combinations of several DNEs. Therefore, especially from the perspective of Green IS, research and practice call for a unifying lens to map effective DNEs to a specific context providing users with an environmentally sustainable choice (Zimmermann et al., 2021). From this perspective, we raise the following research question (RQ):

RQ2.1-1: *In which contexts can digital nudging elements effectively promote environmentally sustainable behavior?*

Existing literature on DNEs to promote ESB is often driven by the different domains (i.e., contexts) and therefore presented as a mosaic in which single blocks are contributed from the respective domains. However, fully exploiting the existing knowledge on DNEs to promote ESB meaningfully in the context of Green IS requires an overarching perspective and structure. Faced with the constantly ongoing climate change and an increasingly digitalized society, we believe it is time that the potentials of DNEs and ESBs are investigated under the usage of a unifying IS lens. This work, therefore, strives to bridge both areas of research and provides a structure for further research to build on.

We, accordingly, conduct a structured literature review following the guidelines of Wolfswinkel et al. (2013). In line with this overarching approach, we use elements of Grounded Theory (Glaser & Strauss, 2017) to examine the existing body of work and develop a framework that aggregates the variety of contexts, decision types, DNEs, and their effectiveness to promote ESB. We, therefore, highlight well-researched and effective DNEs in specific contexts and shed light on blind spots. This paper contributes to research by deriving meta-inferences of context-specific DNEs designs and configurations. Next, by hypothesizing underlying mechanisms between contexts and DNE effectiveness that require further study to verify, and by pointing out missing research, we offer impulses for further research directions. For practice, our framework provides an applicable tool to design effective DNEs for a respective context. We aim to stimulate practitioners from different domains to leverage DNEs to engage their users in ESB.

2.1.2 Theoretical Background

2.1.2.1 Behavioral Science and the Concept of (Digital) Nudging to Promote Environmentally Sustainable Behavior

Nudging describes ways to influence behavior predictably by modifying the environment without limiting the freedom of choice or increasing the cost of alternatives in terms of effort, times, and others (Hansen & Jespersen, 2013; Hausmann & Welch, 2010; Thaler & Sunstein, 2009). The principle of nudging is based on behavioral economics' dual-process theory (Wason & Evans, 1974), which claims that human decision-making could be categorized in an intuitive, cognitive system one or a reason-based system 2 (Stanovich & West, 2000). System 1 is in charge of simple, intuitive, emotional, automatic, and fast decisions ("automatic thinking" (Thaler & Sunstein, 2009, p. 19)), while system 2 is in charge of slower, more supervised, rule-governed, and more effortful decisions ("reflective thinking" (Thaler & Sunstein, 2009, p. 19)). Everyday decisions, such as taking the elevator or the stairs, are credited to system 1, according to Kahneman (2011), while major life decisions or calculations are made in system 2. System 1 deliberately protects system two by converting familiar tasks into automated routines and preventing cognitive overload. Behavior results from decisions made in both modes of thinking, reflective and automatic thinking (Kahneman, 2011). For both kinds of decisions, shortcuts can be taken like listening to social conformity, also known as cognitive biases or heuristics (Kahneman, 2011; Tversky & Kahneman, 1974). While, on the one hand, heuristics support quicker and easier decision-making, they can make decisions prone to error, leading to potentially unfavorable decisions (Shiv & Fedorikhin, 1999). Thaler and Sunstein (2009) state that nudges function by using counteracts to these heuristics and cognitive biases, making nudging suitable for the unconscious, automatic, and the non-automatic, complicated decisions that are typically beyond the cognitive ability of humans.

Increasingly, decisions are taken in an online environment (e.g., websites or apps). People can act differently from an analog environment (Benartzi & Lehrer, 2015; Weinmann et al., 2016). Due to its information richness, digital environments can lead to a choice overload, so that people spend less time concentratedly reading on digital screens (Liu, 2005). Therefore, Weinmann et al. (2016) extended the definition of nudging by focusing on a digital environment and defined digital nudging as the ”use of user-interface design elements to guide people’s choices or influence users’ inputs in online decision environments” (Weinmann et al., 2016, p. 433). Next to its necessity due to increasing choices made online, digital nudging offers several advantages. DNEs can be implemented more rapidly, more cheaply, and in a more customized fashion than in an offline, physical environment because online environments provide instruments for tracking and analyzing individual preferences

Different types of nudges exist and can be implemented in an online environment. As nudging covers a broad spectrum, the number and variety of nudges are unlimited (e.g., as pointed out by Hausmann and Welch (2010)). Prior studies in different application contexts use different names and definitions of nudging elements as no uniform definitions exist. Sunstein (2014) introduced ten analog Nes, i.e., default rules, simplification, reminders, implementation intentions, social norms, ease and convenience, disclosure, warnings, pre-commitment strategies, and consequences. Schubert (2017) introduced the term Green Nudges that aims at promoting ESB and divided them into the simplification of product information (e.g., labels), social norms, and default rules. Lehner et al. (2016) mention the elements simplification, framing, changes to the physical environment, default rules, and social norms as nudging elements to promote sustainable consumption behavior, whereas Zimmermann et al. (2021) found seven DNEs that promote sustainable consumption behavior and ordered them into by their time of application: before (priming, goal setting), during (decoy, defaults), after (feedback, social comparison), and throughout the action (framing). Mirsch et al. (2017) mention similar nudging elements that can be implemented in a digital world. Lembcke et al. (2019) state that prior literature focused on pure offline or pure online user journeys to implement nudging elements. The research team proposes a somewhat blended environment in which the analog and digital world influence or affect each other (unintendedly or intendedly). We focus on nudges implemented in a digital decision-making environment (here: DNE) but can lead to both behavioral target environments – in an analog (e.g., food intake) and digital (e.g., application usage) environment.

The DNEs that have been investigated in different contexts to promote ESB and are therefore included in this study are shortly described and exemplified in Table 2.1-1.

DNE	Time of Application	Definition	Example
Priming	Before action	*Priming* is a way of preparing people for their choice by simulating feelings and thoughts through introducing specific topics, moods, or information like the consequences of their decision before it takes place (Mirsch et al., 2017).	Adding a website page with a visual emphasis on the conscious collection of the store before forwarding customers to the shopping page to nudge them toward buying the more environmentally sustainable product (Roozen et al., 2021).
Social norms	Before action	*Social norms* are "individual's beliefs about the typical and condoned behavior in a given situation" (Kormos et al., 2015, p. 480). Injunctive and descriptive norms exist (Cialdini et al., 1990). Injunctive norms (which have not yet been studied to nudge toward ESB, only in the form of social comparison, see below) characterize a socially desired action (e.g., tip in a restaurant), whereas descriptive norms specify "what is done" (Cialdini et al., 1990, p. 1015) (e.g., "57.23% of similar households prefer a room temperature of 18°C or less in the bedroom." (Kroll et al., 2019, p. 5)	Descriptive norms: Displaying information on the donation willingness of participants in the past (in %) before providing the opportunity to donate to an environmental charity to nudge toward donating (Fanghella et al., 2019).
Goal setting	Before action	*Goal setting* refers to the pre-commitment strategy introduced by Sunstein (2014), meaning that people are more likely to behave in line with their goals if they committed beforehand to do so.	Committing to an energy-saving target (% relative to baseline electricity consumption in kWh) before tracking the consumption over 4.5 months to nudge toward energy-saving behavior (Claire-Michelle Loock et al., 2013).
Default rules	Action	*Default rules* refer to a situation where the preferred choice has been pre-selected and will remain if the individual does nothing (Thaler & Sunstein, 2009). It is based on the need to preserve the status quo (Kahneman, 2011) and procrastinate due to the time and effort required to make active decisions (Sunstein, 2014).	Default C02 compensation in flight booking portals to nudge toward donating C02 offsets (Székely et al., 2016).
Simpli-fication	Action	*Simplification* entails delivering complex (product) information or framing specific characteristics more noticeably (e.g., by using logos) (Sunstein, 2014).	Using logos (e.g., smiling world face) on environmentally sustainable products to nudge toward buying these labeled products (Berger et al., 2020).

DNE	**Time of Application**	**Definition**	**Example**
(Real-time) Feedback	(After) action	*Feedback* supports people to reflect on whether their behavior is/was good or improvable and points out the consequences of the decisions (Cappa et al., 2020). Thus, *feedback* manages to circumvent inertia or procrastination and can be applied to motivate people, similar to reminders (Sunstein, 2014).	Real-time feedback: Using a smart meter in hotel showers to deliver real-time feedback on water consumption by displaying a polar bear standing on a melting ice floe to nudge toward consuming less water when showering (Tiefenbeck et al., 2019). Feedback: Providing detailed and customized feedback on energy consumption regarding its impact in terms of costs and C02 pollution to nudge toward behaving more energy conservatively (Cappa et al., 2020).
Social comparison	After action	*Social comparison* is one specific form of feedback in which consumers receive information on their peers' behavior, which is then compared with their own behavior or consumption (Zimmermann et al., 2021). Social comparison can be divided into descriptive and injunctive feedback (based on social norms. Individuals often orient themselves toward the behavior of others (descriptive) and aim to learn what behavior is desired (injunctive) (Cialdini et al., 1990).	Receiving insights on the consumption of similar or comparative households to understand whether one consumes more or less energy than the regarded peer group (Schultz et al., 2015). Descriptive: Bar chart indicating individuals' weekly energy consumption to the average consumption of similar households (Graml et al., 2011). Injunctive: Displaying grades from A to G (A= a high level of approval of energy consumption, G = a high level of disapproval) (C.-M. Loock et al., 2011).
Framing	Throughout	*Framing* makes use of the bias of "anchoring" (Thaler & Sunstein, 2009), referring to the fact that by presenting the same information in different ways/frames, people tend to decide differently.	Renaming the vegetarian food category on the menu into a pro-environmental (“environmentally friendly main courses for a happy planet” frame instead of a vegetarian frame (“vegetarian main courses”) to nudge toward choosing the more environmentally sustainable vegetarian dish (Krpan & Houtsma, 2020).

Table 2.1-1 Digital nudging elements included in this study (time of application according to Zimmermann et al. (2021))

Following Zimmermann et al. (2021), we order the DNE by their time of application: *before*, *during*, *after*, and *throughout the action*. In addition to the list of Zimmermann et al. (2021), we added *social norms*, which are commonly known in the (D)NE literature (Lehner et al., 2016; Mirsch et al., 2017; Schubert, 2017; Sunstein, 2014). We also found several studies analyzing this DNE to promote ESB (e.g., Berger et al., 2020; Demarque et al., 2015; Momsen & Stoerk, 2014; and others). As Zimmermann et al. (2021) mention *social norms* as one type of *priming,* we categorized *social norms* as a DNE applied *before action*, like *priming*. Similar argumentation counts for including the DNE *simplification* instead of *decoy* in the list of Zimmermann et al. (2021). *Priming* and *goal setting* differ in the pre-commitment strategy (Sunstein, 2014). While for *goal setting*, consumers actively commit to a goal, aiming to increase their motivation to behave in line with the pre-committed goal, *priming* is more general without using a pre-commitment strategy. *Priming* aims to simulate feelings or thoughts to prepare for the decision.

2.1.2.2 Related Work

Research provides evidence that (digital) nudging effectively influences individuals' behaviors toward ESB (e.g., Ferrari et al. (2019), Lehner et al. (2016), Reisch et al. (2021)). Driven from their domain, several studies investigate the efficiency of specific DNEs in a wide range of *behavior contexts* that cause adverse effects on the environment (e.g., *energy*, *food*, *mobility, Fast-Moving-Consumer-Goods (FMCG),* and others). Studies in the context of *energy* aim to influence behavior toward energy conservation (Brandsma & Blasch, 2019; Claire-Michelle Loock et al., 2013; Schultz et al., 2015). Examples include the study by Cappa et al. (2020), which analyzed different forms of *feedback* to foster energy conservative behavior or studies that aim to choose more renewable energy contracts (Momsen and Stoerk, 2014; Pichert and Katsikopoulos, 2008). The context of *food* has been mainly investigated because, despite the growing world population and thus increasing demand for food, the global food system has significant weaknesses in terms of environmental sustainability (Reisch et al., 2021). DNE studies in this context aim at nudging for products or meal choices that cause less negative environmental impacts (Berger et al., 2020). Additionally, *mobility* is one of the few contexts where emissions are still increasing. Thus, it offers excellent potential for DNEs to promote ESB (Chapman, 2007). One example includes the study of Schrills et al. (2020), who aimed to nudge toward selecting battery electric vehicles in car sharing by testing different configurations of the DNE *framing*. Studies in the context of *FMCG* (Grebitus et al., 2020; Roozen et al., 2021) focus on buying decisions for goods characterized by a relatively low price and that are consumed frequently and rapidly, which is why buyers attach little importance to the purchase decision (Leahy, 2011). These contexts represent consumption and behavior areas that significantly impact CO2 emission and resource consumption, leading to tremendous adverse effects on the environment. It becomes apparent that the studies are very strongly *limited to their own context and their selection of DNEs*. Next to these studies, the research provided an overarching overview of single or several (D)NEs to promote ESB in *one specific context* by conducting literature reviews or meta-analyses. The work of Karlin et al. (2015) summarizes the effects of *feedback* on energy conservation or the work of Osbaldiston and Schott (2012). They conducted a meta-analysis on treatments to promote ESB in terms of energy and water conservation and recycling behavior (context: *energy*). Ferrari et al. (2019) gathered findings on how (D)NEs can be used to improve the environmental impact of the food supply chain (context: *food*).

Studies can be distinguished between either analyzing the concrete configuration of a single stand-alone DNE (e.g., extremely strong, strong, weak, and extremely weak social norms to promote pro-environmental food choices (Demarque et al., 2015)) or the comparison between multiple stand-alone DNEs or their combination (e.g., default rules, priming, and their combination when promoting the use of electric cars (Stryja et al., 2017)). Additionally, studies differ in the behavioral target environment (physical vs. digital) of the DNE (Lembcke et al., 2019), hence whether the decision that gets nudged is taken in the digital environment (e.g., managing the heating system via a smart home app) or in a physical environment (e.g., the DNE implemented in an app reminds you to turn down the heating when opening the window, but the heating must be managed physically). As prior research showed that individuals seem to behave differently in a digital environment, we argue that a separate consideration of the physical vs. digital behavioral target environment is necessary to conclude the effectiveness of DNEs. Lastly, studies differ in their type of choice to be influenced: binary (e.g., yes/no), discrete (e.g., choice out of several products), and continuous (e.g., regulating the room temperature) choices (Schneider et al., 2018). While Schneider et al. (2018) examined different DNEs to counteract the biases induced by choice type, no study has analyzed if the use of DNEs has been tested successfully.

Looking at the topic from an IS lens, the domain engaged in theoretically transferring NEs into DNEs (Weinmann et al., 2016), developing design approaches for DNEs (Mirsch et al., 2018; Schneider et al., 2018), and structuring the field, e.g., along the time of interaction (Zimmermann et al., 2021). Research in the area of DNEs to promote ESB still appears to be highly fragmented due to its perspective from the specific behavioral context, leading to difficulty in forming definite conclusions regarding the effectiveness of the various types and guidance on their application. Especially to structure and systematize the development of DNEs, research provides systematic methods (Mirsch et al., 2018; Schneider et al., 2018). For instance, the method of Mirsch et al. (2018) aims to guide the structured development of DNEs along four sequential steps in an iterative method (Figure 2.1-1): Within the first step, the context of the DNE is analyzed, and the goals associated with the DNE are defined. Second, ideation and design of suited DNEs are performed. Third, the DNE is implemented in the chosen technology channel. Fourth, the effectiveness of the DNE is evaluated regarding the intended behavioral change and relevant KPIs.

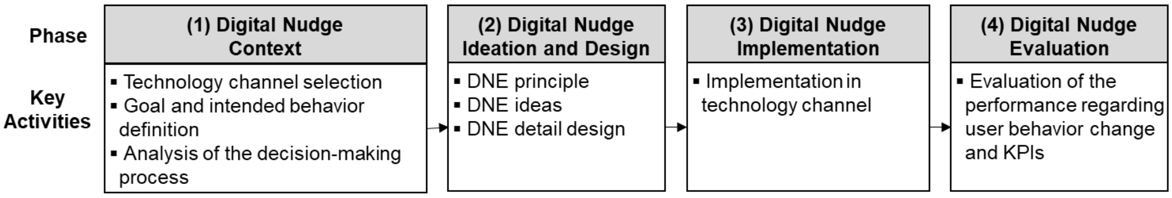

Figure 2.1-1 Digital nudge design method as per Mirsch et al. (2018)

2.1.3 Research Approach

Structured literature reviews are appropriate if a similar research question has been analyzed in different empirical studies and aim at describing, summarizing, evaluating, explaining, or integrating prior results (Fettke, 2006). Applying this method, the researcher can highlight inconsistencies or contradictions and point out the possibility of generalizable results, unsolved problems, and thus research gaps. This paper conducts a systematic literature review to collect existing empirical evidence using DNEs to foster ESB. To answer our research question, we followed the five-stage procedure of Wolfswinkel et al. (2013) to rigorously review and analyze existing literature (see Table 2.1-2). Thus, we started with searching and selecting relevant literature, as proposed in the guidelines for interdisciplinary reviews of Webster and Watson (2002) and vom Brocke et al. (2015). Based on the findings from our literature search, we analyzed the remaining works. As Wolfswinkel et al. (2013) suggest, we used elements of Grounded Theory (Glaser & Strauss, 2017) to code and develop a framework that provides a comprehensive IS lens on ESB-relevant contexts and DNEs investigated in the studies selected.

Stage	Proposed activity	Realization in this work
Define	Identifying the fields of research	Information systems, behavioral science, ecological science
	Determining the appropriate sources	AISeL, Web of Science, Scopus
	Search-string definition	(Nudg* OR “persuasive system*” OR “behavior change”) AND (digital OR technolog* OR “information system*” OR online) AND (sustainab* OR eco-“ OR ecologic* OR environment* OR green).
	Defining the criteria for inclusion and exclusion	Experimental research studies on DNEs to promote ESB
Search	Query within the proposed databases using the search string	Sample of 561 papers, resulting in 463 after filtering for English articles and conference proceedings

Stage	Proposed activity	Realization in this work
Select	Refining the sample of studies to be reviewed	Reduction of the sample down to 56 based on duplicates, abstract, title and full screening, backward search in identified literature reviews and previously known papers
Analyze	Open coding	Development 10 higher-level categories
	Axial coding	Identification of interrelation between core and sub-categories
	Selective coding	Re-conceptualization and development of relationships between concepts
Present	Representing and structuring the content and research article	Context Digital Nudging Elements Framework

Table 2.1-2 Research approach based on Wolfswinkel et al. (2013)

Starting with the *Define* stage, we set the scope of the research, selected a database, and defined a suited search string (Wolfswinkel et al., 2013). DNEs are used in a variety of contexts and disciplines to promote ESB. In accordance with the presented theoretical background, our main scope is to cover the disciplines of IS, behavioral sciences as part of psychology, and ecological sciences. We chose three main databases to perform a query to reflect the current level of research concerning DNEs to promote ESB: First, we chose Web of Science, which contains a large amount of multidisciplinary literature across time (Zupic & Čater, 2015). Second, we enhanced our search field with the Scopus database, which provides a wide range of interdisciplinary content and specialization in global representation (Elsevier, 2021). Third, we searched the AIS eLibrary (AISeL) due to its specialization in worldwide IS literature and focus on conference proceedings, which enables the inclusion of recently published studies (AIS eLibrary, 2021). We built a search string consisting of three components to query the databases. The first component was installed to focus on nudging and behavioral change: (*Nudg* OR "persuasive system*" OR "behavior change"*). To focus on nudging in digital environments, the second component, consisting of (*digital OR technolog* OR "information system*" OR online*) was installed. The third component was used to specialize in ecological sustainability: (*sustainab* OR eco-" OR ecologic* OR environment* OR green*). The operator AND combined the three components resulting in a defined unbiased boolean search string, which was then applied in the following stage (Gusenbauer & Haddaway, 2020). We first defined exclusion and inclusion criteria to select relevant work for our research question. The author team discussed the decisions on ambiguous cases for inclusion or exclusion. Exclusion criteria included: (EC1) studies not written in English or with no full text available, (EC2) research in progress, (EC3) studies mentioning digital nudging as future plans / only as a keyword without providing specific research on DNEs, and (EC4) studies dealing with DNEs that aim at any other behavior change than toward ESB. Therefore, for example, the study by

Fennis et al. (2020) was excluded as the research aim was on nudging toward healthy behavior. Lastly, (EC5) studies were excluded if they did not report empirical evidence (effect size) on the use of DNEs but focused on the design requirements of these DNEs. An example includes the study by Werkmeister et al. (2021), as while they focus on promoting sustainable travel behavior through carpooling, the study aimed to design a mobile application to promote carpooling without empirically testing DNEs of the app. Next to the five exclusion criteria, we defined two inclusion criteria. (IC1) Studies were included that measured an actual behavioral change instead of only measuring the intention of behavioral change. The study of Shevchuk, N. & Oinas-Kukkonen, H. (2019) exemplifies this criterion: they investigate the influence of persuasive systems on motivation and attitude formation and subsequent intention to change ecological behavior. However, since no actual behavioral change, but only changes of intention, is measured, we excluded this study. (IC2) Studies were included that conducted an online experiment/survey in which nudges are implemented in a digital decision environment. An ambiguous example includes the study of Krpan and Houtsma (2020), who tested different category names of vegetarian dishes (DNE *framing*) on a restaurant menu. While the study aimed at optimizing "offline" restaurant menus, the experiment was conducted online, which is why we decided that in this case, the decision is still made in an online environment; hence we included the study. (IC3) Next, we included studies that implemented DNEs focusing on either a digital or physical behavioral target environment. An example of a study focusing on a physical behavioral target environment includes the study by Graham et al. (2011). The study tested the DNE *feedback* in a digital environment (Web portal) to nudge toward driving fewer miles. While the nudge is implemented online, the target environment is physical, as the decision to take the car or not takes place in the physical environment.

Within the *Search* stage, we performed the actual search within the selected databases (Wolfswinkel et al., 2013). In all three databases, the search string was applied to title, abstract, and keywords in October 2021. Also, the search results were filtered for articles and conference proceedings only. The initial search yielded 561 works. After filtering for English papers and conference proceedings, 463 remained (see Figure 2.1-2). In our results, we identified existing literature reviews on (D)Nes to promote ESB (Hummel & Maedche, 2019; Mirsch et al., 2017; Schaer & Stanoevska-Slabeva, 2019; Zimmermann et al., 2021) and conducted a backward search in these papers, which yielded 251 studies. Added these, our search resulted in 687 papers.

Within the *Select* stage, we screened the works, refined the sample (Wolfswinkel et al., 2013), and removed a total of 224 duplicates resulting from the search in three different databases and backward search in the identified literature reviews (e.g., papers that were found in the Scopus database are marked as duplicates if we already identified them in the AISeL database or in the backward search based on the literature reviews). To this sample, we added 8 studies we previously knew but were not included in our search (Larsen et al., 2019). With the collected 471 works, screening the selected studies started. Considering the previously defined inclusion and exclusion criteria, the papers were screened first by title, abstract, and full text. With this, for ambiguous cases, we primarily focused on the enforcement of IC2: Though, in many papers, the study was conducted online, the studied element was implemented in a non-digital environment. Furthermore, we concentrated on papers that affected not only the intention of changing the consumers' behavior but measured an actual behavioral change (IC1). We excluded several papers as the study did not include measuring the effect size according to EC5. After the full-text screening, a collection of 56 papers resulted (see Figure 2.1-2).

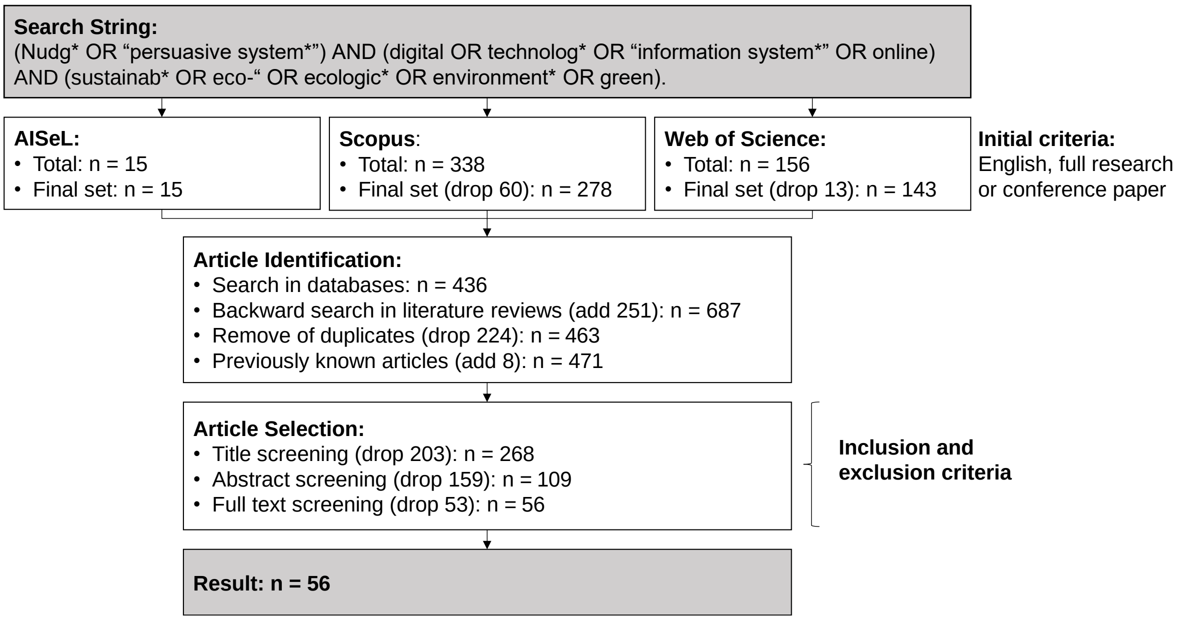

Figure 2.1-2 Structured literature review

For the *Analyze* stage, we followed the suggested coding techniques of Wolfswinkel et al. (2013) to examine the resulting works. We carefully read all selected papers in this stage and highlighted any insight or finding we defined as relevant. All highlighted parts, being words, sentences, or paragraphs, are then considered as 'excerpts.' Building on elements of Grounded Theory (Glaser & Strauss, 2017), we applied open, axial, and selective coding to analyze these excerpts and develop a framework covering the current state of research on DNEs to promote ESB.

We aimed to develop mutually exclusive, higher-level concepts or categories that help structure the field of research (see Figure 2.1-3). We structured these concepts along the main phases of the socio-technical development process for DNEs (Mirsch et al., 2018; Schneider et al., 2018). Therefore, we (1) identified concepts referring to the context and the goals of the DNE. (2) Second, we developed concepts addressing the DNE intervention consisting of DNE design and implementation. (3) Third, we developed concepts addressing the intervention's effectiveness.

(1) Starting with understanding the social context inducing an ESB relevant choice (e.g., *Energy*), we use two key concepts to disentangle the induced choices: First, we classified the type of choice (i.e., binary, discrete, and continuous) as proposed by Schneider et al. (2018). Second, we analyzed in which environment the ESB relevant behavior should occur (i.e., online, offline, or undefined) as proposed by Lembcke et al. (2019).

(2) About the step of nudging design, we examined the DNE intervention of the works. We referred to the DNE typologies used by Lehner et al. (2016), Mirsch et al. (2017), and Zimmermann et al. (2021) (see Table 2.1-1). Moreover, we characterized the setup by the implementation strategy (i.e., combinations of DNEs, the configuration of single stand-alone DNEs, or the comparison of multiple stand-alone DNEs) and the used control variables of the studies (e.g., user preferences, social background, etc.).

(3) Regarding the evaluation of intervention's effectiveness, we coded for the DNE effectiveness categorized by the effect size, significance, and other influence factors outlined in the works (Mirsch et al., 2018). Subsequently, we applied axial coding to draw on the interrelation between categories and their sub categories.

We then applied selective coding to re-conceptualize the categories and developed the relationships between the concepts. As a result of our coding procedure, we obtained central building blocks and connections of our framework developed on top of them to DNEs and ESB (see Figure 2.1-3).

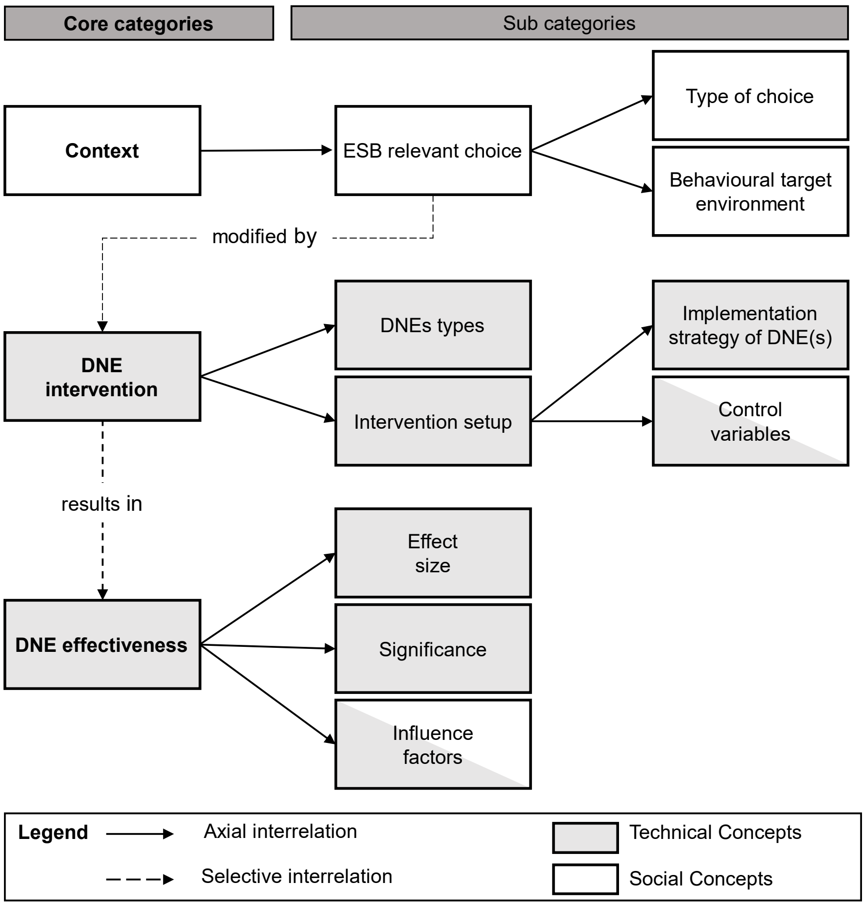

Figure 2.1-3 Building blocks and interrelations from coding

Within the *Present* stage, the discovered perspectives, insights, and ideas are communicated (vom Brocke et al., 2015; Wolfswinkel et al., 2013). For this step, we chose to leverage the insights of our literature review by a framework providing a comprehensive IS lens on DNEs and ESB. The framework is structured along the building blocks obtained from coding and thus covers the main phases of Schneider et al. (2018): Following their logic, we map the context and the underlying choices to promote ESB with DNE interventions and the resulting effectiveness. Thereby, we aim critically shed light on existing research gaps, draw overall conclusions about differences in contexts, and stimulate practitioners by providing an overview of effective DNEs, hence providing guidance when applying the DNE implementation process (Mirsch et al., 2018).

2.1.4 Results

2.1.4.1 Studies on Digital Nudging Elements to Promote Ecologically Sustainable Behavior

Overall, we explored 56 research studies in detail. Table 2.1-3 lists all selected works, presenting information on the context (see Figure 2.1-4), the behavioral target environment by the DNE(s) (i.e., physical, digital, or undefined), the type of choice influenced by the DNE(s) (i.e., binary, discrete, or continuous) and the DNE(s) type investigated (see Figure 2.1-5). More details of the studies can be found in the appendix (Table 2.1-4). Furthermore, the enumeration is used to depict the studies in the following framework (Section 2.1.4.2). Regarding the publication date, most studies were conducted in 2019 (13 studies), followed by 2020 (12 studies), emphasizing that the topic is up-to-date and relevant. One study date back to 2007 in the context of energy. The remaining 27 studies were conducted between 2010 and 2018 (see Table 2.1-3). Analyzing the studies' location, we found 75% of all investigations were conducted in Europe, with the majority (27 studies) originating from Germany, Austria, and Switzerland. All North American studies (10 studies) were conducted in the United States. Two studies were found from Asia, and one from Australia. When analyzing the ESB contexts of the studies, we found eight different contexts (see). Most studies (19) were found in the context of energy, followed by mobility (11) and food (8). Four studies were found in water, FMCG, durable goods, and donation contexts. Next to the explained contexts in Section 2.1.2.2 (energy, food, mobility, FMCG), we exemplify the remaining contexts identified in the literature review: water, durable goods, and donation. Studies in the context of water aim to nudge toward behaving more water conservatively. Examples include the study of Tiefenbeck et al. (2019) that analyzed (real-time) feedback in a smart meter display showing a polar bear on a melting ice floe to increase awareness of water consumption while showering to nudge toward consuming less. Studies in the context of durable goods aim to nudge customers toward choosing environmentally sustainable configurated TVs (Hankammer et al., 2021) or buying more sustainable cars instead of conventional ones (Folkvord et al., 2020). Lastly, studies in the context of donation aim to influence behavior toward increasing the willingness to donate to an environmental charity (Fanghella et al., 2019).

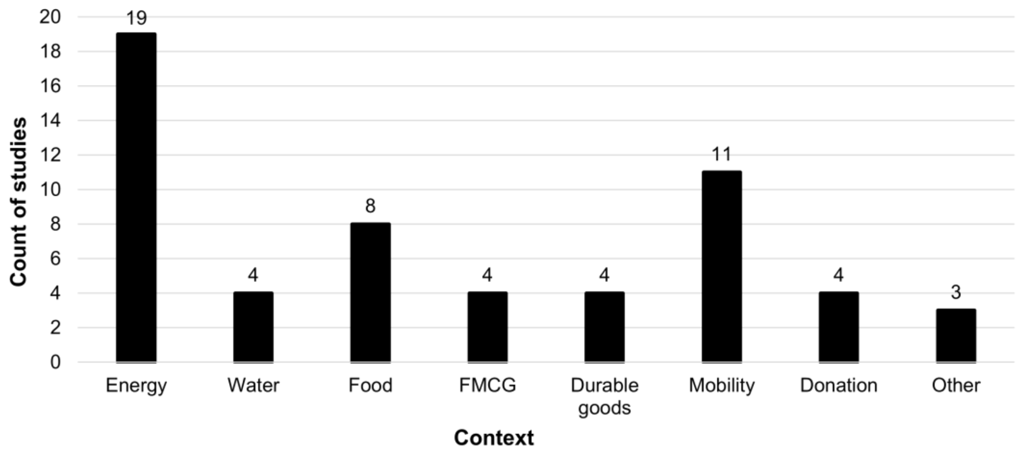

Figure 2.1-4 Studies per context

Regarding the DNEs under investigation, we found that *feedback* was used most often, followed by *default rules*, *priming* and *social comparison*. Since some of the selected studies examine several or combinations of DNEs, the corresponding studies were counted several times.

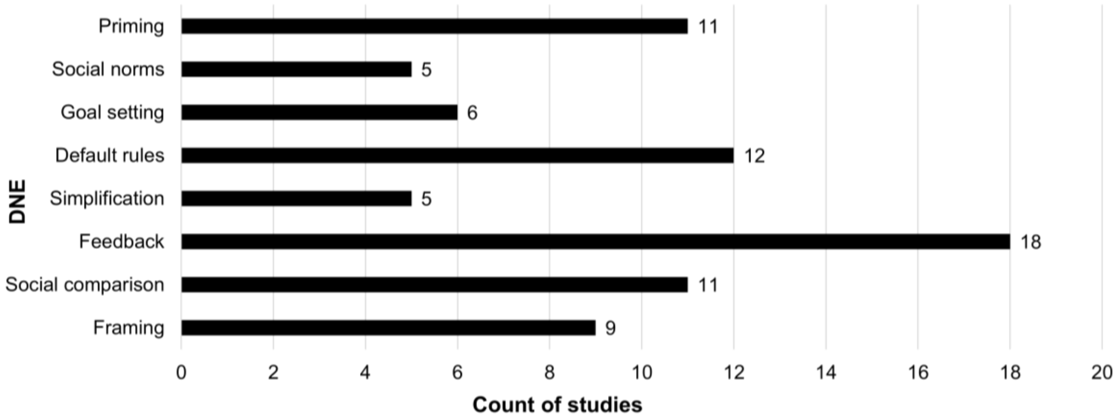

Figure 2.1-5 Studies per Digital Nudging Element type

ID	Study	Context	Behavioral target environment	Type of choice	DNE(s)
1	Abrahamse et al. (2007)	Energy	physical	continuous	Priming, goal setting, feedback
2	Amatulli et al. (2019)	FMCG, Donation	undefined	discrete	Framing
3	Anagnostopoulou et al. (2019)	Mobility	physical	discrete	Feedback
4	Antonides and Welvaarts (2020)	FMCG	digital	discrete	Default rules, framing
5	Arquit Niederberger and Champniss (2018)	Durable Goods	digital	discrete	Simplification
6	Bacon and Krpan (2018)	Food	digital	discrete	Framing
7	Berger et al. (2020)	Food	digital	discrete	Default rules, simplification, social norms
8	Brandsma and Blasch (2019)	Energy	physical	binary	Goal setting, feedback
9	Brent et al. (2015)	Water	physical	continuous	Social comparison
10	Buchanan and Russo (2019)	Energy	physical	discrete	Feedback
11	Cappa et al. (2020)	Energy	digital	continuous	Feedback
12	Codagnone et al. (2016)	Durable Goods	physical	discrete	Simplification
13	Andre Dahlinger et al. (2018)	Mobility	physical	continuous	Feedback
14	André Dahlinger et al. (2018)	Mobility	physical	continuous	Feedback
15	Degirmenci and Recker (2018)	Other	digital	continuous	Social comparison
16	Demarque et al. (2015)	Food	digital	discrete	Social norms
17	Doran et al. (2017)	Mobility	physical	discrete	Social comparison
18	Ebeling and Lotz (2015)	Energy	digital	binary	Default rules

ID	Study	Context	Behavioral target environment	Type of choice	DNE(s)
19	Emeakaroha et al. (2014)	Energy	physical	continuous	Feedback
20	Fanghella et al. (2019)	Donation	undefined	continuous	Priming, social norms
21	Folkvord et al. (2020)	Durable Goods	undefined	binary	Simplification
22	Franzen and Mader (2020)	Donation	undefined	discrete	Priming
23	Gajewski et al. (2021)	Other	digital	binary	Default rules, priming
24	Ghesla et al. (2020)	Energy	physical	continuous	Goal setting, framing
25	Graham et al. (2011)	Mobility	physical	continuous	Feedback
26	Graml et al. (2011)	Energy	physical	continuous	Social comparison
27	Grebitus et al. (2020)	FMCG	digital	discrete	Priming
28	Grinstein and Riefler (2015)	Food	undefined	discrete	Framing
29	Grønhøj and Thøgersen (2011)	Energy	physical	continuous	Feedback
30	Hankammer et al. (2021)	Durable Goods	digital	discrete	Default rules
31	Henkel et al. (2019)	Energy	digital	binary	Default rules, priming
32	Huber et al. (2019)	Mobility	physical	continuous	Priming
33	Kroll et al. (2019)	Energy	digital	discrete	Social norms, goal setting
34	Krpan and Houtsma (2020)	Food	undefined	discrete	Framing
35	Lembcke et al. (2020)	Food	digital	discrete	Feedback
36	Lieberoth et al. (2018)	Mobility	physical	continuous	Goal setting, social comparison
37	C.-M. Loock et al. (2011)	Energy	physical	continuous	Social comparison
38	C.-M. Loock et al. (2012)	Energy	physical	continuous	Social comparison
39	Claire-Michelle Loock et al. (2013)	Energy	physical	continuous	Goal setting
40	Momsen and Stoerk (2014)	Energy	digital	binary	Priming, framing, social comparison, default rules
41	Nilsson et al. (2014)	Energy	physical	continuous	Feedback
42	Prusaczyk et al. (2021)	Food	digital	discrete	Default rules, priming
43	Roozen et al. (2021)	FMCG	digital	discrete	Simplification, priming
44	Schrills et al. (2020)	Mobility	digital	discrete	Framing
45	Schultz et al. (2015)	Energy	physical	continuous	Feedback, social comparison
46	Stryja and Satzger (2019)	Mobility	digital	binary	Default rules, priming, feedback
47	Stryja et al. (2017)	Mobility	digital	discrete	Default rules, priming
48	Székely et al. (2016)	Donation	digital	binary	Default rules
49	Taube and Vetter (2019)	Food	digital	discrete	Default rules
50	Tiefenbeck et al. (2018)	Water	physical	continuous	Feedback
51	Tiefenbeck et al. (2019)	Water	physical	continuous	Feedback
52	Tussyadiah and Miller (2019)	Energy	physical	continuous	Social comparison
53	Wemyss et al. (2019)	Energy	physical	continuous	Social comparison
54	Willis et al. (2010)	Water	physical	continuous	Feedback
55	Wolf (2020)	Other	digital	discrete	Feedback
56	Wunsch et al. (2015)	Mobility	physical	continuous	Social comparison

Table 2.1-3 Results of the literature review

2.1.4.2 Context Digital Nudging Elements Framework

To conceptualize the results of our literature review, we developed the Context Digital Nudging Elements Framework (CDNEF) (see Figure 2.1-6 and Figure 2.1-7) that allowed us to analyze the current status quo on DNEs used to promote ESB in various contexts. This framework uses the building blocks (see Figure 2.1-3) and brings together the context and the accompanying decision situation with effective DNEs and design parameters. Thus, the core structure of the CDNEF is a matrix mapping a context to promote ESB, with DNE types being subject to studies investigating their effectiveness (see Figure 2.1-6).

We arranged the DNEs types (e.g., *default rules*) along the horizontal axis, juxtaposed with the contexts (e.g., *energy*) on the vertical axis (see Figure 2.1-6). Furthermore, the CDNEF includes the behavioral target environment in which the behavior change is desired (e.g., *digital*: the heating is regulated via the smartphone app or physical: users should physically turn down thermostats) (Lembcke et al., 2019). The CDNEF is supplemented by information about the decision options (i.e., building block: *type of choice*) presented in the study, which can have different characteristics (e.g., binary, discrete, or continuous) (Schneider et al., 2018). The results of the covered studies are thus presented in the spanning matrix of the framework corresponding with the IDs from Table 2.1-3. Here, the CDNEF provides information on whether a single stand-alone DNE (square symbol), multiple stand-alone DNEs (circle symbol), or a combination of DNEs (pentagon symbol) were investigated in the studies (i.e., the implementation strategy of DNE(s)). An example of a study that studied a single stand-alone DNE is the study with the ID 16 by Demarque et al. (2015) (see square symbol with ID 16 in Figure 2.1-7), who studied different configurations of the DNE social norms (weak vs. strong norms). Furthermore, we provide information on whether an efficacy with a significant effect was reported (see “Effect significance”, hence coloring in back, grey, or white in Figure 2.1-6 and Figure 2.1-7). Moreover, the framework offers additional information on the effectiveness (see “Further notes on the effect”, hence the use of *, or **, next to the ID in Figure 2.1-6 and Figure 2.1-7). In some studies, the effectiveness could only be confirmed for specific target groups (e.g., the * of the study with the ID 7 from Berger et al. (2020) relates to the fact that the DNE *simplification* only showed significant positive results for environmentally conscious costumers). We marked the study by Wemyss et al. (2019) with ** meaning that the positive effect on energy consumption measured by the use of the DNE *social comparison* (see Figure 2.1-7) declined over time.

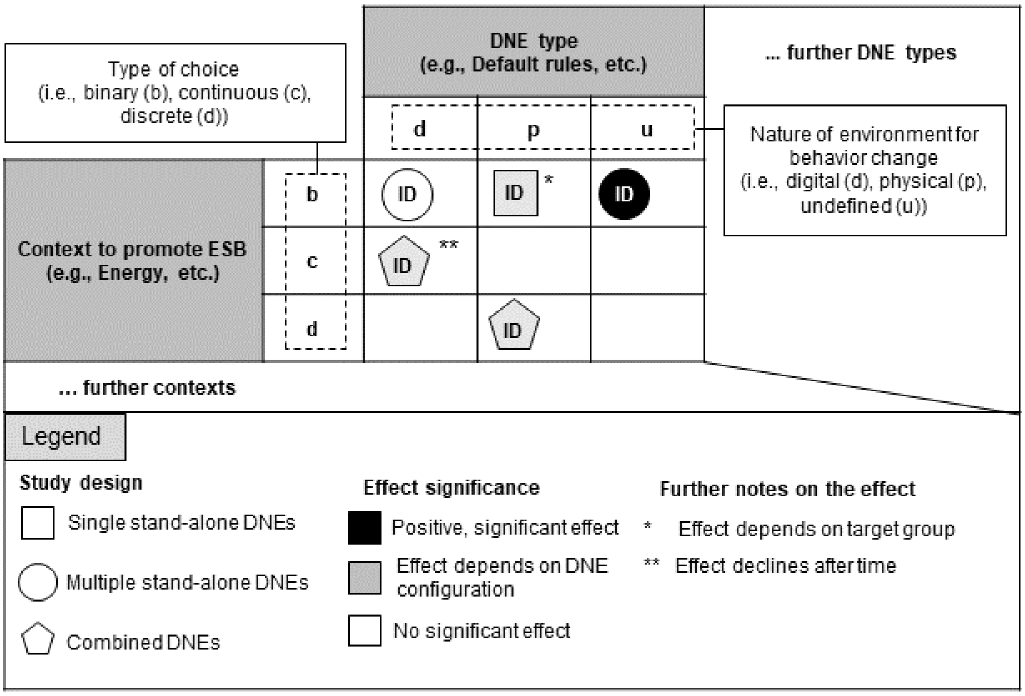

Figure 2.1-6 Simplified version of the Context Digital Nudging Element Framework (CDNEF) (ID refers to paper ID in Table 2.1-3)

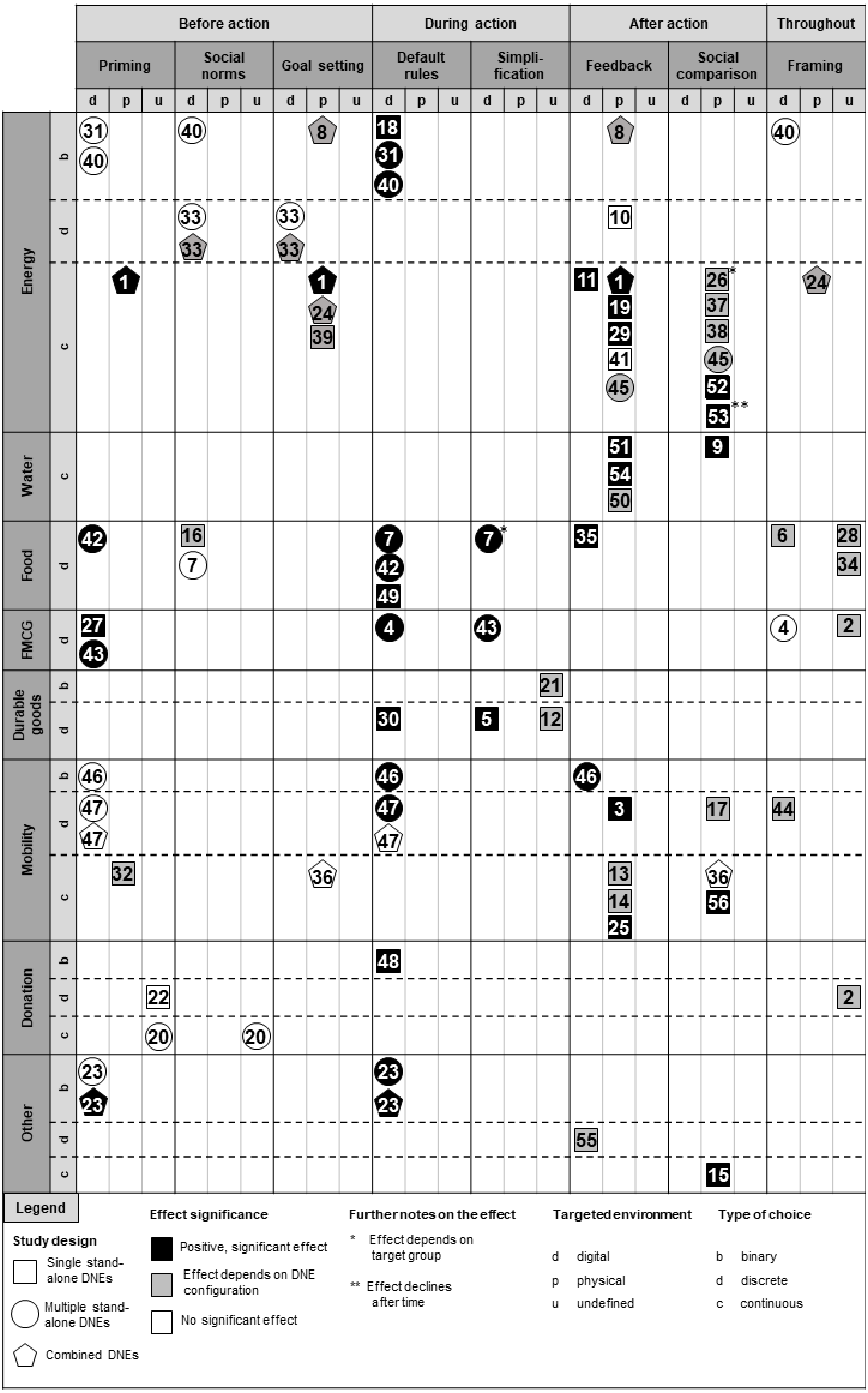

Figure 2.1-7 Context Digital Nudging Element Framework (CDNEF) (ID refers to paper ID in Table 2.1-3)

Regarding the DNEs implemented *before action* (Zimmermann et al., 2021), the DNE *priming* has been primarily investigated in a digital behavioral target environment (8 studies) but showed mixed results. The DNE showed promising results in the context of e-commerce (i.e., *food, FMCG, durable goods*), interestingly for discrete types of choices (Bacon & Krpan, 2018; Grebitus et al., 2020; Prusaczyk et al., 2021). *Priming* has been analyzed in combination (see legend for study design in the CDNEF in Figure 2.1-7) with *goal setting* and *default rules* (twice each). While in the context of *mobility*, the combination of *priming* and *default rules* (discrete choice) (Stryja et al., 2017), did not show a significant and positive result. Moreover, the combination with *goal setting* worked for a continuous choice study in the context of *energy* (Abrahamse et al., 2007) and in combination with *default rules* for a binary choice in the context of socially responsible investment (SRI) (Gajewski et al., 2021). Overall, *priming* seems promising for discrete choices in e-commerce but only with special configuration in the context of *mobility*, *donation*, and SRI (in context: *other*).

The DNE *social norms* was investigated in a few studies providing varying results depending on the context. Overall, *social norms* led to positive results either when combined with another DNE (*goal setting)* (Kroll et al., 2019) or when a specific configuration was analyzed (Demarque et al., 2015). We found studies examining *social norms* in a digital behavioral target environment with significant positive results only in the context of *food* (Demarque et al., 2015). We found no studies focusing on the contexts of *water, FMCG, durable goods, or mobility*. Fanghella et al. (2019) analyzed *social norms* in the context of *donation*, but without significant results.

Goal setting was mainly studied in the context of *energy* and all types of choices. However, we did not find studies analyzing *goal setting* in any other contexts besides Lieberoth et al. (2018), who analyzed the combination of *goal setting* and *social comparison* in *mobility*, without any significant results. Overall, *goal setting* has been investigated mainly in combination with other DNEs: *feedback* (Abrahamse et al., 2007; Brandsma & Blasch, 2019), *social norms* (Kroll et al., 2019), *social comparison* (Lieberoth et al., 2018), and *framing* (Ghesla et al., 2020).

Moving to the DNEs applied *during action*, the DNE *default rules* shows the most promising results and seems to best unleash the potential of the digital world as it has been exclusively investigated in a digital behavioral target environment. Interestingly, *default rules* showed no significant positive results when combined with *priming* in the context of *mobility* while when implementing it alone, it proved effective (Stryja et al., 2017).

While DNEs like *goal setting* or feedback received no attention in the e-commerce area (*food, FMCG, durable goods*), the DNE *simplification* has only been investigated in these contexts so far, mainly for discrete choices (Arquit Niederberger & Champniss, 2018; Berger et al., 2020; Codagnone et al., 2016; Roozen et al., 2021) and once for binary choices (Folkvord et al., 2020) with overall promising results. Three out of the five studies showed positive results. They were investigated in a digital behavioral target environment. At the same time, Folkvord et al. (2020) and Codagnone et al. (2016) reported positive results in an undefined behavioral target environment and dependent on the specific DNE configuration.

Considering DNE interventions *after the action*, *feedback* and *social comparison*, have mainly been investigated in a physical, behavioral target environment. Only *feedback* has been studied in a digital environment (Cappa et al., 2020; Lembcke et al., 2020; Stryja & Satzger, 2019; Wolf, 2020) with encouraging results. Still, most *feedback* studies in the *energy* context analyzed it in a physical environment (Abrahamse et al., 2007; Andre Dahlinger et al., 2018; Degirmenci & Recker, 2018; Emeakaroha et al., 2014) with varying results regarding the effectiveness of the DNE intervention. These DNEs were mainly analyzed in the context of *energy* (Brandsma & Blasch, 2019; Graml et al., 2011; Grønhøj & Thøgersen, 2011; Schultz et al., 2015), *water* (Brent et al., 2015; Tiefenbeck et al., 2018; Tiefenbeck et al., 2019) and *mobility* (André Dahlinger et al., 2018; Andre Dahlinger et al., 2018; Wunsch et al., 2015). Only Lembcke et al. (2019) analyzed the effectiveness of *feedback* in the context of *food*. Overall, for these DNEs, studies focused on the specific configuration (displayed in grey in the CDNEF) in order to be effective (e.g., testing descriptive vs. injunctive social comparison), which we further analyze in the following section.

Framing is the only DNE for which we did not find significant results without investigating specific configurations. Several studies in the context of *food* (Bacon & Krpan, 2018; Grinstein & Riefler, 2015; Krpan & Houtsma, 2020) analyzed different configurations of *framing* and found positive results for specific configurations (e.g., Krpan and Houtsma (2020) investigated different names for the menu heading of vegetarian food and found that all frames, including social, pro-environmental and neutral frames increase vegetarian food choices compared to the traditional vegetarian heading). Even though *framing* seems to be easily implemented into a digital behavioral target environment like *priming* or *default rules*, only four studies (Antonides & Welvaarts, 2020; Bacon & Krpan, 2018; Momsen & Stoerk, 2014; Schrills et al., 2020) investigated it. Hence we cannot support the promising results of Zimmermann et al. (2021).

Overall, the CDNEF provides a framework to analyze the current status of which DNEs were investigated in contexts to promote ESB. The provided perspective indicates that research, on the one hand, has provided many DNE studies for contexts that are directly linked to resource savings or lowered CO2 emissions, i.e., the contexts of *energy*, *water,* and *mobility*. While these contexts seem to receive a lot of attention from a DNE perspective, other contexts, on the other hand, a rarely investigated. Especially the e-commerce sector (e.g., *food*, *FMCG*, *durable goods)* offers few but promising studies.

2.1.5 Discussion

This study provides an analytical lens on the current state of research on digital nudging to promote environmentally sustainable behavior in various contexts (e.g., energy conservative behavior in the context of energy). Based on a structured literature review, we combine the research streams of context-driven studies and the conceptual works in the IS domain to derive a framework (CDNEF) as a holistic, systematized lens of the current state of research is proposed. This work contributes to research by deriving meta-inferences of context-specific DNEs and offering future research directions. For practitioners, the framework provides an applicable tool for effectively designing DNEs for a respective context. Therefore, this section discusses how to supplement existing design processes for DNEs and contribute to their applicability.

2.1.5.1 Implications for Research

In the following, we discuss this study's implications for research. First, this study allows drawing conclusions on context-specific effective designs of DNEs, i.e., by identifying meta-inferences of the current status quo of research on DNE to promote ESB (see Section 2.1.5.1.1). Second, we outline how the framework provides stimulating impulses for future research, i.e., by bringing up questions of underlying mechanisms influencing the effectiveness of DNEs in different contexts (see Section 2.1.5.1.2).

Overall, by covering an extensive range of representative papers, we assist fellow researchers by now quickly assessing the diverse configuration and application of DNEs to promote ESB with one paper rather than roam through numerous articles.

2.1.5.1.1 Design and Effectiveness of Digital Nudging Elements

The CDNEF allows identifying meta-inferences beyond the information provided within the individual studies. These meta-inferences also serve as a starting point toward providing cross-contextual and context-specific design principles for the different DNEs (Meske &

Amojo, 2020) by collecting studies that contain insights on designs of the specific DNE in each context. We, therefore, offer an in-depth understanding of how DNEs can promote ESB in different contexts.

Starting with the cross-contextual findings, we found *default rules* to be the most promising DNE to promote ESB in all contexts. Moreover, this DNE appears highly suited and straightforward to implement in the digital world, as it has been exclusively investigated in a digital behavioral target environment.

Existing literature reviews hitherto mostly used DNEs to structure their analysis. For example, Zimmermann et al. (2021) found mixed results in the DNE *priming*. Therefore, the analysis in this paper is extended to include the dimension of context. Looking at the studies in the specific matrix fields of the CDNEF in detail, we can observe context-specific design differences that might influence its effectiveness. For instance, in the context of *mobility*, studies found that pro-environmental *priming* is less effective (e.g., compared to messages containing cost-related information), akin to results in the *donation* context. But studies in the context of *food* and *FMCG* found pro-environmental *priming* messages to be effective (e.g., displaying "conscious collection" of the store before forwarding the costumer to the shopping page (Roozen et al., 2021)). Similar to the findings in the context of *energy*, where *priming* with environmental consequences of higher energy usage (e.g., global warming (Abrahamse et al., 2007)) increased ESB. We, therefore, shed light on the different configurations of *priming* in the contexts of *mobility* and *donation* compared to the contexts of *food*, *FMCG*, or *energy*. In the first two mentioned contexts, a pro-environmental argumentation in the form of priming messages is less effective. We assume that individual user attitudes and opinions bias these contexts (e.g., vehicles are associated with status).

Focusing on context-specific anomalies, *feedback* is predominantly used in the contexts of *energy* and *water*, targeting physical behavioral environments. *Feedback* as an intervention *after the action* helps quantify and grade the user's performance to optimize its cost-saving strategy. Currently, energy-related studies (except for Cappa et al. (2020)) have only investigated the effects of *feedback* and *social comparison* in a physical target environment. Especially with the rise of smart home applications, this opens an exciting area that could extend the promising results of *feedback* and *social comparison* into a digital behavioral target environment (similar to Kroll et al. (2019), who transferred *social norms* and *goal setting* into a digital target environment, i.e., a smart home app). Hence, when moving into the digital world, the insights allow controlling the necessary change directly toward ESB. For example, around home applications, users can receive direct *feedback* on the sustainability of their behavior (e.g., via digital thermostats). This promotes the development of sustainable behavior patterns in everyday life, which was impossible in a purely physical world. Thus, digitalization offers a valuable opportunity to directly promote ESB than to address convenience aspects solely.

As the CDNEF shows, the *configuration of social comparison* is crucial in the context of *energy* (see grey study IDs, e.g., Graml et al. (2011), C.-M. Loock et al. (2012)). The main findings of the studies applying *social comparison* are that a combination of injunctive and descriptive norms is effective for both low- and high-consumption consumers (Graml et al., 2011; C.-M. Loock et al., 2011; Schultz et al., 2015). For low-consumption consumers, using descriptive feedback (e.g., displaying its own consumption compared to the peer group on a bar chart) only proved to be counterproductive, causing ever higher consumption (Graml et al., 2011; C.-M. Loock et al., 2011; Schultz et al., 2015). In addition to these valuable insights, the remaining study found that the *social comparison* with consumers living in a closer region is more efficient than the comparison with people living further away (C.-M. Loock et al., 2012).

Focusing on further studies testing different configurations of DNEs, the CDNEF sheds light on studies investigating the effectiveness based on specific configurations of *framing* in the context of *food* (Bacon & Krpan, 2018; Grinstein & Riefler, 2015; Krpan & Houtsma, 2020). Bacon and Krpan (2018) found that the use of a separate vegetarian section in restaurant menus even backfired, especially for people that usually eat less meat. In contrast, the use of "chef's recommendation" or the more descriptive naming of the vegetarian meal increased the vegetarian food choice (e.g., "fresh seasonal risotto primavera" instead of "risotto primavera" (Bacon & Krpan, 2018, p. 14). This goes along with the findings of Krpan and Houtsma (2020), where all framing (i.e., environmental, social, and neutral frames) proved to be effective but the vegetarian one.

In the contexts of *food*, *FMCG*, or *durable goods*, the DNE *simplification* offers promising results for interventions *during action* in digital behavioral target environments. Online stores may offer a great opportunity, as labels on physical packaging are not as visible on a supermarket shelf as they are right next to the price or similarly relevant product information in an online store. Looking into the studies in the contexts of *food* and *FMCG*, the DNE simplification was designed focusing on pro-environmental messages (e.g., labels displaying a happy world (Berger et al., 2020)). In contrast, for *durable goods* (e.g., buying an electric car), the labels including financial savings (e.g., lower taxes (Folkvord et al., 2020)) act more efficiently than the focus on environmental impacts. In addition, online stores allow continuous interaction with the customer, which is not yet possible in physical stores. The constant communication with the user interface of the online stores enables, for example, individualized use of DNEs or continuous *feedback* on the customer's behavior. Real-time fe*edback*, for instance, has been investigated in the study of Lembcke et al. (2020) and found to increase the share of organic products for customers with weak purchasing intentions for organic goods. These efforts could be expanded by including feedback on environmental impacts. Additionally, the individualized communication through the user interface offers new opportunities to individualize DNEs for target groups. As such, the study by Berger et al. (2020) considered individual food choice motives and consumption patterns and found that *simplification* (i.e., a label displaying a happy world for sustainable products) is effective for environmentally conscious consumers. This emphasizes the potential to provide individualized choice environments based on personal characteristics and preferences enabled in digital decision environments.

The CDNEF also points out the fields in the matrix in which some studies did not effectively test nudging elements (see white study IDs in Figure 2.1-7). However, a particular configuration proved effective (see grey study IDs in Figure 2.1-7). Starting with *social norms* in the context of food while Berger et al. (2020) did not find positive results for a more unspecific social norm (i.e., "More and more customers choose this sustainable product" (Berger, page 6), Demarque et al. (2015) found that strong social norms (i.e., "90% of previous participants purchased some ecological products" (Demarque et al., 2015, p. 171)) function well. Additionally, the field of *priming* in the context of mobility points out the study undertaken by Huber et al. (2019), who found that cost-related messages function better than pro-environmental measures displayed, while the pro-environmental measure (i.e., "electricity from renewable energy sources to be used, thus protecting the environment" (Huber et al., 2019, p. 7)) did not lead to any effect. In contrast, the studies that did not find positive effects of priming in the context of mobility (Stryja et al., 2017; Stryja & Satzger, 2019) used pro-environmental messages (e.g., promoting eco-friendliness of the electric car (Stryja et al., 2017)). We might conclude that pro-environmental priming is less effective in contrast to cost-related priming in the context of mobility.

2.1.5.1.2 Impulses for Future Research Directions

Next, we shed light on possible future research directions by (1) hypothesizing underlying mechanisms that require further study to verify and (2) by pointing out white spots and missing research.

First, the CDNEF stimulates hypothesizing on possible underlying mechanisms across contexts. Overall, our analysis indicates that the utilization and effectiveness of DNEs enormously vary along with the ESB contexts, which might be due to underlying mechanisms concerning possible trade-offs between cost and ESB. We suggest a relationship between the contextual constraints on the ESB decision: When ESB is associated with reduced consumption, for example, in contexts such as *water* or *energy*, the users attribute an ESB choice with lower costs (e.g., saving energy). Conclusively, this means that in consumption-related contexts, there is a congruence between individuals' economic motivations (i.e., saving costs) and the ESB. This influences the utilization and effectiveness of DNEs. For example, *feedback* and *social comparison* were widely used in *consumption-related* contexts (i.e., *energy* and *water*) in which the DNEs aim to reduce the consumption of energy or water. We hypothesize that the effectiveness of the DNEs in these consumption-related contexts triggers similar motivations of the users, which is saving costs. Examples include nudging toward environmentally sustainable programs for household applicants like washing machines that consume less energy than different programs (Kroll et al., 2019) or nudging toward consuming less electricity by providing feedback in a smart home display (Schultz et al., 2015).

In contrast, in contexts such as *food* or *FMCG*, ESB is rather associated with higher costs. In those contexts, choosing a more environmentally sustainable alternative might refer to higher costs (e.g., organic and regional products) or incurring perceived costs from the targeted waiving of certain products (e.g., fruit is not in season). We, therefore, consider *shopping-related* contexts instead to present trade-off situations between costs and ESB for consumers. Examples include nudging toward vegetarian dishes on restaurant menus (Krpan & Houtsma, 2020) or environmentally sustainable instead of conventional t-shirts in an online store (Roozen et al., 2021). Trade-offs between costs and ESB must not only be financial but also due to missing flexibility and convenience. We suspect this underlying mechanism in the context of *mobility*. We argue that behaving environmentally sustainable in the context of *mobility* might not only increase financial costs but also costs in terms of loss in flexibility (e.g., due to limited ranges of electric vehicles or fixed train schedules). More environmentally sustainable options seem less attractive due to missing availability or high prices.

These findings offer important insight when selecting and designing DNEs for the underlying context (see Section 2.1.5.2 Practical Implication). Thus, in contexts where ESB is directly linked with lower individual consumption, such as *energy* or *water*, a primary individual motivation is triggered (e.g., saving money). In contrast, other contexts pursue ESB goals that are more intangible and do not refer to short-term, personal benefits (e.g., less environmental pollution during production in a distant country). Here, additional motivation toward ESB is needed. Accordingly, we derive the first call for further research to verify the mechanism and its influence on the effectiveness of the DNEs comprehensively. For instance, the context of *energy* has been intensively researched, while knowledge on DNEs in the context of *water* is still lacking. We hypothesize similar effectiveness of the DNEs in these consumption-related contexts (i.e., congruence of cost and ESB), which needs further research to verify.

Along with this finding, we see a clear relation to gamification literature, which is intensely concerned with creating motivation for the desired behavior (Deterding et al., 2011). Gamification can be particularly promising for those contexts that do not create inherent incentives through direct savings (i.e., *mobility* or shopping-related contexts, e.g., *food*, *durable goods, FMCG*). Interestingly, we observed that the element *goal setting*, which is also known as a gamification element (Hsu et al., 2013) has only been studied in the context of *energy*. The investigation of *goal setting* in the contexts where additional motivation is needed (i.e., mobility or shopping-related context) is missing. We see a promising use case for the DNE goal setting, which should be investigated in the future.

Second, we call for future research in several areas. (A) Future research should investigate DNEs before the action (*priming*, *social norms*, *goal setting*) and throughout the action (*framing*) in the context of durable goods. We hypothesize that decisions in these contexts are rather long-term decisions (e.g., buying a new car (Folkvord et al., 2020)). While currently, only DNEs during action (*default rules*, *simplifications*) were studied, DNEs, especially before and throughout the action, might be effective in influencing long-term decisions. (B) DNEs before action have not been intensively studied in the context of *mobility*. Long-term planning is becoming more important to enable behavioral changes in terms of mobility choices. Short-term planning reduces the number of options (e.g., unavailability of car sharing or expensive tickets for public transportation). For example, planning a trip in advance, one can decide between taking the train or renting an electric car, while in this situation, these options seem less attractive due to missing availability or increased prices. (C) Going along with call B, we see a promising application of the DNE *goal setting* in contexts of mobility or shopping-related contexts, where additional motivation is needed to behave ESB, as ESB in these contexts often does not go along with cost savings (e.g., in energy or water contexts). We argue that the impact of enhanced motivation through gamification (i.e., the DNE goal setting) could be even higher in contexts without a financial incentive. (D) Especially in the shopping-related contexts, little research exists on the effectiveness of DNEs after action (*feedback, social comparison*). Digitalization offers an interesting chance to implement these nudges (in a digital target environment), for instance, by providing feedback on the shopping cart regarding its environmental impact or in comparison with its peer group (*social comparison*). (E) By including the differences in the behavioral target environment in the CDNEF (Lembcke et al., 2019), future research can focus on better understanding the differences between the effectiveness of DNEs in a digital vs. physical world (Meske & Amojo, 2020). While currently, studies in the context of energy and water consumption mainly focused on physical targeted environments, through the rise of smart home technology, these insights should be transferred and tested in a digital target environment (similar to Kroll et al. (2019) who tested *social norms* and *goal setting* in a smart home app (digital targeted environment)). (F) With the increasing relevance of ESB, it seems appropriate to investigate further contexts with ESB relevance (e.g., waste management), which have not yet been the focus of previous DNE research. (G) For areas in which several studies have been performed (e.g., feedback in the context of energy), future research can derive design principles for the context-specific DNE, as pointed out above, or perform a meta-analysis to confirm and combine the hypothesis concerning effectiveness in this study.

2.1.5.2 Practical Implications

Aside the research implications, this study also offers practical value. Utility companies, supermarkets, mobility providers, and many more organizations and politics face the urgent need to increase ESB. However, while DNEs can be an effective way to promote ESB, for many practitioners, the systematic application of DNEs still poses challenges (Mirsch et al., 2018). (1) We first assist practitioners by identifying relevant, structured primary studies when developing DNEs, according to Mirsch et al. (2018) (Figure 2.1-1). (2) Second, by summarizing existing knowledge and deriving meta-inferences (see Section 2.1.5.1.1), we make the previously distributed knowledge useable for practitioners.

(1) As pointed out by Meske and Amojo (2020), a key challenge is to translate existing knowledge on DNEs into practical application. This study offers a starting point to meet this challenge. The CDNEF complements existing approaches that aim to structure the development of DNEs, such as the process according to Mirsch et al. (2018) (see Figure 2.1-1). Our

framework assists in performing the key activities of the process by summarizing and pointing out relevant primary studies. For example, in phase 1 (“Digital Nudge Context”), practitioners must analyze the decision-making process. Our CDNEF supports the analysis of the DNE context by providing insights on intended user behavior (i.e., physical or digital) and the decision-making process (i.e., binary, discrete, or continuous). We assist the definition of the intended behavior by shedding light on possible underlying mechanisms (see Section 2.1.5.1.2) between the contexts (e.g., shopping vs. consumption-related context). In phase 2 (“Digital Nudge Ideation and Design”), the CDNEF allows identifying primary studies in the relevant matrix field of the framework. Thereby, it offers insights into concrete design and configuration options for DNEs (e.g., the most effective level of social norms in the context of food (Demarque et al., 2015)) as well as possible combinations and configurations of single DNEs. For the third phase of the process (“Digital Nudge Implementation”) the CDNEF and the contained studies provide a stimulus on how the DNEs can be implemented (e.g., through examples of implementation in the identified studies). However, the central added value of the CDNEF lies in the aggregation of knowledge about the expected effectiveness of DNEs in specific contexts to bring about the desired behavior change (phase 4 “Digital Nudge Evaluation”). Within this phase, the CDNEF can assist in selecting particularly effective DNEs for a given target. Thus, the effectiveness of the DNE design process can be supported by leveraging existing knowledge and pointing out relevant primary studies.

(2) By collecting and summarizing distributed knowledge (see Section 2.1.5.1.1)), we provide insights to DNEs that function robustly independent of the underlying context and configuration (e.g., default rules that seem to be effective when implemented online to promote ESB independent of the underlying context). Also, we provide insights on the differences in the effectiveness of DNEs dependent on the underlying context (e.g., the configuration of *priming* messages in the context of *mobility* or *donation* compared to *energy*, *food*, or *FMCG*). Therefore, we provide practitioners with a guide to better assess which DNEs and design/configuration are most promising for the particular context in the decision-making situation.

2.1.5.3 Limitations and Outlook

Like any research paper, our study is subject to limitations, showing further potential for future research. First, the scope of our work is set on ESB, which is undoubtedly an urgent area that requires action. However, sustainability is a far-reaching endeavor, and thus, the limited context of this work encourages avenues for further research: First, the CDNEF is so far limited to contexts related to DNE research. While this reflects the current scope of this area and covers a wide area of essential decisions, this scope must not be defined as exhaustive and leaves room for further research. Second, on an even more abstract level, the research could even be extended to other aspects of sustainability, such as social aspects.

Second, the framework we developed contributes to research as it offers an analytics lens on the field of ESB by bringing together DNEs and associated contexts. However, since ESB is a rapidly changing field of research, it may be worthwhile to re-run this study in the future to keep up to date with the research progress. As policy intervention increases, there could be significant changes in the pricing structure of products that support ESB. For example, increased CO2 pricing could make ESB products a financially attractive alternative in the long run (Tang et al., 2021).

2.1.6 Conclusion

A change in human behavior is urgently needed to counteract the current environmental deterioration and global warming. With the diffusion of digitalization into our lives, decisions are increasingly made in a digital environment. Aside from removing and limiting choices by legislation or fiscal procedures, digital nudging is a promising technique for influencing human behavior in an environmentally friendly way.

However, the application of DNEs can produce counteractive results if implemented inconsiderately. Due to the highly fragmented structure of existing literature in this research area, we conducted a literature review to identify relevant studies. We carefully analyzed 56 selected studies and developed a framework (CDNEF) that connects the research streams of context-driven studies and the conceptual works in the IS domain. It structures the studies by the contexts in which ESB should be promoted, and the DNEs examined. The findings of the studies (e.g., the effectiveness of DNEs) are categorized in the resulting matrix. Additionally, we include the differences in the studies, meaning if they investigated single stand-alone DNEs, multiple stand-alone DNEs, or a combination of DNEs, the behavioral target environment (digital vs. analog), and the type of choice (binary, discrete, and continuous) which is influenced.

The CDNEF aims to structure the highly fragmented research area of DNEs to promote ESB by using an IS lens. With the increasing relevance of digital decision environments, DNEs gain a vital role in promoting ESB in various contexts. Thus, we aim to bridge the gap between research-driven from the context domain and works focusing on DNEs from other fields (e.g., IS, psychology). The CDNEF contributes to research by calling for grant theory to verify the expected underlying mechanism that influences the effectiveness of DNE in specific contexts.

Next, this study pinpoints research gaps and thus offers future research opportunities. Also, we derive meta-inferences of context-specific DNEs, that are not revealed by examining individual studies focusing on specific DNEs in their underlying context. Moreover, the CDNEF is of practical value as it strives to leverage DNEs in the context of IS development as we assist in selecting and designing effective DNEs in a specific context and the associated decision type.

Overall, DNEs present a promising approach to leveraging digital technologies and counteracting the increasing human-induced environmental deterioration. The presented work aims to stimulate the utilization of DNEs suitable to the specific context and decision situation by giving a digital push with a real impact on our environment.

2.1.7 References

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2007). The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of Environmental Psychology, 27(4),* 265–276. https://doi.org/10.1016/j.jenvp.2007.08.002

AIS eLibrary. (2021). *About the Association for Information Systems.* https://aisel.aisnet.org/about.html

Amatulli, C., Angelis, M. de, Peluso, A. M., Soscia, I., & Guido, G. (2019). The effect of negative message framing on green consumption: An investigation of the role of shame. *Journal of Business Ethics, 157(4),* 1111–1132. https://doi.org/10.1007/s10551-017-3644-x

Anagnostopoulou, E., Magoutas, B., Bothos, E., & Mentzas, G. (2019). Persuasive technologies for sustainable smart cities: The case of urban mobility. In *Companion Proceedings of the 2019 World Wide Web Conference.*

Antonides, G., & Welvaarts, M. (2020). Effects of default option and lateral presentation on consumer choice of the sustainable option in an online choice task. *Sustainability, 12*(13), 5484. https://doi.org/10.3390/su12135484

Arquit Niederberger, A., & Champniss, G. (2018). Flip sides of the same coin? A simple efficiency score versus energy bill savings information to drive consumers to choose more energy-efficient products. *Energy Efficiency, 11(7),* 1657–1671. https://doi.org/10.1007/s12053-017-9542-3

Bacon, L., & Krpan, D. (2018). (Not) eating for the environment: The impact of restaurant menu design on vegetarian food choice. *Appetite, 125,* 190–200. https://doi.org/10.1016/j.appet.2018.02.006

Benartzi, S., & Lehrer, J. (2015). *The Smarter Screen: Surprising Ways to Influence and Improve Online Behavior.* Portfolio/Penguin. https://doi.org/10.1177/09567976177025

Berger, M., Müller, C., & Nüske, N. (2020). Digital nudging in online grocery stores – Towards ecologically sustainable nutrition. In *Proceedings of the 41st International Conference on Information Systems (ICIS).*

Brandsma, J. S., & Blasch, J. E. (2019). One for all? – The impact of different types of energy feedback and goal setting on individuals' motivation to conserve electricity. *Energy Policy, 135,* 110992. https://doi.org/10.1016/j.enpol.2019.110992

Brent, D. A., Cook, J. H., & Olsen, S. (2015). Social comparisons, household water use, and participation in utility conservation programs: Evidence from three randomized trials. *Journal of the Association of Environmental and Resource Economists.*

Buchanan, K., & Russo, R. (2019). Money doesn't matter! Householders' intentions to reduce standby power are unaffected by personalised pecuniary feedback. *PLOS ONE, 14(10),* e0223727. https://doi.org/10.1371/journal.pone.0223727

Calculli, C., D'Uggento, A. M., Labarile, A., & Ribecco, N. (2021). Evaluating people's awareness about climate changes and environmental issues: A case study. *Journal of Cleaner Production, 324,* 129244. https://doi.org/10.1016/j.jclepro.2021.129244

Cappa, F., Rosso, F., Giustiniano, L., & Porfiri, M. (2020). Nudging and citizen science: The effectiveness of feedback in energy-demand management. *Journal of Environmental Management, 269*. https://doi.org/10.101/j.jenvman.2020.110759

Chapman, L. (2007). Transport and climate change: a review. *Journal of Transport Geography, 15(5),* 354–367. https://doi.org/10.1016/j.jtrangeo.2006.11.008

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology, 58(6),* 1002–1014.

Clark, M., & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters, 12(6),* 64016.

Codagnone, C., Veltri, G. A., Bogliacino, F., Lupiáñez-Villanueva, F., Gaskell, G., Ivchenko, A., Ortoleva, P., & Mureddu, F. (2016). Labels as nudges? An experimental study of car eco-labels, *Economia Politica 33(3),* 403–432. https://doi.org/10.1007/s40888-016-0042-2

Dahlinger, A [Andre], Tiefenbeck, V., Ryder, B., Gahr, B., Fleisch, E [Elgar], & Wortmann, F. (2018). The impact of numerical vs. symbolic eco-driving feedback on fuel consumption – A randomized control field trial. *Transportation Research Part D-Transport and Environment, 65,* 375–386. https://doi.org/10.1016/j.trd.2018.09.013

Dahlinger, A [André], Wortmann, F., Ryder, B., & Gahr, B. (2018). The Impact of Abstract vs. Concrete Feedback Design on Behavior Insights from a Large Eco-Driving Field Experiment. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, New York, NY, USA.*

Dedrick, J. (2010). Green IS: Concepts and Issues for Information Systems Research. *Communications of the Association for Information Systems, 27.* https://doi.org/10.17705/1CAIS.02711

Degirmenci, K., & Recker, J. (2018). Creating environmental sensemaking through green is: An experimental study on eco-nudging paper printing behavior. In *Proceedings of the Twenty-fourth Americas Conference on Information Systems (ICIS).*

Demarque, C., Charalambides, L., Hilton, D. J., & Waroquier, L. (2015). Nudging sustainable consumption: The use of descriptive norms to promote a minority behavior in a realistic online shopping environment. *Journal of Environmental Psychology, 43,* 166–174. https://doi.org/10.1016/j.jenvp.2015.06.008

Doran, R., Hanss, D., & Øgaard, T. (2017). Can social comparison feedback affect indicators of eco-friendly travel choices? Insights from two online experiments. *Sustainability, 9(2),* 196. https://doi.org/10.3390/su9020196

Ebeling, F., & Lotz, S. (2015). Domestic uptake of green energy promoted by opt-out tariffs. *Nature Climate Change, 5(9),* 868–871. https://doi.org/10.1038/nclimate2681

Elsevier. (2021). *About Scopus - Abstract and Citation Database | Elsevier.* https://www.elsevier.com/solutions/scopus

Emeakaroha, A., Ang, C. S., Yan, Y., & Hopthrow, T. (2014). A persuasive feedback support system for energy conservation and carbon emission reduction in campus residential buildings. *Energy and Buildings, 82,* 719–732. https://doi.org/10.1016/j.enbuild.2014.07.071

Fanghella, V., d'Adda, G., & Tavoni, M. (2019). On the use of nudges to affect spillovers in environmental behaviors. *Frontiers in Psychology, 10.* https://doi.org/10.3389/fpsyg.2019.00061

Fennis, B. M., Gineikiene, J., Barauskaite, D., & van Koningsbruggen, G. M. (2020). Nudging health: Scarcity cues boost healthy consumption among fast rather than slow strategists (and abundance cues do the opposite). *Food Quality and Preference, 85.* https://doi.org/10.1016/j.foodqual.2020.103967

Ferrari, L., Cavaliere, A., Marchi, E. de, & Banterle, A. (2019). Can nudging improve the environmental impact of food supply chain? A systematic review. *Trends in Food Science & Technology, 91,* 184–192. https://doi.org/10.1016/j.tifs.2019.07.004

Fettke, P. (2006). State-of-the-Art des State-of-the-Art. *Wirtschaftsinformatik, 48(4),* 257–266.

Folkvord, F., Veltri, G. A., Lupiáñez-Villanueva, F., Tornese, P., Codagnone, C., & Gaskell, G. (2020). The effects of ecolabels on environmentally- and health-friendly cars: an online survey and two experimental studies. *The International Journal of Life Cycle Assessment. 25,* 883–899. https://doi.org/10.1007/s11367-019-01644-4

Franzen, A., & Mader, S. (2020). Can Climate Skeptics Be Convinced? The Effect of Nature Videos on Environmental Concern, 12(7). https://doi.org/10.3390/su12072972

Gajewski, J.-F., Heimann, M., & Meunier, L. (2021). Nudges in SRI: The power of the default option. *Journal of Business Ethics, 177,* 547–566. https://doi.org/10.1007/s10551-020-04731-x

Ghesla, C., Grieder, M., Schmitz, J., & Stadelmann, M. (2020). Pro-environmental incentives and loss aversion: A field experiment on electricity saving behavior. *Energy Policy, 137,* 111131. https://doi.org/10.1016/j.enpol.2019.111131

Glaser, B. G., & Strauss, A. L. (2017). The discovery of grounded theory: Strategies for qualitative research. Routledge. https://www.taylorfrancis.com/books/9780203793206 https://doi.org/10.4324/9780203793206

Graham, J., Koo, M., & Wilson, T. D. (2011). Conserving Energy by Inducing People to Drive Less. Journal of Applied Social Psychology, 41(1), 106–118.

Graml, T., Loock, C.-M, Baeriswyl, M., & Staake, T (2011). Improving residential energy consumption at a large using persuasive systems. In *Proceedings of the 19th European Conference on Information Systems (ECIS),* Finland.

Grebitus, C., Roscoe, R. D., van Loo, E. J., & Kula, I. (2020). Sustainable bottled water: How nudging and Internet Search affect consumers' choices. *Journal of Cleaner Production, 267(10).* https://doi.org/10.1016/j.jclepro.2020.121930

Grinstein, A., & Riefler, P. (2015). Citizens of the (green) world? Cosmopolitan orientation and sustainability. *Journal of International Business Studies, 46(6),* 694–714. https://doi.org/10.1057/jibs.2015.1

Grønhøj, A., & Thøgersen, J. (2011). Feedback on household electricity consumption: Learning and social influence processes. *International Journal of Consumer Studies, 35(2),* 138–145. https://doi.org/10.1111/j.1470-6431.2010.00967.x

Gusenbauer, M., & Haddaway, N. R. (2020). Which academic search systems are suitable for systematic reviews or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other resources. *Research Synthesis Methods, 11(2),* 181–217. https://doi.org/10.1002/jrsm.1378

Hagberg, J., Sundstrom, M., & Egels-Zandén, N. (2016). The digitalization of retailing: an exploratory framework. *International Journal of Retail & Distribution Management, 44(7),* 694–712. https://doi.org/10.1108/IJRDM-09-2015-0140

Hankammer, S., Kleer, R., & Piller, F. T. (2021). Sustainability nudges in the context of customer co-design for consumer electronics. *Journal of Business Economics, 91(6),* 897–933. https://doi.org/10.1007/s11573-020-01020-x

Hansen, P., & Jespersen, A. (2013). Nudge and the manipulation of choice: A framework for the responsible use of the nudge approach to behaviour change in public policy. *European Journal of Risk Regulation*, *1*, 3–28.

Hausmann, D., & Welch, B. (2010). Debate: To nudge or not to nudge. *The Journal of Political Philosophy, 18*(1), 123–136. https://doi.org/10.1111/j.1467-9760.2009.00351.x

Henkel, C., Seidler, A.-R., Kranz, J., & Fiedler, M. (2019). How to nudge pro-environmental behaviour: An experimental study. In *Proceedings of the 27th European Conference on Information Systems (ECIS)*

Hsu, S. H., Chang, J.-W., & Lee, C.-C. (2013). Designing attractive gamification features for collaborative storytelling websites. Cyberpsychology, *Behavior and Social Networking, 16(6),* 428–435.

Huber, J., Jung, D., Schaule, E., & Weinhardt, C. (2019). Goal framing in smart charging - Increasing BEV users' charging flexibility with digital nudges. In *Proceedings of the 27th European Conference on Information (ECIS).*

Hummel, D., & Maedche, A. (2019). How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. *Journal of Behavioral and Experimental Economics, 80,* 47–58. https://doi.org/10.1016/j.socec.2019.03.005

IPCC. (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change: [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)].

Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., & Hertwich, E. G. (2016). Environmental Impact Assessment of Household Consumption. *Journal of Industrial Ecology*, *20(3),* 526–536. https://doi.org/10.1111/jiec.12371

Kahneman, D [Daniel]. (2011). Thinking, fast and slow. Penguin Books.

Karlin, B., Zinger, J. F., & Ford, R. (2015). The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin, 141(6),* 1205–1227. https://doi.org/10.1037/a0039650

Kormos, C., Gifford, R., & Brown, E. (2015). The Influence of Descriptive Social Norm Information on Sustainable Transportation Behavior. *Environment and Behavior, 47(5),* 479–501. https://doi.org/10.1177/0013916513520416

Kroll, T., Paukstadt, U., Kreidermann, K., & Mirbabaie, M. (2019). Nudging people to save energy in smart homes with social norms and self-commitment. In *Proceedings of the 27th European Conference on Information Systems (ECIS).*

Krpan, D., & Houtsma, N. (2020). To veg or not to veg? The impact of framing on vegetarian food choice. *Journal of Environmental Psychology, 67.* https://doi.org/10.1016/j.jenvp.2020.101391

Larsen, K. R., Hovorka, D., Dennis, A., & West, J. D. (2019). Understanding the elephant: The discourse approach to boundary identification and corpus construction for theory review articles. *Journal of the Association for Information Systems, 20*(7), 887-927. https://doi.org/ 10.17705/1jais.00556

Leahy, R. (2011). Relationships in fast moving consumer goods markets. *European Journal of Marketing, 45(4),* 651–672. https://doi.org/10.1108/03090561111111370

Lehner, M., Mont, O., & Heiskanen, E. (2016). Nudging – A promising tool for sustainable consumption behaviour? *Journal of Cleaner Production, 134,* 166–177. https://doi.org/10.1016/j.jclepro.2015.11.086

Lembcke, T.-B., Engelbrecht, N., Brendel, A. B., Herrenkind, B., & Kolbe, L. M. (2019). Towards a unified understanding of digital nudging by addressing its analog roots. In *Proceedings of the 23rd Pacific Asia Conference 2019*.

Lembcke, T.-B., Willnat, M., Engelbrecht, N., & Lichtenberg, S. (2020). Behavioral design in online supermarkets: How virtual shopping cart functions impact sustainable consumption. In *Proceedings of the Americas Conference on Information Systems.*

Li, Z., Loveday, D., & Demian, P. (2021). Nudging and usage of thermal comfort-related systems. *Energy and Buildings, 252,* 111480. https://doi.org/10.1016/j.enbuild.2021.111480

Lieberoth, A., Holm Jensen, N., & Bredahl, T. (2018). Selective psychological effects of nudging, gamification and rational information in converting commuters from cars to buses: A controlled field experiment. *Transportation Research Part PART F-Traffic Psychology and Behavior, 55,* 246–261. https://doi.org/10.1016/j.trf.2018.02.016

Liu, Z. (2005). Reading behavior in the digital environment. *Journal of Documentation, 61(6),* 700–712. https://doi.org/10.1108/00220410510632040

Loock, C.-M., Landwehr, J., Staake, T., Fleisch, E., & Pentland, A. (2012). The influence of reference frame and population density on the effectiveness of social normative feedback on electricity consumption. In *Proceedings of the 33rd International Conference on Information Systems (ICIS).*

Loock, C.-M [C.-M.], Staake, T [T.], & Landwehr, J. (2011). Green IS Design and Energy Conservation: An Empirical Investigation of Social Normative Feedback. In *Proceedings of the 32nd International Conference on Information Systems (ICIS).*

Loock, C.-M., Staake, T., & Thiesse, F. (2013). Motivating energy-efficient behavior with green IS: An investigation of goal setting and the role of defaults. *MIS Quarterly, 37(4),* 1313–1332.

Meske, C., & Amojo, I. (2020). Status Quo, Critical Reflection, and the Road Ahead of Digital Nudging in Information Systems Research: A Discussion with Markus Weinmann and Alexey Voinov. *Communications of the Association for Information Systems, 46,* 402–420. https://doi.org/10.17705/1CAIS.04617

Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. In *Proceedings of the 13th Conference on Wirtschaftsinformatik (WI13).*

Mirsch, T., Lehrer, C., & Jung, R. (2018). Making Digital Nudging Applicable: The Digital Nudge Design Method. In *Proceedings of the 39th International Conference on Information Systems (ICIS)*

Momsen, K., & Stoerk, T. (2014). From intention to action: Can nudges help consumers to choose renewable energy? *Energy Policy, 74,* 376–382. https://doi.org/10.1016/j.enpol.2014.07.008

Nilsson, A., Bergstad, C. J., Thuvander, L., Andersson, D., Andersson, K., & Meiling, P. (2014). Effects of continuous feedback on households' electricity consumption: Potentials and barriers. *Applied Energy, 122,* 17–23. https://doi.org/10.1016/j.apenergy.2014.01.060

Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-analysis of proenvironmental behavior experiments. *Environment and Behavior, 44(2),* 257–299. https://doi.org/10.1177/0013916511402673

Prusaczyk, E., Earle, M., & Hodson, G. (2021). A brief nudge or education intervention delivered online can increase willingness to order a beef-mushroom burger. *Food Quality and Preference, 87,* 104045. https://doi.org/10.1016/j.foodqual.2020.104045

Reisch, L. A., Sunstein, C. R., Andor, M. A., Doebbe, F. C., Meier, J., & Haddaway, N. R. (2021). Mitigating climate change via food consumption and food waste: A systematic map of behavioral interventions. *Journal of Cleaner Production, 279,* 123717. https://doi.org/10.1016/j.jclepro.2020.123717

Rennings, K. (2000). Redefining innovation — eco-innovation research and the contribution from ecological economics. *Ecological Economics, 32(2),* 319–332. https://doi.org/10.1016/S0921-8009(99)00112-3

Roozen, I., Raedts, M., & Meijburg, L. (2021). Do verbal and visual nudges influence consumers' choice for sustainable fashion? *Journal of Global Fashion Marketing, 12(4),* 327–342. https://doi.org/10.1080/20932685.2021.1930096

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Climatic Change, 125(2),* 179–192.

Schaer, A., & Stanoevska-Slabeva, K. (2019). Application of digital nudging in customer journeys – A systematic literature review. In *Proceedings of the 25th Americas Conference on Information Systems (AMCIS).*

Schneider, C., Weinmann, M., & Vom Brocke, J. (2018). Digital Nudging: Guiding online user choices through interface design. *Communications of the ACM, 61*(7), 67–73. https://doi.org/10.1145/3213765

Schrills, T., Zoubir, M., Stahl, J., Drozniak, K., & Franke, T. (2020). Good boy here or bad boy far away? Effects of digital nudging on booking decisions in car sharing. In *Proceedings of the 17th International Conference EPCE* (pp. 398–411).

Schubert, C. (2017). Green Nudges: Do They Work? Are They Ethical? *Ecological Economics, 132,* 329–342. https://doi.org/10.1016/j.ecolecon.2016.11.009

Schultz, P. W., Estrada, M., Schmitt, J., Sokoloski, R., & Silva-Send, N. (2015). Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms. *Energy, 90,* 351–358. https://doi.org/10.1016/j.energy.2015.06.130

Shevchuk, N. & Oinas-Kukkonen, H. (2019). Increasing Intention to Adopt Green IS with Persuasive Systems Design: Case JouleBug Mobile Application. In A. Siarheyeva,

C. Barry, M. Lang, H. Linger, & C. Schneider (Eds.), Information Systems Development: Information Systems Beyond 2020 (ISD2019 Proceedings).

Shiv, B., & Fedorikhin, A. (1999). Heart and Mind in Conflict: the Interplay of Affect and Cognition in Consumer Decision Making. *Journal of Consumer Research, 26(3),* 278–292.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *The Behavioral and Brain Sciences, 23(5),* 645-726. https://doi.org/10.1017/S0140525X00003435

Stryja, C., & Satzger, G. (2019). Digital nudging to overcome cognitive resistance in innovation adoption decisions. *Service Industries Journal, 39,* 1123–1139. https://doi.org/10.1080/02642069.2018.1534960

Stryja, C., Satzger, G., & Dorner, V. (2017). A decision support system design to overcome resistance towards sustainable innovations. In *Proceedings of the 25th European Conference on Information Systems (ECIS).*

Sunstein, C. R. (2014). Nudging: A very short guide. *Journal of Consumer Policy 2014 37:4, 37*(4), 583–588. https://doi.org/10.1007/S10603-014-9273-1

Székely, N., Weinmann, M., & vom Brocke, J. (2016). Nudging people to pay CO2 offsets - The effect of anchors in flight booking processes. In *Proceedings of the 24th European Conference on Information Systems (ECIS).*

Tang, W., Li, H., & Chen, J. (2021). Optimizing carbon taxation target and level: Enterprises, consumers, or both? *Journal of Cleaner Production, 282,* 124515. https://doi.org/10.1016/j.jclepro.2020.124515

Taube, O., & Vetter, M. (2019). How green defaults promote environmentally friendly decisions: Attitude-conditional default acceptance but attitude-unconditional effects on actual choices. *Journal of Applied Social Psychology, 49(11),* 721–732. https://doi.org/10.1111/jasp.12629

Thaler, R. H., & Sunstein, C. R. (2009*). Nudge: Improving Decisions about Health, Wealth, and Happiness* (Rev. and expanded ed., with a new afterword and a new chapter). Penguin.

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E [Elgar], Lalive, R., & Staake, T. (2018). Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation. *Management Science, 64(3),* 1458–1476. https://doi.org/10.1287/mnsc.2016.2646

Tiefenbeck, V., Wörner, A., Schöb, S., Fleisch, E [Elgar], & Staake, T [Thorsten] (2019). Real-time feedback promotes energy conservation in the absence of volunteer selection bias and monetary incentives. *Nature Energy, 4(1),* 35–41. https://doi.org/10.1038/s41560-018-0282-1

Tussyadiah, I., & Miller, G. (2019). Nudged by a robot: Responses to agency and feedback. *Annals of Tourism Research, 78,* 102752. https://doi.org/10.1016/j.annals.2019.102752

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

vom Brocke, J., Simons, A., Riemer, K., Niehaves, B., Plattfaut, R., & Cleven, A. (2015). Standing on the shoulders of giants: Challenges and recommendations of literature search in information systems research. *Communications of the Association for Information Systems, 37(1),* 205–224.

vom Brocke, J [Jan], Watson, R. T., Dwyer, C., Elliot, S., & Melville, N. (2013). Green Information Systems: Directives for the IS Discipline. *Communications of the Association for Information Systems, 33*. https://doi.org/10.17705/1CAIS.03330

Wason, P. C., & Evans, J. (1974). Dual processes in reasoning? Cognition, 3(2), 141–154.

Wassan, S., Gulati, K., Ghosh, A., shafi rafiqi, I., Mammani, B. S., Tabbassum, S., & Khaja Mohiddin, M. (2021). Impact of digitalization on retailers and its future trends. Materials Today: Proceedings. Advance online publication. https://doi.org/10.1016/j.matpr.2021.06.238

Watson, D., Fernández, J. A., Wittmer, D., & Pedersen, O. G. (2013). Environmental pressures from European consumption and production. A study in integrated environmental and economic analysis. *Publications Office of the European Union.* https://www.osti.gov/etdeweb/biblio/22079106

Weinmann, M., Schneider, C., & vom Brocke, J . (2016). Digital Nudging. *Business & Information Systems Engineering, 58(6),* 433–436. https://doi.org/10.1007/s12599-016-0453-1

Wemyss, D., Cellina, F., Lobsiger-Kägi, E., Luca, V. de, & Castri, R. (2019). Does it last? Long-term impacts of an app-based behavior change intervention on household electricity savings in Switzerland. *Energy Research & Social Science, 47,* 16–27. https://doi.org/10.1016/j.erss.2018.08.018

Werkmeister, C., Schoormann, T., & Knackstedt, R. (2021). Promoting Carpooling through Nudges: The Case of the University Hildesheim. https://aisel.aisnet.org/wi2021/XStudent/Track03/12

Willis, R. M., Stewart, R. A., Panuwatwanich, K., Jones, S., & Kyriakides, A. (2010). Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households. *Resources, Conservation and Recycling, 54(12),* 1117–1127. https://doi.org/10.1016/j.resconrec.2010.03.004

Wolf, T. (2020). Green gamification: How gamified information presentation affects pro-environmental behavior. In Proceedings of the 4th International GamiFIN Conference.

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems, 22(1),* 45–55. https://doi.org/10.1057/ejis.2011.51

Wunsch, M., Stibe, A., Millonig, A., Seer, S., Dai, C., Schechtner, K., & Chin, R. C. C. (2015). What Makes You Bike? Exploring Persuasive Strategies to Encourage Low-Energy Mobility. *Persuasive, 53–64*. https://doi.org/10.1007/978-3-319-20306-5_5

Zimmermann, S., Hein, A., Schulz, T., Gewald, H., & Krcmar, H. (2021). Digital Nudging Toward Pro-Environmental Behavior: A Literature Review. In *Proceedings of the 25th Pacific Asia Conference on Information Systems (PACIS).*

Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods, 18(3),* 429–472. https://doi.org/10.1177/1094428114562629

2.1.8 Appendix

ID	Study	Context	Behavioral Goal	Summarized DNE(s)
1	Abrahamse et al. (2007)	Energy	Less energy consumption	Priming: tailored information on direct and indirect energy use Goal setting: the goal of 5 % reduction in energy use Feedback: tailored feedback on induvial energy savings
2	Amatulli et al. (2019)	FMCG, Donation	Donations to pro-environmental organizations	Framing: video before buying a shirt/battery/choosing amount of ecological donation
3	Anagnostopoulou et al. (2019)	Mobility	Sustainable travel route choices	Feedback: personalized persuasive interventions regarding urban travel route choice
4	Antonides and Welvaarts (2020)	FMCG	Choice of sustainable make-up product	Default rules: status quo default option regarding the sustainability of a make-up product Framing: lateral presentation of make-up products left-right versus right-left
5	Arquit Niederberger and Champniss (2018)	Durable Goods	Choice of energy-efficient household appliance	Simplification: efficiency scores for household appliances
6	Bacon and Krpan (2018)	Food	Choice of a vegetarian dish on a restaurant menu	Framing: different presentations of vegetarian dishes on a restaurant menu
7	Berger et al. (2020)	Food	Choice of organic products in an online grocery store	Default rules: pre-selection of organic products in a shopping cart of an online grocery store Simplification: icon representing ecologically sustainable classification in an online grocery store Social norms: labeling products as "popular" in an online grocery store
8	Brandsma and Blasch (2019)	Energy	Less energy consumption	Goal setting: self-determined energy conservation goal Feedback: feedback on individual energy conservation in physical or environmental values
9	Brent et al. (2015)	Water	Less water consumption	Social comparison: Home Water Report comparing water usage to neighbors
10	Buchanan and Russo (2019)	Energy	Less energy consumption	Feedback: personalized information of costs of standby power usage
11	Cappa et al. (2020)	Energy	Less energy consumption	Feedback: customized, detailed feedback within the project aligning energy production and demand
12	Codagnone et al. (2016)	Durable Goods	Choice of eco-labeled car	Simplification: eco-labels on motor vehicles
13	Andre Dahlinger et al. (2018)	Mobility	Eco-driving behavior	Feedback: numerical versus symbolic feedback on eco-driving behavior
14	André Dahlinger et al. (2018)	Mobility	Eco-driving behavior	Feedback: abstract versus concrete feedback on eco-driving behavior
15	Degirmenci and Recker (2018)	Other	Less paper consumption	Social comparison: e-mail reporting system on paper consumption
16	Demarque et al. (2015)	Food	Choice of sustainable products in an online grocery store	Social norms: descriptive norms on sustainable products in an online shopping environment
17	Doran et al. (2017)	Mobility	Choice of ecological friendly travel route	Social comparison: comparative feedback on ecological footprint before choosing travel options
18	Ebeling and Lotz (2015)	Energy	Choice of green energy contract	Default rules: default setting on green vs. conventional energy contract

ID	Study	Context	Behavioral Goal	Summarized DNE(s)
19	Emeakaroha et al. (2014)	Energy	Less energy consumption	Feedback: persuasive feedback support system displaying energy usage
20	Fanghella et al. (2019)	Donation	Donations to pro-environmental organizations	Priming: environmental self-identity priming before choosing a donation Social norms: social information on the amount of donations of other users
21	Folkvord et al. (2020)	Durable Goods	Environmentally friendly car choice	Simplification: eco-labels on environmentally friendly cars
22	Franzen and Mader (2020)	Donation		Priming: different videos on the environment and nature before donation
23	Gajewski et al. (2021)	Other	Socially Responsible Investment (SRI)	Default rules: SRI option pre-selected by default Priming: displaying shocking images to prime ethical values
24	Ghesla et al. (2020)	Energy	Less energy consumption	Goal setting: goal to reduce electricity consumption by 5% Framing: utility promised to plant (or not to lant) a tree if the goal is (not) reached
25	Graham et al. (2011)	Mobility	Fewer miles are driven by car	Feedback: monetary vs. pollution feedback that was avoided by not using the car
26	Graml et al. (2011)	Energy	Less energy consumption	Social comparison: descriptive (bar chart that compared their weekly energy consumption (in kilowatt-hours) to the average energy consumption of similar households) vs. injunctive (grades from A to G)
27	Grebitus et al. (2020)	FMCG	Choice of plant-based water bottles	Priming: requiring participants to consider the environmental impact of the product before choosing a bottle
28	Grinstein and Riefler (2015)	Food	Choice of green chocolate bar	Framing: local vs. global framed message on the environmental impact of product
29	Grønhøj and Thøgersen (2011)	Energy	Less energy consumption	Feedback: detailed real-time feedback on households' electricity consumption via LCD monitors
30	Hankammer et al. (2021)	Durable Goods	Sustainable TV configuration	Default rules: pre-selected characteristics of TV with low, medium, and high sustainability impact
31	Henkel et al. (2019)	Energy	Choice of environmentally-friendly search engine	Default rules: automatically to Blackle (eco-friendly alternative) Priming: information on both search engines' energy consumption
32	Huber et al. (2019)	Mobility	Environmentally-friendly charging preferences (electric car)	Priming: Three different (environmental, social, cost) priming messages before entering charging preferences
33	Kroll et al. (2019)	Energy	Less energy consumption	Social norms: information on consumption behavior of comparable households via a smart home app Goal setting: self-commitment to devices to save energy and respective saving goals
34	Krpan and Houtsma (2020)	Food	Choice of a vegetarian dish on a restaurant menu	Framing: reframing the name of vegetarian food with an environmental, social, or neutral frame
35	Lembcke et al. (2020)	Food	Increase the choice of organic products in an online grocery store	Feedback: Real-time spending feedback in the shopping cart
36	Lieberoth et al. (2018)	Mobility	Environmentally friendly travel behavior	Goal setting: pre-commitment in a personal letter to future self or family member Social comparison: Facebook groups to showcase and discuss experiences

ID	Study	Context	Behavioral Goal	Summarized DNE(s)
37	C.-M. Loock et al. (2011)	Energy	Less energy consumption	Social comparison: descriptive (a bar chart that compared their weekly energy consumption (in kilowatt-hours, lower bar) to the average energy consumption of similar households) vs. injunctive (grades from A to G, with A representing a high level of approval of the customer's energy consumption and G representing a high level of disapproval)
38	C.-M. Loock et al. (2012)	Energy	Less energy consumption	Social comparison: injunctive feedback (scale ranges from A (high efficiency) to G (low efficiency)) compared with different reference groups concerning geographical proximity
39	Claire-Michelle Loock et al. (2013)	Energy	Less energy consumption	Goal setting: default goals (low, medium, or high) versus self-set goals regarding electricity consumption
40	Momsen and Stoerk (2014)	Energy	The choice for a renewable energy contract	Priming: Intention-, Memory- and Reassemble Priming of effects of choosing ecological vs. conventional energy contract Framing: additional information on carbon emissions of contracts framed as gain or loss Social comparison: information on which contract neighbors have chosen Default rules: default contract with 50% renewable and 50% conventional energy
41	Nilsson et al. (2014)	Energy	Less energy consumption	Feedback: continuous visual feedback on energy savings via an in-home display
42	Prusaczyk et al. (2021)	Food	Choice for mushroom-beef instead of all-beef burger	Default rules: everyone will be served a beef-mushroom burger, unless specifically asked for all-beef burger Priming: before ordering, information on emission saving between mushroom-beef vs. beef-burger is displayed
43	Roozen et al. (2021)	FMCG	Choice of sustainable instead of conventional t-shirt	Simplification: Information in text form on the sustainability of t-shirts is presented next to it Priming: visual emphasis on the conscious collection before entering the webshop
44	Schrills et al. (2020)	Mobility	Choice of an electric car when booking a car for car sharing	Framing: positive ("if you use e-car sharing") and negative framing ("if you do not use e-car sharing") with global ("global rise in sea level") and local ("sea level in Travemünde")
45	Schultz et al. (2015)	Energy	Less energy consumption	Feedback: real-time feedback on households' electricity consumption either in kW, costs or both Social comparison: real-time feedback on households' electricity consumption in kW and dynamically compared to others
46	Stryja and Satzger (2019)	Mobility	Choice of electric car	Default rules: pre-selected electric car Priming: Solve the word puzzle by unscrambling the sentence "You usually use new and sustainable products." Feedback: a message about carbon dioxide emissions of the chosen type of car
47	Stryja et al. (2017)	Mobility	Choice of an electric car (car rental)	Default rules: "electric" pre-selected as an attribute for "engine type." Priming: slogan which promotes innovativeness and eco-friendliness of electric car

ID	Study	Context	Behavioral Goal	Summarized DNE(s)
48	Székely et al. (2016)	Donation	Carbon offset payments in flight booking processes	Default rules: low, medium, and high pre-selected donation amount
49	Taube and Vetter (2019)	Food	Choice of eco-friendly products in an online grocery store	Default rules: default eco- (vs. conventional) products were put into the participant's shopping cart
50	Tiefenbeck et al. (2018)	Water	Less water consumption (showering)	(Real-time) Feedback: displaying water temperature, energy consumption, and polar bear animation
51	Tiefenbeck et al. (2019)	Water	Less water consumption (showering)	(Real-time) Feedback: displaying water temperature, energy consumption, and polar bear animation
52	Tussyadiah and Miller (2019)	Energy	Less energy consumption	Social comparison: social feedback on behavior provided by a virtual assistant in a hotel room
53	Wemyss et al. (2019)	Energy	Less energy consumption	Social comparison: competitive (save as much) vs. collaborative (10% electricity saving goal)
54	Willis et al. (2010)	Water	Less water consumption	Feedback: bar graph which decreases while showering and alarms after 40L are used
55	Wolf (2020)	Other	Increase daily sustainable behavior	Feedback: visual (tree, which bloomed for ESB or decayed for less sustainable choice), or numerical (specific carbon dioxide emission)
56	Wunsch et al. (2015)	Mobility	Increase bike choice	Social comparison: collecting points based on reported bike trips, shown on a leaderboard, and the possibility to compare own number of bike rides to the average and best participant

Table 2.1-4 Details on studies that resulted from the literature review

2.2 Digital Nudging in Online Grocery Stores – Towards Ecologically Sustainable Nutrition

Abstract: A major driver of global environmental challenges is our current food system. More sustainable practices on the supply side depend on pressure from the demand side: Every individual can contribute to a greener food system by making sustainable food choices. Digital nudging represents a promising approach to foster desirable consumer behavior. Research in the growing online food context is scarce and lacks a comparative analysis of digital nudging elements and their effectiveness regarding different consumer groups. We transferred three nudging elements to the digital choice environment of an online grocery store and conducted a field experiment with 291 participants. Parametric, nonparametric, regression, and cluster analyses showed that default rules are effective for a broad consumer base and simplification for environmentally-conscious consumers to promote ecologically sustainable behavior, while social norms had no effect. The results inform research and practice regarding the potential of digital nudging to foster ecologically sustainable food choices.

Keywords: Digital nudging; Green IS; Ecological sustainability; Food system; Consumer behavior; Green society; Online grocery store

Authors: Michelle Berger, Niclas Nüske, Chiara Müller

Status: This article is published in the proceedings of the 41st International Conference on Information Systems (ICIS), a remote conference due to COVID-19, 2020.

2.2.1 Introduction

Environmental deterioration has become one of the biggest concerns of our times (Plumer and Popovic, 2018). Its severe threat is acknowledged and battled in worldwide cooperation and can be observed, for example, in the sustainable development goals proposed by the United Nations (2015). Most of the environmental deterioration is human-induced, meaning that we ourselves are damaging our basis of existence (Dunlap et al., 2000; Schubert, 2017; Schultz et al., 2005). Information Systems (IS) is seen as an important weapon to address this challenge (Melville, 2010) due to its remarkable influence and ubiquitousness in all areas of our lives. IS researchers have been called upon to apply "the transformative power of IS to create an environmentally sustainable society" (Watson et al., 2010, p. 24). Prior research suggests focusing on IS design approaches that influence human behavior to protect the environment (Melville, 2010). The use of digital nudging elements (DNEs) has proven to be an effective design approach for unconscious and automatic every-day decisions to influence individuals' behaviors in a positive way (Weinmann et al., 2016). Nudging aims to help making better choices by modifying the choice environment without limiting the number of choices through laws, orders, or fiscal methods (Ferrari et al., 2019; Lehner et al., 2016; Thaler & Sunstein, 2009). It has been demonstrated that nudging elements (NEs) have a remarkable potential to enable pro-environmental behavior (Schubert, 2017) and to influence human behavior regarding food consumption decisions in particular (Lehner et al., 2016). DNEs can be implemented quicker, faster, and cheaper than in an offline, physical environment and can be personalized since online environments offer tools to track and analyze individuals' preferences (Weinmann et al., 2016).

Food is a main consumption area that has tremendous negative effects on the environment (Noleppa, 2012). The production and transportation of food cause land depletion, the exhaustion of natural resources, and are responsible for about 26% of the global greenhouse gas (GHG) emissions (Poore & Nemecek, 2018). It is not sufficient to rely on the proactivity of food producers to turn to more conscious and pro-environmental practices. The integration of ecological sustainability aspects into daily food consumption decisions by consumers is of importance as well (Ferrari et al., 2019). Pressure from the demand side must be significantly increased in order to accelerate changes towards ecologically sustainable production and transportation on the supply side (Mont et al., 2014). Consumers struggle when it comes to evaluating the environmental impacts of products (Hoek et al., 2017). But, common informational strategies like displaying numerical information about the product's GHG emissions have not proven to be successful (Spaargaren et al., 2013). Food decisions are mainly based on impulsivity (Mirsch et al., 2017) and given the fact that the consumers' point of contact with the food system is increasingly shifted to online areas, online food suppliers like delivery services or grocery stores as well as policymakers should consider implementing DNEs as a way to influence food choices in an ecologically sustainable manner (Weinmann et al., 2016). Grocery stores especially hold a large responsibility to the society including the support of an ecologically sustainable food system (Pulker et al., 2018). They have the power to stimulate environmentally friendly behavior of consumers and can, therefore, help fighting environmental deterioration (Hawkes, 2008; Oosterveer et al., 2007).

Prior research on NEs in the food domain mainly focuses on coping with obesity and promoting healthy diets (Friis et al., 2017; Oullier et al., 2010; Schwartz, 2007; Wansink, 2004). Some research analyzes the effectiveness of single NEs focusing on the environmental dimension of food, including the NE default rules (Campbell-Arvai et al., 2014; Torma et al., 2018; Vandenbroele et al., 2018), changes to the physical environment (Vandenbroele et al., 2020; Wansink & Cheney, 2005), simplification (also referred to priming or salience) (Bacon & Krpan, 2018; Shearer et al., 2017), and social norms (Demarque et al., 2015; Kallbekken & Sælen, 2013; Linder et al., 2018), however, focusing mainly on eating out or reducing food waste (Ferrari et al., 2019). These NEs furthermore have mostly been applied in an offline, physical context. A separate consideration of DNEs in the online food domain promoting ecologically sustainable shopping behavior is necessary since consumers behave differently online, which is why Weinmann et al. (2016) and Mirsch et al. (2017) called for research about the effect of different DNEs in online environments. To our knowledge, only Demarque et al. (2015) analyzed one of the four named NEs, social norms, as a DNE in an online grocery store to promote ecologically sustainable behavior, without comparing it to other DNEs. Additionally, digital functionalities like tracking the browsing behavior of consumers allow individualizing the DNEs presented to the consumers based on individual characteristics (Benartzi & Lehrer, 2017; Weinmann et al., 2016). We still lack understanding of how effective DNEs are regarding different target groups to consider and implement individualized digital nudging (Mirsch et al., 2017). As a consequence, we aim to answer the following research questions:

RQ2.2-1: *Which of the DNEs default rules, simplification, and social norms are effective in online food shopping contexts regarding the promotion of ecologically sustainable food choices?*

RQ2.2-2: *Do the DNEs differ in their influence on different consumer groups?*

To answer our research questions, we conducted a field experiment including an online grocery shopping task in which we implemented the DNEs in different treatment groups. We analyzed and compared the effectiveness of the different DNEs on ecologically sustainable food choices using parametric and nonparametric statistics and regression analyses. Additionally, we used cluster analysis to determine consumer groups and again employed parametric and nonparametric statistics to examine in which ways the effects of the DNEs differed.

This paper proceeds as follows: We first present the theoretical background compiled from various literature streams such as IS and behavioral science. Subsequently, the methodology and the results are presented. We conclude with a summary, implications, limitations, and proposals for future research.

2.2.2 Theoretical Background

In the following, we present the definition and influencing factors of food sustainability and elaborate on the origin and rising relevance of online grocery stores. Next, we introduce the theoretical background from behavioral science and the concept of nudging. We summarize prior research made in offline and digital nudging (DN) focusing on sustainable food consumption.

2.2.2.1 The Need for Ecologically Sustainable Food Consumption

The current global food system is in many respects far from sustainable in the sense that it ensures nutrition for everyone without compromising economic, social, and environmental bases for future generations (HLPE, 2014). It causes negative impacts on the environment including GHG emissions as well as land, water, and energy exploitation. This leads to a loss in biodiversity, ozone depletion, terrestrial acidification, and contaminated groundwater (Meybeck & Gitz, 2017; Tukker et al., 2011). A growing food demand caused by an increasing world population is leading to an expansion in food production. However, the limited amount of available resources stays constant which emphasizes the need to reorient the current practices towards a more sustainable food system (Ferrari et al., 2019).

Regarding the sustainability of a single product, the environmental impacts of it depend on how and where its components have been produced (Meybeck & Gitz, 2017). Regional production, for example, causes lower pollutant emissions and consumes less energy and raw materials due to shorter transport distances, and fewer requirements for storing, cooling, and packing (Koerber & Kretschmer, 2000; Specht et al., 2016). Whereas organic farming is based on the balance of soil, animals, and plants (Koerber & Kretschmer, 2000) and is seen in the

European organic label, which considers animal welfare, environmental pollution, biological diversity, and renewable energy, chemical, and synthetic inputs (Council regulation (EC) No 834/2007 of 28.06.2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91, 2007). Restrictions of chemical fertilizers and pesticides in organic farming reduce nitrate pollution in water and groundwater. Through organic fertilization and the carefully coordinated cultivation of changing plants, the fertility of the soil is maintained, thus reducing soil erosion and promoting biodiversity. Additionally, organic farming produces less GHG emissions and consumes up to 40% less energy (Koerber & Kretschmer, 2000). Generally speaking, organically produced and regional products are in sum more sustainable than conventional food products and should be primarily consumed on the demand side to transform the supply-side system towards a more sustainable one (Koerber & Kretschmer, 2000; Schlich & Fleissner, 2005). These decisions about food consumption are increasingly made online.

2.2.2.2 Rising Relevance of Online Food Shopping as Choice Environment for Nudging

With the emergence of the internet, electronic commerce (e-commerce) started to grow in the 1990s (Wigand, 1997). E-commerce describes “the process of buying and selling products or services using electronic data transmission via the Internet” (Grandon & Pearson, 2004, p. 197) and includes, but is not limited to, products and services in the segments of fashion, electronics, furniture, and groceries (Striapunina, 2020). Especially through improved payment systems and mobile applications, e-commerce developed quickly, starting in 2005 (Rokicki, 2018). Grocery purchases made online increased since 2006, when only 1% of German consumers bought groceries online, whereas in 2017, already 21% did so (Centraal Bureau voor de Statistiek, 2019). The developments in Asia, where more than 88% of Chinese and 87% of Thais plan to purchase groceries online in the next 12 months (PWC 2018), leave no doubt about online grocery shopping becoming an important pillar of the food retail sector in the future (Centraal Bureau voor de Statistiek, 2019). Major advantages of e-commerce, especially related to grocery purchases made online, include time-savings due to avoid travel to a traditional store or standing in queues, but also higher convenience because of flexibility due to 24h availability and accessibility from different places (Moagar-Poladian et al., 2017; Morganosky & Cude, 2000). Especially in times of uncertainty like the COVID-19 pandemic in 2020, online grocery shopping has become a useful and safe alternative to physical shopping (Gassmann, 2020).

Two different kinds of online grocery stores can be distinguished: virtual supermarkets that only exist online and traditional grocery stores that offer an additional online shop (Morganosky & Cude, 2000). Next to online grocery stores, online food delivery services have emerged, representing restaurants themselves who offer a delivery service, such as Pizza Hut, or intermediaries between multiple consumers and restaurants, like delivery.com (Yeo et al., 2017). Online delivery has increased tremendously starting in 2011 and accounted for 36% of all food orders in 2016 (Hirschberg et al., 2016). Lastly, online platforms also offer subscriptions of meal boxes, like Hello Fresh, which have become popular in the last years (Wunsch, 2019). Online grocery stores, delivery services, and subscription services all represent choice environments in which consumers decide between different food products. These choice environments can be modified by the use of DNE.

2.2.2.3 Digital Nudging towards More Ecologically Sustainable Food Choices

2.2.2.3.1 Behavioral Science and the Concept of Nudging

Nudging describes ways to influence choices by modifying the environment in which choices are presented and framed (Münscher et al., 2016). NEs aim to help individuals make better choices, elicit certain behaviors, and improve life without limiting the freedom of choice or manipulating incentives (Thaler & Sunstein, 2009). NEs should remain transparent and open as they have no manipulative or prohibitive nature (Sunstein, 2014). The concept of nudging is based on the dual process theory of behavioral economics, which suggests that human decision making occurs in an intuitive system 1 or a reason-based system 2 (Stanovich & West, 2000). System 1 is responsible for rather effortless, intuitive, emotional, automatic, and fast decisions, whereas in system 2, slower, controlled, rule-governed, and more effortful decisions develop (Kahneman, 2003). Kahneman (2011) showed that every-day decisions like deciding whether to take the elevator or the stairs could be attributed to system 1, whereas important decisions about one's life occur in system 2. System 1 protects the deliberate system 2 to prevent cognitive overload and turns familiar tasks into automatic routines. For non-automatic routines, information is quickly sorted through and shortcuts are taken which makes every-day intuitive decisions prone to heuristics and cognitive biases like a rule of thumb or gut feelings (Kahneman, 2011; Tversky & Kahneman, 1974). Combined with time pressure or limited cognitive capacity, this leads to faster, but also potentially undesirable decisions (Campbell-Arvai et al., 2014). This is the starting point for nudging. NEs can positively influence the decision-making process for the individual and the society in general by making use of counteracts of these heuristics and cognitive biases caused by psychological effects that might lead to mistakes in decision-making processes (Thaler & Sunstein, 2009).

2.2.2.3.2 The Use of Nudging in Food Contexts to Promote Ecologically Sustainable Choices

Food behavior is highly habitual, making traditional educational approaches to enhance knowledge insufficient when it comes to changing the behavior (van’t Riet et al., 2011). Hence, food choices can mainly be attributed to system 1 as automatic, emotional and intentional decisions with lower amounts of cognitive effort (Kahneman, 2011). This makes food choices prone to nudging. Research provides evidence that nudging is effective in influencing individuals’ food behaviors (Schwartz, 2007; Vandenbroele et al., 2020; Wansink, 2004). Lehner et al. (2016) and Ferrari et al. (2019) reviewed a wide range of research focusing on the effect of NEs to leverage healthier and ecologically sustainable food choices. Lehner et al. (2016) found four NEs to be effective in promoting sustainable behavior concerning energy use, food, and personal transport. These are default rules, changes to the physical environment, simplification and framing of information, and the use of social norms. Ferrari et al. (2019) found similar NEs to be effective regarding consumers’ environmentally-friendly behavior in physical areas like restaurants, canteens, hotels, and supermarkets.

The NE default rules describes a setting in which the preferred option is pre-selected and will be maintained if the person does nothing (Thaler & Sunstein, 2009). It is based on the need for maintaining the status quo (Kahneman, 2011), and the drive to procrastinate due to the dislike and time consumption of making active decisions (Sunstein, 2014). Regarding default rules in food contexts, Campbell-Arvai et al. (2014) found evidence that default meat-free options promote the choice of vegetarian meals when eating out and Kallbekken and Sælen (2013), as well as Vandenbroele et al. (2018), demonstrated that reduced plate size leads to less food waste.

The NE simplification represents the transportation of condensed information about a complex construct and comes along with framing of information to activate certain values (Sunstein, 2014; Thaler & Sunstein, 2009). Framing means that the different choice options are presented in ways that intentionally evoke certain associations of the decision-maker (Thaler & Sunstein, 2009). Information can, for example, be simplified and framed through descriptive labels, or by visualizing consequences (Lehner et al., 2016; Mirsch et al., 2017). Prior research in food contexts focused on redesigning menus in restaurants to promote environmentally-friendly choices (Bacon & Krpan, 2018; Kurz, 2018). Also, Van Gilder Cooke

(2012) used GHG emission labels for burgers and increased sales of lower-carbon-footprint burgers. Linder et al. (2018) proofed the effectiveness of visual cues and information flyers to reduce food waste.

Lastly, social norms are “an individual’s beliefs about the typical and condoned behavior in a given situation” (Kormos et al., 2015, p. 480). The NE social norms utilizes the effect of social pressure and social conformity (Aldrovandi et al., 2015) by giving information about appropriate behavior within a group (Kormos et al., 2015). Injunctive and descriptive norms exist (Cialdini et al., 1990). Injunctive norms describe a generally desired behavior, for example leaving a tip in a restaurant, and proved to be effective in contexts like alcohol use (LaBrie et al., 2010) or gambling (Neighbors et al., 2007). Descriptive norms instrumentalize the behavior of other individuals (Cialdini et al., 1990) by conveying, for example, the following information: “70% bought at least one ecological product” (Demarque et al., 2015, p. 169). Especially in ambiguous or uncertain situations, descriptive norms function well as a heuristic, because they provide the decision-maker with information about socially-accepted behavior (Higgs, 2015). Melnyk et al. (2010) found in their meta-analysis that descriptive norms are effective in influencing the consumers’ behavior in general, and Robinson et al. (2014) confirmed their results regarding eating behavior, also by conducting a meta-analysis. Other research showed an improved ecologically sustainable behavior by the use of descriptive norms, for example by promoting less towel use in hotels (Goldstein et al., 2008) or supporting recycling (Nigbur et al., 2010). In terms of promoting ecologically sustainable behavior related to food, Linder et al. (2018) and Kameke and Fischer (2018) used descriptive norms to reduce food waste and Demarque et al. (2015) promoted ecologically sustainable products in an online grocery store. In the following, we, therefore, refer to descriptive norms when talking about the DNE social norms.

2.2.2.3.3 Digital Nudging for Ecologically Sustainable Food Choices in Online Choice Environments

Making desirable ecologically sustainable daily food choices is hard. Additionally, people tend to be overwhelmed by information overload simply resulting in inaction (Mont et al., 2014). Especially online, people tend to fail to process all relevant data needed to make informed decisions, leading to automated and hurried choices (Benartzi & Lehrer, 2017). The three discussed NEs default rules, simplification, and social norms all have the potential to be transferred to online choice environments and support the decision processes of consumers. We exclude changes to the physical environment for obvious reasons of non-applicability.

Default rules and simplification are not evaluated in online food shopping contexts yet. Research regarding DNEs in online food shopping contexts to promote ecologically sustainable food choices is to our knowledge limited to the work of Demarque et al. (2015) which focusses on the design possibilities of social norms. Consequently, no comparison of the effects of these DNEs exists so far. Due to the rise of online grocery shopping, further research on the effectiveness of different DNEs is needed, especially with the potential of individualizing the usage of DNEs in online choice environments (Mirsch et al., 2017; Weinmann et al., 2016).

2.2.3 Research Process

The development of DNE in online decision environments can be structured along a five-step process consisting of the steps (1) define, (2) diagnose, (3) select, (4) implement and (5) measure according to Weinmann et al. (2016). To answer our research questions, we focus on steps 4 and 5. We perform an online field experiment to demonstrate a cause-and-effect relationship between the independent variable (here: implementation of the DNEs) and the dependent variable (here: ecologically sustainable food shopping behavior (Gravetter & Forzano, 2016). We, therefore, design and implement the three DNEs default rules, simplification, and social norms in an online grocery store. Subsequently, we evaluate their effectiveness considering control variables that might influence the online grocery shopping behavior of individuals.

2.2.3.1 Design and Implementation of the Digital Nudging Elements

The three DNEs were embedded in the decision environment of an online grocery store (see Figure 2.2-1). While implementing the field experiment, the priority was to provide a situation as close to real life and as easy to use as possible (Gravetter & Forzano, 2016). The online grocery store was implemented as a single-page website structured into the columns shopping list, products, and shopping cart. The shopping list indicated which and how many products were to purchase by the participants. The product area contained a scrollable list of different products with three items per row and occupied the largest and most prominent middle column. The entry for each item consisted of a picture of the product, its name and weight or volume, its price per unit, its scaled price per kilogram or liter, and a button to add the item to the shopping cart. The information and depiction of the product data thus match the standards found in real-life online grocery stores of familiar German retail chains. All product data, including product pictures and prices, are based on real-life examples found in the online grocery stores of those chains. The shopping cart column comprised the name and weight or volume, the adaptable quantity, and the price per unit of each added product.

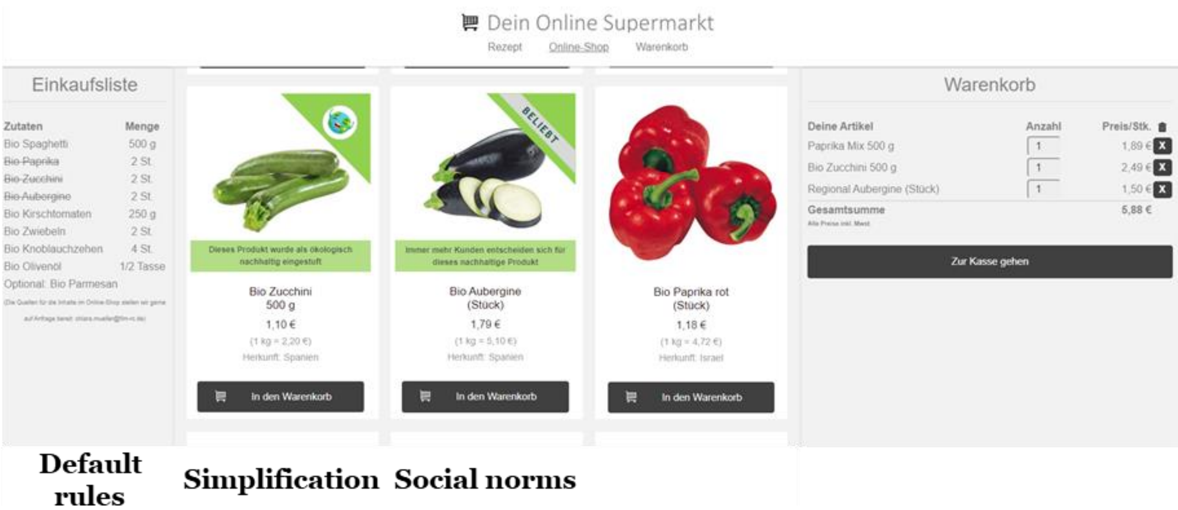

Figure 2.2-1 Online grocery store design with the areas shopping list (left), products (middle), and shopping cart (right)

We implemented the three DNEs as follows. Default rules as a way to provide consumers who are not willing, aware, or able to make decisions with pre-selected options, was realized in the shopping list: we added the marker “Bio” (German for “organic”) in front of each item that the participants were asked to purchase (see left column in Figure 2.2-1). Since products of organic origin are in general more sustainable (Koerber & Kretschmer, 2000; Schlich & Fleissner, 2005), participants were thus nudged to choose products in a more environmentally-friendly fashion. Simplification is meant to comprise complex information in a significantly shorter description or framed depiction. We aim at fostering ecologically sustainable food purchasing behavior, therefore we implemented simplification as an icon of a smiling world and provided the additional short statement “This product was classified as ecologically sustainable” when participants hovered over the picture of the product in question (see icon on red pepper in Figure 2.2-1). Lastly, the DNE social norms was implemented as a banner reading “popular” and the statement “More and more customers choose this sustainable product” was displayed when hovering over the product in question (see eggplant Figure 2.2-1). The intention was to make the participants aware of the behavior of the masses to stimulate socially-conforming sustainable food shopping behavior. Figure 2.2-1 illustrates the online grocery store’s design and examples of the three DNEs. For illustrative purposes, all DNEs are displayed at once in Figure 2.2-1 which differs from the implementation in the field experiment. For the procedure in the field experiment, please see the following section.

2.2.3.2 Design and Implementation of the Field Experiment

To acquire the necessary data to answer our research questions, we created a field experiment that combined a shopping task in the online grocery store described above with an online survey. The field experiment was conducted in German. Prior to the execution of the field experiment, four people took part in a pretest and their feedback regarding, e.g., understandability of the included texts and usability of the online grocery store, was adopted. Subsequently, we administered a participation invitation via several social media channels and email. After clicking on the included link, an introduction informed the participants about the setting of the field experiment as well as our data protection policy which needed to be accepted before continuing. To keep the experiment as realistic and comprehensible as possible, we proceeded as follows. Participants were asked to imagine a scenario in which they planned to cook a meal the next evening following a specific recipe and needed to order the ingredients online. Additionally, we provided the following incentive: we announced that each participant could dispose freely of a fixed amount of thirty euros. By participating in a voluntary price draw, they got the chance to win a) the content of the shopping cart after completion of the shopping task and b) the remaining difference to the total of thirty euros as cash transferal. The aim of presenting the opportunity to win the products as well as the remaining amount of cash was to guarantee a shopping behavior as close to the real preferences of food quality and monetary benefits as possible.

In the next step, participants were transferred to our online grocery store environment. The first page contained an overview of the planned recipe including a picture, a list of nine ingredients, and the cooking instructions. To allow for a maximum number of participants to be able to relate to the scenario and not to exclude individuals with diverse nutritional preferences, we chose an inherently vegan dish with eight required plant-based and one optional vegetarian ingredient (parmesan cheese). The second page displayed the online grocery store as exemplarily presented in Figure 2.2-1. For each of the nine ingredients, there were three products to choose differing in the level of ecological sustainability. The participants were randomly assigned to one of four groups: (1) a control group which shopped without any DNEs, (2) a group with the DNE default rules implemented in the shopping list, (3) one that shopped in an environment that had the DNE simplification, and (4) one with the DNE social norms implemented for the most sustainable product of each ingredient. In the following, we term the groups C (control group), DR (group with DNE default rules), S (group with DNE simplification), and SN (group with DNE social norms), respectively. All participants could only choose one of the three products for each ingredient, and could freely decide on the quantity. They were able to proceed to checkout only after one product of each of the required eight ingredients had been added to the shopping cart.

After checkout, participants were transferred to a concluding survey regarding their food choice and consumption behavior as well as demographic characteristics. The standard single-item Food Choice Questionnaire (FCQ) developed by Onwezen et al. (2019) based on Steptoe et al. (1995) contains twelve questions regarding the motives underlying an individual's typical daily selection of food such as healthiness, price, and ethical concerns. Measurement occurs on a seven-point Likert scale ranging from 1 indicating no importance at all and 7 indicating great importance of the twelve included attributes of food. Following Onwezen et al. (2014, 2019), we created a Self-reported Consumption (SRC) questionnaire which queries the frequency of consumption of food from the categories vegetables, fruit, dairy, fish, and meat in the last month on a seven-point Likert scale ranging from 1 indicating "not this month" to 7 indicating "6-7 times a week". Given the fact that nudging is a subtle way of directing decisions in more favorable directions, it is unlikely that it is the only influence explaining the online grocery shopping behavior of individuals. It most likely depends on individual factors like price sensitivity, general attitude towards sustainable food, and typical food consumption behavior as well, all of which and more are covered by the FCQ and SRC. Thus, we included both questionnaires in our field experiment and as control variables in the following analyses. An overview of the items can be found in Table 2.2-1.

. Both questionnaires were translated into German. Thereby, two German native speakers translated the English items into German in parallel. They afterward resolved discrepancies and agreed on the most suitable translation. Lastly, a non-involved English native speaker translated the German items back into English, thus doublechecking for correctness. Lastly, we included socio-demographic questions based on our own development as well as the German census of 2011 (Statistische Ämter des Bundes und der Länder, 2015). 291 participants completed the field experiment and answered both included control questions correctly. 44.0% of participants were female, 55.5% male. 0.5% identified as diverse. The age of the participants ranged from 15 to 77 with a mean of 29.[3]

The field experiment described above was resumed after five months to take the effect of salience nudging into account. The NE salience means that "[n]ovel, personally relevant or vivid examples and explanations are used to increase attention to [a] particular choice" and is often a part of or blurs with other NEs (Blumenthal-Barby & Burroughs, 2012; Wilson et al.,

[3] Unfortunately, due to a technical error on the part of the service provider of the employed survey software, the socio-demographic information of 102 participants was only partially recorded so that these numbers are based on the data of 189 participants. All further analyses are based on all 291 participants.

2016). Specifically, in our work, the mere graphical emphasis of the sustainable product options itself as shown in Figure 2.2-1 can be interpreted as a salience DNE. Therefore, the question arose whether possible effects of the three focused DNEs can be attributed to increased participant attention alone (salience) or their sustainability-related content as well (S, SN, and, to a limited extent, DR). We consequently reran the field experiment with a fifth group SL (group with DNE salience) where we merely highlighted the most sustainable product options to catch the participants' attention but removed any thematical relation to sustainability. The DNE salience was implemented as an emoji licking its lips to symbolize great taste and the statement "This product is a pleasure" was displayed when hovering over the product in question. We collected 78 additional data sets in this second run. As this data was collected at a different point in time and covered a slightly different population (48% of participants were female, 52% male. The age of the participants ranged from 19 to 76 with a mean of 41.), we only marginally include the SL group in our analyses described below and discuss the implications for our results and further research.

2.2.3.3 Data Analysis

Our paper's focus is on the effectiveness of the three presented DNEs on ecologically sustainable food choices in online grocery stores. To answer our research questions, first a measure for ecologically sustainable food choice behavior needs to be defined. To this end, we assign sustainability ratings to each of the three products for the eight required ingredients. The ratings are based on extensive online research for each product considering, among others, seasonality, organic farming, GHG emissions, and distance travelled to point of sale. Each of the three options of the eight ingredients either obtains a rating of 2 (most environmentally sustainable choice), 1 (second best), or 0 (last). We aggregate the ratings of all eight chosen product options in a measure termed Sustainability Score (SC) for each participant. The SC thus reflects the individual's extent of environmentally sustainable choices made in our field experiment. Its possible value range is 0 to 16.

To answer our first research question which DNEs are how effective in promoting sustainable food shopping behavior in online grocery stores, we first conduct parametric ANOVA as well as nonparametric Kruskal-Wallis tests comparing the SCs of the different treatment groups. Although the treatment groups each consist of more than 30 participants and thus assuming normally distributed data following the Central Limit Theorem is warranted, in the further analyses described below we have to rely on nonparametric tests. We apply both types of tests for all analyses for reasons of consistency and transparency. We proceed to perform a more sophisticated multiple regression analysis with SC as the dependent variable which additionally allows for controlling for the participants' FCQ and SRC.

Regarding the second research question whether the effectiveness of the three DNEs differs between consumer groups, we first partition our participants into subsamples employing two-stage cluster analysis and using FCQ and SRC as input characteristics. Following recommendations from research, we combined hierarchical and partitioning (k-means) techniques which should lead to more accurate clustering compared to the results of the individual approaches alone (Balijepally et al., 2011; Milligan & Cooper, 1987; Punj & Stewart, 1983). We conducted the hierarchical clustering with Ward's minimum variance method and squared Euclidian distances. The Ward's minimum variance algorithm is shown to have superior performance compared to other algorithms (Milligan & Cooper, 1987). Its results are then used as input for partitioning to pre-specify the number of clusters and the starting points for the k-means algorithm. We subsequently compare the FCQ and SRC values between clusters and the SCs between treatments for each identified cluster, again using parametric ANOVA and pairwise post-hoc t-tests as well as nonparametric Kruskal-Wallis and pairwise post-hoc Mann-Whitney-U tests.

2.2.4 Results

The mean and median SCs as well as their standard deviations and interquartile ranges of the control group (C) and the default rules (DR), simplification (S), and social norms (SN) groups differ only slightly. This applies to a comparison to each other as well as the total sample. Shapiro-Wilk tests reject the null hypothesis that the SCs are normally distributed for the treatment groups C, S, and SN. A Bartlett test does not reject the null hypothesis that the SC variance is the same in all treatment groups. Considering the Central Limit Theorem, we apply an ANOVA between the four groups as well as a Kruskal-Wallis test. Both do not reject the null-hypotheses that the SC means or medians of the four groups are the same, rendering pairwise post-hoc tests unnecessary and indicating that there was no effect of the DNEs in promoting sustainable food shopping behavior in online grocery stores. Table 2.2-1 presents the descriptive statistics of the sample and the four treatment groups and the significance levels of the applied tests' p-values. Non-significant test results were excluded for reasons of readability.

		Total	C	DR	S	SN	Shapiro-Wilk normality	Bartlett variance	ANOVA	Kruskal-Wallis	Pairw. t-tests	Pairw. Mann-Whitney-U
	N	291	73	74	68	76						
Sustainability Score	Mean	9.35	9.29	9.55	9.53	9.04	C .					
	Standard deviation	2.92	2.71	3.16	2.97	2.86	S *					
	Median	10	9	10	10	10	SN .					
	Interquartile range	4	4	3	4	4						

*p-value significance codes: *** for < 0.001, ** for < 0.01, * for < 0.05, + for < 0.1*

Table 2.2-1 Descriptive sustainability score statistics of the treatment groups and significance levels of parametric and nonparametric tests for differences between treatment groups

The mean SC of the additional salience (SL) group is 8.38 with a standard deviation of 2.68, a median of 8.5, and an interquartile range of 4. Taking the SL group into account, both the ANOVA and the Kruskal-Wallis test indicate differences between the groups at a 10% significance level. Pairwise t-tests indicate differences between SL and C, DR, and S at a 5 % significance level. Pairwise Mann-Whitney-U tests indicate differences between SL and C and SN at a 10% and DR and S at a 5% significance level. We thus observe hints at a negative effect of the DNE salience on the SV as compared to most of the other groups.

Next, we perform a multiple linear regression analysis with SC as the dependent variable. The allocation to the treatment groups and the set of FCQ and SRC items were included as independent variables. This allows us to consider a multitude of important explanatory factors as control variables which, alongside the DNEs, might have influenced the sustainable food shopping behavior of our field experiment's participants. The VIFs of all 16 items were lower than 2.84, thus indicating that multicollinearity was not to be dealt with. Controlling for both the participants' FCQ and SRC, the DNE default rules had a minor significant positive effect in promoting sustainable food shopping behavior. We find a significantly negative effect of the participant's priority that food be affordable (see Table 2.2-2).

Variable	Description	Estimate	p-value	
Intercept		6.05	0.000	***
Group DR	Default rules	0.80	0.094	.
Group S	Simplification	0.71	0.136	
Group SN	Social norms	0.07	0.876	
FCQ1	Healthy	0.00	0.998	
FCQ2	Enables mood monitoring	0.00	0.969	
FCQ3	Convenient	-0.07	0.568	
FCQ4	Provides pleasurable sensations	0.06	0.669	
FCQ5	Natural	0.17	0.379	
FCQ6	Affordable	-0.33	0.005	**
FCQ7	Helps control weight	-0.06	0.483	
FCQ8	Familiar	0.06	0.574	
FCQ9	Environmentally friendly	0.25	0.195	
FCQ10	Animal friendly	0.03	0.857	
FCQ11	Fairly traded	0.27	0.193	
SRC1	Vegetables	0.25	0.120	
SRC2	Fruit	-0.12	0.330	
SRC3	Dairy	0.02	0.785	
SRC4	Fish	0.05	0.736	
SRC5	Meat	-0.18	0.101	

*p-value significance codes: *** for < 0.001, ** for < 0.01, * for < 0.05, + for < 0.1*

Table 2.2-2 Estimates and p-values of linear regression

To address our second research question, we perform a two-step cluster analysis with the FCQ and SRC items as input variables. We first apply the hierarchical Ward's minimum variance method with squared Euclidian distances. An elbow plot, the gap statistic as well as ten out of thirty calculated indices recommend three as the optimal number of clusters. We therefore proceed to partition our sample into three groups using k-means clustering. To verify the validity of the division of participants into three groups, we a) thoroughly discussed the three-cluster solution and its interpretation within the research team and compared it to solutions with different numbers of clusters. We b) tested the groups for differences between each other regarding their SCs and all FCQ and SRC items using ANOVA and Kruskal-Wallis tests and, if indicated by their results, pairwise post-hoc t-tests and Mann-Whitney-U tests. The full set of SC, FCQ, and SRC values for each cluster as well as the test results can be found in Table 2.2-3. Based on these analyses, we conclude that a three-cluster solution is the most suitable one and that each cluster represents a unique consumer group which can be specified as follows.

		Total	C	DR	S	SN	Shapiro-Wilk normality	Bartlett variance	ANOVA	Kruskal-Wallis	Pairw. t-tests	Pairw. Mann-Whitney-U
C1	N	95	32	18	21	24						
Sustainability score	Mean	10.30	10.00	10.11	11.52	9.75						
	Standard deviation	2.60	2.89	2.70	1.97	2.42			.	.	C-S *	C-S *
	Median	10	10	10	11	10						
	Interquartile range	3	4	2	3	3						
C2	N	90	16	31	23	20						
Sustainability score	Mean	8.36	8.50	9.90	8.13	7.65						
	Standard deviation	2.84	1.75	3.04	3.01	3.03	S *					
	Median	8	8	9	8	7						
	Interquartile range	3	1	4	4	3						
C3	N	106	25	25	24	32						
Sustainability score	Mean	9.34	8.88	9.96	9.13	9.38						
	Standard deviation	3.00	2.83	3.57	2.80	2.84						
	Median	10	9	10	10	10						
	Interquartile range	4	3	4	4	3						

Cluster codes: C1 - environmentally-conscious, C2 - environmentally-unconscious, C3 - pragmatic

*p-value significance codes: *** for < 0.001, ** for < 0.01, * for < 0.05, + for < 0.1*

Table 2.2-3 Descriptive sustainability score statistics of the treatment groups within clusters and results of parametric and nonparametric tests for differences between treatment groups

Cluster 1 - environmentally-conscious participants. These individuals are driven by pro-environmental motives. They score highest in food choice motives regarding naturalness, environmental and animal friendliness, and fair trade (mean cluster scores > 6.01 on seven-point Likert scale). They consume plant-based products most (vegetables and fruit > 6.03) and non-vegetarian animal products least (fish and meat < 1.86) frequently. Environmentally-conscious participants exhibit the highest mean SC of 10.30.

Cluster 2 - environmentally-unconscious participants. These participants exhibit the lowest scores regarding the above-mentioned food choice motives (< 4.85) and consume the least plant-based products (< 5.26) compared to the other clusters. Their mean SC is the lowest (8.36).

Cluster 3 - pragmatic participants. Pragmatic participants occupy the middle of the score spectrum of the different clusters regarding the above-mentioned food choice motives (> 5.97) and simultaneously place the highest value on convenience, price, and familiarity (> 4.49). Their mean SC is 9.34.

A Shapiro-Wilk test rejects the null hypothesis that the SCs are normally distributed for the treatment group S in the environmentally-unconscious cluster. Bartlett tests do not reject the null hypothesis that the SC variance is the same in all treatment groups. Considering the rather small numbers of participants in the different treatment groups within each cluster, we apply a Kruskal-Wallis test between the four groups as well as an ANOVA. Both reject the null-hypotheses that the SC medians or means of the different treatment groups are the same within the environmentally-conscious cluster. Pairwise post-hoc tests specify that there was a significant difference between the control group and the group with the DNE simplification. Regarding our second research question, we find that the DNE simplification has a significant positive effect on sustainable food shopping behavior in the cluster of environmentally-conscious participants. Table 2.2-3 presents the descriptive statistics of the clusters and the comprised four treatment groups and the significance levels of the applied tests' p-values. Non-significant test results were excluded for reasons of readability.

2.2.5 Discussion and Conclusion

Digital technologies are promising tools to address societal problems, including those related to sustainability (Watson et al., 2010). The world's current food system has tremendous detrimental effects on the environment. Changing the ways in which we produce and transport food is a major factor in shaping a sustainable global future. The demand side has the power to accelerate these changes on the supply side by demanding more ecologically sustainable food (Mont et al., 2014). Due to the rising interaction with technologies, the potential of improving individuals' behavior to address societal problems has risen (Melville, 2010). Demand-side food choices are increasingly made online in the context of online grocery stores, delivery services, and food or grocery subscription services. Besides the elimination and restriction of choices through laws or fiscal methods, nudging is a promising tool to influence the individual's behavior in an ecologically sustainable manner (Ferrari et al., 2019; Lehner et al., 2016; Schubert, 2017).

In this study, we tested the effectiveness of the three DNEs default rules, simplification, and social norms to promote ecologically sustainable food choices by conducting an online field experiment with 291 participants. We compared the impact of the different DNEs with each other (RQ1) as well as regarding different consumer groups (RQ2).

We found that the DNE default rules was effective (with a moderate effect size and statistical significance) in an online food context to promote ecologically sustainable food products controlling for their food choice motives and their typical food consumption behavior. For many consumers, daily food choices are likely to occur as automatic and intuitive decision-making processes in system 1 (Kahneman, 2011). Some participants might have subconsciously wanted to maintain the status quo of product selection which was indicated in the shopping list by adding the marker “Bio” in front of each item. Others might have automatically gone with the selection of products nudged in the shopping list because they dislike making decisions or wanted to save time (Sunstein, 2014). The aspect of time-saving as a major advantage of e-commerce (Moagar-Poladian et al., 2017) in the dynamic digital age might have positively interacted with and fostered the effectiveness of the DNE default rules.

The DNE simplification had a significant positive effect on the sustainable shopping behavior of the subgroup of environmentally-conscious participants. These individuals place a high value on naturalness, environmental and animal friendliness, and fair trade. They also consume significantly more plant-based products as compared to the members of the other two identified clusters. Still, the environmentally-conscious participants might generally have difficulties in determining the correct choice regarding ecological sustainability (Spaargaren et al., 2013). The simple summary of the required information as well as a positive framing in the form of a smiling world icon might thus have been highly appreciated, leading the participants to more informed, ecologically sustainable product choices.

Unexpectedly and contradictory to prior research by Demarque et al. (2015), the DNE social norms showed no influence on the sustainable shopping behavior of our field experiment’s participants. Providing them with information about the trend that more and more customers bought sustainable products and flagging the products as popular did not have any effect. This might be due to the low level of uncertainty regarding the choices in our experiment. Higgs (2015) found that the usage of social norms is especially effective in situations with high uncertainty in which following the crowd is perceived as a safe option. The presented products were standard ingredients with which most participants can be expected to be familiar. The DNE social norms might work better for nudging ecologically sustainable new products which are not yet known to a broad customer base.

Lastly, we included the fourth DNE salience in our considerations in order to sort out whether possible observed effects of our three focused DNEs should be attributed to mere attention catching or their thematic relation to sustainability. Based on the limited analyses that we could perform which we will address in the limitations and further research section, we found that solely emphasizing sustainable product options based on a topic which is unrelated to sustainability had an adverse effect on sustainable shopping behavior. The graphical emphasis might have drawn the attention of our field experiments participants, but the thematic focus on taste most likely irritated them or even made them feel manipulated, resulting in the selection of other, less sustainable products. We conclude that based on our results, nudging sustainable choices requires more than flashy ways to draw attention and needs a relation of its content to sustainability.

2.2.5.1 Theoretical Contribution

Our work contributes to the existing literature regarding nudging, digital nudging, and the promotion of ecologically sustainable choices in online food contexts in three ways. (1) Complementing the research by Demarque et al. (2015) about the DNE social norms, we transferred two additional major NEs from the physical to the digital world. Default rules and simplification have been evaluated in physical contexts by Lehner et al. (2016) and Ferrari et al. (2019), but to the best of our knowledge have not yet been applied online regarding the promotion of ecologically sustainable food choices. The concrete design and implementation examples of the DNEs in the field experiment might inform further research in this area. (2) While prior research focused mainly on the implementation and configuration of single (D)NEs, we gathered empirical data about the effectiveness of all three DNEs default rules, simplification, and social norms in a field experiment with 291 participants. This enabled us to compare different DNEs and shed new light on possible differences in their impacts. Regarding the whole sample, we found minor significance for default rules to have succeeded in promoting ecologically sustainable shopping behavior in the context of an online grocery store while simplification and social norms showed no effect. Default rules are thus a suitable one-size-fits-all solution for fostering sustainable food shopping. (3) By considering individual food choice motives (FCQ) and consumption patterns (SRC) and employing clustering techniques, we identified three typical consumer types in our field experiment: environmentally-conscious, environmentally-unconscious, and pragmatic consumers. This enabled us to examine the effectiveness of the different DNEs in different consumer groups. While there were no effects observable in the environmentally-unconscious and the pragmatic clusters, simplification proved to be effective in the environmentally-conscious cluster. This highlights the potential of using online individual consumer data to provide individualized choice environments based on personal characteristics and preferences. Simplification, although not effective regarding the complete consumer base, might be a powerful tool to promote sustainable food shopping behavior in the target group of environmentally-conscious consumers. The same might apply to other DNEs and other consumer groups identified using different individual characteristics and behavior patterns.

2.2.5.2 Practical Implications

Online grocery stores, delivery services, and food or grocery subscription services are on the rise. They are gaining ever more relevance regarding our food consumption and increasingly have the power to influence our food choices towards more ecologically sustainable ones. In our study, the DNE default rules proved to be an effective instrument regarding a broad customer base. Regarding online grocery stores that offer buckets for specific meals or weekly grocery shopping, the DNE could be implemented by pre-selecting only ecologically sustainable products which then can easily be added directly to the shopping cart. Online grocery stores and grocery subscription services could focus on ecologically sustainable products when presenting the ingredients of recipes similar to the implementation in our field experiment. Subscription services could also pre-select ecologically friendly options and require customers to actively decide against them in case they prefer other products. Depending on the data available to online grocery stores, delivery services, and food or grocery subscription services, they might also target environmentally-conscious customers with the DNE simplification which proved to be effective for this specific consumer group in our field study. By providing condensed information about the sustainability of products, dishes, or other offers using labels, icons, or other means of displaying the relevant information, they might provide environmentally-conscious customers with just the nudge they need to transfer their good intentions into concrete choices. If successful, food suppliers might announce rising sales of ecologically sustainable products as part of their marketing campaigns. This can lead to competitive advantages because the environmental awareness of customers has risen and will continue to rise, hence sustainability has become a real business issue for food retailers (Claro et al., 2013).

As a result, consumers could profit from time savings due to reduced decision-making efforts when shopping for groceries as well as health benefits that ecologically sustainable products might bring along. Moreover, the implementation of DNEs supports consumers who wish to follow their societal responsibility to counteract environmental deterioration by choosing products with higher ecological sustainability.

However, we found that the customers' price sensitivity has a negative influence on their SCs. The higher the participants of our field study valued that food is affordable, the less sustainable products they purchased. This is due to the fact that generally, sustainable products are more expensive than conventional products. This relationship needs to be dissolved in order to ensure a global sustainable future. We, therefore, call on legislators and regulators to start or enforce the conversation about how sustainable products can become comparatively cheaper in the future, e.g., through tax instruments or subsidies.

2.2.5.3 Limitations and Further Research

Like all research, this paper is limited regarding several aspects that require further work and development. First, the consideration of DNEs is limited to the three most common ones in the consumption domain. Further, DNEs like feedback or reminders should prospectively be examined and tested in online field experiments. This includes the analysis of and comparison with other NEs such as salience based on data acquired from the same population and the same point in time. Second, the design of the individual DNEs should be analyzed and refined in the future, especially for social norms, which did not show any significant influence on sustainable food shopping behavior in our filed experiment. Similar to Demarque et al. (2015), different levels from weak to strong forms of social norms could be evaluated. The considerations of products with higher consumer uncertainty (Higgs, 2015) like new, more sustainable substitutes for traditional food should also be taken into account regarding social norms. As a positive side effect, the findings of Demarque et al. (2015), who focused on students, could be enriched as students might be more sensitive to social norms compared to other age and social groups. Third, even though we provided an incentive to guarantee a shopping behavior as close to real-life behavior as possible by balancing food sustainability and price, the analysis of real observations from online grocery stores that implemented DNEs would yield important insight about the applicability and effectiveness of the DNEs as well as possible intention-behavior gaps. Fourth, our limited sample size resulted in a limited statistical power. Future research might consider a field experiment in collaboration with food delivery services or supermarkets to, on the one hand, observe real-life shopping behavior, and, on the other hand, increase the sample size. Additionally, different and more specific consumer groups can be identified by collecting more individual characteristics and behavioral data. Lastly, we determined the sustainable product options in our field experiment by mainly relying on information about organic or non-organic origins. Different studies about the ecological sustainability of organic vs. conventional food exist, and science does not yet agree (Clark & Tilman, 2017). However, our results can be adapted to any new findings regardless of the specific definition of ecologically sustainable products.

Overall, we have linked the need for global sustainability with the promising IS tool of digital nudging in the highly relevant online food context. We call on research to further transfer NEs from physical to digital contexts and consider further individualization of DNEs to promote ecologically sustainable food choices.

2.2.6 References

Aldrovandi, S., Brown, G. D. A., & Wood, A. M. (2015). Social norms and rank-based nudging: Changing willingness to pay for healthy food. *Journal of Experimental Psychology: Applied*, *21*(3), 242–254. https://doi.org/10.1037/xap0000048

Bacon, L., & Krpan, D. (2018). (Not) eating for the environment: The impact of restaurant menu design on vegetarian food choice. *Appetite*, *125*, 190–200. https://doi.org/10.1016/j.appet.2018.02.006

Balijepally, V., Mangalaraj, G., & Iyengar, K. (2011). Are we wielding this hammer correctly? A reflective review of the application of cluster analysis in information systems research. *Journal of the Association for Information Systems*, *12*(5), 375–413.

Benartzi, S., & Lehrer, J. (2015). *The Smarter Screen: Surprising Ways to Influence and Improve Online Behavior.* Portfolio/Penguin. https://doi.org/10.1177/09567976177025

Blumenthal-Barby, J. S., & Burroughs, H. (2012). Seeking better health care outcomes: The ethics of using the “nudge”. *The American Journal of Bioethics*, *12*(2), 1–10. https://doi.org/10.1080/15265161.2011.634481

Campbell-Arvai, V., Arvai, J., & Kalof, L. (2014). Motivating sustainable food choices: The role of nudges, value orientation, and information provision. *Environment and Behavior*, *46*(4), 453–475. https://doi.org/10.1177/0013916512469099

Centraal Bureau voor de Statistiek. (2019). *Share of consumers who purchased food or groceries online in selected countries in Europe from 2006 to 2018: Belgium, France, Germany, Italy, Netherlands, United Kingdom*. https://www.statista.com/statistics/915391/e-commerce-purchase-rate-of-food-or-groceries-in-europe-by-country/. Accessed on 2020-04-12.

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology*, *58*(6), 1002–1014.

Clark, M., & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters*, *12*(6). https://doi.org/10.1088/1748-9326/aa6cd5

Claro, D. P., Laban Neto, S. A., & Oliveira Claro, P. B. de (2013). Sustainability drivers in food retail. *Journal of Retailing and Consumer Services*, *20*(3), 365–371. https://doi.org/10.1016/j.jretconser.2013.02.003

Council regulation (EC) No 834/2007 of 28.06.2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91, June 28, 2007.

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007R0834. Accessed on 2020-04-05.

Demarque, C., Charalambides, L., Hilton, D. J., & Waroquier, L. (2015). Nudging sustainable consumption: The use of descriptive norms to promote a minority behavior in a realistic online shopping environment. *Journal of Environmental Psychology*, *43*, 166–174. https://doi.org/10.1016/j.jenvp.2015.06.008

Dunlap, R. E., van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New trends in measuring environmental attitudes: Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues*, *56*(3), 425–442.

Ferrari, L., Cavaliere, A., Marchi, E. de, & Banterle, A. (2019). Can nudging improve the environmental impact of food supply chain? A systematic review. *Trends in Food Science & Technology*, *91*, 184–192. https://doi.org/10.1016/j.tifs.2019.07.004

Friis, R., Skov, L. R., Olsen, A., Appleton, K. M., Saulais, L., Dinnella, C., Hartwell, H., Depezay, L., Monteleone, E., Giboreau, A., & Perez-Cueto, F. J. A. (2017). Comparison of three nudge interventions (priming, default option, and perceived variety) to promote vegetable consumption in a self-service buffet setting. *PloS One*, *12*(5). https://doi.org/10.1371/journal.pone.0176028

Gassmann, M. (2020). *Das Coronavirus wird Einkaufen dauerhaft verändern.* Welt. https://www.welt.de/wirtschaft/article206541365/Coronavirus-Einkaufen-wird-sich-dauerhaft-veraendern.html. Accessed on 2020-03-23.

Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A room with a viewpoint: Using social norms to motivate environmental conservation in hotels. *Journal of Consumer Research*, *35*(3), 472–482. https://doi.org/10.1086/586910

Grandon, E. E., & Pearson, J. M. (2004). Electronic commerce adoption: An empirical study of small and medium US businesses. *Information & Management*, *42*(1), 197–216. https://doi.org/10.1016/j.im.2003.12.010

Gravetter, F. J., & Forzano, L.-A. B. (2016). *Research Methods for the Behavioral Sciences* (5ed.). Cengage Learning.

Hawkes, C. (2008). Dietary implications of supermarket development: A global perspective. *Development Policy Review*, *26*(6), 657–692. https://doi.org/10.1111/j.1467-7679.2008.00428.x

Higgs, S. (2015). Social norms and their influence on eating behaviours. *Appetite*, *86*, 38–44.

Hirschberg, C., Rajko, A., Schumacher, T., & Wrulich, M. (2016). *The changing market for food delivery*. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/the-changing-market-for-food-delivery. Accessed on 2020-04-26.

HLPE. (2014). *Food losses and waste in the context of sustainable food systems: A report by the high level panel of experts on food security and nutrition of the committee on world food security*. FAO.

Hoek, A. C., Pearson, D., James, S. W., Lawrence, M. A., & Friel, S. (2017). Shrinking the food-print: Food behaviours: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly. *Appetite*, *108*, 117–131. https://doi.org/10.1016/j.appet.2016.09.030

Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review*, *93*(5), 1449–1475.

Kahneman, D. (2011). *Thinking, fast and slow*. Macmillan.

Kallbekken, S., & Sælen, H. (2013). 'Nudging' hotel guests to reduce food waste as a win–win environmental measure. *Economics Letters*, *119*(3), 325–327.

Kameke, C. von, & Fischer, D. (2018). Preventing household food waste via nudging: An exploration of consumer perceptions. *Journal of Cleaner Production*, *184*, 32–40.

Koerber, K. von, & Kretschmer, J. (2000). Sustainable nutrition: Health, environmental, economic and social compatibility in the food sector. *Zeitschrift Für Ernährungsökologie*, *1*, 39–46.

Kormos, C., Gifford, R., & Brown, E. (2015). The influence of descriptive social norm information on sustainable transportation behavior: A field experiment. *Environment and Behavior*, *47*(5), 479–501.

Kurz, V. (2018). Nudging to reduce meat consumption: Immediate and persistent effects of an intervention at a university restaurant. *Journal of Environmental Economics and Management*, *90*, 317–341. https://doi.org/10.1016/j.jeem.2018.06.005

LaBrie, J. W., Hummer, J. F., Neighbors, C., & Larimer, M. E. (2010). Whose opinion matters? The relationship between injunctive norms and alcohol consequences in college students. *Addictive Behaviors*, *35*(4), 343–349. https://doi.org/10.1016/j.addbeh.2009.12.003

Lehner, M., Mont, O., & Heiskanen, E. (2016). Nudging – A promising tool for sustainable consumption behaviour? *Journal of Cleaner Production*, *134*, 166–177. https://doi.org/10.1016/j.jclepro.2015.11.086

Linder, N., Lindahl, T., & Borgström, S. (2018). Using behavioural insights to promote food waste recycling in urban households - Evidence from a longitudinal field experiment. *Frontiers in Psychology*, *9,* 352. https://doi.org/10.3389/fpsyg.2018.00352

Melnyk, V., van Herpen, E., & Trijp, H. (2010). The influence of social norms in consumer decision making: A meta-analysis. In Campbell, M.C., Inman, J. & R. Pieters (Eds.), *NA - Advances in Consumer Research* (Vol. 37, pp. 463–464). Association for Consumer Research.

Melville, N. P. (2010). Information systems innovation for environmental sustainability. *Management Information Systems Quarterly*, *34,* 1–21.

Meybeck, A., & Gitz, V. (2017). Sustainable diets within sustainable food systems. *The Proceedings of the Nutrition Society*, *76*(1), 1–11. https://doi.org/10.1017/S0029665116000653

Milligan, G. W., & Cooper, M. C. (1987). Methodology review: Clustering methods. *Applied Psychological Measurement*, *11*(4), 329–354. https://doi.org/10.1177/014662168701100401

Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. In *Proceedings of the 13th Conference on Wirtschaftsinformatik (WI13).*

Moagar-Poladian, S., Dumitrescu, G.-C., & Tanase, I. A. (2017). Retail e-commerce (E-tail) - Evolution, characteristics and perspectives in China, the USA and Europe. *Global Economic Observer*, *5*(1), 167–178.

Mont, O., Lehner, M., & Heiskanen, E. (2014). *Nudging - A tool for sustainable Behaviour?* The Swedish Environmental Protection Agency.

Morganosky, M. A., & Cude, B. J. (2000). Consumer response to online grocery shopping. *International Journal of Retail & Distribution Management*, *28*(1), 17–26. https://doi.org/10.1108/09590550010306737

Münscher, R., Vetter, M., & Scheuerle, T. (2016). A review and taxonomy of choice architecture techniques. *Journal of Behavioral Decision Making*, *29*(5), 511–524. https://doi.org/10.1002/bdm.1897

Neighbors, C., Lostutter, T. W., Whiteside, U., Fossos, N., Walker, D. D., & Larimer, M. E. (2007). Injunctive norms and problem gambling among college students. *Journal of Gambling Studies*, *23*(3), 259–273. https://doi.org/10.1007/s10899-007-9059-3

Nigbur, D., Lyons, E., & Uzzell, D. (2010). Attitudes, norms, identity and environmental behaviour: Using an expanded theory of planned behaviour to predict participation in a kerbside recycling programme. *British Journal of Social Psychology*, *49*(Pt 2), 259–284. https://doi.org/10.1348/014466609X449395

Noleppa, S. (2012). *Climate change on your plate*. Berlin. https://mobil.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Climate_change_on_your_plate.pdf. Accessed on 2020-03-23.

Onwezen, M. C., Bartels, J., & Antonides, G. (2014). The self-regulatory function of anticipated pride and guilt in a sustainable and healthy consumption context. *European Journal of Social Psychology*, *44*(1), 53–68. https://doi.org/10.1002/ejsp.1991

Onwezen, M. C., Reinders, M. J., Verain, M., & Snoek, H. M. (2019). The development of a single-item food choice questionnaire. *Food Quality and Preference*, *71*, 34–45. https://doi.org/10.1016/j.foodqual.2018.05.005

Oosterveer, P., Guivant, J., & Spaargaren, G. (2007). Shopping for green food in globalizing supermarkets: Sustainability at the consumption junction. In J. Pretty, A. S. Ball, T. Benton, J. S. Guivant, D. R. Lee, D. Orr, M. J. Pfeffer, & H. Ward (Eds.), *The SAGE Handbook of Environment and Society* (pp. 411–428). SAGE.

Oullier, O., Cialdini, R., Thaler, R. H., & Mullainathan, S. (2010). Improving public health prevention with a nudge. In O. Oullier & S. Sauneron (Eds.), *Improving public health Prevention with behavioural, cognitive and neuroscience* (pp. 38–46).

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Pulker, C. E., Trapp, G. S. A., Scott, J. A., & Pollard, C. M. (2018). Global supermarkets' corporate social responsibility commitments to public health: A content analysis. *Globalization and Health*, *14*(1), 121. https://doi.org/10.1186/s12992-018-0440-z

Punj, G., & Stewart, D. W. (1983). Cluster analysis in marketing research: Review and suggestions for application. *Journal of Marketing Research*, *20*(2), 134–148. https://doi.org/10.1177/002224378302000204

Robinson, E., Thomas, J., Aveyard, P., & Higgs, S. (2014). What everyone else is eating: A systematic review and meta-analysis of the effect of informational eating norms on eating behavior. *Journal of the Academy of Nutrition and Dietetics*, *114*(3), 414–429. https://doi.org/10.1016/j.jand.2013.11.009

Rokicki, T. (2018). E-commerce market in Europe in B2C. *Information Systems in Management*, *7*(2), 133–140. https://doi.org/10.22630/ISIM.2018.7.2.12

Schlich, E., & Fleissner, U. (2005). The ecology of scale: assessment of regional energy turnover and comparison with global food. *The International Journal of Life Cycle Assessment*, *10*(3), 219–223. https://doi.org/10.1065/lca2004.09.180.9

Schubert, C. (2017). Green nudges: Do they work? Are they ethical? *Ecological Economics*, *132*, 329–342. https://doi.org/10.1016/j.ecolecon.2016.11.009

Schultz, P. W., Gouveia, V. V., Cameron, L. D., Tankha, G., Schmuck, P., & Franěk, M. (2005). Values and their relationship to environmental concern and conservation behavior. *Journal of Cross-Cultural Psychology*, *36*(4), 457–475. https://doi.org/10.1177/0022022105275962

Schwartz, M. B. (2007). The influence of a verbal prompt on school lunch fruit consumption: A pilot study. *The International Journal of Behavioral Nutrition and Physical Activity*, *4*, 6. https://doi.org/10.1186/1479-5868-4-6

Shearer, L., Gatersleben, B., Morse, S., Smyth, M., & Hunt, S. (2017). A problem unstuck? Evaluating the effectiveness of sticker prompts for encouraging household food waste recycling behaviour. *Waste Management (New York, N.Y.)*, *60*, 164–172. https://doi.org/10.1016/j.wasman.2016.09.036

Spaargaren, G., van Koppen, C. K., Janssen, A. M., Hendriksen, A., & Kolfschoten, C. J. (2013). Consumer responses to the carbon labelling of food: A real life experiment in a canteen practice. *Sociologia Ruralis, 84*(3), 432-453. https://doi.org/10.1111/soru.12009

Specht, K., Weith, T., Swoboda, K., & Siebert, R. (2016). Socially acceptable urban agriculture businesses. *Agronomy for Sustainable Development*, *36*(1), 131.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate? *The Behavioral and Brain Sciences*, *23*(5), 645-726.

Statistische Ämter des Bundes und der Länder. (2015). *Zensus 2011: Methoden und Verfahren*. Wiesbaden. Statistisches Bundesamt. https://www.zensus2011.de/SharedDocs/Downloads/DE/Publikationen/Aufsaetze_Archiv/2015_06_ MethodenUndVerfahren.pdf;jsessionid=64CB5E1797D2309E5EE73DC7B58256E9.2_cid389?__blob=publicationFile&v=6. Accessed on 2020-05-01.

Steptoe, A., Pollard, T. M., & Wardle, J. (1995). Development of a measure of the motives underlying the selection of food: The food choice questionnaire. *Appetite*(25), 267–284.

Striapunina, K. (2020). *Prognose zum Umsatz im E-Commerce-Markt nach Segmenten in Deutschland bis 2024*. https://de.statista.com/statistik/daten/studie/487985/umfrage/prognose-der-umsaetze-im-e-commerce-nach-segmenten-in-deutschland/. Accessed on 2020-04-12.

Sunstein, C. R. (2014). Nudging: A very short guide. *Journal of Consumer Policy 2014 37:4*, *37*(4), 583–588. https://doi.org/10.1007/S10603-014-9273-1

Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: Improving decisions about health, wealth, and happiness*. Penguin.

Torma, G., Aschemann-Witzel, J., & Thøgersen, J. (2018). I nudge myself: Exploring 'self-nudging' strategies to drive sustainable consumption behaviour. *International Journal of Consumer Studies*, *42*(1), 141–154. https://doi.org/10.1111/ijcs.12404

Tukker, A., Goldbohm, R. A., Koning, A. de, Verheijden, M., Kleijn, R., Wolf, O., Pérez-Domínguez, I., & Rueda-Cantuche, J. M. (2011). Environmental impacts of changes to healthier diets in Europe. *Ecological Economics*, *70*(10), 1776–1788. https://doi.org/10.1016/j.ecolecon.2011.05.001

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development.* United Nations. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf. Accessed on 2020-03-20.

Van Gilder Cooke, S. (2012, April 9). Why going green can mean big money for fast-food chains. *Time*, 2012. http://content.time.com/time/world/article/0,8599,2111372,00.html. Accessed on 2020-05-01.

van't Riet, J., Sijtsema, S. J., Dagevos, H., & Bruijn, G.-J. de (2011). The importance of habits in eating behaviour. An overview and recommendations for future research. *Appetite*, *57*(3), 585–596.

Vandenbroele, J., Slabbinck, H., van Kerckhove, A., & Vermeir, I. (2018). Curbing portion size effects by adding smaller portions at the point of purchase. *Food Quality and Preference*, *64*, 82–87. https://doi.org/10.1016/j.foodqual.2017.10.015

Vandenbroele, J., Vermeir, I., Geuens, M., Slabbinck, H., & van Kerckhove, A. (2020). Nudging to get our food choices on a sustainable track. *The Proceedings of the Nutrition Society*, *79*(1), 133–146. https://doi.org/10.1017/S0029665119000971

Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers. *Annual Review of Nutrition*, *24*, 455–479.

Wansink, B., & Cheney, M. M. (2005). Super bowls: Serving bowl size and food consumption. *Jama*, *293*(14), 1727–1728. https://doi.org/10.1001/jama.293.14.1727

Watson, Boudreau, & Chen (2010). Information systems and environmentally sustainable development: Energy informatics and new directions for the IS community. *Management Information Systems Quarterly*, *34*(1), 23. https://doi.org/10.2307/20721413

Weinmann, M., Schneider, C., & Vom Brocke, J. (2016). Digital nudging. *Business & Information Systems Engineering*, *58*(6), 433–436. https://doi.org/10.1007/s12599-016-0453-1

Wigand, R. T. (1997). Electronic commerce: Definition, theory, and context. *The Information Society*, *13*(1), 1–16. https://doi.org/10.1080/019722497129241

Wilson, A. L., Buckley, E., Buckley, J. D., & Bogomolova, S. (2016). Nudging healthier food and beverage choices through salience and priming. Evidence from a systematic review. *Food Quality and Preference*, *51*, 47–64. https://doi.org/10.1016/j.foodqual.2016.02.009

Wunsch, N.-G. (2019, May 20). *Food delivery services in Europe - Statistics and facts*. https://www.statista.com/topics/3425/food-delivery-services-in-europe/. Accessed on 2020-04-24.

Yeo, V. C. S., Goh, S.-K., & Rezaei, S. (2017). Consumer experiences, attitude and behavioral intention toward online food delivery (OFD) services. *Journal of Retailing and Consumer Services*, *35*, 150–162.

2.2.7 Appendix

Dimension	Cluster			Significance tests					
	C1 n = 95	C2 n = 90	C3 n = 106	Normality tests [a]	Variance test [b]	ANOVA [c1]	Kruskal-Wallis-Test [c2]	Pairwise post-hoc t-tests [d1]	Pairwise post-hoc Mann-Whitney-U-Tests [d2]
SC	10.295	8.356	9.340	C3*		10.9 ***	20.074 ***	C1-C2***; C1-C3*; C2-C3*	C1-C2***; C1-C3*; C2-C3*
Vegetables	6.695	5.256	6.000	***	***	37.95 ***	62.312 ***	***	***
Fruit	6.032	4.378	5.821	***	*	36.42 ***	53.606 ***	C1-C2***; C2-C3***	C1-C2***; C2-C3***
Dairy	3.905	5.244	6.075	***	***	41.54 ***	56.584 ***	***	***
Fish	1.589	2.278	3.038	***	***	44.28 ***	70.229 ***	***	***
Meat	1.863	4.089	3.858	***	***	61.14 ***	90.329 ***	C1-C2***; C1-C3***	C1-C2***; C1-C3***

*p-value significance codes: *** for < 0.001, ** for < 0.01, * for < 0.05, + for < 0.1*
a) Normality of items is present according to the central limit theorem (n>30). Normality was further tested with the Shapiro-Wilk-Test.
b1) Variance between clusters was tested with the Bartlett's Test.
c1) Differences in means were tested with ANOVA.
c2) Differences in means in case of non-parametric data were tested with the Kruskal-Wallis-Test.
d1) Pairwise differences in means were tested with the t-test.
d2) Pairwise differences in means in case of non-parametric data were tested with the Mann-Whitney-U-Test.

Table 2.2-4 Cluster analysis – Sustainability score (SC) and self-reported consumption (SRC) values per cluster and comparison between clusters

	Cluster			Significance tests					
	C1 n = 95	C2 n = 90	C3 n = 106	Normality tests [a]	Variance test [b]	ANOVA [c1]	Kruskal-Wallis-Test [c2]	Pairwise post-hoc t-tests [d1]	Pairwise post-hoc Mann-Whitney-U-Tests [d2]
Healthy	6.379	4.778	6.085	***	***	87.87 ***	111.740 ***	C1-C2***; C1-C3**; C2-C3***	C1-C2***; C1-C3**; C2-C3***
Enables mood monitoring	5.084	3.600	4.698	***		17.140 ***	30.462 ***	C1-C2***; C2-C3***	C1-C2***; C2-C3***
Convenient	3.821	4.878	5.311	***	*	29.35 ***	49.326 *	C1-C2***; C1-C3***; C2-C3*	C1-C2***; C1-C3***
Provides pleasurable sensation	5.768	5.244	5.557	***		3.321 *	8.689 ***	C1-C2*	C1-C2**; C1-C3.
Natural	6.411	4.856	5.972	***	***	68.55 ***	92.547 **	***	***
Affordable	4.168	4.444	4.906	***		6.399 **	13.673 **	C1-C3***; C2-C3*	C1-C3***; C2-C3*
Helps control weight	4.137	3.322	4.189	***		6.114 **	12.369 ***	C1-C2**; C2-C3**	C1-C2**; C2-C3**
Familiar	3.337	3.844	4.491	C1***; C2**; C3***		14.44 ***	26.043 ***	C1-C2*; C1-C3***; C2-C3**	C1-C2*; C1-C3***; C2-C3**
Environmentally friendly	6.084	4.189	5.613	***	***	83.96 ***	106.43 ***	***	***
Animal friendly	6.116	3.822	5.491	***		89.05 ***	112.12 ***	***	***
Fairly traded	6.011	3.889	5.396	***	*	105.1 ***	122.9 ***	***	***

*p-value significance codes: *** for < 0.001, ** for < 0.01, * for < 0.05, + for < 0.1*

a) Normality of items is present according to the central limit theorem (n>30). Normality was further tested with the Shapiro-Wilk-Test.
b1) Variance between clusters was tested with the Bartlett's Test.
c1) Differences in means were tested with ANOVA.
c2) Differences in means in case of non-parametric data were tested with the Kruskal-Wallis-Test.
d1) Pairwise differences in means were tested with the t-test.
d2) Pairwise differences in means in case of non-parametric data were tested with the Mann-Whitney-U-Test.

Table 2.2-5 Cluster analysis – Food choice questionnaire (FCQ) values per cluster and comparison between

2.3 Digital Nudging to Promote Energy Conservation Behavior – Framing and Default Rules in a Smart Home App

Abstract: Increasingly, new energy-efficient technologies connected to smart home arise and bear great potential of influencing user's decisions. Thereby, behavioral interventions like digital nudging are promising to influence behavior. While nudging has been investigated in several contexts to promote sustainable behavior, little is known about its effectiveness in digital choice environments promoting daily energy conservation behavior, especially through mobile applications. As private households account for a large share of total energy consumption, which needs to be reduced to counteract climate change, we conducted an online survey to test the nudging elements framing and default rules, as well as their combination. We surveyed 231 participants and found a large effect of framing and an even larger effect for the combination. This paper contributes by exploring these digital nudges, which received little attention in prior research, and by providing insights on the design of smart home applications to reduce energy consumption.

Keywords: Digital Nudging, Smart Home Application, Energy Conservation Behavior, Sustainability.

Authors: Michelle Berger, Elias Greinacher, Linda Wolf

Status: This article is published in the proceedings of the 30th European Conference on Information Systems (ECIS) in Timisoara, Romania, 2022.

2.3.1 Introduction

Driven by smart home technologies, which enable individuals to connect and intelligently control household devices, the digital environment has reached our homes and thus affects our daily decisions and habits massively. Such smart home technologies (e.g., smart lighting and heating systems) can be controlled by individuals via a smart home application (app). Therefore, these smart home apps bear a great potential of influencing the user's decisions, for example, on energy consumption. Within these apps, the use of behavioral interventions can additionally help to influence energy conservation behavior. Behavioral interventions using different nudging elements (NE) applied in the physical as well as in the digital environment - which defines the term digital nudging element (DNE) - are already an essential part of the scientific discourse (e.g., Mirsch et al. (2017), Thaler and Sunstein (2009), and Weinmann et al. (2016)). In contrast to restricting the number of options available by rules, regulations, or fiscal measures, (D)NEs intend to support better decision-making by modifying the so-called choice architecture: the shape of the context and environment in which people make decisions (Thaler and Sunstein, 2009).

As human activities, including private energy consumption behavior, are responsible for a substantial share of climate change, a comprehensive reform of our global energy consumption is unavoidable (United Nations Climate Change, 2021). In the context of private energy consumption, the ever-increasing efficiency of digital technologies like energy-efficient heating systems or household devices nurtured hopes to cut down energy consumption and are already part of the scientific discourse (Mills and Schleich, 2012; Schleich, 2019). However, the energy consumption by private households in Germany in 2020 is higher than in 1990 (Federal Environmental Agency of Germany, 2019). That efficiency gains are out-levered by increasing consumption and demand, also known as the rebound effect (Sorrell, 2015). Thus, besides technological progress, behavioral interventions like DNEs in smart home apps can represent an effective way to encounter climate change and therefore need to be analyzed in more detail in the scientific discourse.

Lehner et al. (2016) found four NEs to be effective in encouraging sustainable behavior in energy consumption, personal transportation, and food: default rules, simplification or framing, social norms, and adjustments to the physical environment (which is not applicable as a DNE). In the context of energy consumption, most of the prior studies focus on the implementation of social norms (Loock et al., 2012; Graml et al., 2011; Tussyadiah and Miller, 2019; Schultz et al., 2015) and feedback (Cappa et al., 2020; Schultz et al., 2015; Tussyadiah and Miller, 2019; Abrahamse et al., 2007). Little to no attention has been paid to default rules (i.e., changing the default, e.g., pre-selecting the most sustainable option) and framing (i.e., simplifying complex information, e.g., by using labels or icons such as green leaves) (Lehner et al., 2016). These DNEs show already encouraging results in other sustainability-related contexts, for example, default rules when promoting sustainable food choices (Berger et al., 2020) or framing to promote electronic cars in car rental processes (Schrills et al., 2020). However, research lacks the investigation of these DNEs in the increasingly important context of smart home apps. Prior research shows that the effectiveness of DNEs highly depends on the underlying context. For example, while Berger et al. (2020) did not find significant results of social norms to promote sustainable food choices, Kroll et al. (2019) found significant results in the context of daily energy consumption behavior. Next to the missing investigation of the (D)NEs default rules and framing, studies fall short on investigating the impact of DNE in a digital behavior environment (e.g., smart home apps), while being on the rise (Ali and Yusuf, 2018; Statista, 2021). Consumers can now actively regulate their energy consumption in the same environment, in which the DNE is implemented instead of being nudged in a digital environment (e.g., in-home displays) but taking decisions in a different, physical environment (e.g., physically turning down the heating). Humans behave differently in a digital environment (Liu, 2005), which is why we argue that a separate consideration of the effectiveness of DNEs in a digital behavior environment (i.e., smart home app) is important. Kroll et al. (2019) were the first and so far the only ones who studied the DNEs social norms and self-commitment in mobile smart home apps and provided the basis for further research on the use of further DNEs in this context. As next to social norms, the two NEs of default rules and framing are promising when promoting sustainable behavior; we aim to fill this research gap by addressing the following research question:

RQ2.3-1: *Do the digital nudging elements – framing and default rules – promote energy conservation behavior of individuals in mobile smart home apps?*

To answer this research question, we designed a smart home app and conducted an online experiment in which participants were asked to control four smart home devices through the app. We implemented the DNEs framing and default rules in different treatment groups. We additionally investigated the combination of both nudges, which may result in stronger effects by combining their advances as prior studies suggested (e.g., Kroll et al. (2019), Loock et al. (2012), Andor and Fels (2018)). Afterward, we analyzed the effectiveness of the DNEs using parametric and nonparametric statistics and analyzes. Next to several theoretical implications in digital nudging to promote sustainable behavior, this study contributes to how smart home apps need to be designed to encourage individuals to change their energy conservation behavior.

The paper is structured as follows: We introduce the research design after reviewing the theoretical background on (D)NEs, especially in the context of energy conservation behavior. Subsequently, we present the results. We conclude by discussing the results, pointing out implications, limitations, and further research proposals.

2.3.2 Theoretical Background

2.3.2.1 The Need for Energy Conservation Behavior and the Relevance of Smart Home Apps in that Regard

Improving energy efficiency is widely seen as the most promising response to mitigate climate change. The German Federal Ministry of Economics and Technology identifies advancing energy efficiency in the building sector and increasing personal responsibility for energy efficiency as the most important fields of action for energy efficiency policy (Federal Ministry for Economic Affairs & BMWi).

Driven by technological advances and innovations, energy efficiency has steadily increased in recent decades, indicating that less energy is needed for the same purposes. However, these improvements do not necessarily lead to reductions in energy demand. Instead, they are frequently accompanied by an increase in energy demand, described by the rebound effect (Sorrell, 2015). This effect states that after an increase in efficiency, additional demand for the more efficient product or service may occur, reducing the actual savings (Federal Ministry for Economic Affairs & BMWi, 2020). To back this up with numbers, while the global energy efficiency increased by 1.2% in 2018, the demand grew by 2.2% (International Energy Agency 2019; International Energy Agency, 2022). Considering the context of energy consumption in private households, which accounts for about 29% of the total energy consumption taking Germany as an example (UBA, 2019), innovations such as more energy-efficient technologies like washing machines and dishwashers with environmentally friendly programs or light that can be dimmed in its brightness can enable energy savings. In this context, smart home is an overarching term for various automation processes for connecting and intelligently controlling all kinds of these technical devices in buildings. Driven by increasingly more connected products and the Internet of Things (IoT), this concept is becoming more widespread and aims to focus the opportunities of technological progress on private households (Ali & Yusuf, 2018; Statista, 2021). With a smart home app, individuals can control the smart home devices (e.g., in the selection of the wanted IoT-enabled dishwasher program or controlling the IoT-enabled heating system) by themselves, keep an overview as well as track, and better control their energy consumption. Due to their technological possibilities and easy accessibility, they are an important instrument for improving overall energy reduction (Strese et al., 2010). Moreover, the implementation of smart homes will continue steadily in the coming years due to technological advances like IoT (Statista, 2021).

However, as stated above, the simple existence of innovative technologies like smart home is not enough to reduce energy consumption at home; personal responsibility for energy conservation and, consequently, consumer behavior plays an equally important role in using the technologies effectively. As a result, action needs to be taken to change the energy conservation behavior of individuals. Behavioral research has shown that targeted behavioral interventions, referred to as nudges (R. Thaler & Sunstein, 2009) and their digital counterpart, digital nudges (Weinmann et al., 2016b), can effectively influence human behavior. These could establish themselves as an essential component for better consumption decisions and thus climate protection (Allcott, 2011). As the ideal intermediary for such nudges in private households could be smart home technology, behavioral measures like digital nudging seem to be promising to achieve this goal (Asensio & Delmas, 2016; Lehner et al., 2016a; Claire-Michelle Loock et al., 2013).

2.3.2.2 The Concept of (Digital) Nudging

Nudging describes ways to predictably impact individuals' behaviors by altering the environment in which decisions are made without restricting the freedom of choice or raising the cost of alternatives in terms of effort, time, and other factors (Hansen & Jespersen, 2013; Hausmann & Welch, 2010; R. Thaler & Sunstein, 2009). Behavior results from decisions made consciously and unconsciously (Kahneman, 2011), also known as the dual-process theory of Wason and Evans (1974b). For both unconscious, automatic everyday decisions but also non-automatic, complex routines, shortcuts can be taken like gut feelings or listening to social conformity, also known as heuristics or cognitive biases (Kahneman, 2011; Tversky & Kahneman, 1974). While, on the one hand, heuristics support quick decision-making, they also make decisions prone to error, leading to decisions to the individual's own detriment. The concept of nudging is intended to counteract this and aims to influence psychological effects so that the decision outcome becomes predictable (R. Thaler & Sunstein, 2009). Examples for nudging unconscious, automatic decisions include a change of printer defaults to reduce paper or fake speedbumps painted on the streets as visual illusions to slow down the speed, while examples for nudges addressing rather reflective thinking include calorie postings on menus or energy bills with social comparison (Hansen & Jespersen, 2013). Hence, nudges are likely to be suitable for both routine behavior and consciously made, rather complex decisions.

As decisions are increasingly made in a digital or online behavior environment (e.g., in apps or browsers), Weinmann et al. (2016b) transferred the behavioral insights tested in the physical world to digital environments and defined digital nudging as the "use of user-interface design elements to guide people's choices or influence users' inputs in online decision environments" (Weinmann et al., 2016b, p. 433). The significant advantage of DNEs is that they can be implemented, evaluated, and even personalized quickly and without high costs (Weinmann et al., 2016b). Also, their effectiveness seems promising because individuals spend less time being concentrated while reading on digital screens and suffer from choice overloads and decreasing time spans of sustained attention (Liu, 2005). Tim-Benjamin Lembcke et al. (2019) introduced the concept of "blended environment" and stated that future research should consider the targeted behavior environment to develop a full picture of digital nudging. The authors, therefore, differentiated between the targeted behavior environment (physical vs. digital, e.g., turning on the heating on-site vs. turning on the heating in an app) and the intervention being analog (physical nudge (here: NE), e.g., printed label on the heating reminding you to reduce heating when opening the window) or digital (digital nudge (here: DNE), e.g., *framing* in the form of logos or highlighting by color marking in an app) (Tim-Benjamin Lembcke et al., 2019).

Different lists and definitions of DNEs exist (Lehner et al., 2016a; Mirsch et al., 2017; Weinmann et al., 2016b), including, among others; *default rules*, *social norms*, *framing*, *feedback*, *priming*, *simplification*, and *goal setting* (also referred to as *self-commitment*). As we focus on *default rules* and *framing*, we define both elements in the following: *Default rules* refer to situations where the preferred choice is pre-selected (R. Thaler & Sunstein, 2009) and are defined as "standard choices that determine the result in case people take no action" (Lehner et al., 2016a, p. 169). The NE is based on the need to procrastinate due to the time and effort required (Sunstein, 2014) and preserving the status quo (Kahneman, 2011). Examples include default smaller plate sizes that avoid food waste (Vandenbroele et al., 2018) or the configuration of eco-friendly search engines as default (Henkel et al., 2019). The NE *framing* uses the "anchoring bias", which states that by presenting the same information in multiple ways/"frames", individuals tend to make different decisions (R. Thaler & Sunstein, 2009). The NE *framing* often comes along with the NE *simplification* as it aims at transporting condensed information about complex constructs or by framing specific characteristics more noticeably (e.g., by using logos) (Sunstein, 2014). Examples include using emission labels for burgers to increase customers' choice of Burgers with a lower-carbon footprint (Van Gilder Cooke, 2012) or providing energy-efficient scores in e-commerce for electronic products like washing machines (Arquit Niederberger & Champniss, 2018).

2.3.2.3 (Digital) Nudging to Promote Energy Conservation Behavior

Lehner et al. (2016b) found *default rules*, *simplification* or *framing*, *social norms*, and *adjustments to the physical environment* (which is not applicable as a DNE) to be effective in encouraging sustainable behavior in energy consumption, personal transportation, and food. Little to no attention has been paid to *default rules* and *framing* in the context of daily energy consumer behavior, even though they show encouraging results in related energy-saving contexts. Examples include using *default rules* for energy-saving choices in a web-based configurator for TVs (Hankammer et al., 2021) or choosing renewable energy contracts (Momsen & Stoerk, 2014; Pichert & Katsikopoulos, 2008). The investigation of *framing* also showed meaningful results in sustainable daily behavior contexts, mainly shopping-related, like the choice of sustainable food products in an online supermarket (M. Berger et al., 2020) or choosing the most sustainable product in fast-moving-consumer products (Antonides & Welvaarts, 2020). At least to our knowledge, these promising NEs have not been studied in the context of daily energy consumer behavior neither their combination.

Next to the fact that little to no research exists applying *default rules* and *framing* to promote energy conservation behavior; little research focused on using DNEs in a digital targeted behavior environment (e.g., a smart home app) but mainly focused on physical behavior environments even though when applying DNEs instead of analog NEs (please refer to "blended environments" (Tim-Benjamin Lembcke et al., 2019) introduced in Section 2.3.2.2). Examples of studies analyzing analog NEs targeting a physical behavior environment include Allcott (2011), who mailed letters containing home energy reports to residential customers comparing their energy consumption with their neighbors. By implementing the NE *social norms*, the study succeeded in reducing energy consumption by an average of 2% (participants N=600,000). Regarding rather DNEs, the study of Abrahamse et al. (2007) created a webpage with an energy report to promote energy conservation behavior. Applying the DNEs *priming*, *goal setting*, and *feedback* decreased the energy consumption in the observation period of 5 months of N=189 by 5%. Implementing *feedback* and *goal setting* in a similar setting but on a larger scale with N=1,789, Loock et al. (2013) reduced the energy consumption by 2.3%. Also, in a similar setting using a website that calculated the energy consumption, Graml et al. (2011) analyzed the DNE *social norm* and found positive results.

While existing studies show promising results for the use of DNEs (e.g., websites, in-home displays) and analog NEs (e.g., letters) to promote energy conservation behavior, the studies focused on a physical targeted behavior environment (i.e., energy consumption is determined by, for example, managing the heating system or light switch analog in the physical world). Focusing on digital targeted behavior environments like smart home apps, in which consumers actively regulate their energy consumption in a digital environment, Kroll et al. (2019a) test the effectiveness of the DNEs *self-commitment* and *social norms* to influence consumers' energy conservation behavior in a smart home app. Although the results of the author's pre-study were not significant, they demonstrated that the experimental approach works and present possible modifications. The present study extends the efforts of Kroll et al. (2019a) and transposes the approach for examining the promising NEs of *default rules*, *framing,* and their combination in a similar setting.

2.3.3 Hypothesis Development

Prior studies demonstrated the promising effects of different DNEs to promote sustainable individual behavior. But the diversity of use cases and studied elements emphasize that their effect highly depends on the underlying context (e.g., food vs. mobility vs. energy) and its decision environment regardless of where the DNE is implemented (i.e., physical, for example, by turning on the heating on-site while the DNE is implemented in a web-based tool vs. digital, for example, by turning on the heating in an app in which the DNE is implemented). As humans behave differently in a digital environment (Liu, 2005), a separate investigation of DNE in a digital behavior environment (e.g., smart home apps) is justifiable. We state that especially decisions being made in a digital behavior targeted environment in which the DNE is implemented seem promising to positively influence decision behavior since there is no interruption in the media between the situation that has been nudged (e.g., a website displaying energy consumption) and the actual decision (e.g., turning on or off the lightening or heating). So far, though, research in the context of energy consumption has focused on physical behavior targeted environments (e.g., Abrahamse et al. (2007)). Whilst the use of smart home apps is on the rise (Ali & Yusuf, 2018; Statista, 2021), so far, only Kroll et al. (2019a) have investigated the effectiveness of two different DNEs (*social norms* and *self-commitment*) to promote daily energy conservation behavior when managing smart home devices through the app, hence in a digital behavior environment. Next to *social norms*, the use of *default rules* and *framing/simplification* of information (here: *framing*) are useful DNEs when promoting sustainable behavior (Lehner et al., 2016a). These DNEs have not been studied in the context of daily energy conservation behavior, especially not in a smart home app.

Default rules have been successfully studied in diverse contexts promoting general energy-saving behavior (e.g., Hankammer et al. (2021), Momsen and Stoerk (2014), or Pichert and Katsikopoulos (2008)) and environmentally-friendly everyday behavior (e.g., Henkel et al. (2019), M. Berger et al. (2020), Antonides and Welvaarts (2020)). So far, *default rules* have not been investigated in the context of daily energy usage. But *default rules* are known to bridge the behavior-intention gap, such as living more energy conservatively, which is preferred by far more individuals than those who actually choose energy-saving options (Münscher et al., 2016). To take advantage of a smart home app in which the barrier between intention and behavior is already lower due to the non-existent media break, we, state that by changing the default, more people will choose more energy-conserving options in their daily life when using a smart home app. Hence, we hypothesize the following:

Hypothesis 1 (H1): *Default rules in a smart home app result in more energy-conserving selections than without any behavioral interventions.*

Next to *default rules*, *framing* is a promising DNE for promoting sustainable consumption behavior (Lehner et al., 2016a). Especially for daily, rather unconscious decisions, the intense and straightforward presentation of information revealed promising results for promoting sustainable decisions (e.g., in the context of impulsive food decisions in an online supermarket (M. Berger et al., 2020)). We state that daily energy consumption decisions like choosing a dishwasher program or turning on/off the lights are similar unconscious decisions. Users might not be aware of the environmental consequences of daily choices regarding their energy consumption as food choices in the online supermarket. Hence, breaking down the complex information concerning the energy impact when unconsciously operating household appliances might be helpful to decrease energy consumption. Accordingly, we hypothesize:

Hypothesis 2 (H2): *Framing nudges in a smart home app result in more energy-conserving selections than without any behavioral interventions.*

Nevertheless, the use of single NEs is less common than the combination of several, which strengthens their effects and combines their advantages (Andor & Fels, 2018). For example, *default rules* were successfully combined with *priming* in the context of sustainable investments (Gajewski et al., 2021) or in promoting the usage of electric vehicles (Stryja et al., 2017). In general, studies on DNEs to promote sustainable behavior have analyzed a combination of different NEs (Abrahamse et al., 2007; Fanghella et al., 2019; Gajewski et al., 2021; Stryja et al., 2017). Therefore, we hypothesize:

Hypothesis 3a (H3a): *The combination of default rules and framing in a smart home app results in more energy-conserving selections than without any behavioral interventions.*

As we combine *default rules* with *framing*, we state that the combination of both elements leads to higher energy conservation decisions than the use of *default rules* alone by arguing that framing increases the effect of *default rules* by increasing the user's understanding and comprehensibility of the pre-selected option. This leads to the following hypothesis:

Hypothesis 3b (H3b): *The combination of default rules and framing in a smart home app results in more energy-conserving selections than the single usage of default rules.*

In the sense of completeness and to gain more insights into the effectiveness of the single DNEs, we are also interested in studying the adverse effect of whether the combination of *default rules* and *framing* leads to higher energy savings compared to the single usage of *framing*. Hence, we hypothesize:

Hypothesis 3c (H3c): *The combination of default rules and framing in a smart home app results in more energy-conserving selections than the single usage of framing.*

2.3.4 Research Process

We perform a randomized control trial to test the relationship between the between-subjects independent variables (implementation of the DNEs *default rules*, *framing*, and their combination) and the dependent variable (energy conservation behavior) (Gravetter & Forzano, 2016). First, we design and implement the two DNEs *default rules* and *framing* and their combination in a smart home app to control four smart home devices: light, washing machine, dishwasher, and heater. Consequently, we evaluate the DNEs' effectiveness below.

2.3.4.1 Design and Implementation of the Experiment

We designed a complete set of screen designs simulating a working smart home app and chose suitable smart home devices, which had to be controlled by the participants. Next, we implemented the screen designs in an online experiment, following Kroll et al. (2019a). Our experiment consisted of a brief introduction to the concept of the smart home app before the participants were randomly assigned to one of four groups (A, B, C, D). We asked them to control all four specified devices using different DNEs for each group. Lastly, we collected demographic data.

2.3.4.1.1 Design of Default Rules and Framing in a Smart Home App

We followed the proposals of Fan et al. (2017) in designing the smart home app. To create a modern and realistic app environment, we respected the design guidelines of Neil (2014). Consequently, we integrated a tab bar with a home button, an account avatar, a settings icon, and overview navigation. To ensure a realistic user experience, we constructed a welcome, an overview, and a home screen.

Next, we chose suitable connected devices. The prerequisite was that the selected devices are not merely easy and intuitive to use but also compatible with a smart home system. Following Krishnamurti et al. (2012) and Kroll et al. (2019a), lights, washing machines, dishwashers, and heaters seemed appropriate. In this study, we elaborated on the programs and settings of the focal devices by studying the user manuals, their stated energy consumption, and considering the recommendations of how to save energy as mentioned in Eiselt (2013). Due to their smart home capabilities, we chose the Bosch WAV28G40 as our washing machine and the Bosch SBV4HCX48E as our dishwasher to define the energy consumption for each program. For a broad and valid scale, each device has five selectable options. As a basis for the subsequent analysis, each option implies a different energy conservation level from 1 to 5; where 1 is the lowest and 5 is the highest. Each level serves as a polytomous measuring point. Table 2.3-1 presents an overview of the devices and their related programs; each device appears in its row.

Device	**Energy conservation level**				
	1	**2**	**3**	**4**	**5**
Lights [Brightness in %]	100%	80%	60%	40%	20%
Washing machine [Duration]	Cotton 60 °C 3:20 h:min	Cotton 40 °C 3:20 h:min	Cotton 40 °C 3:20 h:min	Cotton 20 °C 3:05 h:min	Eco 40 – 60 3:40 h:min
Dish washer [Duration & temperature]	Intensive 2:15 h:min & 70 °C	1h 1:00 h:min & 65 °C	Auto 1:40-2:45 h:min & 45-65°C	Silence 4:00 h:min & 50 °C	Eco 4:55 h:min & 50 °C
Heater [Room temperature]	25°C	23°C	21°C	19°C	17°C

Table 2.3-1 Overview of smart home devices and related energy conservation level

To present the five selectable options per device to the user, we allocated each device its own screen. While the upper bar displays the device menu, the center of the screen allows the user to choose between five brightness levels, programs, or room temperature (Figure 2.3-1). To implement the focal DNEs appropriately, we adopted the approach of Karlsen and Andersen

(2019) and the suggestions of Münscher et al. (2016) and Schneider et al. (2018b). We defined a pre-selected option according to the definition of *default rules*. In this case, to conserve energy, the option with the lowest energy consumption for all four devices is pre-selected. We illustrated this with a blue line around the least energy-consuming option and the inverted colored arrow for the washing machine and dishwasher. For light and heating, the blue line ends with a selection point at the least energy-consuming option. With the power switch already on, we also clarified that these options are already set. To further clarify the implemented default rule, we added the information "already pre-selected" for the option we set as default in the survey. For the DNE *framing*, we implemented a green leaf to highlight the option with the lowest energy consumption for all four devices. In addition, we colored the associated font green instead of blue (similar to prior studies in this context (e.g., Roozen et al. (2021)). The green leaf was supposed to symbolize environmental friendliness (Pancer et al., 2015). Thus, the participants should become aware of the consequences associated with their decisions. In the context of this study, we assume that the survey participant perceives the additional design elements as just described. These options were highlighted thus, but not overly obtrusive. Combining the implementation of the two individual nudges resulted in the combination nudge, where the least energy-consuming option was pre-selected and highlighted in each case. Figure 2.3-1 depicts the applied DNEs for all four devices: screen 1 (light) shows the *default rules* seting, screen 2 (washing machine) displays the *framing* condition, screen 3 (dishwasher) combines both nudges, and screen 4 (heater) displays none DNE used for the control group.

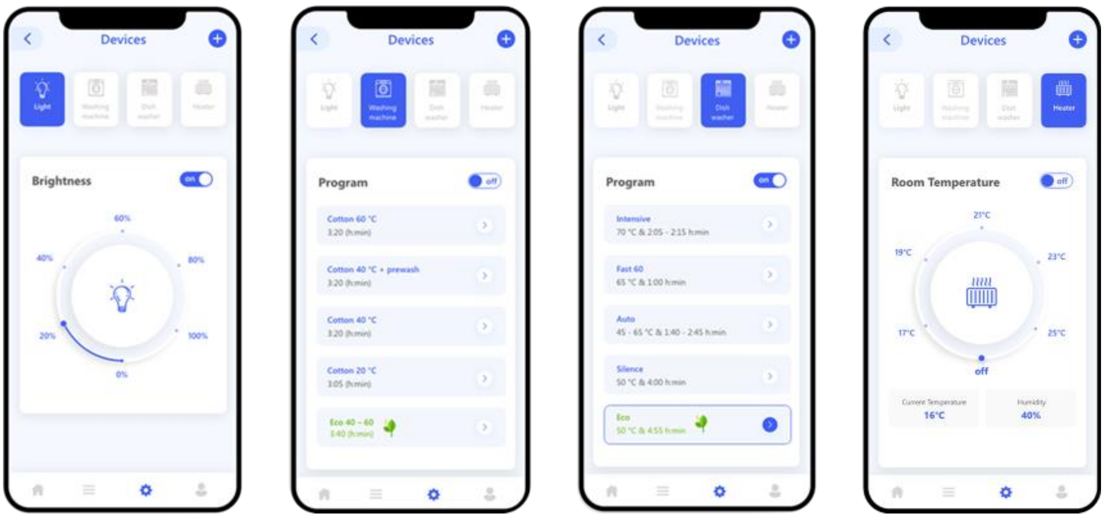

Figure 2.3-1 Screens for each device (light, washing machine, dishwasher, and heater) with their five programs. To exemplify the DNEs, each screen shows different DNEs.

2.3.4.1.2 Design and Implementation of the Online Experiment

Through an initial introduction to smart home and accurately explained scenarios of using the devices, we intended to guide each participant through the survey without the need for prior knowledge. After the welcome slide and the brief primer, the participants were randomly allocated to four groups (A, B, C, D). Every participant saw the same four smart home scenarios and the underlying questions concerning which option they wanted to select (i.e., the different room temperatures for the heating scenario). But the presented screen designs were slightly different – dependent on the groups assigned DNE. All participants in the control group (A) received the screen designs of the device menus without a nudge. Participants belonging to the *default rules* (B), *framing* (C), or combination (D) groups saw the corresponding screen designs shown and discussed in Section 2.3.4.1.1 (see also Figure 2.3-1). Considering the smart home scenarios, the participants were then asked to control all four devices mentioned above through the screen designs. Each participant was shown only the screen design of the four devices, with the nudge assigned to their group. After utilizing the smart home app, the survey requested the demographics. Figure 3.2-2 displays the flow of the experiment. To better understand the subsequent analysis, Figure 3.2-2 illustrates the variables under investigation (where 1 represents the implementation in this group and 0 represents non-implementation). For simplicity, we refer to the combination group when we focus on group D, in which both nudges, and thus both independent variables (*default rules* as well as *framing* is marked with 1), were implemented.

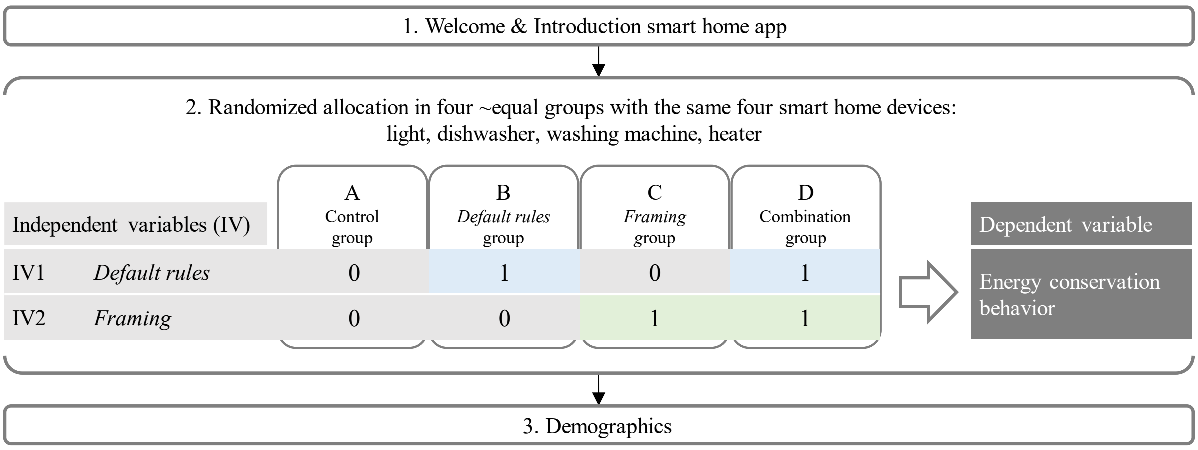

Figure 2.3-2 The procedure of the online experiment and information on the variables (based on Kroll et al. (2019))

Consecutive to a pretest with 20 participants in the first cycle and a revision of the experiment design according to the comments from this pretest, we implemented the questionnaire via the online survey tool of easyfeedback.de. 231 participants completed the online experiment and answered both included control questions correctly. 43.0% of participants were female, 56.5% male and 0.5% identified as diverse. Most of them (55%) were in employment, and about one-third (37%) were students and trainees. The median age of participants was 30, while all age groups from younger than 18 to older than 65 were represented.

2.3.4.2 Data Analysis

The focus of the present study was to test the hypotheses concerning the effectiveness of the applied DNEs - default rules and framing and their combination - on energy conservation behavior. To answer the research question, a measure of the energy conservation behavior in the prevailing use case of the smart home app needed to be defined first. For this purpose, we assigned each selected program within the smart home app to a different energy conservation level (as described in Section 2.3.4.1.1, see Table 2.3-1). As the classification relies on the stated energy consumption, each of the five options per device is rated between 1 (least environmentally sustainable choice), 2, 3, 4, or 5 (highest energy conservation level). Subsequently, we combined the ratings of all four devices that had to be controlled by the participant in the field experiment into a measure called the energy conservation score (ECS). The ECS thus represents the overall degree of energy conservation of the decisions taken by one participant in the online experiment.

To answer our research question, which of the studied DNEs and their combination promote daily energy conservation behavior, we conduct the nonparametric Kruskal-Wallis test to compare the means between the focused groups. Additionally, we conduct pairwise comparisons using the Dunn-Bonferroni test. Normally distributed data must be assumed when calculating the parametric counterpart to the Kruskal-Wallis test, the Analysis of Variance (ANOVA) (Howell, 2012). Since our dependent variable (ECS) is not normally distributed, calculating the ANOVA is only possible to a limited extent, specifically assuming normally distributed data for treatment groups with more than 30 participants, according to the Central Limit Theorem (Lumley et al., 2002). Because of this limitation and the higher power associated with the rank analyzing Kruskal-Wallis tests for distribution-free groups (Kirk, 2012; Wickens & Keppel, 2004), we perform the parametric ANOVA and the associated contrast tests only second to validate the results.

2.3.5 Results

According to Kolmogorov Smirnov and Shapiro-Wilk tests, the variables of the treatment groups (A) and (B) are normally distributed, while the groups (C) and (D) are not. Therefore, we first perform the nonparametric analyses and then, according to the Central Limit Theorem, the parametric ANOVA (Lumley et al., 2002). The Levene-Test indicates variance homogeneity (F(3, 231) = 1.326, p = 0.267). Considering a significance level of 5%, the Kruskal Wallis test rejects the null hypothesis that there are no mean differences between the groups (p = .000). This is confirmed by the ANOVA (p = .000). Table 2.3-2 shows the descriptive statistics of the ECS, assigned to the four treatment groups, as well as the Kruskal Wallis and the ANOVA test statistics.

To allocate the origin of these differences, we proceed with pairwise comparisons (based on the Kruskal Wallis) and contrast tests (based on the ANOVA) of the individual groups. Each null hypothesis states that there is no difference between the groups within each paired comparison. For both calculations, the contrast pairs 1, 2, 3, and 4 reveal statistically significant differences and thus reject the hypotheses H10, H20, H3a0, and H3b0. H3c0 indicates a relevant significance only in the contrast test after the ANOVA (pair 5) (see Table 2.2-3). This is consistent with the elaborated alternative hypotheses H1, H2, H3a, and H3b, while the H3c is only consistent following the ANOVA. Hence, there are effects of all the various implemented DNEs on promoting energy conservation behavior.

Group		**ECS**		**Kruskal Wallis**		**ANOVA**	
	N	**Mean**	**Std. deviation**	**H**	**p-value**	**F**	**p-value**
Control (A)	54	3.028	.808	42.217	.000***	18.139	.000***
Default rules (B)	58	3.500	.628				
Framing (C)	60	3.650	.706				
Combination (D)	59	3.996	.681				
Total	231	3.555	.789				

*Table 2.3-2 Descriptive statistics of the energy conservation score (ECS) and Kruskal Wallis and ANOVA test statistics p-value significance codes: *** for < 0.001, ** for < 0.01, * for < 0.05*

	Pair			**Pairwise comparisons**			**Contrast tests**		
H	**Pair**	**Contrast**		**p-value**	**Effect size r**	**Effect size d**	**p-value**	**Effect size r**	**Effect size d**
$H1_0$	1	A	B	.035*	small	medium	.000***	-	-
$H2_0$	2	A	C	.000***	medium	large	.000***	-	-
$H3a_0$	3	A	D	.000***	large	large	.000***	small	small
$H3b_0$	4	B	D	.001**	medium	medium	.000***	-	-
$H3c_0$	5	C	D	.078	-	-	.008**	-	-

Table 2.3-3 Test statistics of the pairwise comparison and the contrast tests

Subsequent to the pairwise comparison, following the effect sizes "d" by Cohen (1992) as well as the "r" by Gignac and Szodorai (2016) (Table 2.2-3), there is a small to medium effect size for the *default rules* (pair 1), a medium to large effect size for the *framing* (pair 2), a large effect size for the combination of *default rules* and *framing* (pair 3), and a medium effect size for H3b0 (pair 4). Regarding the contrast tests, there only exists a small effect size for pair 3. Even though there are differences in the effect sizes, the results prove the influence of the DNEs on promoting energy conservation behavior. The combination of the DNEs only indicates a significant effect, considering the *default rules* H3b0/pair_4. No significant difference was identified compared to only *framing* H3c0/pair 5 (Table 2.2-3).

2.3.6 Discussion

The present study explored the effectiveness of the DNEs *default rules*, *framing*, and their combination in promoting energy conservation behavior through a smart home app. Overall, we confirmed the effectiveness of DNEs, as affirmed by Weinmann et al. (2016b), Mirsch et al. (2017), and Lehner et al. (2016b).

In accordance with hypothesis H1, *default rule*s are associated with a higher energy conservation behavior, with a small to medium effect size. This indicates that *default rules* can promote energy conservation behavior. Accordingly, smart home app users prefer to maintain the status quo of the pre-selected option or simply want to avoid making active and conscious decisions in such rather daily routine tasks (Kahneman, 2011; Sunstein, 2014). The results build on existing evidence of the effectiveness of *default rules* being it in (1) energy-related contexts (e.g., shopping for energy-efficient products (Hankammer et al., 2021) or choosing an energy contract (Momsen & Stoerk, 2014; Pichert & Katsikopoulos, 2008)) or (2) in daily routine tasks like using a search-engine (Henkel et al., 2019) or doing grocery shopping (M. Berger et al., 2020).

In line with hypothesis H2, *framing* may also promote energy conservation behavior by yielding a medium to large effect size. The green leaf, as an environmentally friendly *framing*, seems to be perceived positively by the participants and encourages them to select more energy-conserving options. Hence, the way the different energy level options are presented seems to influence consumer behavior and the magnitude of the resulting energy efficiency improvements. Our findings are also consistent with the findings of prior studies on using *framing* for relatively unconscious daily shopping behavior (Antonides & Welvaarts, 2020; M. Berger et al., 2020). Interestingly, the effect of *framing* is larger than the effect of *default rules*. This is surprising as *default rules* seemed much more promising in prior literature and have been investigated several more times and in various contexts (e.g., e-commerce, mobility, food, etc.) compared to *framing*.

Lastly, the combination of *default rules* and *framing* reveals a large effect size (H3a) in promoting energy conservation behavior. When comparing each single DNE with the combination of both, we only found a significant effect comparing the combination with *default rules* (H3b), not when considering the single *framing* compared to both DNEs (H3c). This confirms our assumption that *framing* might help to increase the user's comprehensibility of the preselected option by the *default rules*. Similar to Gajewski et al. (2021), who compared *default rules* and *priming*, we strengthen the finding that *default rules* achieve better results if compared with an additional nudge.

Considering the non-significant effect in terms of H3c, apparently, *framing* alone already goes along with a large increase in energy conservation behavior. Hence, the combination did not lead to a significant increase. This again leads to the assumption that in the present study, *framing* overall had a greater impact on the energy conservation behavior than the single DNE *default rules*. However, including *framing* for *default rules* even strengthens its effect.

2.3.6.1 Theoretical Contribution

Besides confirming previous research findings on DNEs in the field of the promotion of sustainable behavior and the validation of the efficacy of DNEs in general, this study contributes to the current state of research in several ways. (1) We extend the effort of Kroll et al. (2019), who were the first to test the DNEs *social norms* and *self-commitment* in a smart home app, hence investigating DNEs to promote daily energy conservation behavior in a digital behavior environment. Compared to the study by Kroll et al. (2019a), which did not find any significant effects so far, our study is the first that reveals significant effects of DNEs in smart home apps to promote energy conservation behavior. (2) We analyzed the two missing DNEs out of Lehner et al.'s (2016) list that promotes sustainable behavior by investigating *default rules* and *framing*. We successfully transferred these DNEs into a mobile app domain. The elaborated design of the implementation of the DNEs can serve as a cornerstone for further research. (3) Our results contribute to a clearer understanding of the individual (D)NE and their related effect sizes. We shed light on *framing* as a promising DNE that has received too little attention in prior studies. (4) While the focus of previous studies is predominantly on applying single DNEs, this study performs the first investigation of the combination of *default rules* and *framing*. Consequently, we provide evidence that combining *default rules* with *framing* increases the effect compared to only including *default rules*.

2.3.6.2 Practical Implications

Smart home apps are on the rise (Ali & Yusuf, 2018; Statista, 2021), gaining more relevance in our everyday lives and having the power to influence our unconscious decision behavior. We shed light on important design (*framing*) and feature (*default rules*) decisions companies and software developers should consider when creating smart home apps. In this way, they could benefit from a "green image" in addition to their ethical and moral obligations. This opens the opportunity to facilitate sustainable behavior when spreading new digital innovations (e.g., smart home technologies). Insights into behavioral science nudging can help to address and reduce the rebound effect, hence avoiding increasing consumption when introducing new, more energy-efficient technologies. Currently, not all household appliances are yet designed in such a way that they can be controlled via a smart home app (digital environment), nor are household appliances from different manufacturers controllable via one smart home app. However, since our results indicate that the application of DNEs via a smart home app can help to improve energy conservation behavior, government regulations and policy-making should provide the basis for promoting and standardizing the possibilities for implementing such apps. To sum it up, our study recommends using DNEs in smart home apps, namely *default rules*, and *framing*, to promote daily energy conservation behavior. As a result of our addressed behavior changes, consumers could profit from cost savings due to smaller energy bills. Moreover, they are supported by following their responsibility in counteracting climate change by conserving more energy and living more sustainably in their daily lives. Overall, in the long run, by incorporating efficient DNEs, behavior changes can help to reduce energy consumption as one of many factors influencing the ongoing climate change.

2.3.6.3 Limitations and Further Research

Like any research paper, our study is subject to limitations. First, experimental approaches lack real-world consequences, such as waiting longer for the dishwasher to finish. Moreover, we did not examine direct app use but screen designs via the online survey tool and described only one scenario (e.g., we did not examine a scenario in which the user wants to turn on the light for work, consequently, might rather decide for brighter options). Additionally, because of the A/B testing approach, there was no actual study of behavior change. Therefore, like all experimental studies, the survey responses in this study are subject to numerous respondent biases – such as social desirability (Furnham, 1986). This could be mitigated, for example, by phrasing questions differently or using a social desirability scale to both identify and control for this factor (van de Mortel, 2008). Supplementary, all results are based on only one measurement. Causal conclusions of any kind can therefore only be drawn to a limited extent since temporality cannot be proven with them. A re-examination with measurement over a more extended period could provide insights into the long-term effect of the DNEs and increase the power of the findings. In this study, we conducted the survey in Germany without a representative sample because of an overrepresentation of the age group between 18 and 35 years, while all other age groups were underrepresented. Even though we argue that this age group is especially suitable for using a smart home app, future studies should consider pre-selecting a balanced sample. Despite the limited degree of representativeness, we rely on sufficiently valid data sets to analyze the online experiment. As O’keefe (2007) suggested, we performed an a-priori power analysis before conducting the online experiment. We calculated a required and total sample size of 180. With 231 participants, this quantity is covered by 128%. We used from the recommendations by Lehner et al. (2016) and Kroll et al. (2019) as well as from the weighted average effect sizes of similar types of interventions aggregated by Osbaldiston and Schott (2012) to set the underlying parameters assumed for effect size and power. In addition, to address the declining power of the study due to the division into four different treatment groups, an even larger sample should be drawn if the study is expanded. Considering the survey design, we assume that the user trusts the predefined program sequences and perceives the additional design elements as described. Beyond that, we do not question the psychological background of the perception of the user interface since there is a separate scientific discourse on this, for example, on technological determinism (Dafoe, 2015; Drew, 2016). Lastly, we analyzed the survey results regarding the participants' demographic data to provide an important first insight into whether the selected DNEs impact energy conservation behavior. However, people do not have a common understanding of climate change and sustainability. Therefore, people's attitudes toward climate change and their need to take action can have an influence on the effectiveness of NEs. Therefore, another limitation of this study is that we have not yet surveyed and evaluated the participants' attitudes towards it, for example, by using the New Ecological Paradigm (NEP) scale (Dunlap et al., 2000).

For further research, we see especially three relevant endeavors. First, based on the promising results of our study, future research could address the challenges faced due to the experimental approach by conducting a field experiment. As our results were encouraging, a field experiment would be worthwhile. Next, further research could include cost-benefit analyses, as only a minority of studies to date have analyzed the benefits and costs of the behavioral interventions in-depth, which is certainly the strongest argument in favor of their implementation.

Finally, so far, the application of the DNEs in smart home apps is limited to our efforts on *default rules* and *framing* as well as *social norms* and *self-commitment* by Kroll et al. (2019a) without considering the effectiveness of the DNEs dependent on participants' characteristics. Both, an examination of all these four DNEs combined in one study, as well as the consideration of specified characteristics (e.g., the NEP (Dunlap et al., 2000)) could provide interesting results. Even though these NEs are most promising when promoting sustainable behavior (Lehner et al., 2016a), additional elements exist. Future research should face the challenge of exploring other DNEs (or their combination) in a similar setup.

2.3.7 Conclusion

Due to the substantial share of (residential) daily energy consumption in greenhouse gas emissions and the negative consequences of the rebound effect independent of the energy-efficient technological innovations, the need for behavior changes becomes increasingly more urgent. The proliferation of smart home apps offers a great opportunity to foster behavior change towards energy conservation using DNEs. This study goes beyond existing research as we analyze DNEs in a digital behavior environment – a smart home app. We explore the question of whether energy conservation behavior can be promoted through the DNEs *default rules, framing,* and their combination and found significant positive results. Especially, we show large positive effects of *framing* and medium effects of the combination of both compared to the single usage of *default rules*. This study contributes to theory in several ways and provides implications for the practical implementation and design of smart home apps. We encourage researchers to engage in the challenge of transferring more NEs to digital environments and to focus on a digital behavior environment, like smart home apps.

Overall, we hope to contribute to the ongoing research efforts concerning the implementation of DNEs to promote sustainable behavior, hence addressing the human-induced environmental deterioration by the behavior of each individual.

2.3.8 References

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2007). The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of Environmental Psychology, 27(4),* 265–276. https://doi.org/10.1016/j.jenvp.2007.08.002

Ali, S., & Yusuf, Z. (2018). *Mapping the Smart-home Market*. The Boston Consulting Group.

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics, 95*(9-10), 1082–1095. https://doi.org/10.1016/J.JPUBECO.2011.03.003

Andor, M. A., & Fels, K. M. (2018). Behavioral economics and energy conservation – A systematic review of non-price interventions and their causal effects. *Ecological Economics*, *148*, 178–210. https://doi.org/10.1016/J.ECOLECON.2018.01.018

Antonides, G., & Welvaarts, M. (2020). Effects of default option and lateral presentation on consumer choice of the sustainable option in an online choice task. *Sustainability*, *12*(13), 5484. https://doi.org/10.3390/su12135484

Arquit Niederberger, A., & Champniss, G. (2018). Flip sides of the same coin? A simple efficiency score versus energy bill savings information to drive consumers to choose more energy-efficient products. *Energy Efficiency, 11(7),* 1657–1671. https://doi.org/10.1007/s12053-017-9542-3

Asensio, O. I., & Delmas, M. A. (2016). The dynamics of behavior change: Evidence from energy conservation. *Journal of Economic Behavior & Organization*, *126*, 196–212. https://doi.org/10.1016/J.JEBO.2016.03.012

Berger, M., Müller, C., & Nüske, N. (2020). Digital nudging in online grocery stores – Towards ecologically sustainable nutrition. In *Proceedings of the 41st International Conference on Information Systems (ICIS).*

Cappa, F., Rosso, F., Giustiniano, L., & Porfiri, M. (2020). Nudging and citizen science: The effectiveness of feedback in energy-demand management. *Journal of Environmental Management*, *269*, 110759. https://doi.org/10.1016/j.jenvman.2020.110759

Cohen, J. (1992). Statistical power analysis. *Current Directions in Psychological Science, 1*(3), 98–101. https://doi.org/10.1111/1467-8721.ep10768783

Dafoe, A. (2015). On technological determinism. *Science, Technology, & Human Values*, *40*(6), 1047–1076. https://doi.org/10.1177/0162243915579283

Drew, R. (2016). Technological determinism. In G. Burns (Ed.), *Wiley Blackwell Companions in Cultural Studies: Vol. 17. A Companion to Popular Culture* (pp. 167–184).

Dunlap, R. E., van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New trends in measuring environmental attitudes: Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues, 56*(3), 425–442.

Eiselt, J. (2013). Optimal Energie sparen beim Bauen, Sanieren und Wohnen. *Optimal Energie Sparen Beim Bauen, Sanieren Und Wohnen.* Advance online publication. https://doi.org/10.1007/978-3-658-03652-2

Fan, X., Qiu, B., Liu, Y., Zhu, H., & Han, B. (2017). Energy visualization for smart home. *Energy Procedia*, *105*, 2545–2548. https://doi.org/10.1016/j.egypro.2017.03.732

Fanghella, V., d'Adda, G., & Tavoni, M. (2019). On the Use of Nudges to Affect Spillovers in Environmental Behaviors. *Frontiers in Psychology*, *10*, 61. https://doi.org/10.3389/fpsyg.2019.00061

Federal Environmental Agency of Germany. (2019). *Auswertungstabellen zur Energiebilanz der Bundesrepublik Deutschland 1990 bis 2019, Stand 09/2020.*

Federal Ministry for Economic Affairs, & Energy. *Die Energie der Zukunft – 8. Monitoring-Bericht*. www.bmwi.de

Federal Ministry for Economic Affairs, & Energy. *Energieeffizienz in Zahlen 2020*. www.bmwi.de

Furnham, A. (1986). Response bias, social desirability and dissimulation. *Personality and Individual Differences*, *7*(3). https://doi.org/10.1016/0191-8869(86)90014-0

Gajewski, J.-F., Heimann, M., & Meunier, L. (2021). Nudges in SRI: The power of the default option. *Journal of Business Ethics*, *177*, 547–566. https://doi.org/10.1007/s10551-020-04731-x

Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, *102*, 74–78. https://doi.org/10.1016/J.PAID.2016.06.069

Graml, T., Loock, C.-M, Baeriswyl, M., & Staake, T (2011). Improving residential energy consumption at a large using persuasive systems. In *Proceedings of the 19th European Conference on Information Systems (ECIS).*

Gravetter, F. J., & Forzano, L.-A. B. (2016). *Research Methods for the Behavioral Sciences* (5ed.). Cengage Learning.

Hankammer, S., Kleer, R., & Piller, F. T. (2021). Sustainability nudges in the context of customer co-design for consumer electronics. *Journal of Business Economics, 91(6),* 897–933. https://doi.org/10.1007/s11573-020-01020-x

Hansen, P., & Jespersen, A. (2013). Nudge and the manipulation of choice: A framework for the responsible use of the nudge approach to behaviour change in public policy. *European Journal of Risk Regulation*, *1*, 3–28.

Hausmann, D., & Welch, B. (2009). Debate: To nudge or not to nudge. *The Journal of Political Philosophy*, *18*(1), 123–136. https://doi.org/10.1111/j.1467-9760.2009.00351.x

Henkel, C., Seidler, A.-R., Kranz, J., & Fiedler, M. (2019). How to nudge pro-environmental behaviour: An experimental study. In *Proceedings of the 27th European Conference on Information Systems (ECIS)*.

Howell, D. C. (2012). *Statistical methods for psychology*. Cengage Learning.

International Energy Agency. (2019) *Global Energy Review 2019: The Latest Trends in Energy and Emissions in 2019.* https://www.iea.org/reports/global-energy-review-2019

International Energy Agency. (2022). *Energy efficiency: The first fuel of a sustainable global energy system*. https://www.iea.org/topics/energy-efficiency

Kahneman, D. (2011). *Thinking, fast and slow*. Macmillan.

Karlsen, R., & Andersen, A. (2019). Recommendations with a nudge. *Technologies*, *7*(2), 45. https://doi.org/10.3390/TECHNOLOGIES7020045

Kirk, R. E. (2012). *Experimental design: Procedures for the behavioral sciences*. Sage Publications.

Krishnamurti, T., Davis, A. L., Wong-Parodi, G., Wang, J., & Canfield, C. (2012). Creating an in-home display: Experimental evidence and guidelines for design. *Applied Energy*, *108*, 448–458. http://openwetware.org/wiki/IHD

Kroll, T., Paukstadt, U., Kreidermann, K., & Mirbabaie, M. (2019). Nudging people to save energy in smart homes with social norms and self-commitment. In *Proceedings of the 27th European Conference on Information Systems (ECIS)*.

Lehner, M., Mont, O., & Heiskanen, E. (2016). Nudging – A promising tool for sustainable consumption behaviour? *Journal of Cleaner Production*, *134*, 166–177. https://doi.org/10.1016/j.jclepro.2015.11.086

Lembcke, T.-B., Engelbrecht, N., Brendel, A. B., & Kolbe, L. (2019). To nudge or not to nudge: Ethical considerations of digital nudging based on its behavioral economics roots. In *Proceedings of the 27th European Conference on Information Systems (ECIS)*.

Liu, Z. (2005). Reading behavior in the digital environment. *Journal of Documentation*, *61(6)*, 700–712. https://doi.org/10.1108/00220410510632040

Loock, C.-M., Landwehr, J., Staake, T., Fleisch, E., & Pentland, A. (2012). The influence of reference frame and population density on the effectiveness of social normative feedback on electricity consumption. In *Proceedings of the 33rd International Conference on Information Systems (ICIS).*

Loock, C.-M., Staake, T., & Thiesse, F. (2013). Motivating energy-efficient behavior with green IS: An investigation of goal setting and the role of defaults. *MIS Quarterly, 37(4),* 1313–1332.

Lumley, T., Diehr, P., Emerson, S., & Chen, L. (2002). The importance of the normality assumption in large public health data sets. *Annual Review of Public Health, 23,* 151–169. https://doi.org/10.1146/annurev.publhealth.23.100901.140546

Mills, B., & Schleich, J. (2012). Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: An analysis of european countries. *Energy Policy, 49,* 616–628. https://doi.org/10.1016/j.enpol.2012.07.008

Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. In *Proceedings of the 13th Conference on Wirtschaftsinformatik (WI13).*

Momsen, K., & Stoerk, T. (2014). From intention to action: Can nudges help consumers to choose renewable energy? *Energy Policy, 74,* 376–382. https://doi.org/10.1016/j.enpol.2014.07.008

Münscher, R., Vetter, M., & Scheuerle, T. (2016). A review and taxonomy of choice architecture techniques. *Journal of Behavioral Decision Making, 29*(5), 511–524. https://doi.org/10.1002/bdm.1897

Neil, T. (2014). *Mobile design pattern gallery* (Vol. 2). O'Reilly Media, Inc.

O'keefe, D. J. (2007). Brief report: Post hoc power, observed power, a priori power, retrospective power, prospective power, achieved power: Sorting out appropriate uses of statistical power analyses. *Communication Methods and Measures, 1*(4). https://doi.org/10.1080/19312450701641375

Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-analysis of proenvironmental behavior experiments. *Environment and Behavior, 44(2),* 257–299. https://doi.org/10.1177/0013916511402673

Pancer, E., McShane, L., & Noseworthy, T. J. (2015). Isolated environmental cues and product efficacy penalties: The color green and eco-labels. *Journal of Business Ethics, 143*(1), 159–177. https://doi.org/10.1007/S10551-015-2764-4

Pichert, D., & Katsikopoulos, K. V. (2008). Green defaults: Information presentation and pro-environmental behaviour. *Journal of Environmental Psychology, 28*(1), 63–73. https://doi.org/10.1016/J.JENVP.2007.09.004

Roozen, I., Raedts, M., & Meijburg, L. (2021). Do verbal and visual nudges influence consumers' choice for sustainable fashion? *Journal of Global Fashion Marketing*, *12*(4), 327–342. https://doi.org/10.1080/20932685.2021.1930096

Schleich, J. (2019). Energy efficient technology adoption in low-income households in the European Union – What is the evidence? *Energy Policy*, *125*, 196–206. https://doi.org/10.1016/j.enpol.2018.10.061

Schneider, C., Weinmann, M., & Vom Brocke, J. (2018). Digital Nudging: Guiding online user choices through interface design. *Communications of the ACM, 61*(7), 67–73. https://doi.org/10.1145/3213765

Schrills, T., Zoubir, M., Stahl, J., Drozniak, K., & Franke, T. (2020). Good boy here or bad boy far away? Effects of digital nudging on booking decisions in car sharing. In *Proceedings of the 17th International Conference EPCE* (pp. 398–411).

Schultz, P. W., Estrada, M., Schmitt, J., Sokoloski, R., & Silva-Send, N. (2015). Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms. *Energy*, *90*, 351–358.

Sorrell, S. Reducing energy demand: A review of issues, challenges and approaches. *Renewable and Sustainable Energy Reviews*, 47.

Statista. (2021). *Prognose zur Anzahl der Smart Home Haushalte in Deutschland für die Jahre 2017 bis 2025(in Millionen)*. https://de.statista.com/prognosen/885611/anzahl-der-smart-home-haushalte-in-deutschland

Strese, H., Seidel, U., Knape, T., & Botthof, A. (2010). Smart Home in Deutschland. *Institut Für Innovation Und Technik*, *46*.

Stryja, C., Satzger, G., & Dorner, V. (2017). A decision support system design to overcome resistance towards sustainable innovations. In *Proceedings of the 25th European Conference on Information Systems (ECIS).*

Sunstein, C. R. (2014). Nudging: A very short guide. *Journal of Consumer Policy 2014 37:4*, *37*(4), 583–588. https://doi.org/10.1007/S10603-014-9273-1

Thaler, R., & Sunstein, C. R. (2009). *Nudge: Improving decisions about health, wealth, and happiness*. Penguin.

Tussyadiah, I., & Miller, G. (2019). Nudged by a robot: Responses to agency and feedback. *Annals of Tourism Research, 78,* 102752. https://doi.org/10.1016/j.annals.2019.102752

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*(4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124

United Nations Climate Change. (2021). *Glasgow Climate Pact*. https://unfccc.int/documents/310475

van de Mortel, T. F. (2008). Faking it: Social desirability response bias in self-report research. *Australian Journal of Advanced Nursing, the, 25*(4), 40–48.

Van Gilder Cooke, S. (2012, April 9). Why going green can mean big money for fast-food chains. *Time,* 2012. http://content.time.com/time/world/article/0,8599,2111372,00.html

Vandenbroele, J., Slabbinck, H., van Kerckhove, A., & Vermeir, I. (2018). Curbing portion size effects by adding smaller portions at the point of purchase. *Food Quality and Preference*, *64*, 82–87. https://doi.org/10.1016/j.foodqual.2017.10.015

Wason, P. C., & Evans, J. (1974). Dual processes in reasoning? *Cognition*, *3*(2), 141–154.

Weinmann, M., Schneider, C., & vom Brocke, J . (2016). Digital Nudging. *Business & Information Systems Engineering, 58(6),* 433–436. https://doi.org/10.1007/s12599-016-0453-1

Wickens, T. D., & Keppel, G. (2004). *Design and analysis: A researcher's handbook*. Pearson Prentice-Hall Upper Saddle River, NJ.

2.4 Promoting Energy Conservation Behavior in a Smart Home App: Kano Analysis of User Satisfaction with Feedback Nudges

Abstract: Smart home technologies and apps are on a rise. This allows to implement digital nudging elements to foster energy-conservation behavior and, thus, contribute to mitigating climate change. Digital nudging via feedback can be effective in improving energy-conservation behavior, as substantial prior research has shown. However, the investigation of users' preferences concerning feedback nudges is missing. This lack of knowledge is crucial, as user satisfaction influences their continuous app usage, a precondition for achieving positive effects. To close this gap, we perform a structured literature review, categorize the feedback nudge features from extant research, and conduct an online survey. Based on survey data and the Kano model, we analyze the effect of feedback nudge features on user satisfaction. Our study complements the traditional focus on the effectiveness of these nudges with a perspective on user satisfaction. The combination of both perspectives suggests which feedback nudge features should be considered for implementation.

Keywords: Digital Nudging, Feedback, Smart Home Application, Energy Conservation Behavior, User Satisfaction

Authors: Michelle Berger, Henner Gimpel, Feline Schnaak, Linda Wolf

Status: This article is published in the proceedings of the 43rd International Conference on Information Systems (ICIS) in Copenhagen, Denmark, 2022.

2.4.1 Introduction

Due to the increasing availability and usage of smart home technologies (He et al., 2021), individuals can connect and intelligently control various household devices, exemplarily the heating system or lighting, by using a smart home application (app). Next to the simple control of various household devices, smart home apps allow for tracking and comparing an individual's energy consumption to others, hence offering the potential to facilitate and motivate users to save more energy. Awareness and reduction of energy consumption are necessary to counteract the challenges of climate change as well as to address political (International Energy Agency, 2022). While efficient technologies such as energy-efficient heating systems spread in the market, the efficiency gains are out-levered by growing consumption — marking a rebound effect (Sorrell, 2015). This can be because individuals underestimate their energy consumption (Bonan et al., 2021), for example, because of missing information (Callery et al., 2021). As a result, behavioral interventions are needed to influence each individual's energy consumption.

Prior research focused on the implementation of nudging elements (NEs) in physical environments (e.g., sending energy reports comparing energy consumption to peer groups (Crago et al., 2020)) and digital environments (e.g., the implementation in smart home apps (M. Berger et al., 2022)). Digital nudging elements (DNEs) are seen as a promising type of behavioral intervention (Hummel & Maedche, 2019; Mirsch et al., 2017; Weinmann et al., 2016b). (D)NEs aim to improve decision-making without changing economic incentives or restricting individuals' freedom of choice. In the context of influencing individuals' energy consumption, smart home apps integrating behavioral interventions bear a great potential to foster energy-conservation behavior (ECB). Prior research on (D)NEs influencing ECB primarily focuses on *feedback nudges* and found overall promising results (e.g., a reduction of energy consumption by 8 to 12% (Karlin et al., 2015)). When investigating *feedback nudges* to foster ECB, prior research configurated the *feedback nudge* differently, for example, by investigating different types of update frequencies (real-time vs. weekly) or different types of energy consumption measurement (e.g., kWh, costs, environmental impact).

While promising insights into the effectiveness of specific *feedback nudge features* (FNFs) already exist, little attention has been paid to the users' satisfaction and acceptability of these FNFs (Fleury et al., 2018; Gu et al., 2019). The investigation of user satisfaction is essential as it positively influences continuous Information Systems (IS) usage (Bhattacherjee, 2001; Gu et al., 2019; Thong et al., 2006). Beyond, continuous use of smart home apps, in which

FNFs are implemented to increase ECB, is crucial to profit from lower energy consumption in the long term. While it is confirmed that user satisfaction contributes to continuance use (e.g., Bhattacherjee, 2001), it is not analyzed how FNFs in a smart home app must be designed to achieve this satisfaction. Therefore, linking the FNFs to user satisfaction is still missing to support continuous smart home app use, hence ECB. Thus, we aim to answer the following research question:

RQ2.4-1: *How do potential smart home app users evaluate a broad set of feedback nudge features designed for nudging towards energy conservation behavior?*

To answer this research question, we first perform a structured literature review and develop an overview of FNFs in smart home apps. To categorize the findings, we develop dimensions and verify them via card sorting. Second, using the Kano model, we evaluate users' perception of these FNFs, that is, whether different FNFs are considered as "must-be," "one-dimensional," or "attractive," or whether users are "indifferent." We do so via an online survey (n = 188). The paper has several theoretical implications relating to *feedback nudging* in promoting ECB, for example, showing that user satisfaction is important to consider besides effectiveness. Further, this study contributes to which FNFs need to be implemented in smart home apps to encourage individuals to change their ECB. The remainder of this paper is structured as follows: First, we describe the theoretical background, followed by the research process. Then, we present and discuss the results. After outlining the contribution of our work, implications for future research are given.

2.4.2 Theoretical Background

2.4.2.1 Rising Relevance of Smart Home Apps

Nowadays, households use smart home technologies more commonly; e.g., in the US 35% of the population had already done so in 2021 (He et al., 2021). According to the definition by Gram-Hanssen and Darby (2018, p. 96) a "smart home is one in which a communications network links sensors, appliances, controls, and other devices to allow for remote monitoring and control […] to provide frequent and regular services to occupants and to the electricity system." In a smart home, users can control and monitor their household appliances through an app which has the potential to facilitate saving energy. This implies a promising response to mitigate the ongoing climate change and reduce political dependencies (International Energy Agency, 2022), especially as households account for a large share of energy consumption.

Technological progress contributes to increasing energy efficiency; an example is household appliances requiring less energy for the same process (Schleich, 2019). However, increasing consumption often exceeds these improvements, leading to the fact that no energy reduction is achieved (rebound effect) (Sorrell, 2015). Therefore, over-reliance on these technologies may bring undesired effects to pro-environmental behavior and reduce the personal responsibility for action because individuals are prone to underestimate their energy consumption (Bonan et al., 2021; Casado-Mansilla et al., 2020). In this context, households' energy consumption is interesting to take a look at, because of the environmental impact and the difficulty of evaluating own behavior due to missing information and feedback (Callery et al., 2021). In this vein, the use of smart home apps can – besides a more pleasant user experience – help to create awareness and to enable the reduction of energy consumption.

2.4.2.2 Continuous Use of Smart Home Apps that Promote Energy-Conservation Behavior

Existing research has shown using *feedback nudges* in smart home apps promotes ECB (Karlin et al., 2015). To profit from these results in the long term and on a large scale, users must continuously use smart home apps in which feedback is implemented for conserving energy. IS continuance and the intention that users will continue to use these apps and not switch to another control option for smart home technologies (e.g., another app) are influenced by user satisfaction (Bhattacherjee, 2001; Gu et al., 2019; Thong et al., 2006).

2.4.2.2.1 Feedback Nudges in a Smart Home App to Promote Energy-conservation Behavior

Nudging refers to methods of influencing people's behaviors predictably by changing the environment in which they make decisions without limiting their freedom of choice or increasing the cost of alternatives in terms of effort, time, and other factors (Hansen & Jespersen, 2013; R. H. Thaler & Sunstein, 2008). Behavior is the result of conscious and unconscious decisions (Kahneman, 2011), also known as Wason and Evans' (1974a) dual-process theory. Heuristics and cognitive biases can affect both unconscious, automatic everyday routines and non-automatic, complex decisions. While heuristics aid in quick decision-making, they also make decisions prone to error, resulting in decisions that are disadvantageous to the individual. Nudging leverages knowledge of heuristics and biases to build decision environments that guide behavior (R. H. Thaler & Sunstein, 2008). An example of nudging addressing unconscious, automatic decisions is reducing the plate size to decrease calorie intake, whereas nudging addressing reflective thinking includes energy bills with social comparisons (Hansen & Jespersen, 2013). As a result, nudges are likely appropriate for both routine behavior and deliberate, rather complex decisions.

Weinmann et al. (2016b) applied these behavioral insights to digital environments, defining digital nudging as the "use of user-interface design elements to guide people's choices or influence users' inputs in online decision environments" (p. 433). The significant advantage of DNEs is that they can be implemented, evaluated, and even personalized quickly and rather cheaply (Weinmann et al., 2016b). Furthermore, their efficacy appears promising because, compared to NEs in physical environments (e.g., *feedback* via letter), when using digital screens people spend less time concentrating while reading, are subjected to choice overload, and have shorter periods of sustained attention (Liu, 2005). This lower concentration of reading on digital screens enables to better influence decisions taken in an online environment, hence gives rise to the implementation of DNEs. This is also discussed in persuasive technology literature. Casado-Mansilla et al. (2020) describe the use of DNEs "as a means to persuade or change the overall behavior [of end-users]" (p.2). Meske and Amojo (2020) classify digital nudging as a subcategory of persuasion because both act on influencing users' minds. Research on persuasive technology precedes research on digital nudging. Thus, all DNEs can be seen as persuasion mechanisms, while this is not true vice versa. We take persuasive technology research into account not to miss any DNEs appearing in this research stream that may not explicitly be designated as a subcategory of digital nudging. With the ongoing shift of individuals' decisions towards digital environments, such as managing a heating system via digital control systems (Li et al., 2021), digital nudging proposes a promising possibility of changing behavior. Prior research demonstrates the promising effectiveness of DNEs in changing behavior toward ecological sustainability (Lehner et al., 2016).

There are several DNE conceptualizations in the literature (Weinmann et al., 2016; Mirsch et al., 2017; Lehner et al., 2016). One conceptualization is the *feedback nudge* which is the focus of this paper. The *feedback nudge* is defined as encouraging people to consider whether their behavior was good or could be improved by highlighting the consequences of the individual's decisions (Cappa et al., 2020). Thus, *feedback* overcomes inertia or procrastination and, therefore, can be used to motivate people (Sunstein, 2014). Examples include *feedback* of the own energy consumption presented on smart home displays (Schultz et al., 2015) or energy consumption of similar consumers displayed in a web portal (C.-M. Loock et al., 2012). The *feedback nudge* has been intensively studied in the last decades for promoting ECB and received increasing attention because of improving sensing technology and energy infrastructure that better allows collecting and proceeding data and quickly sending it to the user (Karlin et al., 2015; C.-M. Loock et al., 2012). The work of Karlin et al. (2015) presents the effects of *feedback* on ECB by conducting a meta-analysis and found overall promising results with an average energy saving of 8% to 12%. When conducting the meta-analysis, Karlin et al. (2015) summarize that studies differ in FNFs, for example, in the frequency of updated and pushed information on energy consumption or the type of energy measurement. Empirical evidence on single FNFs exists; still, research misses an overarching overview of FNFs to promote ECB and an understanding of the effect of FNFs on user satisfaction.

2.4.2.2.2 User Satisfaction to Increase Smart Home App Continuous Use

User satisfaction plays a central role in customer retention and continuous IS use (Bhattacherjee 2001; Thong et al., 2006). Continuous IS use is critical for many businesses (Bhattacherjee, 2001). In the context of smart home, the costs of acquiring new customers vs. retaining existing ones might play a smaller role. But the potential of increasing ECB through the continued use of a smart home app (e.g., through the DNE *feedback*) becomes central as the user can thus contribute to climate change mitigation as well as save money on heating costs, for example. This can even be used for advertising purposes and lead to competitive advantages due to increasing environmental awareness of individuals. This emphasizes the importance of customer retention in a smart home app context. Next to IS specific research focusing on smart home technologies, Gu et al. (2019) found that user satisfaction significantly and positively influences the intention to continue using a smart home, including smart home apps. Accordingly, an aim is to maximize user satisfaction of smart home app users, which influences continuous smart home app usage that includes features incentivizing ECB (Bhattacherjee, 2001; Chun-Hua et al., 2016; Gu et al., 2019). However, so far, it remains unclear which FNFs contribute to user satisfaction.

Simply fulfilling users’ expectations does not necessarily lead to user satisfaction. The different users’ expectations influence the perceived service or product evaluation and thus the respective user satisfaction (Matzler et al., 1996). As a result, research has offered method-independent empirical evidence for the assumption that the user satisfaction construct is multi-factorial (Hölzing, 2008). Bartikowski and Llosa (2004) examine methods for capturing user satisfaction with specific product or service attributes, including the Kano theory of user satisfaction (Kano model). Kano (1984) developed the Kano model, which has been discussed and applied in several theoretical and empirical research projects (Füller & Matzler, 2008;

Löfgren & Witell, 2008). We chose the Kano model because it offers a comprehensive method for analyzing the impact of product or service attributes (i.e., features) on user satisfaction. The Kano model provides a straightforward categorization that can be appropriately used in both theoretical and practical contexts. Furthermore, using the Kano model to evaluate user satisfaction with digital products or services such as mobile applications can already be considered a common practice (e.g., see Gimpel et al. (2021) for an application to a mobile health application and Gimpel et al. (2018) for an application to data privacy measures). The Kano model describes user satisfaction in terms of the degree to which specific product or service features are implemented or available (Kano, 1984). The model distinguishes four main categories of features: attractive quality (delighter), one-dimensional quality (performance need), must-be quality (basic need), and indifferent quality (Matzler et al., 1996). Attractive qualities can inspire users, but as they are not expected, a lack of attractive qualities does not create dissatisfaction while their existence increases satisfaction. One-dimensional qualities are explicitly demanded by users and influence satisfaction in both ways. Must-be qualities are taken for granted and the user only becomes aware of them once they are missing. While they cannot increase satisfaction, users get dissatisfied if must-be qualities are missing. Lastly, indifferent qualities do not lead to satisfaction or dissatisfaction, whether they are present or not. In Table 2.4-1 we list these four categories of features, and Supplemental Material A (Figure 2.4-2) describes their nature.

Categorization	**Users' expectations**	**Effect on satisfaction**	
		if implemented	**if not implemented**
Attractive quality (delighter)	Users do not expect implementation of feature	positive	none
One-dimensional quality (performance need)	Users explicitly demand implementation of feature	positive	negative
Must-be quality (basic need)	Users implicitly demand implementation of feature	none	negative
Indifferent quality	Users are indifferent to implementation of feature	none	none

Table 2.4-1 List of the Kano model factors as described by Matzler et al. (1996)

2.4.3 Research Process

To answer our research question, we first conduct a structured literature review to identify different FNFs. Next, we develop dimensions for the identified FNFs and verify their validity via card sorting. Each FNF can be described in a differentiated manner, making the Kano model the tool of choice for the evaluation of user satisfaction with each of the FNFs individually. To determine whether FNFs are considered "must-be," "one-dimensional," or "attractive" qualities, or whether users are "indifferent", we conduct an online survey.

2.4.3.1 Identification of Feedback Nudge Features

2.4.3.1.1 Structured Literature Review

We conducted a structured literature review following Webster and Watson (2002) and vom Brocke et al. (2015) to gain insights about *feedback* as a NE applied to the context of ECB. The process consists of three phases: (1) literature search, (2) selection, and (3) synthesis (vom Brocke et al., 2015).

(1) We chose a broad search string to get an overview of existing research on the usage of *feedback nudges* to promote ECB, but also to gain insights about all NEs used to promote ECB (Figure 2.3-1). This was done to assess whether *feedback nudges* are the most relevant NEs in the specific context, which was assumed, but not verified so far. In addition, this approach made sure that NEs not termed *feedback* in the extant literature, but falling under our definition of *feedback nudge,* are not missed. Even though we focus on IS research, we searched in all research fields in the databases *AISeL*, *Web of Science,* and *EBSCO Host* as the research topic is interdisciplinary. The search string's first part *nudg* OR persuasive* considers NEs and persuasive systems as these concepts are similar and NEs may occur in persuasive technology literature without being denominated as such. For example, one persuasion strategy to promote ECB defined by Casado-Mansilla et al. (2020) is the comparison of the own ECB with the respective performance of peers, which is analyzed under the term of DNE in other studies (e.g., Crago et al., 2020). Thus, we consider the literature on persuasive technology as an important thread for our research. The second part, *energy OR electricity* limits potentially relevant articles to the area of application in the energy domain. The third part *conserv* OR sav* OR use OR consum* OR efficien** integrates the notion of conservation behavior (based on Karlin et al. (2015)). The search string was applied to topics, abstracts, titles, and keywords. We put filters for peer-reviewed full research articles in the English language published in the last five years (2017-2021) to focus on the most relevant recent studies in addition to established meta-analysis and literature reviews considering literature prior to our time span (e.g., Karlin et al., 2015). In total, the search yielded 606 hits.

(2) After removing duplicates, a three-step selection process comprising title and abstract screening and full reading was conducted (Figure 2.3-1) based on the following priorly determined inclusion criteria (Webster & Watson, 2002): (1) the focus lies on promoting ECB of individuals, (2) the paper researches at least one nudging or persuasive system design element, (3) both analog and digital environments of implementation are relevant, as we wanted to include all forms of nudging currently researched in the field, and (4) an application to a smart home app in the energy-conservation context is conceivable. Defined exclusion criteria are: (1) the paper focuses on gamification elements and (2) the paper's main goal is to discuss the ethical justifiability of nudging. Afterward, we complemented the results by backward and forward searches performed for identified seminal papers. Thus, we considered meta-analyses and systematic literature reviews in the domain (vom Brocke et al., 2015) (Figure 2.4-1). This approach ensures that the state-of-the-art prior to the time span of the literature review is also considered and reflected in the review's results.

(3) Out of the final 58 articles, only six did not focus on *feedback* or a combination of *feedback* with other NEs. This leads to the observation, that *feedback* is the most researched NE in the ECB context. Supplemental Material B (Table 2.4-6) and Supplemental Material C (Table 2.4-7) give an overview of the FNFs elaborated through this systematic literature review. Some appeared with high frequency, such as whether *feedback* was given in real-time or visualized over time, and others were less frequent, as is the case for the visualization in comparison to the previous year's energy consumption. We evaluated the list of FNFs derived from the literature regarding the proposed evaluation criteria by Sonnenberg and vom Brocke (2012) within the author team and with an industry expert of smart home apps. We concluded that the initial list was not complete and added two more FNFs (D3 and F2 in Table 2.4-7 in Supplemental Material C). The final list has 25 FNFs.

(nudg* OR persuasive) AND (energy OR electricity) AND (conserv* OR sav* OR use OR consum* OR efficien*)		
Application to Databases	Web of Science: 532, EBSCO Host: 72, AISeL: 2	= 606 articles
Removal of Duplicates	- 52 duplicates	= 554 articles
Title & Abstract Screening	Inclusion and exclusion criteria, - 476 articles	= 78 articles
Backward/ Forward Search	For seminal papers, + 33 articles	= 111 articles
Full Text Screening	- 59 articles	= 58 articles
Only feedback NEs	- 6 articles (other NEs only)	= 52 articles

Figure 2.4-1 Structured literature review

2.4.3.1.2 Categorization and Cart Sorting

We defined overarching dimensions (in Table 2.4-7 in Supplemental Material C) to cluster the FNFs for preparing the survey (based on Schaffer and Fang (2018)). Card sorting was executed to validate the categorization by eight fellow IS researchers. To develop a dimension, we focused on the FNFs' main characteristic and clustered them based on similarity. For example, dimension A (*update frequency*) consists of the two FNFs *near real-time* (A1) and *periodically* (A2), where the focus clearly lies on the frequency the feedback is updated. We only asked the IS researchers to assign 16 out of 25 FNFs to an overarching dimension via card sorting as the dimension of the remaining 9 FNFs is already predefined in prior literature: *social comparison*. The FNFs in this dimension compare the user's energy consumption to a specific peer group. Even though only 16 out of the 25 FNFs were included in the card sorting procedure, all 25 FNFs are considered for the following survey. We defined overarching dimensions for the 16 FNFs where no dimension was stated in literature so far. We verified the validity of our determined dimensions with the help of closed card sorting, a setup in which it is not possible for the participant to add new dimensions other than the predetermined ones. Card sorting unhides hierarchies, allowing for the adjustment of predetermined dimensions (Capra, 2005; Maida et al., 2012). Following the approach of Capra (2005) and Maida et al. (2012), we based the FNFs' assignment on a dimension of relatedness. Therefore, names and short clarifying descriptions for each dimension were elaborated grasping its main concept. The IS researchers were asked to assign the randomly ordered FNFs to one of the dimensions with the related description. Following the approach of Schaffer and Fang (2018), an option with the name "I cannot assign this feature to any of the other dimensions" was added, so that participants were not forced to categorize FNFs into the predetermined dimensions when they did not see any fit or when they couldn't decide between the given options.

The strength of agreement between the participants is moderate, as indicated by a Fleiss' Kappa of 0.57 (Landis & Koch, 1977). Most FNFs were assigned to our predefined dimensions. Nevertheless, the results indicate that the difference between the dimensions *visualization* and *display unit* was not clear enough. FNFs from both dimensions were frequently assigned to the respective other. Thus, the card sorting shows our intended dimensions need to be revised. As a result, the dimensions *visualization* and *display unit* were merged to one dimension *visualization and display unit* which corresponds to dimension B in our list (see Table 2.4-7 in Supplemental Material C). Finally, we have six dimensions instead of the previously conceived seven where each of our 25 FNFs can be clearly assigned. After the merge, Fleiss' Kappa was 0,61, indicating substantial agreement (Landis & Koch, 1977).

2.4.3.2 Evaluation of Users' Satisfaction of Feedback Nudge Features

2.4.3.2.1 Implementation of the Kano Model

When applying the Kano model, it is most common to use a two-question approach, consisting of a functional and a dysfunctional question (Löfgren & Witell, 2008). Survey participants are first asked about their evaluation of the hypothetical case in which a specific FNF is implemented (functional question) and a case in which it is not (dysfunctional question). Each time, they can choose one of five possible answers (see Table 2.4-2). These answers do not represent a level of acceptance and are not scaled ordinal. The classification of the FNFs into the above-mentioned categories (see Table 2.4-1) depends on the users' answers to both questions (see Table 2.4-2). As proposed by Matzler et al. (1996), we stem the final classification of a FNF based on the respective most frequent individual result. To avoid unjust representations in case the shares of the most frequently chosen categories are close together (Schaule, 2014), we determine the categorization significance (Gimpel et al., 2018; Schaule, 2014). M. C. Lee and Newcomb (1997) propose the use of the variable category strength, which is determined by subtracting the share of the second most frequently chosen category from the share of the most frequently chosen one. With a category strength greater than 6%, the classification to only one category is justified. To determine significance more accurately, we complement the use of the category strength with the approach of Fong (1996). The Fong test calculates a reference value based on observed frequencies and the sample size and assumes significance in case the category strength is higher. If the Fong test does not prove significance, C. Berger et al. (1993) propose to apply the (A, O, M) < > (I, R, Q) rule. The first group consists of the categorizations A (attractive), O (one-dimensional), and M (must-be) having the power to influence user satisfaction. The second group consists of the categorizations I (indifferent), R (reverse), and Q (questionable) not influencing user satisfaction. The rule can be applied if one of the two most frequently mentioned categorizations belongs to one group and the second one belongs to the other group. In case the rule is applicable, the most frequently chosen categorization within the dominant group (>50%) is selected. For the cases where category strength is not significant at the ten-percent level according to the Fong test (Gimpel et al., 2021), and the (A, O, M) < > (I, R, Q) rule is not applicable, the feature will be assigned to a mixed category following M. C. Lee and Newcomb (1997). A mixed category includes all categories that do not significantly differ compared to the most frequently chosen category according to the Fong test (Gimpel et al., 2021). To further analyze a mixed category, Hölzing (2008) uses its total strength to influence user satisfaction (A+O+M). A dynamic view of the qualities is recommended: What the user might be indifferent to today, may soon be a must-be quality (Hölzing, 2008).

		Dysfunctional answer					Legend
		(1)	(2)	(3)	(4)	(5)	O = One-dimensional quality
Functional answer	I like it that way. (1)	Q	A	A	A	O	A = Attractive quality
	It must be that way. (2)	R	I	I	I	M	M = Must-be quality
	I am neutral. (3)	R	I	I	I	M	I = Indifferent quality
	I can live with it that way. (4)	R	I	I	I	M	R = Reverse quality
	I dislike it that way. (5)	R	R	R	R	Q	Q = Questionable result

Table 2.4-2 Derivation of Kano model factors based on Matzler et al. (1996)

For better visualization and verification of the survey results, we take a second, continuous approach by calculating the satisfaction and dissatisfaction coefficients (C. Berger et al., 1993; Schaule, 2014). The satisfaction coefficient (value between 0 and 1) is calculated by the sum of all participants that categorized a feature as a factor able to increase their satisfaction (i.e., attractive and one-dimensional quality) divided by the sum of all participants that categorized a feature as attractive, one-dimensional, must-be or indifferent. The dissatisfaction coefficient (value between -1 and 0) differs in that it takes the factors that can decrease satisfaction, thus of must-be and one-dimensional quality, into the numerator. The explanatory power of these coefficients is the mean importance of features over all participants for both improving satisfaction and avoiding dissatisfaction. We provide the results in Table 2.4-6 in Supplemental Material B.

2.4.3.2.2 Survey

To evaluate users' satisfaction with FNFs, we conducted an online survey using Lime Survey. To ensure high-quality results, we first ran a pretest with four IS researchers and one industry expert followed by the main survey. Using the insights of the pretest, we modified the survey by giving further explanations, deleting redundant information, and rephrasing unclear questions.

After welcoming the participants, we explained smart home and presented screenshots of a fictional smart home app to ensure that all participants have the same understanding of the context (M. Berger et al., 2022). In the main part, participants were put into the situation to evaluate the potential FNFs concerning their ECB. For each of the 25 FNFs, the participants answered the pair of functional and dysfunctional questions (Table 2.4-7 in Supplemental Material C). As we conducted the survey in German, the translation of the five answer options previously presented by Hölzing (2008) was used. Between the questions for FNFs F7 and

F8, we integrated a trap question to see whether participants complete the survey attentively. In the last part, we queried sociodemographic background.

We recruited via social media and e-mail. The survey was completed by 206 German-speaking participants. After filtering for participants, that correctly answered the trap question, the final sample consists of 188 participants. The sample consists of students (28.7%), employees (56.4%), retirees and people that are unable to work (4.3%), civil servants (3.7%), and others (6.9%). The participants' age ranges from 18 to 72 years with an average of 33.2 years. Men (46.3%), women (53.2%) and non-binary people (0.5%) completed the survey. The share of participants, who already use a smart home app, is 31.4%.

2.4.4 Results

2.4.4.1 Feedback Nudge Features

Table 2.4-3 gives an overview of the 25 identified FNFs (primarily from the structured literature review), categorized into six dimensions A-F (please find a detailed description of each dimension in Table 2.4-7 in Supplemental Material C). For each FNF, a description is provided. Generally, FNFs are not mutually excluding and can be implemented together. Thus, when using them in smart home app design, any number of FNFs can be chosen for implementation and every possible combination of FNFs is conceivable. The only exception is dimension A (*update frequency*), where the implementation of only one FNF is more useful to keep the implementation effort low. For dimension F (*social comparison*) it seems most convenient to implement only one or two FNFs to avoid overwhelming the user with information.

In bold: Dimension, in plain font: FNFs		**Description of FNFs**
A. Update frequency		
A1	Near real-time	Energy consumption is updated at short time intervals (e.g., every 30 minutes).
A2	Periodically	Energy consumption is updated on a weekly basis.
B. Visualization and display unit		
B1	Over time	Energy consumption is visualized in a graph over a certain period of time, e.g., over the last months/ weeks/ days/ hours.
B2	Previous year's energy consumption	The monthly energy consumption is compared to the energy consumption in the same month exactly one year ago.
B3	Comparison with similar housing situation	Energy consumption is compared to the standard and visualized based on input parameters, e.g., household size or occupied square meters.
B4	Display in kWh	Energy consumption is displayed in kilowatt-hours.
B5	Display in Euro	Energy consumption is displayed in costs incurred for the app user.
B6	Display of the environmental impact	Energy consumption is displayed in CO_2 emissions.

In bold: Dimension, in plain font: FNFs		Description of FNFs
C. Level of coverage/granularity		
C1	Overview of all devices	An overview value for all appliances indicates energy consumption.
C2	Appliance-specific	Energy consumption is measured and indicated for each appliance individually, e.g., lighting, dishwasher, washing machine, heating.
D. Push notifications		
D1	High energy consumption	Push notifications alert to current high energy consumption.
D2	Peak energy consumption period	Push notifications alert to peak energy consumption periods.
D3	High proportion of green electricity in the energy grid	Push notifications alert to times when a lot of electricity from renewable sources is available in the energy grid.
E. Saving opportunities		
E1	Technical advice	Technical advice for a more energy-efficient use of appliances is given.
E2	Financial savings	Possible financial savings from reducing energy consumption are given.
E3	Environmental contribution	The possible environmental contribution of reducing energy consumption is shown in corresponding CO_2 emissions.
F. Social comparison		
F1	Average - all	Energy consumption is compared with the average of all app users.
F2	Most efficient - all	Energy consumption is compared with that of the most efficient app users (e.g., the upper 15%).
F3	Average - similar housing situation	Energy consumption is compared with the average of other app users with similar input parameters, e.g., household size, occupied square meters.
F4	Most efficient - similar housing situation	Energy consumption is compared with that of the most efficient app users (e.g., the upper 15%) with similar input parameters (e.g., household size, occupied square meters).
F5	Average - neighborhood	Energy consumption is compared with the average of app users in the neighborhood.
F6	Most efficient - neighborhood	Energy consumption is compared with the most efficient app users (e.g., the upper 15%) in the neighborhood.
F7	Average - network	Energy consumption is compared to the average of app users in a network (e.g., friends or relatives).
F8	Most efficient - network	Energy consumption is compared with that of the most efficient app users (e.g., the upper 15%) in a network (e.g., friends or relatives).
F9	Ranking	Energy consumption is given in the form of a ranking of app users.

Table 2.4-3 The elaborated feedback nudge features (FNFs) assigned to the dimensions (A-F) including descriptions

2.4.4.2 Users' Perception of Feedback Nudge Features

The results of our analysis based on the Kano model are shown in Table 2.4-4. For each FNF, we present the category strength and the final categorization as one of the Kano model factors. We illustrate the process of finding the final categorization for FNF B1. Its category strength (subtracting the sum of the second most frequently chosen categorization M from the most frequently chosen categorization O) is merely 1%. This category strength is not significant according to the Fong test (Fong, 1996). In the next step, we check whether the (A,O,M) < > (I,R,Q) rule can be applied. It is not applicable as both, the most and the second most frequently chosen factor, belong to the (A,O,M) group. Consequently, the FNF is assigned to a mixed group and all four categorizations are listed in the order of descending frequency of occurrence.

#	**Dimension** and FNF	Category strength	Catego-rization
A	**Update frequency**		
A1	Near real-time	20%*	I
A2	Periodically	8%*	M
B	**Visualization and display unit**		
B1	Over time	1%[2]	O,M,A,I
B2	Previous year's energy consumption	5%[1]	A
B3	Comparison with similar housing situation	3%[1]	A
B4	Display in kWh	18%*	M
B5	Display in Euro	9%*	A
B6	Display of the environmental impact	14%*	M
C	**Level of coverage/granularity**		
C1	Overview of all devices	11%*	A
C2	Appliance-specific	4%[1]	A
D	**Push notifications**		
D1	High energy consumption	2%[1]	A
D2	Peak energy consumption period	6%[1]	I
D3	High proportion of green electricity in the energy grid	17%*	A
E	**Saving opportunities**		
E1	Technical advice	3%[1]	A
E2	Financial savings	8%[1]	A
E3	Environmental contribution	5%[1]	A
F	**Social comparison**		
F1	Average - all	47%*	I
F2	Most efficient - all	60%*	I
F3	Average - similar housing situation	5%[1]	A
F4	Most efficient - similar housing situation	38%*	I
F5	Average - neighborhood	44%*	I
F6	Most efficient - neighborhood	50%*	I
F7	Average - network	28%*	I
F8	Most efficient - network	51%*	I
F9	Ranking	31%*	I

Legend	
* =	Categorization significant at ten-percent level according to Fong test
[1] =	(A,O,M) < > (I,R,Q) rule applicable
[2] =	(A,O,M) < > (I,R,Q) rule not applicable
A =	Attractive quality
O =	One-dimensional quality
M =	Must-be quality
I =	Indifferent quality

Table 2.4-4 Empirical results of the feedback nudge features' (FNFs') evaluation via the Kano model

In total, ten FNFs are considered by the participants to be of indifferent quality which means, that no distinctive interpretations toward any direction can be done. Three out of the 25 FNFs are categorized as must-be qualities (i.e., if implemented with no effect, if not implemented with a negative effect on user satisfaction): updated *periodically* (A2), *display in kWh* (B4), and *display of the environmental impact* (B6). No FNF can directly be categorized as one-dimensional quality (i.e., if implemented with a positive, if not implemented with a negative effect on user satisfaction). However, *visualization over time* (B1), the only FNF assigned to the mixed category, is most frequently categorized as one-dimensional quality. Finally, eleven FNFs are categorized as attractive qualities (i.e., if implemented with a positive, if not implemented with no effect on user satisfaction). All FNFs belonging to the dimensions *level of coverage/granularity* (C) and *saving opportunities* (E) can be attractive to users. More attractive FNFs can be found in the dimensions *visualization and display unit* (B), *push notifications* (D), and *social comparison* (F).

To further analyze the survey results, we visualized the FNFs' categorization in a satisfaction-dissatisfaction diagram (Figure 2.4-3 in Supplemental Material D), indicating a low share of FNFs categorized as must-be and one-dimensional qualities and high shares of FNFs that participants see as indifferent or attractive qualities. Eight out of nine FNFs of the dimension *social comparison* (F) appear in a well-separated cluster, indicating an overall evaluation of indifference by participants. The diagram further shows that FNFs categorized as attractive quality are closer to a value of 0.5 than 1.0 indicating relatively low category strengths. Thus, FNFs of attractive quality were also frequently assigned to other categories by participants.

Consequently, it is considered worth complementing these results with a more detailed look at the categorization of FNFs per participant. Table 2.4-5 presents the minimum, median, mean, and maximum count of categorizations as a specific factor of the Kano model on participant-level. For example, participants saw an average of 6.3 out of 25 FNFs as an attractive quality; at least one participant evaluated even 20 FNFs as attractive quality. Furthermore, the shares of participants who categorized zero or at least ten FNFs as one of the six factors are indicated. With 56% of participants who categorized at least ten FNFs as indifferent quality, this factor is strongest. However, only 11% of participants evaluated none of the FNFs as attractive which implies that overall, *feedback nudges* to promote ECB have a significant impact on the satisfaction of a very large share of users: For 89% of participants, the FNFs had the possibility to improve their satisfaction within the smart home app (see Table 2.4-5).

	min	**med**	**mean**	**max**	**none**	**>=10**
Attractive quality	o	6	6.3	20	11%	25%
One-dimensional quality	o	2	3.0	25	24%	8%
Must-be quality	o	3	3.1	17	15%	2%
Indifferent quality	o	10	10.2	24	1%	56%
Reverse quality	o	1	2.1	15	45%	4%
Questionable result	o	0	0.2	2	84%	0%

Table 2.4-5 Statistics of categorizations per Kano model factor and participant

2.4.5 Discussion

The realization of the FNFs categorized as must-be quality may be considered a prerequisite for smart home apps, as they lead to user dissatisfaction if not implemented. Three FNFs were assigned as must-be qualities: updated *periodically* (A2), *display in kWh* (B4), and *display of the environmental impact* (B6). Additionally, the FNF B1 (*visualization over time)* is assigned to both categories, must-be (32.5%) and one-dimensional quality (33%). Both categories lead to user dissatisfaction if not implemented and should therefore be in focus. Hence, we regard all four FNFs (A2, B4, B6, and B1) as FNFs that should be implemented to avoid user dissatisfaction, which negatively influences continuous app usage (Bhattacherjee, 2001). Regarding FNF B1 (*visualization over time*), Karlin et al. (2015) and Chatzigeorgiou and Andreou (2021) state that nowadays, the comparison with historical values is considered a standard for energy-conservation intervention. This goes along with our findings. Additionally, the FNF B6 *(display of the environmental impact)* opens an interesting discussion. The result of being a must-be quality is consistent with the findings of Nolan et al. (2008) who state that users cite concerns about the environment as a key motivator to engage in ECB, hence users expect it as a FNF in a smart home app. Also, Nolan et al. (2008) found that it is less effective in promoting ECB compared to other FNFs. This is an important and interesting finding as it implies that only focusing on FNFs that are efficient in promoting ECB, and therefore disregarding for example F6 *(display of the environmental impact)* jeopardizes user satisfaction, and hence continuous app usage (Bhattacherjee, 2001). It is therefore essential to integrate must-be FNFs next to effective FNFs to enable long-term effects on ECB through continuous app usage.

Next up are FNFs of attractive quality. Users would not miss them but may be delighted by them. Hence, their implementation implies the opportunity to please the user. Attractive quality FNFs are the largest group (11 out of 25) and open the opportunity to individualize the app based on the FNFs that provide user satisfaction for the individual (e.g., implementing a *comparison with similar housing situation* (B3) or *push notification on high energy consumption* (D1)). These FNFs are not expected by users and can therefore be implemented optionally. At this point, our results emphasize individualization and personalization as prior research mentioned (Buckley, 2020). The app can either allow the user to add or delete individual FNFs him- or herself or already make this arrangement based on user information. This is especially relevant for the FNFs categorized as attractive quality as our survey indicates relatively low category strengths which means that participants also assign these FNFs frequently to other categories.

Finally, ten FNFs being of indifferent quality do not influence user satisfaction. This means that the user is not interested in including these FNFs, for example, in a personalized set of FNFs in a smart home app. But our results provide important insights into which FNFs should be focused on if it influences ECB and is additionally easy to implement. Out of the ten indifferent FNFs, eight belong to dimension F (*social comparison*). In academic literature, the effect of FNFs belonging to the dimension *social comparison* (F) is discussed controversially. Karlin et al. (2015) as well as the literature review of Fischer (2008) point out that no effect could be found regarding the effect of *social comparison* on ECB. In contrast, in our literature review, we identified studies that measured effect sizes for different FNFs of the dimension *social comparison*, for example, Brülisauer et al. (2020) and Nemati and Penn (2020). As the second-mentioned studies have been published recently, the observation that features may change the categorization throughout time (Hölzing, 2008) should be considered. Additionally, academic research is — to the best of our knowledge — still missing to compare the effect size of different *social comparison* FNFs. Therefore, further investigation is needed here if conclusions are to be drawn about the implementation of *social comparison* FNFs. Another FNF of indifferent quality is whether *feedback* is updated in *near real-time* (A1). As this FNF has no impact on user satisfaction, it may or may not be implemented depending on the implementation effort (e.g., availability of real-time data, continuous connection to the network). The last FNF which is categorized indifferent is a push notification that alerts the user *peak energy consumption periods* (D2). However, the literature indicates that push notifications for peak load times can contribute to users' ECB (Di Cosmo & O'Hora, 2017; Jorgensen et al., 2021). In this context, especially the period in which the push notification is displayed to the user is decisive (Jorgensen et al., 2021).

Focusing on the results of FNFs in each dimension, we found that concerning the *update frequency* (dimension A), users only expect the app to deliver feedback *periodically* (A2, must-be quality) while being indifferent about *near real-time feedback* (A1, indifferent quality). As pointed out by Karlin et al. (2015), it is important to note that researchers differ in their definition of how often the feedback is updated vs. how often users receive the feedback. As dimension A refers to the former, the results implicate that users do not expect to always see real-time data on their energy consumption, which should simplify the app development and overall set-up of the smart home as continuous real-time data availability is not necessary.

The dimension *visualization and display unit* (B) is of specific importance to users as every FNF influences user satisfaction. The FNFs *display in kWh* (B4) and *display of the environmental impact* (B6) considered as must-be qualities as well as the FNF *visualization over time*

(B1) considered in a mixed category (must-be and one-dimensional) are all recommended for implementation as it is expected as a standard in this context (Chatzigeorgiou & Andreou, 2021; Karlin et al., 2015) while not necessarily affecting ECB. Karlin et al. (2015) found that the comparison with historical values, in our case FNFs B1 and B2, does not impact feedback effectiveness. The remaining FNFs of this category (*previous year's energy consumption* (B2), *comparison with similar housing situation* (B3), and *display in Euro* (B5)) are evaluated as attractive qualities, which have the potential to increase user satisfaction and should therefore be configurated individually if the user is interested in these *visualization and display* options.

Both FNFs of the dimension *level of coverage/granularity* (C), namely *overview of all appliances* (C1) and *appliance-specific feedback* (C2) are viewed by the participants as attractive qualities, while none of them is categorized as must-be quality. Karlin et al. (2015) study the same levels of granularity and found that more granular feedback for specific appliances rather than on the whole-home level did not have a positive effect on ECB. They argue that this might be due to lacking knowledge of what to do with the granular information and that it is only relevant to them at particular points in time and not generally. Our data, therefore, rather suggest implementing FNF C1 as the effort of providing more granular appliance feedback does not pay off positively in terms of user satisfaction or environmental benefit (ECB).

Push notifications (D) consist of the indifferent FNF *peak energy consumption period* (D2) and two FNFs considered as attractive qualities: *high energy consumption* (D1) and *high proportion of green electricity in the grid* (D3). The implementation of *push notifications* is therefore optional. But considering the two attractive FNFs, we observe that the latter was the FNF with the highest share of participants seeing it as attractive quality (41.5%) throughout the whole set of the 25 FNFs. Thus, its implementation might delight a large share of users.

Similar accounts for *saving opportunities* (E) as all FNFs are categorized as attractive qualities, the implementation is optional without risking user dissatisfaction. Prior research provides different outcomes so far on the effect of messaging on *saving opportunities* (E). In their meta-analysis, Karlin et al. (2015) found that price messaging did not lead to ECB, but the combination with external incentives or goal-setting did increase ECB. In a more recent study, Mi et al. (2020) found a 14% increase in household energy saving of cost-benefit feedback (E2) compared to the control group. Therefore, implementing these FNFs in a smart home app additionally to FNFs that generate user satisfaction seems promising. In addition, these FNFs can be connected to external incentives or goal-setting nudging to reach even more promising results.

Lastly, the dimension *social comparison* (F) is mostly categorized as indifferent quality, therefore its FNFs' implementation should depend on the promising effect on ECB (as discussed above). Only the FNF F3 (*average - similar housing situation*) is categorized as attractive quality, hence bearing the potential to increase user satisfaction. Prior studies found positive effects on implementing F3 to increase ECB (Mukai et al., 2022; Sudarshan, 2017), emphasizing the possibility, that the user can optionally add this FNF.

2.4.5.1 Theoretical contribution

This paper contributes to the body of knowledge about digital nudging to promote ECB. Specifically, it focuses on FNFs in a smart home app. In academic and practitioner-oriented literature, the promotion of ECB by using different DNEs as well as nudges in analog settings has been studied in depth. Until now, little research has been done using smart home apps as the digital interface (M. Berger et al., 2022). Yet, this specific interface is important as it is increasingly used, relates to major energy-related decisions (esp. heating, air conditioning, electricity), and cannot be assumed to be perceived like other interfaces. We shed light on the upside of nudging through *feedback* beyond its mere informative value. Our paper consists of four main contributions.

First, we provide insights into different FNFs that have been investigated in relation to ECB. We consolidate existing knowledge and provide an overview of dimensions with FNFs that can be regarded when investigating *feedback nudges* in smart home apps. Second, we link different FNFs to user satisfaction, which we state to support continuous usage based on known IS literature (Bhattacherjee, 2001; Thong et al., 2006). By conducting a survey based on the Kano model, we shed light on different users' expectations and their influence on user satisfaction. We especially point out, that next to the focus on FNFs that were shown to have significant positive effects on ECB, it is important to also implement FNFs that are considered as must-be qualities by users. Neglecting them due to a lack of efficiency in improving behavior would reduce user satisfaction. Must-be qualities support continuous smart home app usage, which in the long run, can lead to ECB. Third, by pointing out FNFs that belong to attractive qualities, being optional FNFs that can be personalized by each individual user, we offer possibilities to integrate personalization and individualization in a smart home app.

Lastly, having FNFs that are categorized as indifferent qualities, we point out further investigation to focus on these FNFs that provide the largest effect on ECB, as they do not impact user satisfaction at all.

In summary, besides the effectiveness of nudges in steering behavior, their effect on user satisfaction is important. Our work complements the traditional focus on DNEs' effectiveness with a perspective on user satisfaction. Users' evaluation of FNFs as presented in this paper is a point of orientation for researchers who study *feedback* for ECB in smart home apps, but also in the broader context of digital interfaces.

2.4.5.2 Practical implications

As smart home technologies are already widely used in many households, the use of smart home apps controlling these technologies to influence ECB is nearby. With the findings of this paper, we provide practitioners with an overview of which FNFs may be implemented in a smart home app to generate user satisfaction and thereby support the continuous use of smart home apps. Since FNFs can have a large implementation overhead, especially regarding the temporal resolution and data privacy issues, for example when comparing individuals' values with comparative values from neighbors, it is very helpful to know which FNFs really contribute to user satisfaction. As smart home apps should not be overloaded with FNFs, our findings also present a selection of FNFs that are best implemented optionally in a personalized area so that users can personally decide to activate them (FNFs with attractive qualities). To define which FNFs should be available for this personalized area our results in combination with the literature regarding effectiveness should be analyzed (see the Discussion section).

2.4.5.3 Limitations and future research

Researchers and practitioners should be aware of the following limitations. The presented FNFs were derived from a systematic literature review that considered publications in academic literature throughout the past five years (2017-2021), combined with a forward and backward search to access established FNFs. We discuss the findings in terms of completeness with an industry expert. Yet, the findings could be further complemented by practical insights. Additionally, according to the Kano model survey procedure participants answered a functional and a dysfunctional question for each of the 25 FNFs which is quite lengthy. This may have influenced the concentration of participants and might partially explain the high dropout rate (out of 328 participants, 122 (37%) dropped out throughout the process). Additionally, the effect of the FNF B1 (*visualization over time*) on user satisfaction is not clear since B1 is the only FNF in a mixed category. In our study we made no distinction between the time horizon in which the visualization is displayed, we only asked about a "visualization over time" and named the examples months, weeks, days, or hours. To make a more precise analysis, differentiation between various time horizons is necessary, which might resolve the mixed categorization of B1. Lastly, the approach lacks real-world consequences. When going through the survey, participants had to imagine how each FNF could look like and might understand the given descriptions of the FNFs differently. In our setup, participants only had to evaluate each FNF once. In real-life situations when they are nudged by the FNFs every time they open the app, the results might differ. Lastly, when interpreting the survey results it is important to have in mind that they reflect the categorization only for a given point in time. Consistent with the observation that in general, features go through a lifecycle and may change the categorization throughout time (Hölzing, 2008), we found that those FNFs considered as basic needs are relatively well studied. We expect FNFs that are assigned to the indifferent or attractive quality to possibly eventually be classified as must-be quality.

For further research, we emphasize four endeavors. First, we measured aggregated user satisfaction of a set of 25 FNFs. Thereby we do not consider differences dependent on participants' individuality. As our results show that individual perceptions differ, research can be taken a step further by looking at different subgroups. In the given context, it might be interesting to analyze the impact of the environmental attitude, for example by using the New Ecological Paradigm, or of the technological affinity of participants. Additionally, the current sample of the survey done in Germany cannot be considered representative, as the mean age is 33.2 years and thus significantly lower than the mean age of the German population (44.6 years (Statistische Ämter des Bundes und der Länder, 2021)). Even though we argue that older age groups may not be the most important target group for smart home apps, due to the promising findings we are planning to expand the survey to consider a balanced sample for additional findings. Next, in this paper, we synthesized our results of users' expectations by applying the Kano model for certain FNFs with effect strengths on those measured by prior research on ECB. Measuring the whole set of FNFs for isolated effect sizes on ECB would contribute to the regarded user preferences. Thus, taking on another research focus, our findings on user satisfaction could be complemented by interpreting whether the implementation of the FNFs assigned to the attractive or indifferent quality is worth it from the point of view of promoting ECB.

2.4.6 Conclusion

The need for behavior changes towards ECB becomes increasingly urgent. The increasing availability and usage of smart home technologies provide a promising opportunity for implementing DNEs as a behavioral intervention in a smart home app to foster ECB. Prior research focused on the promising DNE *feedback* to decrease energy consumption and tested different FNFs. While valuable knowledge on the effectiveness of specific FNFs exists, the investigation of the users' expectations and preferences concerning these FNFs is missing. This is crucial to support user satisfaction, influencing continuous app usage. We aim to close this gap and created a set of 25 FNFs categorized into six dimensions, that were verified via a card sorting with IS researchers. To empirically investigate users' preferences, we conducted a survey with 188 participants based on the Kano model and measured the users' perceptions of the identified FNFs as must-be, one-dimensional, attractive, or indifferent qualities. We illustrate essential and optional FNFs that can increase user satisfaction and avoid user dissatisfaction, hence enabling continuous app usage. We call attention to the fact, that when implementing a smart home app to enable ECB, the focus should not only be on effectiveness but also on user satisfaction, as these two do not necessarily correspond. By pointing out FNFs that belong to attractive qualities, we offer a possibility to enable personalized app design by each individual user. Lastly, identifying FNFs categorized as indifferent qualities, we point out to focus on these indifferent FNFs that provide the largest effect on ECB, as they do not impact user satisfaction at all. Our findings expand the understanding of implementing behavioral interventions in terms of *feedback* when designing smart home technologies to encourage ECB directly through the ongoing trend of digitalization. As user satisfaction supports continuous app use, we hope to contribute toward ECB in the long term.

2.4.7 References

Bartikowski, B., & Llosa, S. (2004). Customer satisfaction measurement: comparing four methods of attribute categorisations. *The Service Industries Journal*, *24*(4), 67–82.

Berger, C., Blauth, R., Boger, D., Bolster, C., Burchill, G., & DuMouchel, W. (1993). Kano's methods for understanding customer-defined quality. *Center for Quality Management Journal*, 3–36.

Berger, M., Greinacher, E., & Wolf, L. (2022). Digital nudging to promote energy conservation behavior – Framing and default rules in a smart home app. In *Proceedings of the 30th European Conference on Information Systems (ECIS).*

Bhattacherjee, A. (2001). Understanding information systems continuance: An expectation-confirmation model. *MIS Quarterly*, *25*(3), 351–370.

Bonan, J., Cattaneo, C., d'Adda, G., & Tavoni, M. (2021). Can social information programs be more effective? The role of environmental identity for energy conservation. *Journal of Environmental Economics and Management*, *108*, 1–28. https://doi.org/10.1016/j.jeem.2021.102467

Brülisauer, M., Goette, L., Jiang, Z., Schmitz, J., & Schubert, R. (2020). Appliance-specific feedback and social comparisons: Evidence from a field experiment on energy conservation. *Energy Policy*, *145*, 1–9. https://doi.org/10.1016/j.enpol.2020.111742

Buckley, P. (2020). Prices, information and nudges for residential electricity conservation: A meta-analysis. *Ecological Economics*, *172*, 1–14. https://doi.org/10.1016/j.ecolecon.2020.106635

Callery, P. J., Goodwin, C. C., & Moncayo, D. (2021). Norm proximity and optimal social comparisons for energy conservation behavior. *Journal of Environmental Management*, *296*, 1–8. https://doi.org/10.1016/j.jenvman.2021.113332

Cappa, F., Rosso, F., Giustiniano, L., & Porfiri, M. (2020). Nudging and citizen science: The effectiveness of feedback in energy-demand management. *Journal of Environmental Management*, *269*, 110759. https://doi.org/10.1016/j.jenvman.2020.110759

Capra, M. G. (2005). Factor analysis of card sort data: An alternative to hierarchical cluster analysis. In *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting*, Los Angeles, USA.

Casado-Mansilla, D., Tsolakis, A. C., Borges, C. E., Kamara-Esteban, O., Krinidis, S., Avila, J. M., Tzovaras, D., & López-de-Ipiña, D. (2020). Socio-economic effect on ICT-based persuasive interventions towards energy efficiency in tertiary buildings. *Energies*, *13*(7), 1–26. https://doi.org/10.3390/en13071700

Chatzigeorgiou, I. M., & Andreou, G. T. (2021). A systematic review on feedback research for residential energy behavior change through mobile and web interfaces. *Renewable and Sustainable Energy Reviews, 135,* 1–16. https://doi.org/10.1016/j.rser.2020.110187

Chun-Hua, H., Jung-Jung, C., & Kai-Yu, T. (2016). Exploring the influential factors in continuance usage of mobile social Apps: Satisfaction, habit, and customer value perspectives. *Telematics and Informatics, 33*(2), 342–355. https://doi.org/10.1016/j.tele.2015.08.014

Crago, C. L., Spraggon, J. M., & Hunter, E. (2020). Motivating non-ratepaying households with feedback and social nudges: A cautionary tale. *Energy Policy,* 1–10.

Di Cosmo, V., & O'Hora, D. (2017). Nudging electricity consumption using TOU pricing and feedback: evidence from Irish households. *Journal of Economic Psychology, 61*, 1–14. https://doi.org/10.1016/j.joep.2017.03.005

Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency, 1*(1), 79–104. https://doi.org/10.1007/s12053-008-9009-7

Fleury, S., Jamet, É., Michinov, E., Michinov, N., & Erhel, S. (2018). A priori acceptability of various types of digital display feedback on electricity consumption. *Le Travail Humain, 81*(3), 247–267. https://doi.org/10.3917/th.813.0247

Fong, D. (1996). Using the self-stated importance questionnaire to interpret Kano questionnaire results. *Center for Quality Management Journal, 5*(3), 21–24.

Füller, J., & Matzler, K. (2008). Customer delight and market segmentation: An application of the three-factor theory of customer satisfaction on life style groups. *Tourism Management*, *29*(1), 116–126.

Gimpel, H., Kleindienst, D., Nüske, N., Rau, D., & Schmied, F. (2018). The upside of data privacy – delighting customers by implementing data privacy measures. *Electronic Markets*, *28*(4), 437–452. https://doi.org/10.1007/s12525-018-0296-3

Gimpel, H., Manner-Romberg, T., Schmied, F., & Winkler, T. J. (2021). Understanding the evaluation of mHealth app features based on a cross-country Kano analysis. *Electronic Markets, 31*(4), 765–794. https://doi.org/10.1007/s12525-020-00455-y

Gram-Hanssen, K., & Darby, S. J. (2018). "Home is where the smart is"? Evaluating smart home research and approaches against the concept of home. *Energy Research & Social Science, 37*, 94–101.

Gu, W., Bao, P., Hao, W., & Kim, J. (2019). Empirical examination of intention to continue to use smart home services. *Sustainability*, *11*(19), 1–12. https://doi.org/10.3390/su11195213

Hansen, P., & Jespersen, A. (2013). Nudge and the manipulation of choice: A framework for the responsible use of the nudge approach to behaviour change in public policy. *European Journal of Risk Regulation*, *1*, 3–28.

He, T., Jazizadeh, F., & Arpan, L. (2021). AI-powered virtual assistants nudging occupants for energy saving: proactive smart speakers for HVAC control. *Building Research & Information*, 1–16. https://doi.org/10.1080/09613218.2021.2012119

Hölzing, J. A. (2008). *Die Kano-Theorie der Kundenzufriedenheitsmessung*. Gabler. https://doi.org/10.1007/978-3-8349-9864-4

Hummel, D., & Maedche, A. (2019). How effective is nudging? A quantitative review on the effect sizes and limits of empirical nudging studies. *Journal of Behavioral and Experimental Economics*, *80*, 47–58. https://doi.org/10.1016/j.socec.2019.03.005

International Energy Agency. (2022). *Energy saving actions by EU citizens could save enough oil to fill 120 super tankers and enough natural gas to heat 20 million homes*. https://www.iea.org/news/energy-saving-actions-by-eu-citizens-could-save-enough-oil-to-fill-120-super-tankers-and-enough-natural-gas-to-heat-20-million-homes

Jorgensen, B. S., Fumei, S., & Byrne, G. (2021). Reducing peak energy demand among residents who are not billed for their electricity consumption: Experimental evaluation of behaviour change interventions in a university setting. *International Journal of Environmental Research and Public Health*, *18*(16), 1–16. https://doi.org/10.3390/ijerph18168406

Kahneman, D. (2011). *Thinking, fast and slow*. Macmillan.

Kano, N. (1984). Attractive quality and must-be quality. *Hinshitsu (Quality, the Journal of Japanese Society for Quality Control)*, *14*, 39–48.

Karlin, B., Zinger, J. F., & Ford, R. (2015). The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin*, *141*(6), 1205–1227. https://doi.org/10.1037/a0039650

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174.

Lee, M. C., & Newcomb, J. F. (1997). Applying the Kano methodology to meet customer requirements: NASA's microgravity science program. *Quality Management Journal*, *4*(3), 95–106. https://doi.org/10.1080/10686967.1997.11918805

Li, T., Fooks, J. R., Messer, K. D., & Ferraro, P. J. (2021). A field experiment to estimate the effects of anchoring and framing on residents' willingness to purchase water run-off management technologies. *Resource and Energy Economics*, *63*, 1–10. https://doi.org/10.1016/j.reseneeco.2019.07.001

Liu, Z. (2005). Reading behavior in the digital environment. *Journal of Documentation*, *61*(6), 700–712. https://doi.org/10.1108/00220410510632040

Löfgren, M., & Witell, L. (2008). Two decades of using Kano's theory of attractive quality: a literature review. *Quality Management Journal*, *15*(1), 59–75.

Loock, C.-M., Landwehr, J., Staake, T., Fleisch, E., & Pentland, A. (2012). The influence of reference frame and population density on the effectiveness of social normative feed-back on electricity consumption. In *Proceedings of the 33rd International Conference on Information Systems (ICIS).*

Maida, M., Maier, K., & Obwegeser, N. (2012). Evaluation of techniques for structuring multi-criteria decision problems. In *Proceedings of the International Conference on Information Resources Management*.

Matzler, K., Hinterhuber, H. H., Bailom, F., & Sauerwein, E. (1996). How to delight your customers. *Journal of Product & Brand Management*, *5*(2), 6–18.

Meske, C., & Amojo, I. (2020). Status quo, critical reflection, and the road ahead of digital nudging in information systems research: A discussion with Markus Weinmann and Alexey Voinov. *Communications of the Association for Information Systems*, 402–420. https://doi.org/10.17705/1CAIS.04617

Mi, L., Qiao, L., Du, S., Xu, T., Gan, X., Wang, W., & Yu, X. (2020). Evaluating the effect of eight customized information strategies on urban households' electricity saving: A field experiment in China. *Sustainable Cities and Society*, *62*, 1–31. https://doi.org/10.1016/j.scs.2020.102344

Mirsch, T., Lehrer, C., & Jung, R. (2017). Digital nudging: Altering user behavior in digital environments. In *Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI13).*

Mukai, T., Nishio, K., Komatsu, H., & Sasaki, M. (2022). What effect does feedback have on energy conservation? Comparing previous household usage, neighbourhood usage, and social norms in Japan. *Energy Research & Social Science*, *86*, 1–10. https://doi.org/10.1016/j.erss.2021.102430

Nemati, M., & Penn, J. (2020). The impact of information-based interventions on conservation behavior: A meta-analysis. *Resource and Energy Economics*, *62*, 1–19. https://doi.org/10.1016/j.reseneeco.2020.101201

Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative social influence is underdetected. *Personality & Social Psychology Bulletin*, *34*(7), 913–923. https://doi.org/10.1177/0146167208316691

Schaffer, O., & Fang, X. (2018). What makes games fun? Card sort reveals 34 sources of computer game enjoyment. In *Proceedings of the 24th Americas Conference on Information Systems (AMCIS).*

Schaule, M. S. (2014). *Anreize für eine nachhaltige Immobilienentwicklung - Nutzerzufriedenheit und Zahlungsbereitschaft als Funktion von Gebäudeeigenschaften bei Büroimmobilien* [Dissertation]. TU München, München.

Schleich, J. (2019). Energy efficient technology adoption in low-income households in the European Union – What is the evidence? *Energy Policy*, *125*, 196–206. https://doi.org/10.1016/j.enpol.2018.10.061

Schultz, P. W., Estrada, M., Schmitt, J., Sokoloski, R., & Silva-Send, N. (2015). Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms. *Energy*, *90*, 351–358. https://doi.org/10.1016/j.energy.2015.06.130

Sonnenberg, C., & vom Brocke, J. (2012). Evaluations in the science of the artificial–reconsidering the build-evaluate pattern in design science research. In *International Conference on Design Science Research in Information Systems* (pp. 381–397). Springer.

Sorrell, S. (2015). Reducing energy demand: A review of issues, challenges and approaches. *Renewable & Sustainable Energy Reviews*, *47*, 74–82. https://doi.org/10.1016/j.rser.2015.03.002

Statistische Ämter des Bundes und der Länder. (2021). *Durchschnittsalter der Bevölkerung in Deutschland von 2011 bis 2020.*

Sudarshan, A. (2017). Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives. *Journal of Economic Behavior & Organization*, *134*, 320–335. https://doi.org/10.1016/j.jebo.2016.12.015

Sunstein, C. R. (2014). Nudging: A very short guide. *Journal of Consumer Policy 2014 37:4*, *37*(4), 583–588. https://doi.org/10.1007/S10603-014-9273-1

Thaler, R. H., & Sunstein, C. R. (2008). *Nudge - Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Thong, J. Y., Hong, S.-J., & Tam, K. Y. (2006). The effects of post-adoption beliefs on the expectation-confirmation model for information technology continuance. *International Journal of Human-Computer Studies*, *64*(9), 799–810. https://doi.org/10.1016/j.ijhcs.2006.05.001

vom Brocke, J., Simons, A., Riemer, K., Niehaves, B., Plattfaut, R., & Cleven, A. (2015). Standing on the shoulders of giants: Challenges and recommendations of literature search in information systems research. *Communications of the Association for Information Systems*, *37*. https://doi.org/10.17705/1CAIS.03709

Wason, P. C., & Evans, J. (1974). Dual processes in reasoning? *Cognition*, *3*(2), 141–154.

Webster, J., & Watson, R. T. (2002). Guest editorial: Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, *26*(2), 13–23.

Weinmann, M., Schneider, C., & vom Brocke, J. (2016). Digital nudging – Guiding judgment and decision-making in digital choice environments. *Business & Information Systems Engineering*, *58*(6), 433–436. https://doi.org/10.1007/S12599-016-0453-1

2.4.8 Supplemental Material

2.4.8.1 Material A

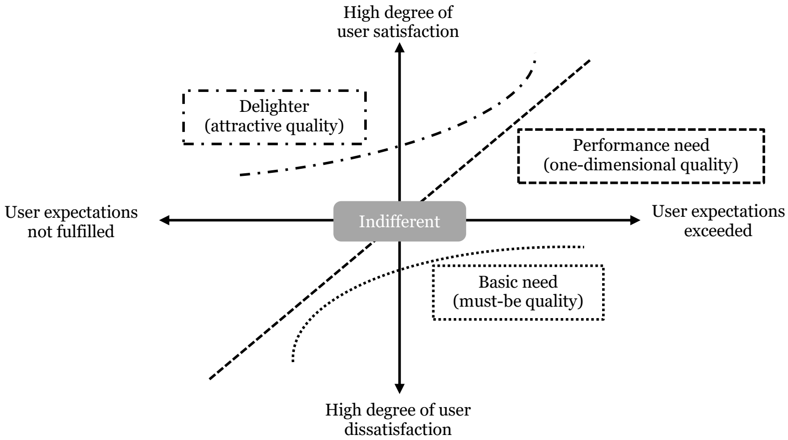

Figure 2.4-2 Factors of the Kano Model (Kano, 1984) as described by Matzler et al. (1996) and applied to the smart home app context

2.4.8.2 Material B

#	**Dimension /** Feature	**Sources**
A	**Update frequency**	
A1	Near real-time	Chatzigeorgiou and Andreou (2021), Di Cosmo and O'Hora (2017),He et al. (2021), Marangoni and Tavoni (2021), Nemati and Penn (2020), Tiefenbeck et al. (2019), Fang et al. (2020), Aydin et al. (2018), Geelen et al. (2019), Fleury et al. (2018), Zangheri et al. (2019), Asmare et al. (2021), Buckley (2020), Caballero and Della Valle (2021), Jung et al. (2021), H. B. Kim et al. (2020), Ruokamo et al. (2022), Casado-Mansilla et al. (2020), Bergquist and Nilsson (2018), Khanna et al. (2021), Ziqiao Li et al. (2021), Zhuangai Li and Cao (2021)
A2	Periodically	Callery et al. (2021), Crago et al. (2020), Khanna et al. (2021), Myers and Souza (2018), Myers and Souza (2020), Sudarshan (2017), Lee et al. (2020), Mi et al. (2019)
B	**Visualization and display unit**	
B1	Over time	Chatzigeorgiou and Andreou (2021), Asmare et al. (2021), Buckley (2020), Caballero and Della Valle (2021), Crago et al. (2020), Fanghella et al. (2021), Fels and Andor (2018), Henry et al. (2019), Jorgensen et al. (2021), Jung et al. (2021), Khanna et al. (2021), H. B. Kim et al. (2020), Marangoni and Tavoni (2021), Meub et al. (2019), Myers and Souza (2018), Myers and Souza (2020), Sudarshan (2017), Casado-Mansilla et al. (2020), Chiu et al. (2020), Aydin et al. (2018), Geelen et al. (2019), Fleury et al. (2018), Lee et al. (2020), Mi et al. (2019), Mi et al. (2021), Mukai et al. (2022), Tiefenbeck et al. (2018), Zangheri et al. (2019)
B2	Previous year's energy consumption	Mukai et al. (2022)
B3	Comparison with similar housing situation	Buckley (2020), Fleury et al. (2018)
B4	Display in kWh	Chatzigeorgiou and Andreou (2021), Brandsma and Blasch (2019), Buckley (2020), Caballero and Della Valle (2021), Chen and Qin (2021), Di Cosmo and O'Hora (2017), Henry et al. (2019), Jung et al.

#	**Dimension** / Feature	**Sources**
		(2021), J. H. Kim and Kaemingk (2021), Marangoni and Tavoni (2021), Mi et al. (2020), Wong-Parodi et al. (2019), Fang et al. (2020), Chiu et al. (2020), Andor et al. (2020), Geelen et al. (2019), Bergquist and Nilsson (2018), Fleury et al. (2018), Lee et al. (2020), Mukai et al. (2022)
B5	Display in Euro	Chatzigeorgiou and Andreou (2021), Brandsma and Blasch (2019), Buckley (2020), Crago et al. (2020), Di Cosmo and O'Hora (2017), Jung et al. (2021), J. H. Kim and Kaemingk (2021), Meub et al. (2019), Sudarshan (2017), Chiu et al. (2020), Aydin et al. (2018), Geelen et al. (2019), Bergquist and Nilsson (2018), Lee et al. (2020)
B6	Display of the environmental impact	Chatzigeorgiou and Andreou (2021), Brandsma and Blasch (2019), Mi et al. (2020), Fang et al. (2020)
C	**Level of coverage/granularity**	
C1	Overview of all devices	Chatzigeorgiou and Andreou (2021), Meub et al. (2019), Zangheri et al. (2019)
C2	Appliance-specific	Nemati and Penn (2020), Chatzigeorgiou and Andreou (2021), Brülisauer et al. (2020), Zangheri et al. (2019)
D	**Push notifications**	
D1	High energy consumption	H. B. Kim et al. (2020)
D2	Peak energy consumption period	Brandon et al. (2019), Di Cosmo and O'Hora (2017), Jorgensen et al. (2021)
D3	High proportion of green electricity in the energy grid	We added this FNF after evaluating the set of FNFs derived from literature regarding the proposed evaluation criteria by Sonnenberg and vom Brocke (2012) within the authors team and one industry expert of smart home apps.
E	**Saving opportunities**	
E1	Technical advice	Nemati and Penn (2020), Chen and Qin (2021), H. B. Kim et al. (2020)
E2	Financial savings	Nemati and Penn (2020),He et al. (2021), H. B. Kim et al. (2020), Mi et al. (2020), Ornaghi et al. (2018)
E3	Environmental contribution	Nemati and Penn (2020), Mi et al. (2020), Myers and Souza (2020), Ornaghi et al. (2018), Mi et al. (2021)
F	**Social comparison**	
F1	Average - all	Brülisauer et al. (2020), Fleury et al. (2018)
F2	Most efficient - all	We added this FNF after evaluating the set of FNFs derived from literature regarding the proposed evaluation criteria by Sonnenberg and vom Brocke (2012) within the authors team and one industry expert of smart home apps.
F3	Average - similar housing situation	Meub et al. (2019), Sudarshan (2017), Mukai et al. (2022)
F4	Most efficient - similar housing situation	Mukai et al. (2022)
F5	Average - neighborhood	Nemati and Penn (2020), Bonan et al. (2020), Bonan et al. (2021), Brandon et al. (2019), Brülisauer et al. (2020), Callery et al. (2021), Chen and Qin (2021), Crago et al. (2020), Henry et al. (2019), Jorgensen et al. (2021), H. B. Kim et al. (2020), Myers and Souza (2018), Myers and Souza (2020), Andor et al. (2020)
F6	Most efficient - neighborhood	Nemati and Penn (2020), Bonan et al. (2020), Bonan et al. (2021), Caballero and Della Valle (2021), Callery et al. (2021), Crago et al. (2020), Jorgensen et al. (2021), J. H. Kim and Kaemingk (2021), Myers and Souza (2018), Myers and Souza (2020), Andor et al. (2020)

#	**Dimension /** Feature	**Sources**
F7	Average - network	Nemati and Penn (2020), Brülisauer et al. (2020), Charlier et al. (2021), Wong-Parodi et al. (2019), Chiu et al. (2020)
F8	Most efficient - network	Nemati and Penn (2020), Charlier et al. (2021), Wong-Parodi et al. (2019), Chiu et al. (2020)
F9	Ranking	Jorgensen et al. (2021), Zhou (2020), Fleury et al. (2018)

Table 2.4-6 Overview on the feedback nudge features (FNFs) elaborated through the systematic literature review

2.4.8.3 Material C

In bold: Dimension (description), in plain: FNFs		**Item in functional and dysfunctional form**
A. Update frequency (Frequency with which your energy consumption is updated in the smart home app.)		
A1	Near real-time	Your energy consumption is updated at 30-minute time intervals.
		Your energy consumption is not updated in real time.
A2	Periodically	Your energy consumption is updated on a weekly basis.
		Your energy consumption is not updated on a weekly basis.
B. Visualization (The visualization indicates how your energy consumption is displayed in the smart home app.)		
B1	Over time	Your energy consumption is visualized in a graph over a certain period of time, for example over the last months/ weeks/ days/ hours.
		Your energy consumption is not visualized over time.
B2	Previous year's energy consumption	Your monthly energy consumption is visualized including the comparative value of the energy consumption in the same month exactly one year ago.
		Your energy consumption is not visualized in comparison with the previous year.
B3	Comparison with similar housing situation	Your energy consumption is compared to the standard and visualized on the basis of input parameters such as household size or occupied square meters.
		Your energy consumption is not visualized on the basis of comparative values for your housing situation.
B4	Display in kWh	Your energy consumption is displayed in kilowatt hours.
		Your energy consumption is not displayed in kilowatt hours.
B5	Display in Euro	Your energy consumption is displayed in euros according to the costs incurred for you.
		The costs incurred by you in euros for your energy consumption are not displayed.
B6	Display of the environmental impact	Your energy consumption is displayed in CO2 emissions.
		The environmental impact of your energy consumption is not displayed.
C. Level of coverage/granularity (The level of coverage/granularity indicates the level of detail at which you receive information on your energy consumption.)		
C1	Overview of all devices	Your energy consumption is measured and indicated as an overview value for all appliances.
		An overview value for all appliances is not available.
C2	Appliance-specific	Your energy consumption is measured and indicated for each appliance individually (lighting, dishwasher, washing machine, heating).
		An appliance-specific measurement is not given.
D. Push notifications (Information is displayed on your smartphone screen through proactive messages from the smart home app.)		
D1	High energy consumption	Push notifications alert you to your current high energy consumption.
		You will not receive push notifications when your energy consumption is high.

In bold: Dimension (description), in plain: FNFs		**Item in functional and dysfunctional form**
D2	Peak energy consumption period	Push notifications alert you to peak energy consumption periods. (For your information: The daily energy demand distribution of households shows peaks during certain hours of the day. This temporary high demand leads to high utilization of the energy grid. To ensure security of supply, energy conservation behavior is important, especially during peak energy consumption periods).
		You will not receive a push notification during peak energy consumption periods.
D3	High proportion of green electricity in the energy grid	Push notifications alert you to times when, due to weather conditions (e.g., a lot of wind, a lot of sun), a lot of electricity from renewable sources is available in the energy grid and when you should preferentially switch on appliances such as your dishwasher or washing machine to use this electricity directly.
		If there is a high proportion of green electricity in the energy grid, you will not receive a push notification.
E. Saving opportunities (You will be shown how to reduce your energy consumption and, if applicable, what impact the savings can have.)		
E1	Technical advice	Technical advice on how to use your appliances more energy-efficiently is given.
		Technical advice is not given.
E2	Financial savings	Possible financial savings from reducing your energy consumption are given.
		Possible financial savings are not given.
E3	Environmental contribution	The possible environmental contribution of reducing your energy consumption is shown in corresponding CO2 emissions.
		The possible environmental contribution is not shown.
F. Social comparison (Your energy consumption is compared with that of different peer groups, such as all smart home app users, those with a similar housing situation, your neighborhood, or your network.)		
F1	Average - all	Your energy consumption is compared with the average of all app users.
		The comparison with the average of all app users does not take place.
F2	Most efficient - all	Your energy consumption is compared with that of the 15% most efficient app users.
		The comparison with the most efficient of all app users does not take place.
F3	Average - similar housing situation	Your energy consumption is compared with the average of other app users with similar input parameters (e.g., household size, occupied square meters).
		The comparison with the average of app users with a similar housing situation does not take place.
F4	Most efficient - similar housing situation	Your energy consumption is compared with that of the 15% most efficient app users with similar input parameters (e.g., household size, occupied square meters).
		The comparison with the most efficient app users with a similar housing situation does not take place.
F5	Average - neighborhood	Your energy consumption is compared with the average of app users in your neighborhood.
		The comparison with the average of app users in the neighborhood does not take place.
F6	Most efficient - neighborhood	Your energy consumption is compared with the 15% most efficient app users in your neighborhood.
		The comparison with the most efficient app users in the neighborhood does not take place.
F7	Average - network	Your energy consumption is compared to the average of app users in your network (e.g., friends, relatives).
		The comparison with the average of app users in your own network does not take place.
F8	Most efficient - network	Your energy consumption is compared with that of the 15% most efficient app users in your network.

In bold: Dimension (description), in plain: FNFs		**Item in functional and dysfunctional form**
		The comparison with the most efficient app users in your own network does not take place.
F9	Ranking	Your energy consumption is given in the form of a ranking of app users with whom you want to compare yourself.
		A ranking does not take place.

Table 2.4-7 The feedback nudge features (FNFs) derived from literature and assigned to dimensions (A-F) and including the items of the Kano questionnaire

2.4.8.4 Material D

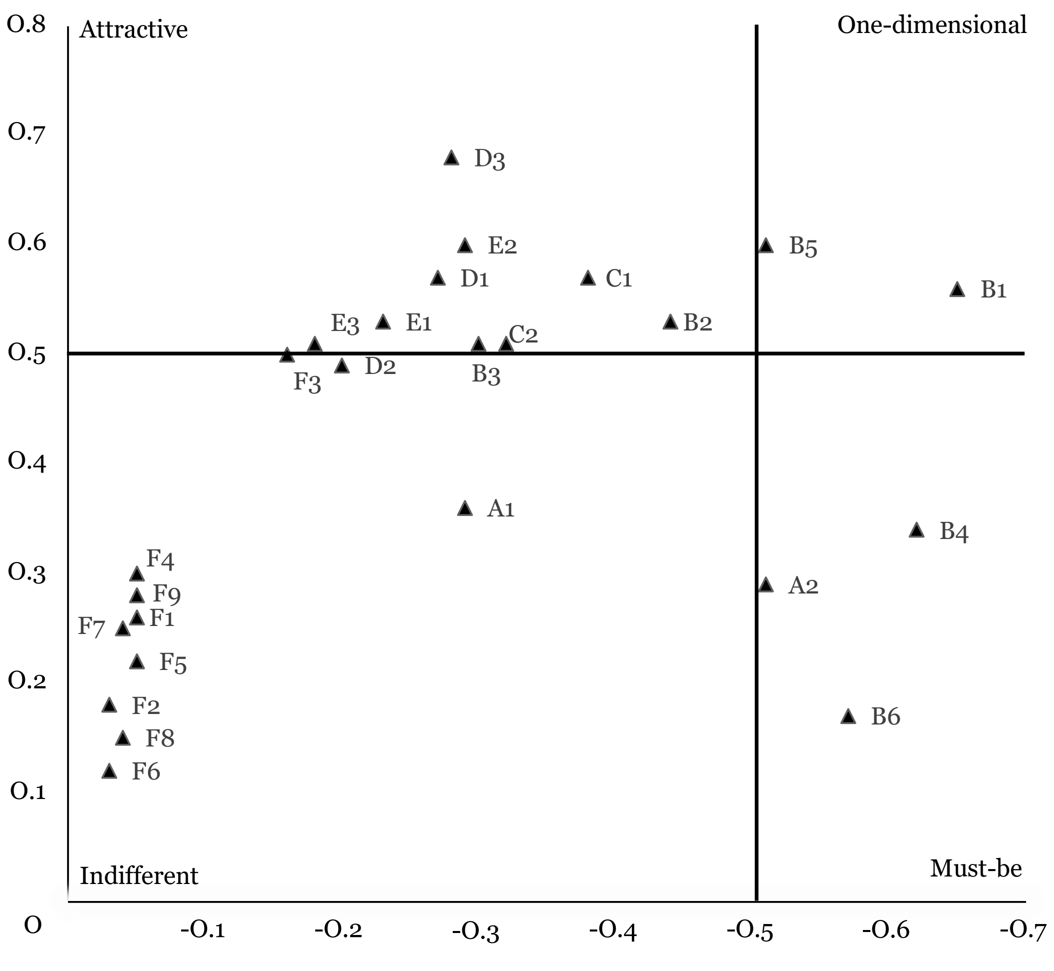

Figure 2.4-3 Feature nudge feature's (FNF's) categorization in a satisfaction-dissatisfaction diagram

2.4.8.5 References of the Supplemental Material

Andor, M. A., Gerster, A., Peters, J., & Schmidt, C. M. (2020). Social Norms and Energy Conservation Beyond the US. *Journal of Environmental Economics and Management*, *103*, 1–16. https://doi.org/10.1016/j.jeem.2020.102351

Asmare, F., Jaraitė, J., & Kažukauskas, A. (2021). The effect of descriptive information provision on electricity consumption: Experimental evidence from Lithuania. *Energy Economics*, *104*, 1–11. https://doi.org/10.1016/j.eneco.2021.105687

Aydin, E., Brounen, D., & Kok, N. (2018). Information provision and energy consumption: Evidence from a field experiment. *Energy Economics*, *71*, 403–410. https://doi.org/10.1016/j.eneco.2018.03.008

Bergquist, M., & Nilsson, A. (2018). Using social norms in smart meters: the norm distance effect. *Energy Efficiency*, *11*(8), 2101–2109. https://doi.org/10.1007/s12053-018-9709-6

Bonan, J., Cattaneo, C., d'Adda, G., & Tavoni, M. (2020). The interaction of descriptive and injunctive social norms in promoting energy conservation. *Nature Energy*, *5*(11), 900–909. https://doi.org/10.1038/s41560-020-00719-z

Bonan, J., Cattaneo, C., d'Adda, G., & Tavoni, M. (2021). Can social information programs be more effective? The role of environmental identity for energy conservation. *Journal of Environmental Economics and Management*, *108*, 1–28. https://doi.org/10.1016/j.jeem.2021.102467

Brandon, A., List, J. A., Metcalfe, R. D., Price, M. K., & Rundhammer, F. (2019). Testing for crowd out in social nudges: Evidence from a natural field experiment in the market for electricity, *116*(12), 5293–5298. https://doi.org/10.1073/pnas.1802874115

Brandsma, J. S., & Blasch, J. E. (2019). One for all? – The impact of different types of energy feedback and goal setting on individuals' motivation to conserve electricity. *Energy Policy*, *135*, 110992. https://doi.org/10.1016/j.enpol.2019.110992

Brülisauer, M., Goette, L., Jiang, Z., Schmitz, J., & Schubert, R. (2020). Appliance-specific feedback and social comparisons: Evidence from a field experiment on energy conservation. *Energy Policy*, *145*, 1–9. https://doi.org/10.1016/j.enpol.2020.111742

Buckley, P. (2020). Prices, information and nudges for residential electricity conservation: A meta-analysis. *Ecological Economics*, *172*, 1–14. https://doi.org/10.1016/j.ecolecon.2020.106635

Caballero, N., & Della Valle, N. (2021). Tackling energy poverty through behavioral change: A pilot study on social comparison interventions in social housing districts.

Frontiers in Sustainable Cities, *2*, Article 601095, 1–20. https://doi.org/10.3389/frsc.2020.601095

Callery, P. J., Goodwin, C. C., & Moncayo, D. (2021). Norm proximity and optimal social comparisons for energy conservation behavior. *Journal of Environmental Management*, *296*, 1–8. https://doi.org/10.1016/j.jenvman.2021.113332

Casado-Mansilla, D., Tsolakis, A. C., Borges, C. E., Kamara-Esteban, O., Krinidis, S., Avila, J. M., Tzovaras, D., & López-de-Ipiña, D. (2020). Socio-economic effect on ICT-based persuasive interventions towards energy efficiency in tertiary buildings. *Energies*, *13*(7), 1–26. https://doi.org/10.3390/en13071700

Charlier, C., Guerassimoff, G., Kirakozian, A., & Selosse, S. (2021). Under pressure! Nudging electricity consumption within firms. Feedback from a field experiment. *The Energy Journal*, *42*(1), 129–155. https://doi.org/10.5547/01956574.42.1.ccha

Chatzigeorgiou, I. M., & Andreou, G. T. (2021). A systematic review on feedback research for residential energy behavior change through mobile and web interfaces. *Renewable and Sustainable Energy Reviews*, *135*, 1–16. https://doi.org/10.1016/j.rser.2020.110187

Chen, H., & Qin, B. (2021). Does the nudge effect persist? Evidence from a field experiment using social comparison message in China. *Bulletin of Economic Research*, 1–38.

Chiu, M.-C., Kuo, T.-C., & Liao, H.-T. (2020). Design for sustainable behavior strategies: Impact of persuasive technology on energy usage. *Journal of Cleaner Production*, *248*, 1–12. https://doi.org/10.1016/j.jclepro.2019.119214

Crago, C. L., Spraggon, J. M., & Hunter, E. (2020). Motivating non-ratepaying households with feedback and social nudges: A cautionary tale. *Energy Policy*, 1–10.

Di Cosmo, V., & O'Hora, D. (2017). Nudging electricity consumption using TOU pricing and feedback: evidence from Irish households. *Journal of Economic Psychology*, *61*, 1–14. https://doi.org/10.1016/j.joep.2017.03.005

Fang, X., Goette, L., Rockenbach, B., Sutter, M., Tiefenbeck, V., Schoeb, S., & Staake, T. (2020). Complementarities in behavioral interventions: Evidence from a field experiment on energy conservation. *Discussion Paper Series University of Bonn and University of Mannheim – CRC TR 224*, 1–63.

Fanghella, V., Ploner, M., & Tavoni, M. (2021). Energy saving in a simulated environment: An online experiment of the interplay between nudges and financial incentives. *Journal of Behavioral and Experimental Economics*, *93*, 1–10. https://doi.org/10.1016/j.socec.2021.101709

Fels, K., & Andor, M. A. (2018). Behavioral economics and energy conservation - a systematic review of nonprice interventions and their causal effects. *Ecological Economics*(148), 178–210. https://doi.org/10.5194/gmd-2016-10-SC1

Fleury, S., Jamet, É., Michinov, E., Michinov, N., & Erhel, S. (2018). A priori acceptability of various types of digital display feedback on electricity consumption. *Le Travail Humain*, *81*(3), 247–267. https://doi.org/10.3917/th.813.0247

Geelen, D., Mugge, R., Silvester, S., & Bulters, A. (2019). The use of apps to promote energy saving: a study of smart meter–related feedback in the Netherlands. *Energy Efficiency*, *12*(6), 1635–1660. https://doi.org/10.1007/s12053-019-09777-z

He, T., Jazizadeh, F., & Arpan, L. (2021). AI-powered virtual assistants nudging occupants for energy saving: proactive smart speakers for HVAC control. *Building Research & Information*, 1–16. https://doi.org/10.1080/09613218.2021.2012119

Henry, M. L., Ferraro, P. J., & Kontoleon, A. (2019). The behavioural effect of electronic home energy reports: Evidence from a randomised field trial in the United States. *Energy Policy*, *132*, 1–18. https://doi.org/10.1016/j.enpol.2019.06.039

Jorgensen, B. S., Fumei, S., & Byrne, G. (2021). Reducing peak energy demand among residents who are not billed for their electricity consumption: Experimental evaluation of behaviour change interventions in a university setting. *International Journal of Environmental Research and Public Health*, *18*(16), 1–16. https://doi.org/10.3390/ijerph18168406

Jung, M., Cho, D., & Shin, E. (2021). Repairing a cracked mirror: The heterogeneous effect of personalized digital nudges driven by misperception. *Production and Operations Management*, *30*(8), 2586–2607. https://doi.org/10.1111/poms.13396

Kano, N. (1984). Attractive quality and must-be quality. *Hinshitsu (Quality, the Journal of Japanese Society for Quality Control)*, *14*, 39–48.

Khanna, T. M., Baiocchi, G., Callaghan, M., Creutzig, F., Guias, H., Haddaway, N. R., Hirth, L., Javaid, A., Koch, N., Laukemper, S., Löschel, A., Del Zamora Dominguez, M. M., & Minx, J. C. (2021). A multi-country meta-analysis on the role of behavioural change in reducing energy consumption and CO2 emissions in residential buildings. *Nature Energy*, *6*(9), 925–932. https://doi.org/10.1038/s41560-021-00866-x

Kim, H. B., Iwamatsu, T., Nishio, K., Komatsu, H., Mukai, T., Odate, Y., & Sasaki, M. (2020). Field experiment of smartphone-based energy efficiency services for households: Impact of advice through push notifications. *Energy and Buildings, 223*, 1–12. https://doi.org/10.1016/j.enbuild.2020.110151

Kim, J. H., & Kaemingk, M. (2021). Persisting effects of social norm feedback letters in reducing household electricity usage in Post-Soviet Eastern Europe: A randomized controlled trial. *Journal of Economic Behavior & Organization*, *191*, 153–161. https://doi.org/10.1016/j.jebo.2021.08.032

Lee, E., Kang, M., Song, J., & Kang, M. (2020). From intention to action: Habits, feedback and optimizing energy consumption in South Korea. *Energy Research & Social Science, 64*, 101430. https://doi.org/10.1016/j.erss.2020.101430

Li, Z., & Cao, X. (2021). Analysis of information feedback on residential energy conservation and the Implications: The case of china. *Frontiers in Environmental Science, 9*, Article 626890, 1–13. https://doi.org/10.3389/fenvs.2021.626890

Li, Z., Loveday, D., & Demian, P. (2021). Nudging and usage of thermal comfort-related systems. *Energy and Buildings*, *252*, 111480. https://doi.org/10.1016/j.enbuild.2021.111480

Marangoni, G., & Tavoni, M. (2021). Real-time feedback on electricity consumption: evidence from a field experiment in Italy. *Energy Efficiency*, *14*(1), 1–17. https://doi.org/10.1007/s12053-020-09922-z

Matzler, K., Hinterhuber, H. H., Bailom, F., & Sauerwein, E. (1996). How to delight your customers. *Journal of Product & Brand Management*, *5*(2), 6–18.

Meub, L., Runst, P., & Leyen, K. von der (2019). Can APPealing and more informative bills ‘nudge’ individuals into conserving electricity? *Cege Discussion Papers*(372), 1–15. https://doi.org/10.2139/ssrn.3414328

Mi, L., Ding, C., Yang, J., Yu, X., Cong, J., Zhu, H., & Liu, Q. (2019). Using goal and contrast feedback to motivate Chinese urban families to save electricity actively — A randomized controlled field trial. *Journal of Cleaner Production*, *226*, 443–453. https://doi.org/10.1016/j.jclepro.2019.04.068

Mi, L., Gan, X., Sun, Y., Lv, T., Qiao, L., & Xu, T. (2021). Effects of monetary and non-monetary interventions on energy conservation: A meta-analysis of experimental studies. *Renewable and Sustainable Energy Reviews*, *149*, 1–11. https://doi.org/10.1016/j.rser.2021.111342

Mi, L., Qiao, L., Du, S., Xu, T., Gan, X., Wang, W., & Yu, X. (2020). Evaluating the effect of eight customized information strategies on urban households' electricity saving: A field experiment in China. *Sustainable Cities and Society*, *62*, 1–31. https://doi.org/10.1016/j.scs.2020.102344

Mukai, T., Nishio, K., Komatsu, H., & Sasaki, M. (2022). What effect does feedback have on energy conservation? Comparing previous household usage, neighbourhood usage, and social norms in Japan. *Energy Research & Social Science*, *86*, 1–10. https://doi.org/10.1016/j.erss.2021.102430

Myers, E., & Souza, M. (2018). Social norms and personalized messaging to promote energy conservation: evidence from a university residence hall. *2018 Agricultural & Applied Economics Association Annual Meeting*, 1–23.

Myers, E., & Souza, M. (2020). Social comparison nudges without monetary incentives: Evidence from home energy reports. *Journal of Environmental Economics and Management*, *101*, 1–62. https://doi.org/10.1016/j.jeem.2020.102315

Nemati, M., & Penn, J. (2020). The impact of information-based interventions on conservation behavior: A meta-analysis. *Resource and Energy Economics*, *62*, 1–19. https://doi.org/10.1016/j.reseneeco.2020.101201

Ornaghi, C., Costanza, E., Kittley-Davies, J., Bourikas, L., Aragon, V., & James, P. A. (2018). The effect of behavioural interventions on energy conservation in naturally ventilated offices. *Energy Economics*, *74*, 582–591. https://doi.org/10.1016/j.eneco.2018.07.008

Ruokamo, E., Meriläinen, T., Karhinen, S., Räihä, J., Suur-Uski, P., Timonen, L., & Svento, R. (2022). The effect of information nudges on energy saving: Observations from a randomized field experiment in Finland. *Energy Policy*, *161*, 1–15. https://doi.org/10.1016/j.enpol.2021.112731

Sonnenberg, C., & vom Brocke, J. (2012). Evaluations in the science of the artificial–reconsidering the build-evaluate pattern in design science research. In *International Conference on Design Science Research in Information Systems* (pp. 381–397). Springer.

Sudarshan, A. (2017). Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives. *Journal of Economic Behavior & Organization*, *134*, 320–335. https://doi.org/10.1016/j.jebo.2016.12.015

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E., Lalive, R., & Staake, T. (2018). Overcoming salience bias: How real-time feedback fosters resource conservation. *Management Science*, *64*(3), 1458–1476. https://doi.org/10.1287/mnsc.2016.2646

Tiefenbeck, V., Wörner, A., Schöb, S., Fleisch, E., & Staake, T. (2019). Real-time feedback promotes energy conservation in the absence of volunteer selection bias and monetary incentives. *Nature Energy*, *4*(1), 35–41. https://doi.org/10.1038/s41560-018-0282-1

Wong-Parodi, G., Krishnamurti, T., Gluck, J., & Agarwal, Y. (2019). Encouraging energy conservation at work: A field study testing social norm feedback and awareness of monitoring. *Energy Policy*, *130*, 197–205. https://doi.org/10.1016/j.enpol.2019.03.028

Zangheri, P., Serrenho, T., & Bertoldi, P. (2019). Energy savings from feedback systems: A meta-studies' review. *Energies*, *12*(3788), 1–18. https://doi.org/10.3390/en12193788

Zhou, Y. (2020). Social comparison and energy conservation: Mechanism, heterogeneity and timing. *Heterogeneity and Timing (August 2020)*, 1–52. https://doi.org/10.2139/ssrn.3700441

3 Maintaining Mental Health when Interacting with Digital Technologies

3.1 How to Prevent Technostress at the Digital Workplace: A Delphi Study

Abstract: Technostress is a rising issue in the changing world of digital work. Technostress can cause severe adverse outcomes for individuals and organizations. Thus, organizations face moral and legal responsibility and economic pressure to prevent employees' excessive technostress. As technostress develops over time, it is crucial to prevent it throughout the process of its emergence instead of only reacting after adverse outcomes occur. Contextualizing the Theory of Preventive Stress management to technostress, we synthesize and advance existing knowledge on inhibiting technostress. We develop a set of 24 technostress prevention measures based on qualitative and quantitative contributions from a Delphi study. Based on expert feedback, we characterize each measure and assess its relevance in addressing specific technostressors. Our paper contributes to research by transferring the Theory of Preventive Stress Management into the context of technostress, hence offering an alternative view to technostress inhibitors by adding a time perspective through the implementation of primary, secondary, and tertiary prevention measures. For practice, we offer a comprehensive and applicable overview of measures organizations can implement to prevent technostress.

Keywords: Technostress, technostress prevention, technostress inhibitors, technostress creators, Delphi study

Authors: Michelle Berger[4], Ricarda Schäfer, Marco Schmidt, Christian Regal, Henner Gimpel

Status: This article is a working paper.

[4] Please note that in this research article, I was the lead author.

3.1.1 Introduction

Information and communication technologies (ICTs) have become ubiquitous in our private and business lives. The COVID-19 pandemic accelerated this trend as many workplaces were transferred to telework offices, and ICTs, such as videoconferencing tools, substitute personal contact. Although digitalization and ICTs generally facilitate work activities and enable new ways of work (Becker et al., 2020), the increased use of ICTs may also create technostress, contributing to individuals' overall experience of stress. Thereby, technostress describes any stress from using ICTs (Ragu-Nathan et al., 2008). It has become a severe issue with societal, economic, and personal consequences such as impaired individuals' health or decreased work productivity (Ragu-Nathan et al., 2008; Srivastava et al., 2015). While technostress can also have positive effects – techno-eustress (Benlian 2020; Califf et al., 2020; Tarafdar et al., 2019) – we focus on the negative side, techno-distress, which is prevailing in literature (e.g., Pirkkalainen et al., 2019; Weinert et al., 2020).

Technostress is mostly described as a process, starting with technology environmental conditions that refer to attributes of specific ICT (e.g., push notifications) and represent a demand to the individual. The individual next appraises if the demand demonstrates a threat or a challenge, indicating a *technostressor* (Ayyagari et al., 2011; Ragu-Nathan et al., 2008; Tarafdar et al.,, 2019). This then leads to a *technostress response* (i.e., physiological, psychological, and coping responses) (Califf et al., 2020; Tarafdar et al., 2019; Riedl et al., 2012; Lazarus & Folkman 1984). In the long term, the experienced technostress response can lead to serious *adverse outcomes* including severe health impairments, such as burnout, depression, or exhaustion (Maier et al., 2015). Stressful ICT-related events do not necessarily have to lead to an adverse course of the technostress process. There exists a variety of actions that can mitigate the adverse effects throughout the stress process. It is, therefore, crucial to not only react after adverse health outcomes already arose.

While several approaches to prevent technostress exist under the label *technostress inhibitors*, their theorization and integration in the technostress process are highly scattered (Jena, 2015; Ragu-Nathan et al., 2008; Tarafdar et al., 2011; Tarafdar et al., 2015). Examples of technostress inhibitors include providing organizational support or ICT training courses (Ragu-Nathan et al., 2008). So far, it remains unclear at which stage of the technostress process the existing measures influence the process, how measures differ, or how they can be grouped for more structured assessments. However, more specific knowledge of the role and characteristics of prevention measures in the technostress process is important for both research and practice.

This knowledge is important for research for setting up more targeted empirical studies on the implementation, use, and efficacy of such measures. Further, the knowledge is important for researchers designing technostress prevention measures. Practitioners require more fine-grained knowledge of prevention measures to set up an appropriate preventive technostress management system in their organization.

In this realm, the *Theory of Preventive Stress Management* can help to understand how throughout the technostress process, the experience of stress can be reduced (Hargrove et al., 2011; James C. Quick et al., 1997; James C. Quick & Quick, 1979). The theory includes a time perspective on different time windows for preventing stress. The theory recommends intervening throughout the process and divides possible measures into three categories: primary, secondary, and tertiary preventive measures (James C. Quick et al., 1997; James C. Quick & Quick, 1979). Transferring the Theory of Preventive Stress Management into the technostress world, preventive technostress management includes *primary prevention* targeting the technostressors, thus focusing on the cause of stress (Hargrove et al., 2011), *secondary prevention* targeting the technostress response, thus including actions designed to improve the individual's response (e.g., improving coping skills). Lastly, *tertiary prevention* aims to treat the symptoms of distress and targets the very end of the process. By contextualizing the Theory of Preventive Stress Management to the narrower context of technostress following the guidelines of Hong et al. (2014), we transfer previously generated insights in prevention theory to the technostress domain. We argue that the technostress domain can profit from this novel, complementary viewpoint.

Prior research in the context of preventive stress management emphasizes the role of organizations in preventing individuals' stress and promoting employees' and organizations' well-being (Hargrove et al., 2011). Since many technostressors stem from ICT use at work, organizations face the moral and legal responsibility to improve employee health by preventing excessive work-related technostress. Some countries, such as Germany, have even imposed legal requirements for organizations to assess and reduce employees' negative psychological responses (e.g., caused by technostress) at work.[5] Not only does the prevention of technostress reduce negative consequences for employees' health, but it saves organizations the costs of substituting employees on sick leave, among others. An analysis and comprehensive knowledge base

[5] German Occupational Safety and Health Act of 7th August 1996 (Federal Law Gazette p. 1246), as amended by Article 1 of the Act of 22 December 2020 (Federal Law Gazette p. 3334)

of technostress prevention measures an organization can introduce are needed to enable organizations to reduce technostress among the employees proactively. So far, prior research has analyzed the influence of single measures (Day et al., 2012; Valta et al., 2021) or technology characteristics (Ayyagari et al., 2011; Becker et al., 2020) on selected technostressors. Given the severity of technostress' adverse outcomes, however, research needs to provide organizations with guidance on what measures they can implement to prevent technostress for their employees (Brivio et al., 2018). Hence, our research aim is to identify technostress prevention measures and characterize them in terms of (1) their basic approach to preventive technostress management, (2) their applicability, and (3) their relevance in targeting technostressors.

To achieve this aim, we synthesize and advance a knowledge base of technostress prevention measures by using the existing Theory of Preventive Stress Management as a theoretical basis that we apply to technostress. We assess characteristics for the applicability of the technostress prevention measures in practice. To do so, we conduct a structured literature review on organizational measures that inhibit technostress and reframe them into actionable technostress prevention measures that can be applied in organizational settings throughout the stages of the technostress process. We enrich the resulting list by conducting multiple focus group workshops followed by a Delphi study with industry experts, yielding 24 validated prevention measures. Based on the experts' assessments, we produce a description for each prevention measure, a classification of several characteristics, and, in the case of primary prevention measures, an indication of the technostressors they are expected to target.

Our study advances both technostress theory and practice. We contribute to technostress literature by transferring the general Theory of Preventive Stress Management into the more specific context of technostress. We provide insights on the different measures currently present, and we enrich their understanding through the characterization of their basic approach to technostress prevention (primary vs. secondary technostress prevention) and their applicability. Therein, we offer a basis for understanding the different roles of prevention. The characterization in terms of the measure's applicability highlights the need to carefully select measures that fit the specific organizational context. Our study also sheds light on the dynamics underlying technostress prevention and links specific primary measures to specific technostressors, revealing that single prevention measures are no one-fits-all solutions. Overall, by uniting different perspectives on technostress prevention, we contribute towards substantial benefits for organizations, individuals, and societies by potentially reducing healthcare costs and preventing adverse personal and organizational outcomes (Maier et al., 2015; Ragu-Nathan et al., 2008; Srivastava et al., 2015).

3.1.2 Theoretical Background on Techno-Distress as a Specific Form of Human Stress

In their daily life, people use a large variety of ICTs, including devices such as smartphones or laptops and applications that facilitate business processes by providing tools for inter- and intra-organizational communication and collaboration (Dittes & Smolnik 2019; Zuppo 2012). ICTs shape modern work life and contribute to many positive facets of work, such as the potential to work from home or seamless collaboration across countries. For example, during the COVID-19 pandemic, ICTs allow many companies to uphold their operation despite stay-at-home and social distancing orders (Ketter et al., 2020). However, the intensive use of ICTs also risks employees' health and performance. One of these risks is technostress. Technostress is a specific form of human stress that is triggered by the use of IS (Tarafdar et al., 2019). Human stress has been extensively studied and is often explained through Lazarus & Folkman's (1984) Transactional Theory of Stress (Ayyagari et al., 2011; Ragu-Nathan et al., 2008; Tarafdar et al., 2019). The theory conceptualizes stress as a process that includes the existence of internal and external demands (e.g., time pressure, social conflicts), which the individual assesses in two appraisal steps. First, the individual subconsciously evaluates if the demand falls into the category of positive, irrelevant, or stressful. If categorized as stressful, the demand may threaten the individual, indicating a stressor. Next, the individual subconsciously examines if the available resources are sufficient to cope with the stressor (Lazarus & Folkman 1984). The process is therefore followed by an interdependent cycle of physiological and psychological responses (e.g., negative emotional states) and coping (i.e., behavior in response to stressors) that run in parallel, repeatedly, and cannot be separated in time (Califf et al., 2020; Lazarus & Folkman 1984; Tarafdar et al., 2019). This process, in turn, may lead to adverse outcomes such as decreased health or lower productivity.

Transferring the Transactional Theory of Stress into the digital world, Tarafdar et al. (2019) describe technostress as the "stress process activated due to the use of IS" (p. 8). Like stress in general, technostress can be positive (Techno-Eustress) or negative (Techno-Distress) (Tarafdar et al., 2019). In the following, we focus on the negative side of the technostress process and specifically the prevention of that negative side of technostress. The technostress process is sketched in Figure 3.1-1 based on Califf et al. (2020), Tarafdar et al. (2019) and Riedl et al. (2012): An individual's *technology environmental condition* includes potential sources of a technology-related stressful situation. The individual exposed to a demand from the environment appraises if the demand is harmful. If the demand is appraised as harmful it is a *technostressor*. Technostressors are "conditions or factors that can create stress because of ICT use" (Tarafdar et al., 2015, p. 106) and "are appraised by the individual as damaging" (Tarafdar et al., 2019, p. 9). When confronted with a technostressor, this leads to a multifaceted *technostress response*. The technostress response includes short-term physiological (e.g., the release of cortisol, adrenaline, and noradrenaline) and psychological (e.g., negative affect) responses that lead to coping responses (e.g., avoiding or stopping IS use).[6] Coping response describes "actions or emotions to overcome or deal with the threat or hindrance the individual perceives from the" technostressor (Tarafdar et al., 2019, p. 20). Examples include seeking social or technical support (Pirkkalainen et al., 2019; M. Schmidt et al., 2021; Weinert et al., 2020). Coping is undoubtedly crucial to mitigate technostress but is performed entirely by the affected individual only after the technostressor has emerged. In parallel, the individuals experience a psychological or physiological response like negative emotions (e.g., anxiety, hostility) or an increase in cortisol, or a fast heart beating (Califf et al., 2020; Riedl et al., 2012). The sequence of the psychological or physiological response and the coping response cannot be clearly separated in time and can run in parallel and repetitively. Therefore, we summarize this interdependent cycle as a technostress response, consisting of psychological, physiological, and coping responses. We define *technostress response* as an interdependent, repeatedly, and potentially parallel process of negative psychological and/or physiological states caused by the technostressor (i.e., psychological and physiological response) and the application of actions or emotions to deal with the threat of the technostressor (i.e., coping response) (based on Califf et al. (2020), Tarafdar et al. (2019), Riedl et al. (2012), and Lazarus & Folkman (1984)). In the long-term, the technostress response can lead to adverse *technostress outcomes*, especially when the technostress response is intense and long-lasting or frequently repeated. These include adverse outcomes for the individual, such as sleeping problems or emotional exhaustion – as well as adverse organizational outcomes like decreasing productivity, lower levels of job

[6] Riedl et al. (2012) focus on physiological responses, Califf et al. (2020) on psychological responses, Tarafdar et al. (2019) on coping responses. In Figure 3.1-1, we follow Lazarus & Folkman (1984) in summarizing these types of responses as a general (techno)stress response, since these different responses are interdependent and not clearly separable in time.

satisfaction, and less organizational commitment (e.g., H. Gimpel et al., 2018; Maier et al., 2015; Riedl et al., 2012; Srivastava et al., 2015).

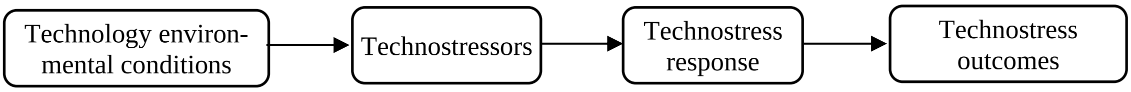

Figure 3.1-1 Technostress process (adapted from Figure 2 in Tarafdar et al. (2019), Figure 2 in Califf et al. (2020), and Figure 1 in Riedl et al. (2012))

Several technostressors have been discussed in the literature. Tarafdar et al. (2007) and Ragu-Nathan et al. (2008) were the first to develop and empirically validate scales for five technostressors: *overload*, *invasion*, *complexity*, *insecurity*, and *uncertainty*.[7] In subsequent research, these technostressors have been applied in many studies in different contexts and are well-established today (e.g., Becker et al., 2020; Fuglseth & Sørebø, 2014; Maier et al., 2019; Pirkkalainen et al., 2019). In another seminal technostress paper, Ayyagari et al. (2011) identify *unreliability*, *role ambiguity*, and *invasion of privacy* as additional technostressors. Further, Galluch et al. (2015) and Tams et al. (2018) propose ICT-enabled *interruptions* as another technostressor in work environments. While various other technostressors have been suggested in the literature (e.g., Fischer et al., 2021; Maier et al., 2012; Maier et al., 2015; Riedl et al., 2012), we did not consider them in our study because they are either specific to a particular technology, can be subsumed under another technostressor, or were published after the start of the Delphi study. The nine mentioned technostressors included in this research are presented in Table 3.1-1.

Techno-stressor	**Description**
Complexity	"Situations where the complexity associated with ICTs makes users feel inadequate as far as their skills are concerned and forces them to spend time and effort in learning and understanding various aspects of ICTs" (Tarafdar et al., 2007, p. 315).
Insecurity	"Situations where users feel threatened about losing their jobs as a result of new ICT replacing them, or to people who have a better understanding of the ICT" (Tarafdar et al., 2007, p. 315).
Interruptions	Situations in which ICTs or ICT-based sources cause the user to shift their attention away from the task they are working on at that moment (Galluch et al., 2015).
Invasion	"The invasive effect of ICTs in terms of creating situations where users can potentially be reached anytime, employees feel the need to be constantly 'connected,' and there is a blurring between work-related and personal contexts" (Tarafdar et al., 2007, p. 315).
Invasion of Privacy	Situations in which users "are becoming increasingly concerned that their privacy could be invaded by computer technologies. The problem is acerbated due to the present work pressures, which create an unspoken value that appreciates individuals who are constantly available" (Ayyagari et al., 2011, p. 841).
Overload	"Situations where ICTs force users to work faster and longer" (Tarafdar et al., 2007, p. 315).

[7] The original naming used the prefix "techno-" for each of these technostressors. We omit this prefix for brevity. Tarafdar et al. (2007), Ragu-Nathan et al. (2008) and others use the term 'technostress creator' rather than 'technostressor.' We treat these terms as synonyms and follow Tarafdar et al. (2019) in using technostressor.

Techno-stressor	Description
Role Ambiguity	Situations in which "there is uncertainty as to whether an individual should expend his or her resources to perform the task requirements at work or to acquire new skills. These competing demands between the job and learning new skills constrain individual abilities" (Ayyagari et al., 2011, p. 842).
Uncertainty	"Contexts where continuing changes and upgrades in an ICT unsettle users and create uncertainty for them, in that they have to constantly learn and educate themselves about the new ICTs." (Tarafdar et al., 2007, p. 315)
Unreliabil-ity	"System malfunctions and other IT-hassles" (T. Fischer & Riedl, 2015, p. 1462) caused by ICTs that are perceived to increase workload due to the necessity to repeat tasks (Ayyagari et al., 2011).

Table 3.1-1 Considered technostressors

3.1.3 Applying the Theory of Preventive Stress Management to Techno-Distress

The Theory of Preventive Stress Management originally developed by Quick & Quick (1979), has roots in preventive medicine and public health. Nowadays, it is well established (Quick 1997; Hargrove et al., 2011). The theory tells us that there exists a variety of specific actions that can reduce stress throughout the stress process (Quick & Quick 1979). To contextualize the Theory of Preventive Stress Management into the specific context of technostress, we follow the guidelines by Hong et al. (2014). Quick & Quick (1984b) defined preventive stress management as "an organizational philosophy and set of principles that employ specific methods for promoting individual and organizational health while preventing individual and organizational distress" (p. 13). It is important to note that the Theory of Preventive Stress Management takes a broader view of Stress than the technostress theory. As the definition of preventive stress management shows, stress is seen as a phenomenon at the individual and organizational levels. The Theory of Preventive Stress Management considers stress itself as an overarching rubric for how individuals and organizations react and adjust to their environments and becomes specific for the concepts of stressor, stress response, and distress. Quick et al. (1997, p. 6) distinguish between individual distress and organization distress with the latter being "the degree of deviation an organization experiences from a healthy, productive level of functioning." Stress is not bad per-se – it can have positive and constructive outcomes that support performance. However, "excessive, prolonged, intense, or mismanaged stress at the workplace" result in physiological, psychological, and behavioral deviations from an individual's healthy functioning (Quick et al. 1997, p. 18). The aggregate of this individual-level distress becomes organizational distress. This conceptualization of stress and specifically stress outcomes also on the organizational level is uncommon for technostress research. However, it is compatible with technostress research suggesting that the organizational environment including the technological environment is an important determinant of technostress (e.g., Tarafdar et al., 2019) and it is in line with research on technostress inhibitors as organizational mechanisms to reduce technostress (e.g., Ragu-Nathan et al., 2008).

The Theory of Preventive Stress Management builds on five guiding principles which are also applicable to technostress management (James C. Quick et al., 1997). The five principles of (techno)stress management are:

1. Individual and organizational health are interdependent. Organizations cannot achieve organizational goals like high levels of productivity or flexibility without healthy individuals. This principle contributes to the need for organizations to develop preventive technostress management as part of their overall management of employee health and safety.
2. Leaders have responsibility for individual and organizational health. This leadership challenge and responsibility includes diagnosing technostress issues in the organization and selecting and implementing related technostress prevention measures. Leadership has responsibility for technostress management; however, also all employees have a responsibility for their health and their co-workers' health.
3. Individual and organizational distress is not inevitable. The Theory of Preventive Stress Management suggests that preventive managerial actions may mitigate distress. For this, they must anticipate and influence stressors and stress processes. This paper's practical contribution relates to the second and third guiding principles in supporting leaders in selecting adequate technostress prevention measures.
4. Each individual and organization reacts uniquely to stress. This is well in line with technostress theories and suggests that preventive technostress management needs to be tailored to specific organizations and needs to allow flexibility for individuals.
5. Organizations are ever-changing, dynamic entities. This implies that preventive technostress management cannot be a one-time effort but needs to be constantly evaluated and developed to meet the interests of the organization and the employees.

Beyond these guiding principles, the Theory of Preventive Stress Management considers the stress process and a translated overlay which is composed of preventive interventions (Quick & Quick 1979, Quick et al., 1997, Hargrove et al., 2011). One of the fundamental premises of preventive medicine is that preventive measures can target each stage in the life history of a dis-ease to slow, stop, or revert the progression of the disease. Applied to stress, this means that preventive measures can address various points in the stress process. “Primary prevention is aimed at modifying the organizational stressors that may eventually lead to distress. Secondary prevention aims at changing individual stress responses to necessary demands. Tertiary prevention at-tempts to minimize the amount of individual and organizational distress that results when organizational stressors and resulting stress responses have not been adequately controlled” (Quick et al., 1997, p. 154). In the distinction between individual and organizational stress, primary and secondary prevention targets individual stress and tertiary prevention may target both individual and organizational stress.

Primary stress prevention is stressor-directed. It targets reducing, modifying, or managing the stressor's frequency, duration, and/or intensity. The Theory of Preventive Stress Management refers to organizational stressors as it focuses on work stress. These organizational stressors result from task, role, physical, and interpersonal demands. Specifically for technostress, the organizational stressors are activated due to the use of IS. These stressor-directed interventions are located at the onset of the process directly related to the stressors and represent the most efficient and effective means of prevention (James C. Quick & Quick, 1979). Hargrove et al. (2011) mention social support as an important primary prevention measure, for example, a woman being bullied by co-workers experiences less distress if her co-workers and her boss support her by being “on her side”. Another example is mentoring or buddy programs that especially support new employees (Hargrove et al., 2011).

As primary prevention might not be effective for all individuals and in every setting, *secondary stress prevention* aims at improving how individuals respond to the respective stressor (James C. Quick et al., 1997). Hence, secondary stress prevention is response-directed. Hargrove et al. (2011) name exercise and wellness programs to be the most common secondary stress prevention measure, that are useful in improving individuals’ stress response. These examples highlight an important difference between primary and secondary stress prevention measures: Primary stress prevention measures tend to be rather specific for a stressor. Secondary stress prevention measures tend to be more general as different stressors might result in the same stress response.

Tertiary stress prevention concerns the treatment, compensation, and rehabilitation of the sick suffering from enduring health outcomes (e.g., providing medical aid) (Hargrove et al., 2011; James C. Quick et al., 1997). These interventions are outcome-directed. As they intervene after the onset of adverse outcomes (e.g., burnout or depression regarding individual health outcomes), they are at the individual level mainly related to medical or psychiatric treatments.

Figure 3.1-2 positions the prevention measures along the technostress process. It is important to note that secondary and tertiary prevention are not alternatives but complements of primary stress prevention (J. D. Quick et al., 1998). In general, excessive, prolonged, and intense stress that will eventually lead to adverse outcomes at the individual level and, consequently, on the organizational level should be prevented as early as possible.

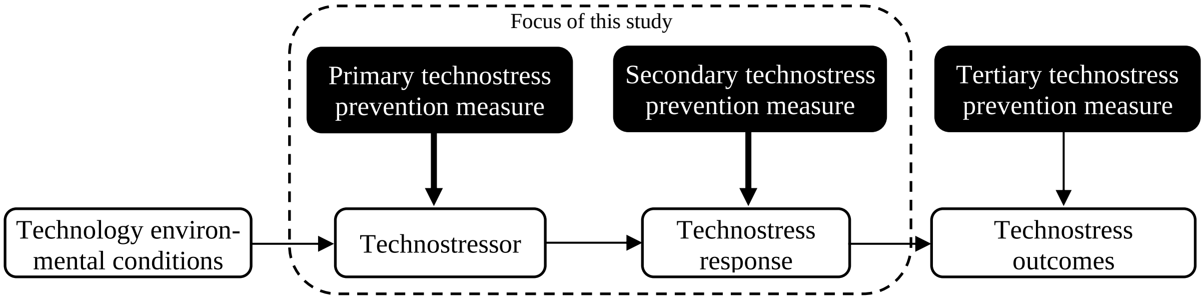

Figure 3.1-2 Preventive stress management model (adapted from Figure 1 in Hargrove et al. (2011) and Figure 8.1 in Quick et al. (1997))

In bringing the Theory of Preventive Stress Management to technostress, we acknowledge that the terms technostress inhibitors and technostress prevention measure are interchangeable. Here we face a trade-off: technostress inhibitor would provide a better linkage to extant technostress research while technostress prevention measure provides a stronger linkage to the Theory of Preventive Stress Management. Existing technostress studies using the term *technostress inhibitors* refer to “organizational mechanisms that have the potential to reduce the effects of technostress” (Ragu-Nathan et al., 2008, p. 422). As summarized by Sarabadani (2018), technostress inhibitors are theorized to either (1) act as antecedents to technostressors, hence reducing the technostressor itself (Jena, 2015; Tarafdar et al., 2011; Tarafdar et al., 2015), (2) moderate the relationship between technostressor and outcomes (Ragu-Nathan et al., 2008), or (3) decrease the adverse outcomes (e.g., job satisfaction, sales performance, organizational commitment) directly (Jena, 2015; Ragu-Nathan et al., 2008; Tarafdar et al., 2011). Comparing existing research in the field of technostress inhibitors to the previously presented insights on preventive stress management shows that the terms inhibitor and prevention refer to the same concept. The three mentioned mechanisms of inhibitors align well with the three stages of prevention (primary, secondary, and tertiary). The terminology of prevention has not been widely used in the context of technostress. Only Salo et al. (2017) used the foundation of LaMontagne et al. (2007), which is based on the Theory of Preventive Stress Management, to structure individuals' ways of reducing technostress without introducing the term technostress prevention. Salo et al. (2017) categorized five different individual measures into stressor reduction (e.g., modification of IT features), stressor toleration (e.g., modification of personal reactions to IT stressors), and recovery from strain (e.g., online/offline venting). Building on the work of LaMontagne et al. (2007), this classification is equivalent to the classification of primary, secondary, and tertiary stress prevention measures. However, while Salo et al. (2017) study individuals' coping with technostress, preventive stress management theory emphasizes the duty of organizations to promote individual and organizational health and to minimize individual and organizational distress to create an organization in which their employees can thrive and produce (Hargrove et al., 2011; James C. Quick et al., 1997). We proceed to use the term *technostress prevention measure* to build on existing knowledge of preventive stress management.

Building on James C. Quick et al.'s (1997, p. 49) definition of preventive stress management, we define *preventive technostress management* as an organizational philosophy and set of principles that employ specific measures to inhibit techno-distress in order to promote individual and organizational health. The set of five principles was described above. The measures are *technostress prevention measures*. We integrate both existing knowledge on technostress inhibitors and the differentiation between primary, secondary, and tertiary preventive measures in the conceptual model of preventive technostress management. The model is based on the technostress process of Tarafdar et al. (2019) and Califf et al. (2020) (Figure 3.1-1), synthesized with the Theory of Preventive Stress Management in organizations (Quick & Quick 1979, Quick et al., 1997, Hargrove et al., 2011) (Figure 3.1-2).

In analogy with general stress prevention (James C. Quick et al., 1997), we characterize the three technostress prevention stages as follows: *Primary technostress prevention* targets reducing the frequency, duration, and/or intensity of one or multiple technostressors. One example of primary technostress prevention is the development of team norms or reachability rules to avoid work-related communication when not appreciated.

Secondary technostress prevention aims at improving the individuals' technostress responses consisting of coping responses and psychological and physiological responses. An example of a secondary technostress prevention measure is providing an ICT helpdesk. At this point, the differentiation between secondary technostress prevention measures and technostress coping becomes apparent: technostress coping refers to the behavior an individual adopts when affected by a technostressor (e.g., calling the ICT helpdesk or seeking social support). Secondary technostress prevention measures are organizational-level measures that aim at improving the individual coping skills or resources and positively influence the psychological or physiological responses, for example, by offering platforms to exchange experiences on ICT use, training to improve individual coping skills, or the setup of an ICT helpdesk. Secondary technostress prevention measures do not concern the actual execution of the coping response but aim to optimize the possibility of coping.

Tertiary technostress prevention concerns the treatment, compensation, and rehabilitation of adverse individual or organizational technostress outcomes. We focus on primary and secondary but not tertiary technostress prevention because the latter is mainly relevant to medical or psychiatric treatment and least specific to technostress. Table 3.1-2 provides an overview of the key constructs of our conceptual model of work-related technostress prevention and their definitions.

Construct	**Definition**
Technostress[8]	Negative "stress process activated due to the use of IS" (Tarafdar et al., 2019, p. 8) including technology environment conditions, technostressors, technostress responses, and adverse outcomes for the individual and the organization.
Technology environmental conditions	Attributes or features of the information and communication technologies that surround individuals at work (Ayyagari et al., 2011; Becker et al., 2020).
Technostressors	"Conditions or factors that can create stress because of ICT use" (Tarafdar et al., 2015, p. 106).
Technostress response	An interdependent, repeatedly, and potentially parallel process of physiological and/or negative psychological states caused by the technostressor (i.e., physiological and psychological response) and the application of actions or emotions to deal with the threat of the technostressor (i.e., coping response) (based on Califf et al. (2020), Tarafdar et al. (2019), and Riedl et al. (2012)).
Technostress outcomes	Individual strains (i.e., physiological, psychological, and behavioral consequences) and adverse organizational outcomes caused by technostress (Ragu-Nathan et al., 2008).
Technostress inhibitors	"Organizational mechanisms that have the potential to reduce the effects of technostress" (Ragu-Nathan et al., 2008, p. 422).
Preventive technostress management	an organizational philosophy and set of principles that employs specific measures to inhibit techno-distress in order to promote individual and organizational health (adapted from Quick & Quick 1984b).
Primary technostress prevention	Taking measures for reducing, modifying, or managing technostressors' frequency, duration, and/or intensity (adapted from James C. Quick et al. (1997)).
Secondary technostress prevention	Taking measures for improving individuals' psychological, physiological, and coping responses to technostressors (adapted from James C. Quick et al. (1997)).
Tertiary technostress prevention	Taking measures for the treatment, compensation, and rehabilitation from adverse individual or organizational technostress outcomes (adapted from James C. Quick et al. (1997)).

Table 3.1-2 Summary of relevant constructs

[8] Note that this is definition of technostress follows the paper's focus on techno-distress.

3.1.4 Research Process for Identifying and Characterizing Primary and Secondary Technostress Prevention Measures

We conducted a Delphi study with 13 experts from research and practice (Figure 3.1-3 and Figure 3.1-4) to achieve our research aim of identifying and characterizing technostress prevention measures in terms of (1) their basic approach to technostress prevention, (2) their applicability, and, (3) in case of primary technostress prevention measures, their relevance in targeting technostressors.

To provide an appropriate starting point for the Delphi study based on theoretical and practical knowledge, we included a preliminary phase 0 to prepare a sound set of potential technostress prevention measures. Theoretical knowledge was drawn from a structured literature review (Webster and Watson 2002) on measures that may be qualified to prevent work-related technostress. To validate and expand the list of technostress prevention measures, we conducted two focus group workshops (Kitzinger 1995) with experts from research and practice before conducting phases 1-3 of the Delphi study. The central part of the Delphi study builds on these measure candidates to, again, validate, but especially to detail the technostress prevention measures. Since literature has not yet produced and documented extensive knowledge on the characteristics of technostress prevention measures, an exploratory qualitative research method is appropriate. Unlike other exploratory qualitative research methods, Delphi studies support explorative, consensus-seeking research such as problem identification, concept development, and prioritization and have become a popular research method in IS research (Okoli and Pawlowski 2004; Skinner et al., 2015). The iterative design of Delphi studies allows participants to learn from each other over a longer period of time, reflect on their opinions, and collectively develop results. The Delphi study addresses the research question by a) evaluating the list of technostress prevention measures concerning relevance, completeness, and understandability, b) characterizing the technostress prevention measures, and c) relating the primary technostress prevention measures to the nine considered technostressors presented in Section 3.1.2.

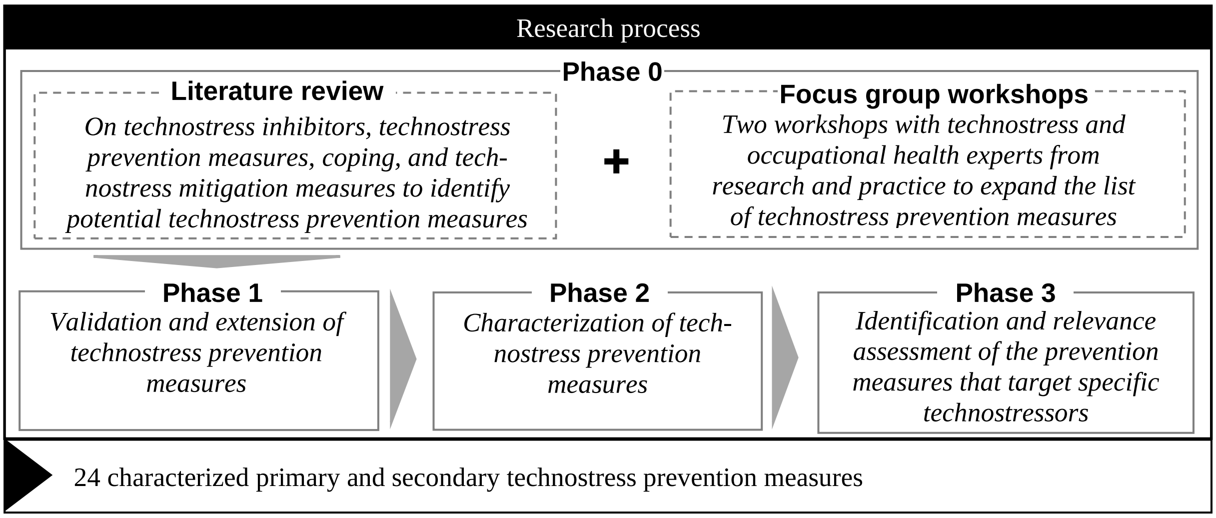

Figure 3.1-3 Research process

3.1.4.1 Phase 0: Structured Literature Review and Focus Group Workshops

To prepare the Delphi study, we conducted a structured literature review on technostress inhibitors, technostress prevention measures, technostress coping measures, and technostress mitigation measures to identify known measures for reducing and eliminating technostress, which can be interpreted and converted into technostress prevention measures (Webster and Watson 2002). In theory, coping is not part of primary and secondary prevention. We nevertheless included it as a search term because some scholars provide examples of coping measures that can be used as input to develop technostress prevention measures. One reason for the lack of clear concepts could be the novelty of technostress prevention within the research stream. As suggested by vom Brocke et al. (2015) and Webster and Watson (2002), the literature review comprised three phases: (1) literature search, (2) selection of relevant literature, and (3) analysis of the results.

We defined a search string, databases, and inclusion and exclusion criteria (vom Brocke et al., 2015). As the literature on technostress prevention is highly dispersed and often described under different terminology, we chose a broad search string that considers adjacent concepts and literature from various disciplines (information systems, organizational science, health, and psychology). Therefore, we searched for topics, abstracts, titles, and keywords that matched the search string ((“technostress” OR “techno stress” OR “digital stress”) AND (“prevent*” OR “reduc*” OR “mitigat*” OR “overcome” OR “cop*” OR “inhibit*”)) in the three databases Web of Science, PubMed, and AISeL as well as in the Journal of Business Economics. In total, we found 204 articles. After filtering for English, peer-reviewed, full research articles (n = 192), removing duplicates (n = 167), and adding previously known articles according to Larsen et al. (2019) our set consisted of 169 articles. Based on our selection criteria, we conducted a three-step selection process, including title, abstract, and full-text review (Levy and Ellis 2006; Okoli and Schabram 2010). The selection criteria included: (1) the article is within the domain of technostress, and (2) the article includes at least one recommendation for preventing technostress (at work/in organizations) following our definition of technostress prevention measures. After the title screening, 100 articles remained. The abstract screening excluded an additional 42 articles, resulting in 58 articles that went into detailed analysis. For details, please see Figure 3.1-5 in the appendix. Finally, the full-text screening resulted in a list of 38 relevant articles (Table 3.1-5 in the appendix).

Independently from the literature review, we conducted two focus group workshops with technostress and occupational health experts from research and practice (Table 3.1-6 in the appendix) to potentially expand the list of technostress prevention measures. The workshops aimed to identify recent or modern concepts for dealing with technostress that are being applied in practice but are not (yet) embedded in literature. Therefore, in the first focus group workshop, eight experts from practice and four from research developed a set of technostress prevention measures guided by a moderator and a minute taker (Conklin and Hayhoe 2010). The participants' areas of expertise include information systems, psychology, and occupational health and safety. The workshop's procedure was inspired by Then et al. (2015). The participants collected and discussed possible technostress prevention measures that organizations can take by making targeted changes to technologies, organizations, or individuals. A second moderated workshop with five experts (four from practice, one from research) expanded on the first workshop's results. The participants were introduced to the technostressors to develop adequate technostress prevention measures. To guarantee the privacy and foster an open atmosphere, we refrained from recording and transcribing the workshops. Instead, we created a photo protocol by taking photographs of the final whiteboards and collected the focus groups' notes as field notes (Miles and Huberman 1994) – a valid qualitative data source in workshops (Ørngreen and Levinsen 2017). Based on this information, the moderators of the two workshops summarized the results and prepared them for the participants. The participants then had the opportunity to add to or adjust the summaries until all participants were satisfied.

With the two workshops, we collected 94 technostress prevention measure candidates on different levels of detail. From the 38 relevant literature articles, we extracted 34 distinct recommendations for preventing technostress (Figure 3.1-5 in the appendix). Two researchers jointly categorized the measure candidates, grouped them on the same level of detail, and fitted them to our definition of technostress prevention. This procedure yielded an initial list of 24 technostress prevention measures that went into the Delphi study. We used the detailed technostress prevention measure candidates to describe and exemplify the aggregated technostress prevention measures. We formulated the underlying inhibiting effect and a measure's description based on both input sources during this process.

3.1.4.2 Phases 1, 2, and 3: The Delphi Study

Our study is a slightly modified ranking-type Delphi study (Schmidt 1997), a common Delphi study approach (Paré et al., 2013). The ranking-type Delphi study proposed by Schmidt (1997) consists of three phases: (1) brainstorming to discover the issues, (2) narrowing down to determine the most important issues, and (3) ranking the issues. Similar to other published Delphi studies (Paré et al., 2013), we merged the first and second phases because the literature review and the focus group workshops in phase 0 already structured the topic. Instead, we added a phase for characterizing each technostress prevention measure. Each phase consisted of two rounds to validate the previous round's result (Figure 3.1-4), which is appropriate for producing credible results (Skinner et al., 2015). Consequently, our Delphi study consisted of three phases:

(1) Validation and extension of technostress prevention measures

(2) Characterization of technostress prevention measures

(3) Identification and relevance assessment of primary technostress prevention measures that target specific technostressors

To ensure that the participants of our Delphi study are knowledgeable experts in technostress and are aware of the issue in the larger world around them (Delbecq et al., 1975; Keeney et al., 2006; Skinner et al., 2015), we applied the following selection criteria (Okoli and Pawlowski 2004): experts should (1) be responsible for, for example, occupational safety/medicine, psychological risk assessment/operational health management, or human resources, (2) have experience in the field of technostress, stress management, or occupational health and safety, (3) have at least three years of work experience, and (4) be frequent users of ICTs themselves. These requirements ensured that all experts were familiar with technostress and possible technostress prevention measures. We ensured that all experts professionally deal with stress management programs (all work on general occupational stress management; some focus on technostress management). Not every expert had experience with all measures presented but at least with multiple technostress prevention measures. Thus, they can assess the measures, evaluate them, and estimate the implementation. Experts had the choice not to provide assessments on individual measures when they felt they had insufficient information or experience with the measure. But this option was never used in the Delphi study. We have no indication for systematic differences in the assessment of measures by the experts depending on the expert's first-hand experience with a measure as compared to only abstract knowledge about the measure. Such differences could have occurred in phases 2 to 3. In the progression of the Delphi study, the experts' assessments tended to converge, given even less basis to differentiate by experience. Hence, we report aggregate results from the entire panel.

To ensure broad topic coverage, we recruited experts from different industries and company sizes via our industrial network and several occupational health and safety events on the topic of technostress. We reached out to a total of 50 possible experts. Of those, 15 experts fulfilled the selection criteria and agreed to participate in our Delphi study. None of them participated in the focus group workshops in Phase 0. One participant missed the first round, and another dropped out after the first round. Thus, 13 experts completed each round, an appropriate panel size (Linstone and Turoff 2002; Paré et al., 2013). Table 3.1-7 in the appendix provides additional information on the panel.

The Delphi study took place via the online survey tool LimeSurvey and lasted five months (August to December 2020). In each round, we invited all experts to participate via e-mail and provided detailed instructions. To provide the experts with sufficient guidance, we e-mailed them their answers and suggestions from the previous round, an overview of the changes made based on all experts' suggestions, and descriptive information on quantitative evaluations after each round. Thereby, the experts could reflect on their opinion based on the aggregated results from all experts. Also, experts could provide free text feedback in addition to quantitative assessments. Through the free text feedback, we also provide the opportunity to state that one has had too little experience with the measure for assessing it. Following the suggestion of Strasser (2016), Okoli and Pawlowski (2004), and Skinner et al. (2015), participants were not known to each other by name, and we did not show the individual results of other panelists to ensure anonymity and avoid bias.

In the *first phase*, we introduced the experts to the 24 technostress prevention measure candidates and suggested a description of each measure and its inhibiting effects. We asked the experts to rate each technostress prevention measure's relevance for preventing technostress on a scale ranging from 0 to 6 (0 = "not relevant" to 6 = "highly relevant"). Generally, literature on the Delphi method suggests identifying the key issues (Paré et al., 2013) or most important issues (Schmidt, 1997) in the respective context. In our study, this means identifying the most relevant prevention measures. Therein, relevance always refers to 1) a relation between two entities in a context, 2) to an intention, and 3) to an assessment of the effectiveness of the relation regarding the intention (Cosijn & Ingwersen, 2000; Saracevic, 2007). In our study, the context is technostress, and the relation is between technostress prevention measures and parts of the technostress process. Specifically, primary prevention measures relate to technostressors, while secondary prevention measures relate to responses to technostressors (also see Figure 3.1-2 for the underlying model). The intention is to prevent technostress and effectiveness relates to the ability of a measure to reduce technostress, i.e., mitigate the negative impact of technostressors on individuals (primary prevention) or mitigate negative stress responses (secondary prevention). Hence, we define the relevance of a technostress prevention measure as the assessment of the measure's effectiveness in preventing the negative effects of technostress. The experts' judgment on relevance thus inherently relates to the expected effectiveness of a prevention measure. Since directly assessing the effectiveness or expected effectiveness might be perceived to suggest a level of precision of measurement that our Delphi study could not deliver, experts judged the broader concept of relevance. *Phase 1* introduced the experts to the 24 technostress prevention measure candidates and suggested a description of each measure and their inhibiting effects. We asked the experts to rate each technostress prevention measure's relevance for preventing technostress on a scale ranging from 0 ("not relevant") to 6 ("highly relevant"). Literature on the Delphi method suggests to identify the key issues (Paré et al., 2013) or most important issues (Schmidt, 1997) in the respective context. In our study, this means identifying the most relevant prevention measures. Relevance in general refers to 1) a relation between two entities in a context, 2) to an intention, and 3) to an assessment of the effectiveness of the relation regarding the intention (Cosijn & Ingwersen, 2000; Saracevic, 2007). In our study, the context is technostress at work, and the relation is between technostress prevention measures and parts of the technostress process. Specifically, primary prevention measures relate to technostressors, while secondary prevention measures relate to technostress responses. The intention is to prevent technostress. Effectiveness relates to the ability of a measure to reduce technostress, i.e., mitigate technostressors (primary prevention) or mitigate negative stress responses (secondary prevention). Hence, we define the relevance of a technostress prevention measure as the assessment of the measure's effectiveness in preventing the negative effects of technostress. The experts' judgment on relevance thus inherently relates to the expected effectiveness of a prevention measure. Directly assessing effectiveness is not possible in a Delphi study. Assessing expected or perceived effectiveness would in principle be possible in a Delphi study. However, using the term effectiveness might be perceived to suggest a level of precision of measurement that our Delphi study could not deliver. Hence, we asked the experts to assess the broader concept of relevance.

We queried qualitative feedback regarding each measure's evaluation and overall comprehensibility by providing optional text fields. Additionally, the experts were asked to review the entire list, emphasizing its completeness regarding the most relevant technostress prevention measures and adding further measures if necessary. For evaluating this phase, we examined the written qualitative feedback and the relevance assessment. We defined consensus on the technostress prevention measures' relevance as a state in which (1) the experts mention no further wording changes or new technostress prevention measures and (2) more than 75% of the experts assess each measure's relevance with a score of 3 (middle option) or higher. To avoid bias by individual experts, recommendations for description changes or additions of technostress prevention measures were only implemented if at least two experts made suggestions in that direction. The experts did not yet reach a consensus in the first round. Based on their feedback, two measures of the initial set were merged, and one new measure was added. In the second round, we presented the aggregated results of the first round to the experts. This round resulted in a consensus, yielding the final set of technostress prevention measures. To take a first step toward the technostress prevention measures' categorization, three authors separately grouped the technostress prevention measures into primary and secondary preventions based on the measures' descriptions. For each measure with different categorizations of the three researchers, they discussed them together until they agreed. Figure 3.1-4 summaries key aspects of this first phase and the following phases.

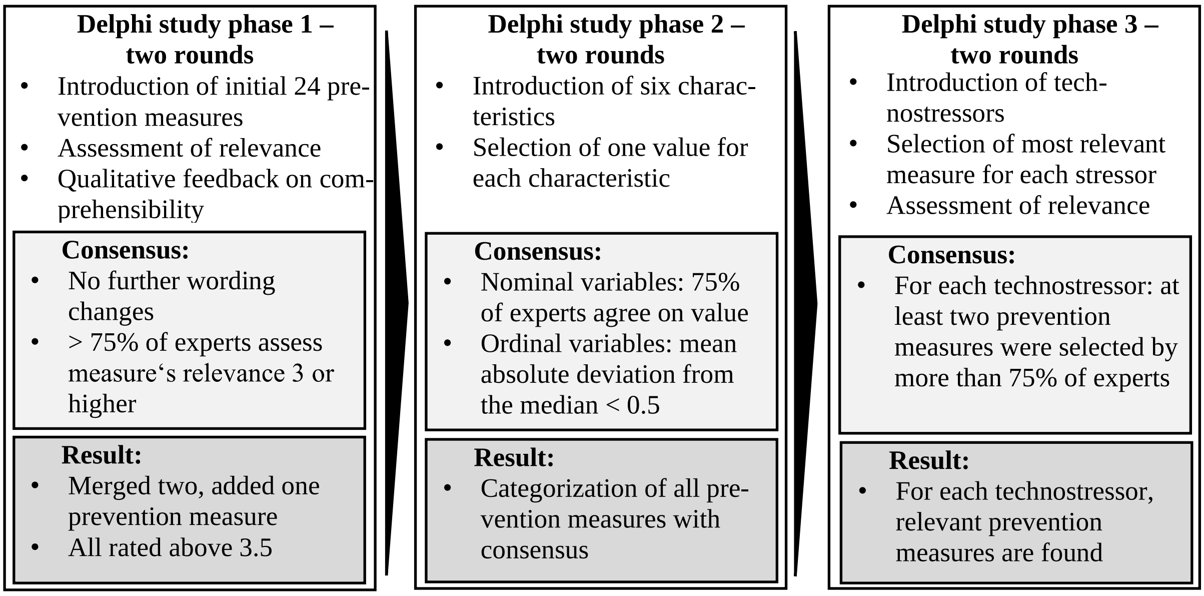

Figure 3.1-4 Phases 1, 2, and 3 of the Delphi study

Phase 2 introduced the experts to different characteristics of technostress prevention measures through short explanatory descriptions and figures. The characteristics were developed by the research team with the help of practitioners from organizational health and safety and represent a valuable step to better understand technostress prevention. Each expert could indicate one manifestation for each characteristic. The six characteristics are:

(1) Entity of change describes whether the technostress prevention measure alters an organization's I) technology, II) organizational structures and procedures, or III) the individuals' skills and abilities (based on Murphy and Sauter (2004)). Technology, organizational structures, and organizational procedures relate to the technology environment conditions. Individual skills and abilities relate to the individual perceiving and assessing demands from the environment. Each of the three levels refers to the entity affected by the measure, which is always implemented by the organization to prevent technostress (in line with principle 3 of (techno)stress prevention; see Section 3.1.3).

(2) Target group describes whether the technostress prevention measure targets I) all employees, II) management only, or III) other specific groups. This characteristic again relates to Principle 4 of (techno)stress prevention management as the first step to account for the heterogeneity of individuals. Specifically considering management relates to principle 2 which places a specific responsibility on the leadership team that serves as a role model and determines essential aspects of the employees' work environment.

(3) Organization size determines if the technostress prevention measure is suitable for organizations with at least I) one or more, II) ten or more, III) 50 or more, IV) 250 or more, V) 500 or more, or VI) 2,500 or more employees. Principle 4 of (techno)stress prevention management suggests that not all organizations are alike. Including the organization size is one broad category in the direction of accounting for the heterogeneity of organizations.

(4) Duration of implementation and time to operational use distinguishes between technostress prevention measures that take I) less than one year, II) 1-3 years, or III) more than three years to become operational. While the principles of (techno)stress management suggest that stress is not inevitable (principle 3) and that leaders should select and implement technostress prevention measures, this process cannot happen instantaneously. Characterizing the duration between the selection of a prevention measure to be

implemented until this measure is operational captures one element of time lack in realizing the effects of technostress prevention management.

(5) Time until the effect of the technostress prevention measure is realized in the operational business can take I) less than half a year, II) 0.5-1 year, or III) more than one year. Individual and organizational health are interdependent (principle 1) and both individuals and organizations react (principle 4). However, this reaction is not instantaneous upon the use of prevention measures but may take time. Characterizing the time from the operational use of a prevention measure until the effects of the measure are realized on the induvial and organizational levels is the second element of time lack in realizing the effects of technostress prevention management.

(6) Duration of the technostress prevention measure's effect may be I) less than one year, II) 1-3 years, or III) more than three years. A technostress prevention measure implemented may have long-term effects but the effect may also fade out. One reason is that organizations are ever-changing, dynamic entities (principle 5). Hence, characterizing the duration of the effect aims at informing technostress prevention management regarding the likely need to repeatedly reassess the state of technostress and its prevention in an organization.

In both rounds of Phase 2, we evaluated the results based on the characteristics' mode (for nominal characteristics 1 and 2) and the characteristics' median (for ordinal characteristics 3, 4, 5, and 6). For characteristics with a nominal scale, the consensus is reached if 75% of the experts agree on the same characteristic (i.e., the mode). For characteristics with an ordinal scale, we defined consensus as an average absolute deviation from the median below 0.5. To further evaluate the consensus between the experts, we calculated Fleiss' Kappa for all six characteristics. The received values range from 0.01 to 0.43 in round 1 of Phase 2. Here, experts had not yet consensus. In round 2 of Phase 2, Fleiss' Kappa increased to 0.79-1.00. Except for organization size (0.79, substantial agreement), all Fleiss' Kappa values indicate an almost perfect agreement (Landis & Koch, 1977). Again, consensus on the characterization of the technostress prevention measures was reached after two rounds.

In *Phase 3*, the experts were given a definition and an illustrative example of each technostressor as presented by Henner Gimpel et al. (2020). The experts then selected the prevention measures expected to be most relevant for mitigating each technostressor. In the following, we discuss the relevance of prevention measures for specific technostressors. As the results are based on expert assessments in a small sample, we do not indicate absolute and quantifiable relationships, but use relevance as a measure for giving a trend statement on the expected relationship. The trend statements serve as the foundation for potential statistical analyses in the future.

For primary technostress prevention measures, this means that the measure is expected to reduce the corresponding technostressor directly. For secondary prevention measures, we do not present this relationship because one technostressor can trigger several technostress responses and one technostress response can be triggered several technostressors. Therefore, the association of the relevance relationship between secondary prevention measures and technostressor is not clear. Based on the results, we assess both the set of primary technostress prevention measures relevant for each technostressor as well as the set of technostressors to which a single prevention measure is expected to be relevant. We asked the experts to assess the relevance of the selected technostress prevention measures for the specific technostressor on a scale ranging from 0 (“not relevant”) to 6 (“highly relevant”). To evaluate the connections between technostressors and technostress prevention measures, we counted how often each technostress prevention measure was selected for each of the nine considered technostressors. We declared consensus when five or more technostress prevention measures were selected by more than 75 % of the experts (that is, at least ten experts). In the second round, all technostressors met this criterion. Accordingly, the Fleiss’ Kappa values indicating the degree of agreement between the experts for each of the nine considered technostressors increased from 0.09 to 0.33 in round 1 to 0.72 (substantial agreement) to 0.94 (almost perfect agreement) in round 2 of Phase 3.

Lastly, based on our overall results, we present propositions that contain insights gained through applying the Theory of Preventive Stress Management to technostress and knowledge developed throughout our structured literature review, focus group workshops, and the Delphi study.

3.1.5 Results on Primary and Secondary Technostress Prevention Measures

Our research process resulted in a list of 24 technostress prevention measures, out of which 17 measures can be categorized as primary technostress prevention and seven as secondary technostress prevention measures (Table 3.1-3). Primary technostress prevention measures include, for example, the implementation of reachability management. By establishing reachability management, such as defining when employees are available for work-related communication, technostressors can be reduced. In contrast, secondary technostress prevention measures include the provision of ICT support. Assisting employees with fast and competent support for technical issues using ICTs allows them to better response to technostressors. The individual technostress response consists of coping responses and psychological and physiological responses (see Section 3.1.3).

In comparison to the technostress prevention measures synthesized from literature during phase 0, we merged the two technostress prevention measure candidates foster sensitization regarding technostress and foster self-reflection regarding technostress into foster sensitization and self-reflection regarding technostress based on experts' input during the Delphi study (measure 24, Table 3.1-3). Additionally, we added a new measure (measure 21, *train technostress coping competencies*) based on experts' suggestions. Besides these apparent changes to the list of technostress prevention measures, the experts' qualitative feedback in the Delphi study's first phase suggested changes concerning the configurations of single technostress prevention measures. One expert, for example, pointed to the importance that, "especially for inexperienced employees with an IT problem, the IT helpdesk [measure 19, *provide ICT support*; note from the authors] staff should convey a feeling of trust and respect". Many of these suggestions are reflected in the descriptions of the measures. In addition, multiple experts stressed that organizational offers suggested by measures 17 (*train effective self-management and time management*) and 24 (*foster sensitization and self-reflection regarding technostress*) should not be mandatory, as that might even increase employees' stress.

In addition, various experts emphasized the relevance of a diverse portfolio of measures. Although measures targeting individual-level change are important, these measures bear the risk of outsourcing the responsibility for technostress prevention from the organization to the individual. Therefore, the complementary implementation of organizational and technical changes is essential. The 24 technostress prevention measures give a comprehensive overview of available measures in organizational settings and indicate the diversity of technostress prevention opportunities. Table 3.1-3 presents the complete list of technostress prevention measures, including their inhibiting effects and descriptions. The column "#" indicates how many times the technostress prevention measure was mentioned in the literature; "-" indicates that the technostress prevention measure was self-developed during the focus group workshops or the Delphi study. The four self-developed measures are measure 1, focus the ICT landscape, measure 5 use gamification, measure 10 *agree on binding ICT usage guidelines*, and measure 21 *train* *technostress coping competencies*. Measure 1 refers to the situation of having several and redundant systems for the same task (e.g., video conferencing) and information distributed in the organization. The measure aims at reducing the number of systems to a reasonable level and especially involves employees in selecting appropriate systems and ICTs for the given task (e.g., to also offer room for practices like “bring your own device” if this simplifies the process and collaboration). Measure 5 *use gamification* targets the ICT design by including game elements, for example, levels, points, rewards, or badges. ICTs might also react with humor in certain situations. In this way, users are introduced to ICTs through playful behavior. It is important to note that through the Delphi study, we found that participation in such games should be voluntary to avoid (perceived) performance monitoring. Measure 10 *agree on binding ICT usage guidelines* goes in a similar direction as measure 1 but emphasizes the importance of transparency on which ICT is used for which purpose and under what conditions. Measure 21 *train technostress coping competencies* is also highly relevant in the Theory of Preventive Stress Management and separates the constructs of coping from preventive technostress measures (Quick et al., 1997). Sufficient coping skills are highly important to effectively deal with technostress (Salo et al., 2020; Schmidt et al., 2021; Weinert et al., 2020). The preventive measure trains employees’ individual technostress coping behavior being part of their technostress response. Coping includes, for example, positive reappraisal, changing the perception of an IT event, or seeking help from colleagues (Beaudry & Pinsonneault 2005; Beaudry & Pinsonneault 2010).

The list of technostress prevention measures is structured along with the differentiation into primary and secondary prevention and the distinction between measures enabling changes to technologies, organizations, or individuals. The overview of references referring to the measures is presented in the appendix in Table 3.1-5.

No.	Technostress Prevention Measure	#	Inhibiting Effect	Description
			Primary Technostress Prevention Measures	
			Enabling Changes to Technology	
1	Focus the ICT landscape	-	Establishing an ICT landscape that meets job-specific requirements can reduce the frequency, duration, and/or intensity of technostressors.	The company reduces the selection of available technologies to a reasonable level and avoids redundancies of systems and information. Employees are involved in the selection process and can use the appropriate media for a given situation (e.g., a chat for informal agreements).
2	Adapt a stress-sensitive digital workplace design	2	Adapting a digital workplace to the needs of employees can reduce the frequency, duration, and/or intensity of technostressors.	The design of workplaces in the organization regards ergonomic aspects and technostressors, for example, by integrating rest areas and (digitally enabled) creative or group rooms. As a result, employees can use an environment suitable for their individual digital work situations.
3	Apply human-centered release management	5	Establishing good planning and consideration of employees' needs for technology-related changes in the form of updates can reduce the frequency, duration, and/or intensity of technostressors.	For good release management, the company bundles changes to ICTs and works towards an effective ICT infrastructure. The change of ICTs is oriented towards the employees' needs, which are collected through formats such as the helpdesk or the mentor. Likewise, "inexperienced" employees are involved in the survey of needs. The effectiveness of the ICT infrastructure is regularly reviewed and provided in sufficient capacity.
4	Apply human-centered ICT design	3	Tailoring ICTs to the needs of employees can reduce the frequency, duration, and/or intensity of technostressors.	ICTs are designed regarding the reduction of technostressors and are improved through continuous user involvement. Technologies that are intuitive to use and ergonomic are preferred. For example, inefficient ICT interfaces are reduced, and work-relevant information is made accessible barrier-free and straightforward. Employees have an active involvement in changes at an early stage.
5	Use gamification	-	Using playful and rewarding elements in ICTs can reduce the frequency, duration, and/or intensity of technostressors.	ICTs are expanded in a reasonable scope to include playful elements that motivate employees, for example, by collecting points for the use of ICTs. The use of gamification should be implemented voluntarily and professionally to avoid performance monitoring.
			Enabling Changes to Organizational Structures and Routines	
6	Foster a cooperative culture	8	Fostering a cooperative (rather than competitive) culture with digitalization as a common goal can reduce the frequency, duration, and/or intensity of technostressors.	The company defines guiding principles and develops and establishes a digital-compatible and cooperative culture. Employees' active involvement and role model by managers help implement the culture long-term and sustainably.
7	Develop a mission statement for digital collaboration	5	Fostering open communication and high transparency regarding the requirements and expectations in dealing with ICTs can reduce the frequency, duration, and/or intensity of technostressors.	An interdisciplinary team develops a company-wide mission statement for digital collaboration in a participatory way. The way of communication through and with ICTs will be clearly defined company-wide and followed up in the long term.

No.	Technostress Prevention Measure	#	Inhibiting Effect	Description
8	Introduce an employee data security concept	1	Providing transparency over how work-related data collected by technology is processed and used, particularly in performance monitoring, can reduce the frequency, duration, and/or intensity of technostressors.	The company introduces a data security concept regarding the accessibility, use, and processing of information and data regarding employees' behavior. The concept is regularly communicated transparently to the workforce. The data security concept is revised and updated regularly to ensure that it is up to date.
9	Agree on binding ICT usage guidelines	-	Providing transparency regarding which technologies are used for which purpose helps employees avoid technostress. Joint guidelines from employee representatives and management increase acceptance among the entire staff, which can reduce the frequency, duration, and/or intensity of technostressors.	Binding ICT usage guidelines are concluded within the company that clearly defines the goals, purposes, and framework conditions for using ICTs. The guidelines are revised and updated regularly to ensure that they are up to date.
10	Consciously manage ICT-related change	1	Providing good and structured support with technology-related change processes can reduce the frequency, duration, and/or intensity of technostressors.	The company actively adapts ICTs to changing internal requirements following good change management. Employees are informed early and comprehensively about the reasons and consequences of the change and can efficiently continue using the changing technologies through training.
11	Develop team norms for the use of ICTs	7	Explicitly communicating rules for handling ICTs for team-internal tasks (e.g., preferred communication channels or file storage) can reduce the frequency, duration, and/or intensity of technostressors.	The team develops rules and guidelines for handling ICTs derived from the company-wide guidelines during team-internal workshops. These rules will be explicitly communicated, documented, and passed on to new employees and continually refined in the long term in an interactive process, allowing quick adaptions. This includes, for example, the definition of rules on which communication tool should be used for which purpose.
12	Establish reachability management	2	Creating a common understanding of when, why, and how employees are available for work-related communication can reduce the frequency, duration, and/or intensity of technostressors.	The company defines clear reachability rules, which specify under what conditions and when ICTs are used. These rules are agreed upon together in collective agreements (where there is employee representation). Reachability rules are considered when selecting suitable technologies, for example, to enable the selection of unavailable times.
			Enabling Changes to Individuals	
13	Train managers to successfully lead in the digital working world	11	Having digitalization-friendly, inspiring, and employee-oriented leadership can build a trusting and supportive relationship between managers and team members, thus can reduce the frequency, duration, and/or intensity of technostressors.	The company prepares managers for digitalization challenges in workshops by jointly developing key aspects of digital employee management. For example, this includes supporting employees by making time and other resources available to facilitate effective self- and time management.

No.	Technostress Prevention Measure	#	Inhibiting Effect	Description
14	Train managers for leading distributed team members	1	Having good skills in coordinating distributed teams among managers can reduce the frequency, duration, and/or intensity of technostressors.	The company offers workshops for managers to develop important aspects of leading distributed teams and train in the effective coordination and organization of tasks with ICTs.
15	Provide role models with technological changes	5	Showing role models in the healthy use of ICTs and effective support of employees in the event of changes can reduce the frequency, duration, and/or intensity of technostressors.	The company offers workshops for managers to train the healthy use of ICTs and an appropriate way of dealing with change processes. In this way, managers exemplify the use of the newly introduced technologies and serve as role models (e.g., regarding reachability expectations), and support employees in dealing with change.
16	Train mentors for digital topics	5	Providing a personal mentor, who assists employees with technical questions, can reduce the frequency, duration, and/or intensity of technostressors.	Employees can request a mentor as a trusted contact person for questions on digital and technical issues. The mentor regularly provides tips and tricks for using ICTs. The inhibition threshold to ask questions is lowered.
17	Train effective self-management and time management	10	Practicing good self and time management skills can reduce the frequency, duration, and/or intensity of technostressors.	The company offers voluntary training courses that introduce important aspects of self-management and time management regarding their digital working style. This training includes integrating short breaks into the daily work routine to prevent fatigue and a drop in performance. It enables employees to use ICTs independently, efficiently, and in a beneficial way to their health..
			Secondary Technostress Prevention Measures	
			Enabling Changes to Technology	
18	Provide supportive ICTs	7	Providing ICTs that support employees in their technostress response, especially in adopting new work routines as coping measures.	Employees can access ICTs with functions that can support them in dealing with technostressors (i.e., changing their technostress response). These include, for example, reminders of breaks, exercise, or important tasks.
Enabling Changes to Organizational Structures and Routines				
19	Provide ICT support	11	Providing competent, fast, and empathetic support for technical questions and problems that allows employees to change their technostress response.	The company sets up a helpdesk to provide employees with fast and competent support for technical questions or problems using ICTs. The helpdesk is trained in the avoidance of technostress and, to purely first-level support, can also respond to requests from overburdened ICT users so that they feel they are taken seriously. All employees know that they can get help from the helpdesk without reproach.
			Enabling Changes to Individuals	
20	Train monotasking	3	Offering training to focus on only one task at a time helps employees to change their technostress response.	The company offers voluntary training courses that inform employees about the advantages of monotasking – that is, focusing on only one task at a time –, teach approaches to efficient work design, and accompany employees' testing of these approaches in everyday work.

No.	Technostress Prevention Measure	#	Inhibiting Effect	Description
21	Train technostress coping competencies	-	Providing technostress coping training help employees to change their technostress response.	The company offers voluntary technostress coping training to their employees that enables them to reduce or eliminate strain caused by technostress. These measures include, for example, the conscious use of ICTs or the avoidance of stressful ICT characteristics.
22	Offer platforms to exchange experience on ICT use	5	Offering sharing formats that enable employees to exchange information on how to use ICTs help employees to change their technostress response by strengthening community sense.	The company establishes forums (preferably in person or as a hybrid format), through which employees can exchange experiences and best practices in dealing with ICTs. Experts moderate these platforms to facilitate joint learning.
23	Provide ICT training	13	Providing training in in-depth technical skills and strengthening media competence helps employees to change their technostress response.	The company offers voluntary training courses that teach employees advanced skills in the use of ICTs. During several pieces of training, employees learn how to use ICTs and practice the transfer in their daily work. These courses are offered especially when new technologies are introduced. Company-wide regulations ensure that every employee is entitled to this training.
24	Foster sensitization and self-reflection regarding technostress	11	Supporting awareness of the causes, effects, and outcomes of technostress and one's working methods helps employees to change their technostress response.	The company offers voluntary training courses that sensitize employees to the dangers of technostress and teach them a toolbox of targeted strategies that help avoid technostress. Exemplary tools include introspection and self-reflection strategies to identify pitfalls of digital work and adapt their way of working.

Table 3.1-3 Technostress prevention measures that are sorted by their basic approach to technostress prevention
– the column '#' indicates how many times the measure (e.g., input that helped to formulate the measure) was mentioned in the literature. '-' indicates that the measure is self-developed

To better structure and compare the different types of technostress prevention measures, experts characterized them on a set of characteristics during the Delphi study. Each technostress prevention measure's complete characterization is presented in Table 3.1-8 and Table 3.1-9 in the appendix. The first characteristic (*entity of change*) relates to the entity affected by the technostress prevention measure and comprises the technological, organizational, and individual levels (Murphy & Sauter, 2004). This differentiation stems from Murphy & Sauter's (2004) effort to structure interventions that avoid negative influences on worker health and safety. Measures at the technological level concern the implementation and use of well-designed ICTs that serve their purpose. At the organizational level, measures focus on changing organizational structures, processes, and guidelines (e.g., code of conduct, and operating instructions). Lastly, changes on the individual level comprise technostress prevention measures that create a change in the individual, for example, their behavior. The manifestations of this characteristic are distributed relatively evenly across the 24 measures. The subheadings in Table 3.1-3 structure the classification (e.g., measures underneath the subheading “Enabling Changes to Individuals” refer to measures that affect the individual level). Six of the 24 measures address the technological level (e.g., measure 3, *apply human-centered release management*), eight address the organizational level (e.g., measure 12, *establish reachability management*), and ten address the individual level of prevention (e.g., measure 17, *train effective self-management and time management*). Technostress prevention measures on all three levels (technological, organizational, individual) can act as primary or secondary prevention (Murphy & Sauter, 2004; Pirkkalainen et al., 2019; Salo et al., 2017; Weinert et al., 2020). However, the characterization shows very different distributions of the three levels when comparing the two types of prevention. For primary prevention, most measures (7/17, ~41%) initiate change on the organizational level, while the technological and individual levels are each addressed by five measures (roughly 29%). In contrast, five of the seven secondary technostress prevention measures (71%) are changing the individual, and only one measure each refers to technological and organizational change, respectively. Primary technostress prevention measures on the technological level alter the technological environment in such a way that employees experience fewer ICT-related demands. Complementary, secondary technostress prevention measures on the technological level refer to measures that aim at providing employees with technological resources to improve their perception of and response to technostressors (e.g., helping employees by reminding them to take breaks). While individual-level secondary technostress prevention measures mainly address the techno-stressed individual’s internal factors (e.g., knowledge, skills, experience), individual-level primary technostress prevention measures primarily target a change of other individuals’ behaviors, thus, shaping the social environment.

Target group and *organization size* concern the applicability of the measure for specific people and organizations. On the characteristic of the target group, we observe no fundamental differences between primary and secondary technostress prevention. In terms of the appropriate organization size, nine measures are suitable for organizations with as few as ten employees, 13 measures for at least 50 employees, and two measures require at least 250 employees to be conducted effectively. While most measures in our study (21) are suitable to all employees, three are relevant to management only. Interestingly, most primary technostress prevention measures (13/17, ~76%) require at least 50 employees to be applicable. With secondary prevention, five of seven measures (~71%) are already applicable with as few as ten employees.

This indicates that the build-up of employee resources to better react to technostressors (i.e., secondary prevention) is often already feasible with only a few individuals. In contrast, measures initiating large-scale technological and organizational changes require more advanced organizational structures and larger organizations.

Lastly, the characteristics of *implementation duration*, *time from implementation until effect realization*, and *effect duration* take a time perspective. The results show that half of the measures can be implemented and brought to operational use in less than one year (e.g., measure 16, *train mentors for digital topics*). In contrast, eleven measures require 1-3 years, and one measure even three years. These numbers indicate that the initial effort for many measures is relatively low, which is important for reducing the barrier to successful prevention. Similarly, the time required until the effect of the respective measure becomes apparent in operational business is less than half a year for ten measures (e.g., measure 21, *train technostress coping competencies*), up to one year for 13 measures, and more than one year for only one measure (measure 6, *foster a cooperative culture*). The effect of six technostress prevention measures is characterized to last less than one year, while 18 measures show a positive effect between one to three years (e.g., measure 1, *focus the ICT landscape*). Regarding primary vs. secondary technostress prevention measures, a clear tendency can be observed. The *average implementation duration* and *time until effect realization* are longer for primary than secondary technostress prevention. However, the *effect duration* for primary prevention was assessed to last 1-3 years for 14 of the 17 measures (~82%), while of the secondary technostress prevention measures, only four of seven measures (~57%) last 1-3 years and the rest less than one year.

Next, we asked for a relevance assessment on which primary technostress prevention measures are expected to target which technostressor. For each technostressor, we identify two to six measures that the experts assess as the most relevant. The resulting scores serve as a basis for confirmative quantitative statistical analyses on the relevance of different technostress prevention measures on the set of technostressors. Table 3.1-4 presents these relations and graphically displays the average relevance (scale from 0 to 6) of the measures for the respective technostressor for all primary technostress prevention measures. The measures are sorted according to their accumulated relevance score. Table 3.1-10 in the appendix represents the complete list of numerical relevance ratings, and the number of experts who mentioned the measure as highly relevant is provided.

No.	Technostress Prevention Measure	Complexity	Insecurity	Interruptions	Invasion	Invasion of Privacy	Overload	Role Ambiguity	Uncertainty	Unreliability
4	Apply human-centered ICT design	●	○	○	○	◕	○	●	○	●
13	Train managers to successfully lead in the digital working world	○	●	○	●	◕	○	○	◑	○
1	Focus on the ICT landscape	●	○	○	○	○	○	●	○	◕
17	Train effective self-management and time management	○	○	◕	●	○	◕	○	○	○
11	Develop team norms for the use of ICTs	○	○	◕	●	◕	○	○	○	○
12	Establish reachability management	○	○	●	●	○	◑	○	○	○
6	Foster a cooperative culture	○	◑	○	◕	◕	○	○	○	○
15	Provide role models with technological changes	●	●	○	○	○	○	○	○	○
16	Train mentors for digital topics	○	●	○	○	○	○	◑	◑	○
5	Use gamification	○	○	○	○	○	○	○	●	○
2	Adopt a stress-sensitive digital workplace design	○	○	◑	○	○	○	○	○	◔
3	Apply human-centered release management	◕	○	○	○	○	○	○	○	○
8	Introduce an employee data security concept	○	○	○	○	◕	○	○	○	○
9	Agree on binding ICT usage guidelines	○	○	○	○	◕	○	○	○	○
10	Consciously manage ICT-related change	◑	○	○	○	○	○	○	○	○
7	Develop a mission statement for digital collaboration	○	○	○	○	○	○	○	○	○
14	Train managers for leading of distributed team members	○	○	○	○	○	○	○	○	○

○	◔	◑	◕	●
No focus (relevance<4.0)	Somehow relevant (4.0 <= relevance <4.5)	Relevant (4.5 <= relevance <5.0)	Very relevant (5.0 <= relevance <5.5)	Direct focus (relevance >=5.5)

Table 3.1-4 Relevance of primary prevention measures to reduce technostressors

When assessing the relations, no two technostressors share the same set of relevant technostress prevention measures. However, some patterns exist. For example, two technostress prevention measures can potentially help prevent both unreliability and role ambiguity. Similarly, overload and invasion share two prevention measures. Accordingly, these pairs of technostressors can be addressed through similar prevention measures. Each technostress prevention measure is selected as a technostressor's most relevant measure between zero to four times. Interestingly, two primary technostress prevention measures (measure 14, *train managers for leading* *distributed team members*, and measure 7, *develop a mission statement for digital collaboration*) are not selected to be most relevant for any technostressor. This fact does not mean that the measures are generally not relevant for preventing technostress. However, it does indicate that industry experts do not expect them to be among the most relevant measures for addressing one of the nine considered technostressors. In contrast, two technostress prevention measures (measure 4, *apply human-centered ICT design*, and measure 13, *train managers to successfully lead in the digital working world*) are relevant to four different technostressors. This finding indicates that the two are rather general technostress prevention measures that are suitable for multiple technostress sources. Other measures (e.g., measure 9, *agree on binding ICT usage guidelines,* and measure 10, *consciously manage ICT-related change*) are only relevant to one technostressor. These measures are expected to be specialized in addressing a particular technostressor.

In summary, we provide three propositions on technostress prevention measures and their relationship to technostressors, which are based on the insights resulting from our Delphi study. The propositions serve as the first foundations for future studies and need to be tested in empirical research in the future. It is important to emphasize that our propositions refer to the context of technostress in professional life with the organization as the entity that can prevent technostress among its employees.

Proposition 1: *Primary prevention measures differ with respect to whether they are relevant for reducing only one or several technostressors.*

Focusing on the relationship between technostressors and primary technostress prevention measures, we found patterns regarding the relevance of primary technostress prevention measures to reduce the frequency, duration, or/and intensity of technostressors. Our results indicate that not every measure addresses all technostressors equally. Some measures are relevant to one or a few specific technostressors, while other measures target a broader set of technostressors. For example, measure 8 (*Introduce an employee data security concept*) is explicitly concerned with increasing data security and reducing related risks. The measure is very focused on one specific downside of digitalized workplaces and, as a result, targets only one technostressor: Invasion of privacy. In contrast, measure 13 (*Train managers to successfully lead in the digital working world*) addresses the very general topic of digital leadership. Strong digital leaders can help improve technostress stemming from all types of technostressors by identifying sources of technostress in time. The measure thus affects several technostressors (i.e., insecurity, invasion, invasion of privacy, and uncertainty). Table 3.1-4 gives the first indication of this matching, which requires future empirical research to verify.

Proposition 2: *Technostressors differ in whether they are addressable through only a few or many primary technostress prevention measures.*

Considering technostressors as the baseline (columns in Table 3.1-4), few observations emerge. Not all technostressors share the number and relevance levels of prevention measures through which they can be targeted. Consequently, some technostressors might be more difficult to address, requiring very few specific measures for prevention. Others, however, exhibit a larger set of measures as potential prevention tools. For example, invasion is indicated to be addressable through several different measures. The technostressor addresses a vague feeling of having to be connected and there are many ways to change this perception. Unreliability, on the other hand, is only matched with three measures in our study. As unreliability describes stress from technical failure, the options for prevention are more limited: improve technical reliability or improve coping with failures.

Proposition 3: *Compared to secondary prevention, primary technostress prevention measures represent a longer-term approach with a longer effect duration, but also require higher initial efforts.*

Deep-diving into the characteristics of primary and secondary prevention measures in Table 3.1-8 and Table 3.1-9 of the appendix, we identified that primary measures require higher average initial efforts for implementation and effect realization than secondary prevention measures. Simultaneously, they also yield longer-term positive effects. This leads to the assumption that primary technostress prevention can be seen as a long-term approach to preventing technostress, while secondary technostress prevention measures often present a short- and mid-term solution to preventing technostress. Primary prevention measures often target the technological and organizational environment. Therein, changes in the form of prevention measures often affect many people and entities, making their implementation more complex. Once a change (for example, a new IT infrastructure) is implemented, however, it lasts for a longer period of time, as it is not dependent on individuals. In comparison, secondary prevention measures often address specific individuals and their response to technostressors. Training and courses can quite quickly improve an individual's coping skills, lowering the required implementation efforts. On the downside, the effects of training do not always last long and completely vanish if an employee leaves the organization or switches roles.

3.1.6 Discussion

Reducing the adverse outcomes of technostress is essential. In an ideal world, organizations invest in addressing technostress at an early level (Brivio et al., 2018). To sustainably reduce technostress, organizations need to implement ex-ante measures to prevent future stressful situations caused by technostressors, and they need to support their employees in responding to technostress. To drive knowledge on prevention in the technostress field and assist practitioners in implementing successful technostress prevention, we transfer the existing Theory of Preventive Stress Management into the technostress context, narrowing down the application context and becoming more specific in this new context (Hargrove et al., 2011; Quick et al., 1998). Similar to Salo et al. (2017), who also used the Theory of Preventive Stress Management as a foundation to summarize individuals' ways of mitigating technostress (e.g., modification of IT use routines), we use the theory as theoretical grounding for organizations' ways of preventing technostress. We synthesized the existing knowledge on ex-ante reduction and elimination of technostress in the literature review of phase 0. We reframed and enriched existing technostress inhibitors and further mitigation measures to 24 actionable technostress prevention measures that can be applied in organizational settings (see Table 3.1-5 in the appendix for a complete overview of all references and their measures that served as an input for our technostress prevention measures). To assess the relevance and improve completeness, we evaluated and extended all measures with experts from practice and research. Many of the technostress prevention measures presented in this paper have in some form been mentioned in technostress literature (e.g., provide ICT training or provide supportive ICTs) (e.g. Adam et al., 2017; Pfaffinger et al., 2020). However, by synthesizing and expanding the fragmented knowledge, we present 24 preventive technostress measures. Twenty of these were derived from literature, enriched by the focus group discussion, and grouped on the same level of detail. Four measures were newly developed during the focus group discussion and the Delphi study. By structuring all measures in terms of their basic approach to technostress prevention (i.e., primary and secondary technostress prevention as well as the entity affected), we contribute a common starting ground for addressing technostress prevention from an organizational view. We also related the primary technostress prevention measures to nine established technostressors to increase practical applicability and to build the foundation for extensive empirical analyses in future research. The list of characterized measures represents the diverse possibilities of work-related technostress prevention and is the first comprehensive collection of relevant technostress prevention measures in technostress literature.

3.1.6.1 Contributions and Implications for Research

With our study, we follow Tarafdar et al.'s (2019) call for 1) a more thorough investigation of how altering technological aspects in an organizational environment can prevent technostress and 2) applying a methodological approach in technostress research that complements the current focus of technostress research on surveys.

Our results go along with findings in the general context of preventive stress management and detail them for technostress: The importance of leaders has been emphasized in the context of preventive stress management (Macik-Frey et al., 2007; James Campbell Quick, 1992). Because of the critical role of leaders, it can be beneficial for organizations to also target primary stress prevention measures to leaders (e.g., executive coaching, and peer support) (Hargrove et al., 2011). Arguably, leaders play a similarly important role in technostress prevention as in the prevention of stress in general. Looking at the most relevant primary technostress prevention measures, we find that measure 13, *Train managers to successfully lead in the digital working world* is the second most relevant (Table 3.1-4). Further concerning prior findings on primary stress prevention measures in general, the provision of instrumental (e.g., buddies or mentoring programs), informational (e.g., improvement of the flow of information), and emotional (e.g., increasing emotional understanding among employees) support proofed effective as primary preventive interventions (J. C. Quick & Quick, 1984). In the specific context of technostress, we also identified all types of the mentioned support measures with a specific focus on ICTs: Measure 15, *provide role models with technological changes*, and measure 16, *train mentors for digital topics* (8^{th} and 9^{th} most relevant primary technostress prevention measure), relate to the first category of "instrumental support". Informational support is addressed by the third relevant technostress prevention measure, measure 1, *focus on the ICT landscape* (Table 3.1-4) by reducing the complexity and avoiding redundancies of information. Lastly, emotional support is mainly addressed by measure 6, *foster a cooperative culture* (6^{th} most relevant primary technostress prevention measure). While the most relevant primary preventive stress measures can be found in the nine most relevant primary technostress prevention measures, we additionally found purely ICT-specific measures like the most relevant measure 4, *Apply human-centered ICT design*. Thereby, we confirm and expand the existing knowledge by narrowing down the context to technostress.

The implication for research is threefold: Researchers working on analyzing or designing technostress inhibitors can use the prevention framing and approach literature on general stress prevention to obtain further theoretical grounding for their technostress research. Further, they can use our list and structure of technostress prevention measures as a broad overview of measures in the otherwise fragmented literature. This helps them in scoping their studies concerning the technostress prevention measures (also termed technostress inhibitors) to consider. Finally, researchers working on stress prevention in other domains besides technostress might consider our set of technostress prevention management as inspiration for identifying similar prevention measures in other specific stress contexts or in abstracting them from technostress to general stress prevention research.

Regarding the second contribution, our efforts in characterizing the different technostress prevention measures in terms of their applicability also help structure the field of preventive technostress management. We offer the possibility to describe measures or groups of measures on a shared set of characteristics. This possibility is important to better compare and classify similar measures in future research. Technostress research can make use of this grouping by not having to assess every measure individually but by being able to assess groups of measures that are identical or similar in their characteristics. We found that primary technostress prevention measures require high initial efforts but yield long-term effects. Therein, primary technostress prevention measures deem a suitable long-term approach for designing workplaces that are technostress free. In contrast, most secondary prevention measures target individuals and require fewer implementation efforts. Thus, they present an opportunity for short- and mid-term prevention of technostress by enabling employees to better react to technostressors in the phase before they have been eliminated permanently. For future research, the implementation and effect duration classification also help design more appropriate studies on testing the actual effectiveness of the different measures. For example, a measure that takes one year to create a positive effect cannot reasonably be assessed in a six-month field study.

Third, we contribute to research by shedding light on the relevance of primary technostress prevention measures to reduce technostressors. We provide initial evidence that prevention measures are expected to address different technostressors, and prevention is no one-fits-all mechanism. Therein, we built on, validated, and extended the few studies that assessed selected prevention measures' potential for specific technostressors (e.g., Galluch et al., 2015; M. Schmidt et al., 2021; Valta et al., 2021). For example, our results confirm and expand the findings of Valta et al. (2021), who investigated seven measures (e.g., ICT training, contact person) to reduce single technostressors. The authors found that, for example, homogenizing the ICT landscape (here: measure 1, *focusing the ICT landscape*) reduces the technostressor *complexity*. This goes along with our results (e.g., measure 1 is highly relevant for complexity, see Table

3.1-4). We expanded the results by finding more technostress prevention measures that are expected to be relevant for preventing complexity (e.g., measure 3 *apply human-centered release management*, measure 4 *apply human-centered ICT design*, and measure 10 *consciously manage ICT-related change*). Stemming from the descriptive results of the expert panel, our results serve as the first foundation for relevance. Scholars in the field can build on these results, and further theorize on the relationship between individual technostress prevention measures (or sets of such measures with similar characteristics) on specific technostressors.

3.1.6.2 Practical Implications

Organizations have a moral, legal, and economic obligation to address work-related technostress among employees. Moral in the sense of having the responsibility to offer a workplace that is safe and healthy. Legal in the sense that countries like Germany have established laws on an organization's duty to protect employees' physical and psychological well-being. Economic in the sense that technostress can impair an individual's health and work performance and negatively impact an organization's performance (Tarafdar et al., 2015). As adverse outcomes from technostress are not acute events but develop over time, it is important to prevent technostress throughout the process, rather than only reacting after adverse outcomes arise. This indicates a need to support organizations in their prevention efforts by providing research results with actionable, practical more fine-grained knowledge on preventive technostress management system in their organization.

Our research demonstrates the diversity of available prevention measures and, thus, supports organizations in finding a set of measures applicable to their specific setting. Especially for organizations new to technostress prevention, our list of measures offers an information source to understand what different aspects prevention can comprise. Most measures are primary technostress prevention measures. This is noteworthy because secondary prevention is prevalent in job-related stress prevention practice, even though primary prevention is deemed more effective as it tackles stress at its source (LaMontagne et al., 2007). By offering a rich set of primary technostress prevention measures, we support organizations in establishing a comprehensive approach to preventive technostress management.

In terms of characterization, our study shows that most measures are available for organizations of all sizes. However, the measures differ strongly in the technostressors they address, their implementation costs, or their required expert knowledge. Further, most measures require relatively little time until implementation and effect realization. These are encouraging news for practice that might take away some of the burdens when starting with technostress prevention. The characterization of measures also serves as decision support for organizations. When choosing measures, one can easily filter measures by the relevant criteria (e.g., size or entity of change) to be presented with a set of appropriate measures.

The propositions on the relations of measures and technostressors have substantial implications for practice. The relevance of technostress prevention measures is expected to be significantly impacted by the technostressor responsible for the technostress. Hence, as the first step to technostress prevention, organizations must identify the critical technostressors within their workforce. Only once an organization knows which technostressors cause technostress to what extent they can effectively select prevention measures. Different measures or sets of prevention measures might be appropriate depending on whether one or multiple technostressors are prevalent. Especially if resources are scarce (typically), it is crucial to prioritize the most severe technostressors concerning prevention.

3.1.6.3 Limitations and Future Research

Like any research paper, our study is subject to limitations. First, our results are based on the expertise of a limited number of 13 panelists and, before the Delphi study, a structured literature review and 17 experts in focus groups. We are convinced that our panel is diverse because panelists stem from different organizations of different industries and sizes. Still, we can make no formal claim about the panel's representativeness. Even though our Delphi study panel's structure and size fit our research purpose, the measures' relevance should be interpreted as a trend statement indicating propositions on the relevance of primary and secondary prevention measures for different technostressors. These propositions need to be evaluated in more extensive quantitative empirical research in the future to make definitive, generalizable claims. In this context, the experts assess average technostress prevention measures' relevance However, like with any prevention, their success may highly depend on individual differences and characteristics. For example, demographics, professional experience, or computer self-efficacy potentially affect how strongly people experience technostress and how effective a prevention measure is. To address this limitation, the above-mentioned quantitative study could also assess the significance of such confounding variables, similar to existing studies such as Tams et al.'s (2018) work.

Second, we examined the measures' effects on nine technostressors. While the selection comprises the most frequently studied sources of technostress, the literature holds further technostressors, for example, the disclosure of private information as a technostressor specific to online social networks (Maier et al., 2012). Also, since the research field is currently rapidly advancing, new technostressors were proposed in the meantime. One example is Fischer et al. (2021), who developed ten stressor categories, including new constructs like social environment or technical support. Consequently, some newer technostressors found no consideration in the Delphi study. Further technostressors could be included in future works.

Third, we did not narrow the organizational scope to industries or company sizes. We kept the scope broad because this first overview of organizational prevention is aimed to be relevant for all types of organizations. However, some of our results might depend on the respective industry, especially concerning prevention measures for individual technostressors. This should be considered when applying the measures in organizations, and an additional individualization of measures to industries could be required.

For future research, we see four promising endeavors. First, based on our results, more targeted empirical studies on the implementation, use, and efficacy of technostress prevention measure can be conducted in the future. As a starting point, we formulate three propositions, that can be tested empirically in future quantitative studies. To evaluate the relevance of technostress prevention measures, we used the comprehensive expertise of our Delphi study's panelists. In this approach, we gathered qualitative feedback and assessments from experts with substantial organizational health experience. Combining this approach with empirical and quantitative assessments can be promising for future research. Building on the insights of Tams et al. (2014), such quantitative assessments should incorporate physiological (e.g., NeuroIS, that is, the use of physiological measures to assess information systems-related phenomena (Tams et al., 2014)) and psychological/self-reported data to most holistically cover the extent of technostress. For example, the research could measure technostress in organizations via established questionnaires and physiological stress measures (e.g., salivary alpha-amylase), select and implement different technostress prevention measures, and then quantitatively measure technostress again to assess the measures' real effectiveness.

Second, the developed overview of technostress prevention measures is important for researchers to design technostress prevention measures in the future. Future research can zoom into specific measures and analyze their concrete implementation or possible relation to technostressors. Examples include the study of Becker et al. (2020) that focuses on the design of digital workplaces (i.e., here measure 2, *adapt a stress-sensitive digital workplace design*), specifically the influence of specific technology characteristics profiles existing at a digital workplace on technostressors.

Next, our study derives work-related technostress prevention measures that enable technological, organizational, and individual changes. On the technological level, the prevention measures are mostly generic in that they generally refer to ICTs. It would be valuable to assess specific ICTs (e.g., e-mail applications or data management software) as a next step. One could also develop additional prevention measures that target any technostress from the respective ICTs or group of ICTs.

Lastly, in this paper, we address single prevention measures. In real-life scenarios, organizations will apply sets and portfolios of such measures. To increase applicability, it would thus be precious to create a) quantification of the effect of different prevention portfolios (including any positive and negative interdependencies) and b) a handbook/ guideline on how to develop and implement such a portfolio in each setting.

3.1.7 Conclusion

Understanding technostress and its adverse outcomes have emerged as a popular research endeavor. How closely related technostress is with an organizational work-related context is becoming even more apparent during the current COVID-19 pandemic. The use of ICTs to fulfill tasks at work is central, even more, when personal meetings and interactions are not allowed. Still, the health of employees must not be forgotten. Research has extensively investigated the potential effects of technostress on employees' health and organizational performance (Fuglseth & Sørebø 2014; Ragu-Nathan et al., 2008; Srivastava et al., 2015; Tarafdar et al., 2007; Tarafdar et al., 2015). Few research papers have also looked into ways of mitigating the adverse outcomes of technostress (e.g. Ragu-Nathan et al., 2008; Weinert et al., 2020).

Our study goes beyond existing research in that we contextualize the Theory of Preventive Stress Management to technostress and address the ex-ante prevention of technostress from an organizational perspective. We apply a Delphi study yielding a list of 24 relevant technostress prevention measures that address work-related technostress. Our study characterizes these measures concerning their entity of change, organizational size, target group, duration of implementation, realization duration, and effect duration. Lastly, we shed light on what prevention measures are expected to address specific technostressors effectively. This paper's contribution lies in creating a theoretical basis for technostress prevention, a unification of existing prevention and technostress mitigation or inhibition studies, and a first step towards structuring the dynamics underlying prevention measures. For practice, we offer valuable support for organizations to fulfill their moral, legal, and economic responsibility to reduce technostress among their employees. The relevance of technostress research will continue to rise with an ever-increasing trend towards digitalization and digital work. We are thus excited to contribute to understanding what it takes to make digital workplaces technostress-free.

3.1.8 References

Adam, M. T. P., Gimpel, H., Maedche, A., & Riedl, R. (2017). Design blueprint for stress-sensitive adaptive enterprise systems. *Business & Information Systems Engineering, 59*(4), 277–291. https://doi.org/10.1007/s12599-016-0451-3

Al-Fudail, M., & Mellar, H. (2008). Investigating teacher stress when using technology. *Computers & Education, 51*(3), 1103–1110. https://doi.org/10.1016/j.compedu.2007.11.004

Arnetz, B. B. (1996). Techno-stress: A prospective psychophysiological study of the impact of a controlled stress-reduction program in advanced telecommunication systems design work. *Journal of Occupational & Environmental Medicine, 38*(1), 53–65. https://doi.org/10.1097/00043764-199601000-00017

Ayyagari, R., Grover, V., & Purvis, R. (2011). Technostress: technological antecedents and implications. *MIS Quarterly, 35*(4), 831. https://doi.org/10.2307/41409963

Beaudry, & Pinsonneault (2005). Understanding User Responses to Information Technology: A Coping Model of User Adaptation. *MIS Quarterly*, *29*(3), 493. https://doi.org/10.2307/25148693

Beaudry, A., & Pinsonneault, A. (2010). The other side of acceptance: Studying the direct and indirect effects of emotions on information technology use. *MIS Quarterly, 34*(4), 689–710. https://doi.org/10.2307/25750701

Becker, J., Berger, M., Gimpel, H., Lanzl, J., & Regal, C. (2020). Considering characteristic profiles of technologies at the digital workplace: The influence on technostress. *Proceedings of the 41st International Conference on Information Systems (ICIS).*

Benlian, A. (2020). A daily field investigation of technology-driven spillovers from work to home. *MIS Quarterly*, *44*(3), 1259–1300. https://doi.org/10.25300/MISQ/2020/14911

Brivio, E., Gaudioso, F., Vergine, I., Mirizzi, C. R., Reina, C., Stellari, A., & Galimberti, C. (2018). Preventing Technostress Through Positive Technology. *Frontiers in Psychology, 9*, 2569. https://doi.org/10.3389/fpsyg.2018.02569

Califf, C., Sarker, S [Saonee], & Sarker, S [Suprateek] (2020). The bright and dark sides of technostress: A mixed-methods study involving healthcare IT. *MIS Quarterly*, *44*(2). https://doi.org/10.25300/MISQ/2020/14818

Cao, X., & Yu, L. (2019). Exploring the influence of excessive social media use at work: A three-dimension usage perspective. *International Journal of Information Management, 46,* 83–92. https://doi.org/10.1016/j.ijinfomgt.2018.11.019

Caro, D. H., & Sethi, A. S. (1985). Strategic management of technostress. The chaining of pro-metheus. *Journal of Medical Systems, 9*, 291–304. http://doi.org/10.1007/BF00992568

Carolan, S., Harris, P. R., Greenwood, K., & Cavanagh, K. (2017). Increasing engagement with an occupational digital stress management program through the use of an online facili-tated discussion group: Results of a pilot randomised controlled trial. *Internet Interven-tions, 10,* 1–11. https://doi.org/10.1016/j.invent.2017.08.001

Chandra, S., Shirish, A., & Srivastava, S. C. (2019). Does technostress inhibit employee inno-vation? Examining the linear and curvilinear influence of technostress creators. *Communications of the Association for Information Systems, 44*(19), 299–331. https://doi.org/10.17705/1CAIS.04419

Chen, J. V., Anh Tran, & Trang Nguyen (2019). Understanding the discontinuance behavior of mobile shoppers as a consequence of technostress: An application of the stress-cop-ing theory. *Computers in Human Behavior*, *95*, 83–93. https://doi.org/10.1016/j.chb.2019.01.022

Conklin, J., & Hayhoe, G. (2010). Focus group workshop. In *Proceedings of the 2010 IEEE International Professional Communication Conference* (pp. 273–274). https://doi.org/10.1109/IPCC.2010.5530023

D’Arcy, J., Herath, T., & Shoss, M. K. (2014). Understanding employee responses to stress-ful information security requirements: A coping perspective. *Journal of Management Information Systems*, *31*(2), 285–318. https://doi.org/10.2753/MIS0742-1222310210

Day, A., Paquet, S., Scott, N., & Hambley, L. (2012). Perceived information and communica-tion technology (ICT) demands on employee outcomes: The moderating effect of or-ganizational ICT support. *Journal of Occupational Health Psychology, 17*(4), 473–491. https://doi.org/10.1037/a0029837

Delbecq, A. L., van de Ven, A. H., & Gustafson, D. H. (1975). Group techniques for program planning: a guide to nominal group and Delphi processes. *Group & Organization Studies, 1*(2), 256–256. https://doi.org/10.1177/105960117600100220

Delpechitre, D., Black, H. G., & Farrish, J. (2019). The dark side of technology: examining the impact of technology overload on salespeople. *Journal of Business & Industrial Marketing, 34*(2), 317–337. https://doi.org/10.1108/JBIM-03-2017-0057

Dittes, S., & Smolnik, S. (2019). Towards a digital work environment: the influence of col-labo-ration and networking on employee performance within an enterprise social media plat-form. *Journal of Business Economics, 89*(8-9), 1215–1243. https://doi.org/10.1007/s11573-019-00951-4

Elie-Dit-Cosaque, C., Pallud, J., & Kalika, M. (2011). The influence of individual, contextual, and social factors on perceived behavioral control of information technology: A field theory approach. *Journal of Management Information Systems, 28*(3), 201–234. https://doi.org/10.2753/MIS0742-1222280306

Fischer, T., Reuter, M., & Riedl, R. (2021). The digital stressors scale: Development and vali-dation of a new survey instrument to measure digital stress perceptions in the work-place context. *Frontiers in Psychology, 12*, 607598. https://doi.org/10.3389/fpsyg.2021.607598

Fischer, T., & Riedl, R. (2015). Theorizing technostress in organizations: A cybernetic approach. In *Proceedings of the 11th Conference on Wirtschaftsinformatik (WI11)*. https://aisel.aisnet.org/wi2015/97

Fuglseth, A. M., & Sørebø, Ø. (2014). The effects of technostress within the context of employee use of ICT. *Computers in Human Behavior, 40*, 161–170. https://doi.org/10.1016/j.chb.2014.07.040

Galluch, P., Grover, V., & Thatcher, J. (2015). Interrupting the workplace: Examining stressors in an information technology context. *Journal of the Association for Information Systems*, *16*(1), 1–47. https://doi.org/10.17705/1jais.00387

Gimpel, H., Lanzl, J., Manner-Romberg, T., & Nüske, N. (2018). Digitaler Stress in Deutschland: Eine Befragung von Erwerbstätigen zu Belastung und Beanspruchung durch Arbeit mit digitalen Technologien. *Hans Böckler Stiftung*.

Gimpel, H., Berger, M., Regal, C., Urbach, N., Kreilos, M., Becker, J., & Derra, N. (2020). Belastungsfaktoren der digitalen Arbeit: Eine beispielhafte Darstellung der Faktoren, die digitalen Stress hervorrufen. *Projektgruppe Wirtschaftsinformatik des Fraunhofer FIT, Augsburg.* https://doi.org/10.24406/fit-n-581326

Hargrove, M. B., Quick, J. C., Nelson, D. L., & Quick, J. D. (2011). The theory of preventive stress management: a 33-year review and evaluation. *Stress and Health*, *27*(3), 182–193. https://doi.org/10.1002/smi.1417

Hong, W., Chan, F. K. Y., Thong, J. Y. L., Chasalow, L. C., & Dhillon, G. (2014). A framework and guidelines for context-specific theorizing in information systems research.

Information Systems Research, 25(1), 111–136. https://doi.org/10.1287/isre.2013.0501

Hung, W.-H., Chen, K., & Lin, C.-P. (2015). Does the proactive personality mitigate the adverse effect of technostress on productivity in the mobile environment? *Telematics and Informatics, 32*(1), 143–157. https://doi.org/10.1016/j.tele.2014.06.002

Jena, R. K. (2015). Technostress in ICT enabled collaborative learning environment: An empirical study among Indian academician. *Computers in Human Behavior, 51*, 1116–1123. https://doi.org/10.1016/j.chb.2015.03.020

Keeney, S., Hasson, F., & McKenna, H. (2006). Consulting the oracle: ten lessons from using the Delphi technique in nursing research. *Journal of Advanced Nursing, 53*(2), 205–212.

Ketter, W., Padmanabhan, B., Pant, G., & Raghu, T. S. (2020). Special issue editorial: Addressing societal challenges through analytics: An ESG ICE framework and research agenda. *Journal of the Association for Information Systems, 21*(5), 1115–1127. https://doi.org/10.17705/1jais.00631

Khedhaouria, A., & Cucchi, A. (2019). Technostress creators, personality traits, and job burnout: A fuzzy-set configurational analysis. *Journal of Business Research, 101,* 349–361. https://doi.org/10.1016/j.jbusres.2019.04.029

Kim, G., & Kim, S. (2014). How does technostress influence employees' role and performance in an organization? The moderating effect of innovation support. *Information Systems Review*, *16*(2), 97–124. https://doi.org/10.14329/isr.2014.16.2.097

Kitzinger, J. (1995). Qualitative research. Introducing focus groups. *BMJ Clinical Research 311*(7000), 299-302. https://doi.org/10.1136/bmj.311.7000.299

Kloker, S. (2020). Non-addictive information systems. *Information Systems Frontiers, 22*(3), 549–562. https://doi.org/10.1007/s10796-020-10011-w

LaMontagne, A. D., Keegel, T., & Vallance, D. (2007). Protecting and promoting mental health in the workplace: Developing a systems approach to job stress. *Health Promotion Journal of Australia: Official Journal of Australian Association of Health Promotion Professionals, 18*(3), 221–228. https://doi.org/10.1071/he07221

Landis, J. R., & Koch, G. G. (1977). The Measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159. https://doi.org/10.2307/2529310

Larsen, K. R., Hovorka, D., Dennis, A., & West, J. D. (2019). Understanding the elephant: The discourse approach to boundary identification and corpus construction for theory review articles. *Journal of the Association for Information Systems, 20*(7), 887-927. https://doi.org/ 10.17705/1jais.00556

Lazarus, R. S., & Folkman, S. (1984). *Stress, Appraisal, and Coping.* Springer.

Lee, M.-S., Lee, J., Park, B.-J., & Miyazaki, Y. (2015). Interaction with indoor plants may reduce psychological and physiological stress by suppressing autonomic nervous system activity in young adults: A randomized crossover study. *Journal of Physiological Anthropology, 34*(21). https://doi.org/10.1186/s40101-015-0060-8

Levy, Y., & Ellis, T. J. (2006). A systems approach to conduct an effective literature review in support of information systems research. *Informing Science: The International Journal of an Emerging Transdiscipline, 9*, 181-212 https://doi.org/10.28945/479

Linstone, H. A., & Turoff, M. (2002). *The Delphi Method: Techniques and Applications (second edition)*. Addison-Wesley Reading, MA.

Macik-Frey, M., Quick, J. C [James Campbell], & Nelson, D. L [Debra L.] (2007). Advances in occupational health: From a stressful beginning to a positive future. *Journal of Management*, *33*(6), 809–840.

Maier, C., Laumer, S., Eckhardt, A., & Weitzel, T. (2012). Online social networks as a source and symbol of stress: An empirical analysis. In *Proceedings of the 33rd International Conference on Information Systems (ICIS).*

Maier, C., Laumer, S., Weinert, C., & Weitzel, T. (2015). The effects of technostress and switching stress on discontinued use of social networking services: a study of Facebook use. *Information Systems Journal*, *25*(3), 275–308. https://doi.org/10.1111/isj.12068

Maier, C., Laumer, S., Wirth, J., & Weitzel, T. (2019). Technostress and the hierarchical levels of personality: a two-wave study with multiple data samples. European *Journal of Information Systems, 28*(5), 496–522. https://doi.org/10.1080/0960085X.2019.1614739

Manning, J. B., Blandford, A., Edbrooke-Childs, J., & Marshall, P. (2020). How contextual constraints shape midcareer high school teachers' stress management and use of digital support tools: Qualitative study. *Mental Health, 7*(4), e15416. https://doi.org/10.2196/15416

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. SAGE.

Murphy, L. R., & Sauter, S. L. (2004). Work organization interventions: State of knowledge and future directions. *Sozial- und Präventivmedizin*, *49*(2), 79–86. https://doi.org/10.1007/s00038-004-3085-z

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: an example, design considerations and applications. *Information & Management,* 42(1), 15–29. https://doi.org/10.1016/j.im.2003.11.002

Okoli, C., & Schabram, K. (2010). *A guide to conducting a systematic literature review of information systems research*. In Sprouts.

Ørngreen, R., & Levinsen, K. (2017). Workshops as a Research Methodology. *Electronic Journal of e-Learning*, *15*(1), 70–81.

Paré, G., Cameron, A.-F., Poba-Nzaou, P., & Templier, M. (2013). A systematic assessment of rigor in information systems ranking-type Delphi studies. *Information & Management, 50*(5), 207–217. https://doi.org/10.1016/j.im.2013.03.003

Pfaffinger, K. F., Reif, J. A. M., Spieß, E., & Berger, R. (2020). Anxiety in a digitalised work environment. *Gruppe. Interaktion. Organisation. Zeitschrift für Angewandte Organisationspsychologie (GIO*), 51(1), 25–35. https://doi.org/10.1007/s11612-020-00502-4

Pirkkalainen, H., Salo, M., Tarafdar, M., & Makkonen, M. (2019). Deliberate or instinctive? Proactive and reactive coping for technostress. *Journal of Management Information Systems*, *36*(4), 1179–1212. https://doi.org/10.1080/07421222.2019.1661092

Quick, J. C., & Quick, J. D. (1984). How good working relationships can help relieve pressures on the job. *Management Review*, *73*(5), 43–45.

Quick, J. D., Quick, J. C., & Nelson, D. L [D. L.]. (1998). The theory of preventive stress management in organizations. In C. Cooper (Ed.), *Theories of Organizational Stress (1st ed., pp. 246–268).* Oxford Univ. Press.

Quick, J. C., & Quick, J. D. (1979). Reducing stress through preventive management. *Human Resource Management (Pre-1986)*, *18*(3), 15.

Quick, J. C., Quick, J. D., Nelson, D. L., & Hurrell, J. J. (1997). *Preventive stress management in organizations* (rev. ed.). American Psychological Association.

Quick, J. C. (1992). Crafting an organizational culture: Herb's hand at South-west Airlines. *Organizational Dynamics, 21*(2), 45–56.

Quick, J. C., & Quick, J. D. (1984). *Organizational stress and preventive management. McGraw-Hill series in management.* McGraw-Hill.

Ragu-Nathan, T. S., Tarafdar, M., Ragu-Nathan, B. S., & Tu, Q. (2008). The consequences of technostress for end users in organizations: Conceptual development and empirical validation. *Information Systems Research, 19*(4), 417–433. https://doi.org/10.1287/isre.1070.0165

Revilla Munoz, O., Alpiste Penalba, F., & Fernandez Sanchez, J. (2016). The skills, competences, and attitude toward information and communications technology recommender system: An online support program for teachers with personalized recommendations. *New Review of Hypermedia and Multimedia, 22*(1-2, SI), 83–110. https://doi.org/10.1080/13614568.2015.1036132

Richardson, K. M., & Rothstein, H. R. (2008). Effects of occupational stress management intervention programs: a meta-analysis. *Journal of Occupational Health Psychology, 13*(1), 69.

Richter, S., & Richter, A. (2020). Digital nomads. *Business & Information Systems Engineering, 62*(1), 77–81. https://doi.org/10.1007/s12599-019-00615-1

Riedl, R., Kindermann, H., Auinger, A., & Javor, A. (2012). Technostress from a neurobiological perspective. *Business & Information Systems Engineering, 4*(2), 61–69. https://doi.org/10.1007/s12599-012-0207-7

Salo, M., Makkonen, M., & Hekkala, R. (2020). The interplay of IT users' coping strategies: Uncovering momentary emotional load, routes, and sequences. *MIS Quarterly, 44*(3), 1143–1175. https://doi.org/10.25300/MISQ/2020/15610

Salo, M., Pirkkalainen, H., Chua, C., & Koskelainen, T. (2017). Explaining information technology users' ways of mitigating technostress. In *Proceedings of the 25th European Conference on Information Systems (ECIS).*

Sarabadani, J. (2018). 10 years of research on technostress creators and inhibitors: synthesis and critique. In *Proceedings of the 24th Americas Conference on Information Systems (AMCIS)*.

Saunders, C., Wiener, M., Klett, S., & Sprenger, S. (2017). The impact of mental representations on ICT-related overload in the use of mobile phones. *Journal of Management Information Systems, 34*(3), 803–825. https://doi.org/10.1080/07421222.2017.1373010

Saxena, D., & Lamest, M. (2018). Information overload and coping strategies in the big data context: Evidence from the hospitality sector. *Journal of Information Science, 44*(3), 287–297. https://doi.org/10.1177/0165551517693712

Schmidt, M., Frank, L., & Gimpel, H. (2021). How adolescents cope with technostress: A mixed-methods approach. *International Journal of Electronic Commerce, 25*(2), 154-180. https://doi.org/10.1080/10864415.2021.1887696

Schmidt, R. C. (1997). Managing Delphi surveys using nonparametric statistical techniques. *Decision Sciences*, *28*(3), 763–774. https://doi.org/10.1111/j.1540-5915.1997.tb01330.x

Skinner, R., Nelson, R. R., Chin, W. W., & Land, L. (2015). The Delphi method research strategy in studies of information systems. *Communications of the Association for Information Systems, 37*. https://doi.org/10.17705/1CAIS.03702

Srivastava, S. C., Chandra, S., & Shirish, A. (2015). Technostress creators and job outcomes: Theorising the moderating influence of personality traits. *Information Systems Journal, 25*(4), 355–401. https://doi.org/10.1111/isj.12067

Stich, J.-F., Tarafdar, M., Stacey, P., & Cooper, C. (2019). Appraisal of email use as a source of workplace stress: A person-environment fit approach. *Journal of the Association for Information Systems,* 20, 132–160. https://doi.org/10.17705/1jais.00531

Strasser, A. (2016). Delphi method variants in information systems research: A taxonomy Development and application. *The Electronic Journal of Business Research Methods, 15*(2), 120-133.

Tams, S., Hill, K., Guinea, A. O. de, & et al. (2014). NeuroIS-alternative or complement to existing methods? Illustrating the holistic effects of neuroscience and self-reported Data in the context of technostress research. *Journal of the Association for Information Systems*, *15*(1), 723–752.

Tams, S., Thatcher, J. B., & Grover, V. (2018). Concentration, competence, confidence, and capture: An experimental study of age, interruption-based techno-stress, and task performance. *Journal of the Association for Information Systems*, *19*(9), 857–908. https://doi.org/10.17705/1jais.00511

Tarafdar, M., Cooper, C. L., & Stich, J.-F. (2019). The technostress trifecta - Techno eustress, techno distress and design: Theoretical directions and an agenda for research. *Information Systems Journal*, *29*(1), 6–42. https://doi.org/10.1111/isj.12169

Tarafdar, M., Pullins, E. B., & Ragu-Nathan, T. S. (2015). Technostress: negative effect on performance and possible mitigations. *Information Systems Journal, 25*(2), 103–132. https://doi.org/10.1111/isj.12042

Tarafdar, M., Tu, Q., & Ragu-Nathan, T. S. (2010). Impact of technostress on end-user satisfaction and performance. *Journal of Management Information Systems, 27*(3), 303–334. https://doi.org/10.2753/MIS0742-1222270311

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., & Ragu-Nathan, T. S. (2007). The impact of technostress on role stress and productivity. *Journal of Management Information Systems, 24*(1), 301–328. https://doi.org/10.2753/MIS0742-1222240109

Tarafdar, M., Tu, Q., Ragu-Nathan, T. S., & Ragu-Nathan, B. S. (2011). Crossing to the dark side: Examining creators, outcomes and inhibitors of technostress. *Communications of the ACM, 54*(9), 113. https://doi.org/10.1145/1995376.1995403

Then, K., Ranking, J., & All, E. (2015). Focus group research: what is it and how can it be used?. *Canadian Journal of Cardiovascular Nursing*, *24*(1):16-22.

Turel, O., & Gaudioso, F. (2018). Techno-stressors, distress and strain: the roles of leadership and competitive climates. *Cognition, Technology & Work, 20*(2), 309–324. https://doi.org/10.1007/s10111-018-0461-7

Valta, M., Pflügner, K., & Maier, C. (2021). Guiding companies to reduce technostress: A mixed-methods study deriving practice-oriented recommendations. In *Proceedings of the 54th Hawaii International Conference on System Sciences (HICSS).*

vom Brocke, J., Simons, A., Riemer, K., Niehaves, B., Plattfaut, R., & Cleven, A. (2015). Standing on the shoulders of giants: Challenges and recommendations of literature search in information systems research. *Communications of the Association for Information Systems, 37(1)*, 205–224.

Webster, J., & Watson, R. T. (2002). Guest editorial: Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, *26*(2), 13–23.

Weinert, C., Maier, C., Laumer, S., & Weitzel, T. (2020). Technostress mitigation: An experi-mental study of social support during a computer freeze. *Journal of Business Economics, 90*(8), 1199–1249.https://doi.org/ 10.1007/s11573-020-00986-y

Weinstein, E. C., Selman, R. L., Thomas, S., Kim, J.-E., White, A. E., & Dinakar, K. (2016). How to cope with digital stress: The recommendations adolescents offer their peers online. *Journal of Adolescent Research, 31*(4), 415–441. https://doi.org/10.1177/0743558415587326

Wiholm, C., Arnetz, B., & Berg, M. (2000). The impact of stress management on computer-related skin problems. *Stress Medicine, 16*(5), 279–285. https://doi.org/10.1002/1099-1700(200010)16:5<279::AID-SMI866>3.0.CO;2-H

Yu, T.-K., Lin, M.-L., & Liao, Y.-K. (2017). Understanding factors influencing information communication technology adoption behavior: The moderators of information literacy and digital skills. *Computers in Human Behavior, 71*, 196–208. https://doi.org/10.1016/j.chb.2017.02.005

Yun, H., Kettinger, W. J., & Lee, C. C. (2012). A new open door: The smartphone's impact on work-to-life conflict, stress, and resistance. *International Journal of Electronic Commerce*, *16*(4), 121–152. https://doi.org/10.2753/JEC1086-4415160405

Zuppo, C. M. (2012). Defining ICT in a boundaryless world: The development of a working hierarchy. *International Journal of Managing Information Technology, 4,* 13-22. https://doi.org/ 10.5121/IJMIT.2012.4302

3.1.9 Appendix

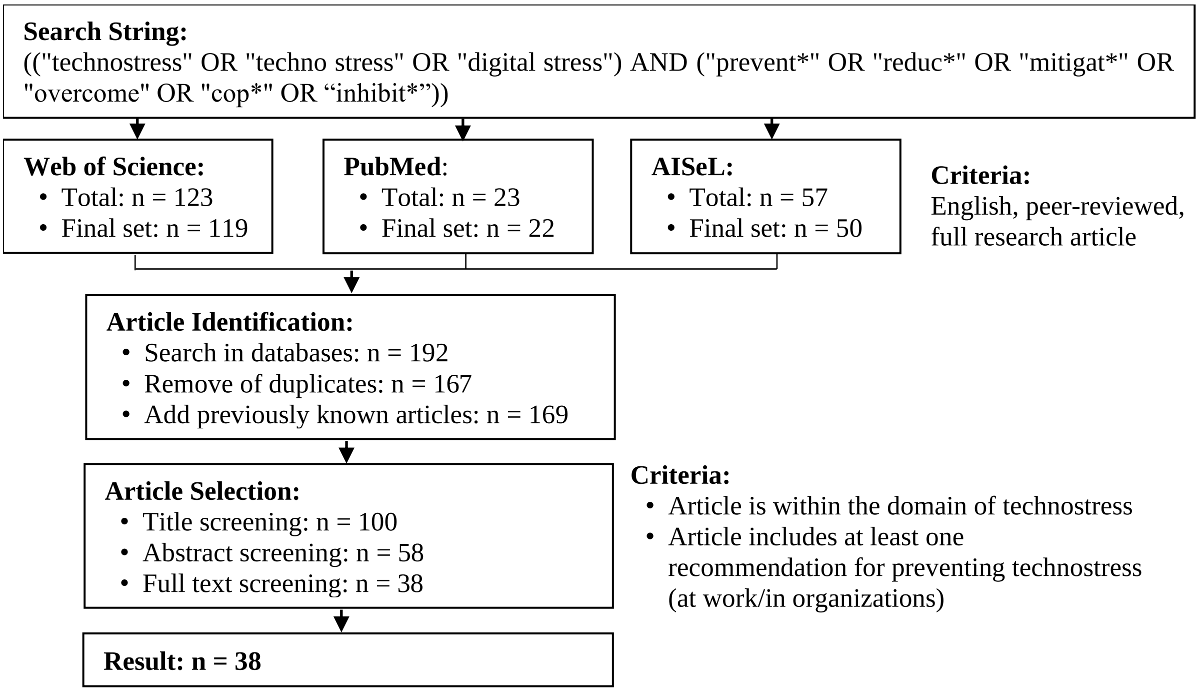

Figure 3.1-5 Literature review process

Study	**Context**	**Mentioned potential prevention measures**	**Used as an input for following prevention measure**
Adam et al. (2017)	Work-related technostress	Stress-sensitive adaptive enterprise systems to support users to reduce technostress	(18) Provide supportive ICTs
Al-Fudail and Mellar (2008)	Technostress of teachers	Resources (reliable technology), social support (mentoring), technical support, IT training	(16) Train mentors for digital topics (19) Provide ICT support (23) Provide ICT training
Arnetz (1996)	Work-related technostress	Healthy and productive design of the workplace, training programs	(2) Adopt a stress-sensitive digital workplace design (23) Provide ICT training
A. Benlian (2020)	Technostress spillovers from work to home	Social support (coaching), facilitates employees' awareness of technostress through mentoring, supportive culture concerning accessibility, management leadership	(6) Foster a cooperative culture (7) Develop a mission statement for digital collaboration (13) Train managers to successfully lead in the digital working world (16) Train mentors for digital topics (24) Foster sensitization and self-reflection regarding technostress
Cao and Yu (2019)	Technostress through social media at work	Sensibilization and awareness to enable behavior changes for social media usage that is actively managed	(17) Train effective self-management and time management (24) Foster sensitization and self-reflection regarding technostress

Study	**Context**	**Mentioned potential prevention measures**	**Used as an input for following prevention measure**
Caro and Sethi (1985)	Work-related technostress	Technological planning, culture, technostress monitoring systems, self-development programs	(3) Apply human-centered release management (18) Provide supportive ICTs (6) Foster a cooperative culture (23) Provide ICT training
Carolan et al. (2017)	Work-related technostress	Discussion groups, time management, information on stress	(17) Train effective self-management and time management (22) Offer platforms to exchange experience on ICT use (24) Foster sensitization and self-reflection regarding technostress
Chandra et al. (2019)	Technostress and employee innovation	Sensibilization, training, social support (mentor)	(16) Train mentors for digital topics (23) Provide ICT training (24) Foster sensitization and self-reflection regarding technostress
Chen et al. (2019)	Technostress through mobile apps in leisure time	Sensibilization, self-reflection, time management, monotasking	(17) Train effective self-management and time management (20) Train monotasking (24) Foster sensitization and self-reflection regarding technostress
D'Arcy et al. (2014)	Security-related technostress	Helpdesk, awareness programs, education, and awareness security policies	(18) Provide supportive ICTs (6) Foster a cooperative culture (8) Introduce an employee data security concept (19) Provide ICT support (11) Develop team norms for the use of ICTs (23) Provide ICT training (24) Foster sensitization and self-reflection regarding technostress
Day et al. (2012)	Work-related technostress	Assistance like helpdesk, mentor, leader, culture, and clear communication guidelines	(18) Provide supportive ICTs (6) Foster a cooperative culture (7) Develop a mission statement for digital collaboration (19) Provide ICT support (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (16) Train mentors for digital topics
Delpechitre et al. (2019)	Salespeople's technostress	Increase self-efficacy	(23) Provide ICT training
Elie-Dit-Cosaque et al. (2011)	Work-related technostress	Top management support, supportive leadership style	(13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes

Study	**Context**	**Mentioned potential prevention measures**	**Used as an input for following prevention measure**
Fuglseth and Sørebø (2014)	Work-related technostress	Helpdesk, supportive leadership style, end-user training, user involvement, knowledge sharing	(3) Apply human-centered release management (19) Provide ICT support (11) Develop team norms for the use of ICTs (23) Provide ICT training (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (22) Offer platforms to exchange experience on ICT use
Galluch et al. (2015)	Work-related technostress	Timing control, method control, resource control	(11) Develop team norms for the use of ICTs (17) Train effective self-management and time management
Hung et al. (2015)	Personality and technostress	Proactive personality traits (training, self-reflection)	(24) Foster sensitization & self-reflection regarding technostress
Khedhaouria and Cucchi (2019)	Technostress of senior managers	Self-management, time-management, availability, supportive leadership style	(12) Establish reachability management (17) Train effective self-management and time-management (13) Train managers to successfully lead in the digital working world (20) Train monotasking
Kim and Kim (2014)	Work-related technostress	Supportive leadership style, helpdesk	(19) Provide ICT support (13) Train managers to successfully lead in the digital working world
Kloker (2020)	Technostress in daily lives	Situation management, gratification management, expectation management	(24) Foster sensitization and self-reflection regarding technostress
M.-S. Lee et al. (2015)	Technostress in general	Interaction with indoor plants	(2) Adopt a stress-sensitive digital workplace design
Manning et al. (2020)	Technostress of high school teacher	Trustful culture, leading style	(18) Provide supportive ICTs (6) Foster a cooperative culture (13) Train managers to successfully lead in the digital working world
Pfaffinger et al. (2020)	Work-related technostress	Expectation management, training, self-management, time-management, leadership style, helpdesk	(11) Develop team norms for the use of ICTs (19) Provide ICT support (12) Establish reachability management (23) Provide ICT training (17) Train effective self-management and time management (13) Train managers to successfully lead in the digital working world (14) Train managers for leading of distributed team members

Study	Context	Mentioned potential prevention measures	Used as an input for following prevention measure
Pirkkalainen et al. (2019)	Work-related technostress	Training to raise awareness, encourage self-reflection, and self-management	(4) Apply human-centered ICT design (23) Provide ICT training (24) Foster sensitization and self-reflection regarding technostress (17) Train effective self-management and time management
Ragu-Nathan et al. (2008)	Work-related technostress	Organizational and technological support, user involvement	(3) Apply human-centered release management (4) Apply human-centered ICT design (6) Foster a cooperative culture (19) Provide ICT support (10) Consciously manage ICT-related change (23) Provide ICT training (15) Provide role models with technological changes
Revilla Munoz et al. (2016)	Technostress of Teachers	Support program	(19) Provide ICT support (22) Offer platforms to exchange experience on ICT use
Richter and Richter (2020)	Technostress of digital nomads	Expectation management	(7) Develop a mission statement for digital collaboration (11) Develop team norms for the use of ICTs
Saunders et al. (2017)	Techno-overload	Monotasking	(20) Train monotasking
Saxena and Lamest (2018)	Technostress on a business manager	Personal and organizational coping (supportive systems, monotasking, training, helpdesk)	(18) Provide supportive ICTs (7) Develop a mission statement for digital collaboration (19) Provide ICT support (17) Train effective self-management and time management (13) Train managers to successfully lead in the digital working world
Stich et al. (2019)	Technostress through E-mail Usage	Self-reflection on e-mail usage, expectation management concerning individual's preferences concerning e-mail overload	(7) Develop a mission statement for digital collaboration (11) Develop team norms for the use of ICTs (24) Foster sensitization and self-reflection regarding technostress
Tarafdar et al. (2007)	Work-related technostress	ICT training, communication about the need of ICT, leadership style, discussion forums	(23) Provide ICT training (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (22) Offer platforms to exchange experience on ICT use

Study	Context	Mentioned potential prevention measures	Used as an input for following prevention measure
Tarafdar et al. (2015a)	Work-related technostress	Self-efficacy, organizational mechanism (helpdesk), technology competence, user involvement	(3) Apply human-centered release management (19) Provide ICT support (23) Provide ICT training
Tarafdar et al. (2010)	Work-related technostress	User involvement in the design of IS and change management	(3) Apply human-centered release management (4) Apply human-centered ICT design
Turel and Gaudioso (2018)	Work-related technostress	Supportive leadership style and culture with less competition	(6) Foster a cooperative culture (11) Develop team norms for the use of ICTs (13) Train managers to successfully lead in the digital working world
Weinert et al. (2020)	Individual perspective of technostress mitigation	Instrumental and social support	(19) Provide ICT support (16) Train mentors for digital topics
Weinstein et al. (2016)	Technostress in daily lives	Online discussion forums	(22) Offer platforms to exchange experience on ICT use
Wiholm et al. (2000)	Work-related technostress	Stress management training	(24) Foster sensitization and self-reflection regarding technostress (17) Train effective self-management and time management
Yu et al. (2017)	Technology adaption	Training, user involvement for selection of media, and the design of technology	(17) Train effective self-management and time management (23) Provide ICT training
Yun et al. (2012)	Office-home smartphones and technostress	Supportive culture to minimize work-to-life conflict and tools to support this	(6) Foster a cooperative culture (18) Provide supportive ICTs

Table 3.1-5 Result of the literature review

Code	Role	Workshop
Part1	Researcher focusing on the digitalization of the workplace working for a German university	First
Part2	Head of human resources department in an SME focusing on customer acquisition and retention	First
Part3	Member of the works council working for a manufacturer of entertainment and communication technology with over 2,000 employees	First
Part4	An employee working for an SME focusing on customer acquisition and retention	First
Part5	Professor for business and information systems engineering at a German university	First
Part6	A person in charge of psychological risk assessments working for an occupational health management service provider responsible for over one million employees	Both
Part7	Consultant with a focus in working-time and work organization focusing on SME	Both
Part8	Psychologist and trainer working for an occupational health management service provider responsible for over one million employees	Both
Part9	An emergency psychologist working for an occupational health management service provider responsible for over one million employees	Second
Part10	A researcher with a focus in working-time and work organization at a federal institute focusing on occupational safety and health	Second

Table 3.1-6 Participants of the focus group workshops

Code	Role
Exp1	Senior ombudsman for severely disabled persons at an aircraft manufacturer responsible for health management
Exp2	Experienced employer representative working for the employers' association for a major industry in the country
Exp3	Occupational physician in the field of healthiness and well-being for a large workers' compensation company
Exp4	Former vice-chairman of a works council and lecturer at a training institute for works councils focusing among others on remote work and stress management
Exp5	Employee representative working for a national trade union center for a large trade union in the country
Exp6	Scientific director of a federal institute focusing on occupational safety and health management
Exp7	Senior researcher at an institute focusing on remote work and qualification
Exp8	Head of health management at the human resources department for a company in the construction industry
Exp9	Senior safety specialist at the human resources department for a company in the construction industry responsible for corporate health measures, among others stress management and remote work
Exp10	Occupational safety specialist at the human resources department for a company in the baking industry, responsible for stress management in the company
Exp11	Systemic consultant in and with organizations for a company in the baking industry regarding health and stress management
Exp12	Head of occupational safety at the human resources department for a company in the construction industry responsible for corporate health measures, among others during remote work
Exp13	26 years experience with psychosocial counseling and psychological coaching for employees and managers in large companies as a social consultant with a focus on, e.g., work-life-balance, stress, remote working

Table 3.1-7 Delphi study panelists

#	Technostress Prevention Measure	Prevention Type	Entity of Change	Target Group	Organization Size	Implementation Duration	Realization Duration	Effect Duration
1	Focus the ICT landscape	Primary	Technology	All	Min. 50	1-3 years	Less than 0.5 years	1-3 years
2	Adapt a stress-sensitive digital workplace design	Primary	Technology	All	Min. 10	1-3 years	Less than 0.5 years	1-3 years
3	Apply human-centered release management	Primary	Technology	All	Min. 50	Less than 1 year	0.5-1 year	1-3 years
4	Apply human-centered ICT design	Primary	Technology	All	Min. 50	Less than 1 year	Less than 0.5 years	1-3 years
5	Use gamification	Primary	Technology	All	Min. 50	1-3 years	0.5-1 year	Less than 1 year
6	Foster a cooperative culture	Primary	Organization	All	Min. 50	1-3 years	More than 1 year	1-3 years
7	Develop a mission statement for digital collaboration	Primary	Organization	All	Min. 50	1-3 years	0.5-1 year	1-3 years
8	Introduce an employee data security concept	Primary	Organization	All	Min. 10	Less than 1 year	Less than 0.5 years	1-3 years
9	Agree on binding ICT usage guidelines	Primary	Organization	All	Min. 50	1-3 years	0.5-1 year	1-3 years
10	Consciously manage ICT-related change	Primary	Organization	All	Min. 50	1-3 years	0.5-1 year	1-3 years
11	Develop team norms for the use of ICTs	Primary	Organization	All	Min. 50	More than 3 years	Less than 0.5 years	1-3 years

Table 3.1-8 Characterization of prevention measures (1-11) in terms of their basic approach to technostress prevention and their applicability in practice

#	Technostress Prevention Measure	Prevention Type	Entity of Change	Target Group	Organization Size	Implementation Duration	Realization Duration	Effect Duration
12	Establish reachability management	Primary	Organization	All	Min. 10	Less than 1 year	0.5-1 year	Less than 1 year
13	Train managers to successfully lead in the digital working world	Primary	Individual	Mgmt.	Min. 50	1-3 years	0.5-1 year	1-3 years
14	Train managers for leading of distributed team members	Primary	Individual	Mgmt.	Min. 50	1-3 years	0.5-1 year	1-3 years
15	Provide role models with technological changes	Primary	Individual	Mgmt.	Min. 50	1-3 years	0.5-1 year	1-3 years
16	Train mentors for digital topics	Primary	Individual	All	Min. 250	Less than 1 year	Less than 0.5 years	1-3 years
17	Train effective self-management and time management	Primary	Individual	All	Min. 10	Less than 1 year	0.5-1 year	Less than 1 year
18	Provide supportive ICTs	Secondary	Technology	All	Min. 10	Less than 1 year	Less than 0.5 years	Less than 1 year
19	Provide ICT support	Secondary	Organization	All	Min. 250	Less than 1 year	Less than 0.5 years	1-3 years
20	Train monotasking	Secondary	Individual	All	Min. 10	Less than 1 year	Less than 0.5 years	1-3 years
21	Train technostress coping competencies	Secondary	Individual	All	Min. 10	Less than 1 year	Less than 0.5 years	Less than 1 year
22	Offer platforms to exchange experience on ICT use	Secondary	Individual	All	Min. 50	Less than 1 year	0.5-1 year	1-3 years
23	Provide ICT training	Secondary	Individual	All	Min. 10	1-3 years	0.5-1 year	1-3 years
24	Foster sensitization and self-reflection regarding technostress	Secondary	Individual	All	Min. 10	Less than 1 year	0.5-1 year	Less than 1 year

Table 3.1-9 Characterization of prevention measures (12-24) in terms of their basic approach to technostress prevention and their applicability in practice

PM	**Complex-ity**	**Insecu-rity**	**Inter-ruptions**	**Invasion**	**Invasion of Privacy**	**Overload**	**Role Ambigu-ity**	**Uncer-tainty**	**Unrelia-bility**	**∑ crea-tors**
1	6,00 (11x)						5,92 (13x)		5,08 (13x)	**3**
2			4,85 (13x)						4,00 (11x)	**2**
3	5,00 (10x)									**1**
4	6,00 (13x)				5,00 (11x)		5,92 (13x)		6,00 (13x)	**4**
5								5,58 (12x)		**1**
6		4,92 (13x)		5,00 (13x)	5,09 (11x)					**3**
7										**0**
8					5,23 (13x)					**1**
9					5,15 (13x)					**1**
10	4,92 (12x)									**1**
11			5,08 (13x)	5,83 (12x)	5,00 (12x)					**3**
12			6,00 (13x)	6,00 (13x)		4,83 (12x)				**3**
13		6,00 (12x)		5,85 (13x)	5,00 (11x)			4,92 (13x)		**4**
14										**0**
15	5,92 (13x)	5,92 (13x)								**2**
16		6,00 (12x)					5,08 (12x)	5,15 (13x)		**3**
17			5,00 (13x)	5,92 (12x)		5,17 (12x)				**3**
∑	**5**	**4**	**4**	**5**	**6**	**2**	**3**	**3**	**3**	

Table 3.1-10 Detailed results on the relevance of primary prevention measures to reduce technostressors

3.2 Considering Characteristic Profiles of Technologies at the Digital Workplace: The Influence on Technostress

Abstract: Workplaces develop more and more to digital workplaces. However, this may lead to technostress. An understanding of the profiles of technologies used at the digital workplace, their interplay, and how they influence technostress is valuable as it can assist developers of technologies and designers of workplaces to prevent technostress. Therefore, we analyze literature and conduct expert interviews to identify ten characteristics of digital technologies that relate to technostress. By analyzing data from 4,560 employees, we evaluate the characteristics. Furthermore, we develop characteristic profiles of multiple technologies used at the respondent's digital workplace. Lastly, we investigate their influence on technostress creators using structural equation modeling. We find that the different portfolios of technology profiles influence technostress creators in different manners. Our contributions are identifying additional characteristics of digital technologies, showing the importance of investigating workplaces as a whole, and highlighting design opportunities for health-oriented workplaces that alleviate technostress.

Keywords: Digital technologies, characteristics of digital technologies, digital workplace, technostress, digital stress, mixed methods research, structural equation modeling

Authors: Julia Becker, Michelle Berger, Henner Gimpel, Julia Lanzl, Christian Regal

Status: This article is published in the proceedings of the 41st International Conference on Information Systems (ICIS), a remote conference due to COVID-19, 2020.

3.2.1 Introduction

Digitalization, driven by a wide variety of digital technologies, has led to multifaceted changes for individuals, economies, and society (Fitzgerald et al., 2013; Gimpel et al., 2018a). Digital technologies are ubiquitous in private but also in business lives. They have changed the workplace from a narrowly defined and time-bound place to a partly virtual and temporally and locally independent existence (Zuppo 2012). At the beginning of the year 2020, the COVID-19 pandemic led to the imposition of confinement or contact restrictions in many countries. Work was transferred to home offices where possible. For many, this meant a new level of virtual work. This may have a long-term impact on the equipment of many workplaces with digital technologies and their use even after the end of the pandemic.

Digital technologies include devices like smartphones or tablets but also applications that can facilitate business processes by providing tools for inter- and intra-organizational communication and collaboration (Zuppo 2012). Today's workplace does not only consist of a single digital technology but many, which enable effective ways of working, defined as a digital workplace (Gartner 2020). The design of the digital workplace has become an important factor in increasing the productivity of knowledge workers (Köffer 2015). However, the increased usage of digital technologies in the changing world of work may cause stress, leading to potentially negative reactions in individuals. Research has noted this specific form of stress as technostress (Ayyagari et al., 2011; Tarafdar et al., 2007; Tarafdar et al,. 2011; Tarafdar et al., 2019), which has first been introduced by clinical psychologist Craig Brod as “a modern disease [caused by one’s] inability to cope with new computer technologies in a healthy manner” (Brod 1984, p. 16).

In the last years, researchers focused on different aspects of technostress including technostress creators (e.g. Tarafdar et al. (2007) , strains (e.g. Gimpel et al. (2018b)), technostress inhibitors (e.g. Ragu-Nathan et al. (2008) and coping behaviors (e.g. Pirkkalainen et al. (2019)). Ayyagari et al. (2011) emphasized the question of which role the different characteristics of digital technologies play in terms of technostress. The characteristics of digital technologies refer to the functional and non-functional features perceived by the user, which can be pursued directly or indirectly. Many other researchers followed the call of Ayyagari et al. (2011) that their list of proposed characteristics might not be exhaustive and that the introduction of new technologies in the future might also result in new characteristics. Therefore, Maier et al. (2015) analyzed characteristics of enterprise resource planning (ERP) systems, Salo et al. (2019) focused on characteristics of social network services, and Hung et al. (2015) regarded mobile phone characteristics influencing technostress. In summary, there exist additional characteristics resulting from further research focusing on specific technologies or contexts that extend the list of Ayyagari et al. (2011). However, to eliminate the black box phenomenon between technologies and technostress, further research is needed. Currently, there is no research that uses the extended list of characteristics to analyze their influence on technostress and no review of whether there are also other characteristics beyond that.

Furthermore, Ayyagari et al. (2011) analyzed the influence of technology characteristics on technostress by incorporating all digital technologies that are used at the workplace of their respondents without referring to a specific technology. Therefore, it is not ensured that respondents only think about one digital technology they use at work when answering the questionnaire. Instead, it is conceivable that the respondents mix their perception of using many different digital technologies, maybe even with those they use at home. This is also one of the significant drawbacks that Ayyagari et al. (2011) mentioned by themselves in their limitations section. However, analyzing the relation between the characteristics of one specific technology and technostress might seem to be by far more precise and concrete, as it does not mix-up and allow for bias when participants have different technologies in mind. On the other side, it does not properly reflect reality. Typically, people use a combination, and hence, the assessment of technostress incorporates the experiences with multiple digital technologies and not only with a specific technology. However, there are no considerations to assess the characteristics of specific digital technologies building digital technology profiles in order to summarize these across all technologies used at the user's workplace to explain the connection with technostress. Research on the design of digital workplaces examined people-focused and process-focused design approaches, in which information exchange and sharing documents or project support was regarded, without the impact on technostress (Williams and Schubert 2018). Therefore, an understanding of characteristics of digital technologies, their interplay at the workplace, and how they influence technostress will be valuable as it can assist developers of digital technologies and designers of workplaces in a way that can prevent technostress.

Therefore, we aim to add to technostress literature by addressing the following three research questions (RQ):

RQ3.2-1: *Which characteristics of digital technologies with relation to technostress exist?*

RQ3.2-2: *How does the characteristic profile of specific digital technologies look like?*

RQ3.2-3: *What is the influence of characteristic profiles of digital technologies used at the workplace on technostress?*

In order to answer our research questions, we apply mixed methods. First, we conceptualize the relevant characteristics of digital technologies based on extant literature and qualitative research. Next, to be able to evaluate the characteristics quantitatively, we collect existing items scales, develop new multi-item scales where necessary, and perform an initial reliability and validity test of our scales via card-sorting and a quantitative pre-test. Then, we further validate the scales in a large-scale survey with both exploratory (EFA) and confirmatory factor analyses (CFA). Based on survey data, we develop characteristic profiles of multiple specific technologies used at the respondent's workplace and determine their influence on technostress using structural equation modeling (SEM).

Our paper is structured as follows: Section 3.2.2 introduces the theoretical background, including the characteristics of digital technologies that have already been found to influence technostress. Section 3.2.3 presents the methodology, while section 3.2.4 describes the development of the digital technology profiles based on interviews with experts and focus groups as well as a survey with 4,560 users of digital technologies in different organizations. Section 3.2.5 analyzes the relationship between the developed digital technology profiles of specific technologies with technostress. Finally, section 3.2.6 discusses these results and concludes the paper.

3.2.2 Theoretical Background and Related Work

Digital workplaces are characterized by the set of digital technologies provided to execute one's work effectively, irrespective of the location, and whether the task is performed alone or with others (Williams & Schubert 2018). Bharadwaj et al. (2013, p. 471) define digital technologies as "combinations of information, computing, communication, and connectivity technologies" and refer to the importance of the interplay of digital technologies. Digital technologies include social, mobile, analytics, and cloud technologies, as well as the internet of things, and are known by the SMACIT acronym (Sebastian et al., 2017). Vial (2019) also includes platforms, the internet, software, and blockchain to the term of digital technologies, whereas only platforms are mentioned frequently in research articles (Tan et al., 2015; Tiwana et al., 2010). Elements of a digital workplace include digital technologies accessible by every stakeholder and interaction is possible without any physical limitations (Dahlan et al., 2018). The objective of digital workplaces is to improve collaboration and communication in the organization and has gained relevance in the past years (Yalina 2019). The design of a digital workplace is crucial for the worker's productivity, especially for knowledge workers (Köffer 2015; Yalina 2019). People-focused and process-focused design principles exist, dealing with information exchange and project support issues (Williams and Schubert 2018). Dery et al. (2017) illustrated how one can successfully design digital workplaces to drive organizational success. They mention that positive employee experiences of collaborating with others and dealing with the complexity of digital workplaces enable innovation and name possible improvements for the digital workplace, including fast log-in and mobility, but do not consider the possible effects on the individuals' well-being.

Besides the positive effects of the use of digital technologies including an increase in productivity, effectiveness, and efficiency (Bharadwaj 2000; Melville et al., 2004), research has shown the potential of digital technologies to cause technostress, as a specific form of stress that is perceived by end-users of digital technologies (Brod 1984; Ragu-Nathan et al., 2008). Technostress is not created by the technology itself but emerges from the interaction of human users with digital technologies. Whether technostress emerges depends on the user's resources, capabilities, assessments, and the type of technology (Gimpel et al., 2019). Ayyagari et al. (2011) developed a technostress framework consisting of the main concepts of stress (technostress creators and strains) and the IT artifact consisting of technology characteristics (see Figure 3.2-1). Following this framework, a user's perception of features and attributes of digital technology (technology characteristics) can lead to stress-creating stimuli which again create responses and outcomes for the user (strains) (Ayyagari et al., 2011; Salo et al., 2019).

Figure 3.2-1 Technostress framework by Ayyagari et al. (2011)

Digital technologies can be characterized in different ways depending on the point of view, e.g., along with their physical components, approaches, and concepts (Berger et al., 2018). Concerning the link of digital technologies with technostress, prior research analyzed characteristics of single digital technologies (Hung et al., 2015; Salo et al., 2019; Westermann et al., 2015) or digital technologies in general (Ayyagari et al., 2011; Tarafdar et al., 2007). Analyzing social networking services as one digital technology, Salo et al. (2019) found two main characteristics: (1) self-disclose features regarding information about oneself and (2) information cue paucity referring to the limited, one-sided information delivery. Hung et al. (2015) characterized mobile technologies by high accessibility, mobility, ubiquity, and connectivity. Additionally, Westermann et al. (2015) found that push notifications are often assessed to be disturbing, which can also be seen as a characteristic. Ayyagari et al. (2011) defined characteristics of digital technologies in general based on how individuals perceive them in use. Ayyagari et al. (2011) found six characteristics categorized in usability, dynamic, and intrusive features. Usability features are usefulness, complexity, and reliability. The single dynamic feature is the pace of change. Intrusive features are presenteeism and anonymity. Adding to these six characteristics, Tarafdar et al. (2019) mention mobility.

Regarding technostress creators, Tarafdar et al. (2007) and Ragu-Nathan et al. (2008) developed and empirically validated scales for five factors, which create technostress among individuals. The first dimension is techno-overload, describing situations where greater workload and higher speed are caused by digital technologies. Secondly, techno-invasion describes the effect of being constantly reachable and connected, leading to a blurring boundary between work and private life. The third creator is called techno-complexity, which describes the feeling of not having the needed skills and experiences to deal with the complexity of digital technologies and being forced to spend time and effort in learning it. Techno-insecurity describes the fear of losing one's jobs due to automation or missing skills to deal with digital technologies. Lastly, techno-uncertainty refers to the feeling of having to constantly develop one's abilities and knowledge due to continuing technology changes and upgrades.

Prior research has also pointed out the outcomes of technostress. The most recorded strain is the negative effect on end-user satisfaction, followed by job satisfaction, performance, productivity, and organizational commitment (Sarabadani et al., 2018). Tarafdar et al. (2007) stated that higher technostress results in lower productivity. Ragu-Nathan et al. (2008) showed that technostress creators decrease job satisfaction as well as organizational and continuance commitment. Both are emphasized by Tu et al. (2005), who found that next to lower productivity, also higher employee turnover can result from technostress. Concerning individuals' health, Mahapatra and Pati (2018) found that, in an Indian context, techno-invasion and techno-insecurity can lead to burnout which, in turn, is associated with several negative outcomes on the organizational and individual level including lower productivity, job satisfaction, and higher absenteeism as well as depression and anxiety (Maslach et al., 2001). For German employees, Gimpel et al. (2018b) found that higher levels of technostress go along with a higher number of people reporting to suffer from headaches, fatigue, sleeping problems, and exhaustion, for example.

3.2.3 Research Process

As we strive to answer three interconnected questions, our research process is divided into three parts, each of them applying a combination of various methods. We conduct a mixed-methods approach, as described by Venkatesh et al. (2013). It includes and integrates qualitative as well as quantitative investigations, which, according to Venkatesh et al.'s (2013) scheme, serve developmental purposes.

First of all, we aim to identify the characteristics of digital technologies that relate to technostress. For identifying and conceptualizing the characteristics of digital technologies, we follow steps one to six of the process of MacKenzie et al. (2011). We conduct a literature research and interviews with experts and focus groups. Based on this, we develop multi-item survey scales for the characteristics of specific digital technologies. The scales and individual items are refined based on results from card-sorting regarding their content and face validity. Next, we perform a pre-test and an exploratory factor analysis (EFA) and, again, refine the scales and individual items.

Second, the resulting scales are then used in a large-scale quantitative survey. For the validation, the data is split into two random subsets. On the first subset, an additional EFA is carried out to examine the revised items. Finally, a confirmatory factor analysis (CFA) is performed on the second subset to validate the scales. Furthermore, we used the data to calculate a normed characteristics profile for specific technologies by aggregating the answers across many respondents.

Third, as we argue that technostress does not solely depend on the usage of a single technology but on the combination of all technologies used at the workplace, we, hence, use in the further course the digital technology profiles of the used technologies at the respondents' workplace. Therefore, we use covariance-based structural equation modeling (SEM) to estimate the effect on technostress.

3.2.4 The Development of Digital Technology Profiles

3.2.4.1 Theoretical Conceptualization

In order to build the foundation for our research, in a first step, we conducted a literature search. The focus was to identify technologies and their characteristics in relation to technostress (creators). To cover the full picture, the search additionally comprised literature of linked outcomes like stress and strain (including health and well-being). The list covered a broad picture of literature in different areas. Databases, namely EBSCO Business Source Premier, EBSCO Academic Search Premier, EBSCO Psych, Web of Science, and PubMed, were searched in the languages English and German. Because the seminal paper by Tarafdar et al. (2007) was published in 2007, only publications from this year onwards were included. The list of search strings is available in Supplemental Material A (Table 3.2-7). Types of publications that were considered are (academic) journals, reviews, proceedings, books, book chapters, and dissertations. Overall, 273 articles relevant for our research were identified.

To enrich the insights from the literature research, we interviewed practitioners and experts. The semi-structured interview guideline included questions about technostress creators, technologies for which usage may cause stress, and technology characteristics, which the subjects believed to cause stress and stressful usage behaviors. The complete interview guideline can be found in Supplemental Material B (Table 3.2-8). In total, 15 people participated in face-to-face interviews, including employee and employer representatives, experts from occupational health management, ethics, ergonomics, informatics, and human resource management. Each interview lasted between 30 and 90 minutes. The number of interviews was determined by content saturation, meaning interviews were conducted until no new aspects were identified and named by our experts. Interviews were audio-recorded, transcribed, and continuously analyzed through MAXQDA with a formalized coding strategy. Categories were built deductively because the interviews were structured in sections with questions concerning technologies, their characteristics, and how these exactly relate to technostress. These particular aspects guided the analysis to gain a better understanding of the relationship.

Following on from this, six focus groups were conducted (between 5 and 8 participants each) consisting of employees and managers from four different organizations (n=33). The groups covered different occupational groups and hierarchies. Participants were contacted by a responsible from the respective company and were asked to take part voluntarily. The groups almost got identical task descriptions to the experts. First, they named the technologies they use at the workplace and their characteristics. They rated which of these caused the most stress. Besides, they were asked for (short-term and long-term) consequences and successful strategies to cope with the stress. The guideline for the focus group workshop is available in Supplemental Material C (Table 3.2-9). The aim was to get insights from the practical perspective and collect examples for aspects that were named by our experts. All group discussions were recorded by an observer and the results documented in a picture protocol. Again, the results were written down, coded, and aggregated. For the technologies, for example, categories were identified when they named one specific software product (e.g., Edge as an example for an Internet browser). The result of these steps is a conceptual understanding of nine characteristics of digital technologies relating to technostress. See Table 3.2-1 for their definition. Please note that in a later quantitative pre-test, one characteristic (information provision) was split into two (push and pull). For brevity of presentation, Table 3.2-1 already shows this split. Simplicity of use refers to the characteristic complexity by Ayyagari et al. (2011). It was renamed to avoid confusion with the technostress creator techno-complexity (Ragu-Nathan et al., 2008). Reachability refers to the characteristic presenteeism by Ayyagari et al. (2011) and was renamed to avoid confusion with a common psychological phenomenon describing the feeling of obligation by employees to go to work even though they are ill.

Characteristic	**Definition**
Anonymity	Degree to which the use of a digital technology stays anonymous and cannot be identified by others (in accordance with Ayyagari et al. (2011)).
Intangibility of Results	Degree to which results of the work with a digital technology are immaterial in nature and therefore intangible (self-developed).
Mobility	Degree to which a digital technology is useable independent of the location and enables to work from almost anywhere (self-developed).
Pace of Change	Degree to which a digital technology changes dynamically and rapidly (in accordance with Ayyagari et al. (2011)).
Pull[9]	Degree to which information of a digital technology is provided only on request (self-developed).
Push9	Degree to which a digital technology automatically provides new information while using it (in accordance with Westermann et al. (2015)).
Reachability	Degree to which a digital technology enables the individual to be contacted by third parties (in accordance with presenteeism in Ayyagari et al. (2011)).
Reliability	Degree to which a digital technology works reliably and is free of errors and crashes (in accordance with Ayyagari et al. (2011)).
Simplicity of Use	Degree to which a digital technology can be used without major effort or training (in accordance with complexity in Ayyagari et al. (2011)).
Usefulness	Degree to which a digital technology supports the accomplishment of tasks and enhances job performance (in accordance with Ayyagari et al. (2011)).

Table 3.2-1 Characteristics of digital technologies, their source, and definition.

[9] Please note that pull and push were first conceptualized as one characteristic with pull and push at opposite ends of the continuum. It was revised in later steps. Notifications may, only in some cases for some features, be configured by the user for certain technologies. Hence, individual settings of the users were not considered, and items were phrased with a general wording.

3.2.4.2 Operationalization and Evaluation of Characteristics

For the development of scales for the characteristics of digital technologies, we followed the guidelines of MacKenzie et al. (2011). Based on this, we collected items for already existing characteristics and further created items for newly identified characteristics resulting in the first draft of our scales. We created our items to be short and simple and use appropriate language for employees. During the development, we carefully made sure that the items only address one single aspect (i.e., no connection of different statements in one item) in order to prevent confusion among the respondent. Thereby, we also considered recommendations proposed by Podsakoff et al. (2003) to avoid common method bias by "improving scale items" (Podsakoff et al., 2003, p. 888). We used the anchor points of the existing rating scales to retain the interpretability and comparability of the results with the existing studies.

To evaluate content validity, we conducted a card-sorting via an online matching task with fellow researchers (n=39) in which they were asked to map items to characteristics (definition of the constructs) (Moore and Benbasat 1991). 85% correct matches were defined as the minimum boundary for the retainment of an item. Out of the 26 items, 22 were mapped correctly to the related construct by more than 85% of the persons, so we did not change them. The remaining four items were matched correctly by less than 85% of the participants. Thus, we changed the wording of these items to fit the corresponding construct better, provide more clarity, and reduce ambiguity. This step of item generation finished with the revised scales.

To evaluate the structure of our scales and validate our reworked items, we conducted a pretest. 445 respondents who were acquired via an online panel took part in the study. The data was collected anonymously as far as possible (some socio-demographic questions were included to evaluate the quality of the intended sample). Participants were instructed to respond honestly and gave informed consent to participation. This was done to further minimize common-method bias by "protecting respondent anonymity and reducing evaluation apprehension" (Podsakoff et al., 2003, p. 888). This principle was applied to all data collection processes. To get a better understanding of the participant's digital workplace, each respondent of our survey stated his or her usage of 40 technologies (Nüske et al., 2019), evaluated by 0 = "no usage", 1 = "monthly usage", 2 = "weekly usage", 3 = "daily usage", and 4 = "several times a day". The list of technologies included common hardware used at the workplace like a printer, laptop or stationary phone, software like text, table, and presentation programs, simulation programs, statistical and analysis tools, networks like cloud systems, intranet, wifi, and technologies like virtual augmented reality and mixed reality. Participants evaluated their perception regarding the characteristics of one randomly selected technology that they used at least weekly. We decided to give each participant only one technology to reduce dropouts due to the length of the survey.

We performed an EFA (parallel analysis revealed nine factors that were extracted using principal axis factoring with an oblimin rotation) to carefully assess the quality of our questionnaire and did a preliminary analysis of all scales. The result of this EFA properly reflected our assumption of the factor structure of the scales with nine underlying technology characteristics. However, we faced some problems. First of all, we observed a few severe cross-loadings between the constructs simplicity of use and reliability. Also, we originally derived a bipolar construct “information provision” that contained aspects about how digital technologies provide users with information distinguishing whether the information has to be requested explicitly by the user (pull) or whether they are provided automatically when available (push). Regarding the issues with the properties of the items of this characteristic, we decided to redefine it and created two separate scales for push and pull as they seem to be more than two ends of one construct. The two scales refer to the original settings of the technologies. Items were phrased with a general wording, that did not consider the individual settings of the user. In some cases, of course, it is possible to adjust the individual settings (e.g., turn off notifications on the lock screen of the smartphone) but this does not apply to all devices and features. In addition, organizational policies possibly interact with personal preferences (e.g., a user may be able to set his stationary telephone on mute, but he does not use this option because the supervisor expects him/her to be reachable on the phone for customers). Finally, we revised the items accordingly.

To go on in our evaluation and validation process, we conducted a large-scale study distributing a questionnaire that, among other things, contained our scales on characteristics of digital technologies. These were assessed with the same procedure as in the pre-test: each participant rated the characteristics of one randomly drawn technology from the list of 40, which (s)he uses. To evaluate the respondent's technostress level, the items belonging to the five technostress creators introduced by Tarafdar et al. (2007) and Ragu-Nathan et al. (2008), namely techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty were included in the survey. This served the last step of our research to test for the influence of technology profiles on technostress. We acquired respondents for the surveys via an external research panel focusing on German employees. Respondents were paid for participation in the study. We included control variables to review the representability of our sample. These comprised gender, employment status, occupational title and sector, number of hours worked per week, and education. The sample for the evaluation consisted of 4,560 respondents. The distribution of participants was representative of the German working population with respect to the control variables age, gender, and occupational sector.

We used a five-point Likert-type rating scale from 0 = "I do not agree at all" to 4 = "I totally agree" to measure the technostress creators as well as the characteristics of digital technologies. All questions were presented in German. If necessary, the items were translated. Therefore, multiple German native speakers translated the questions in parallel. They met afterward to resolve discrepancies and agree on the most suiting translation. For more detailed information about the final scales used in this study and their sources, see Table 3.2-6 in the Appendix. For a list of the technologies, see Supplemental Material D (Table 3.2-10).

As the EFA in the pre-test showed few severe cross-loadings between some constructs, we reinvestigated the factor structure with an EFA in the data set of the main study. Therefore, we split our study population into two evenly large subsets. On the first subset (n=2,280), we performed the EFA (parallel analysis revealed ten factors that were extracted using principal axis factoring with an oblimin rotation). This time no problematic cross-loadings of the items on a competing construct were observed. For more detailed information on the results of this EFA see Supplemental Material E (Table 3.2-11). Following the EFA, we performed a CFA on the second subset (n=2,280) with maximum likelihood estimation of fifteen latent factors (ten characteristics of digital technologies, five technostress creators) that were allowed to intercorrelate in the model to analyze our measurement model further. The descriptive statistics, item reliabilities, and internal consistency are presented in Table 3.2-2.

Construct	**No. of Items**	**Mean**	**Standard Deviation**	**Loadings**	**Cronbach's α**	**AVE**
Anonymity	4	1.78	1.10	0.76-0.92	0.89	0.82
Intangibility of Results	6	1.58	1.10	0.60-0.90	0.92	0.80
Mobility	5	2.55	1.27	0.76-0.93	0.93	0.85
Pace of Change	4	1.78	1.15	0.92-0.94	0.96	0.93
Pull	3	2.47	1.00	0.74-0.89	0.83	0.80
Push	3	2.07	1.17	0.75-0.85	0.85	0.81
Reachability	4	2.71	1.24	0.92-0.95	0.97	0.94
Reliability	3	2.92	0.89	0.86-0.93	0.93	0.90
Simplicity of Use	3	3.13	0.89	0.81-0.92	0.90	0.87
Usefulness	4	2.81	1.05	0.82-0.90	0.92	0.86
Techno-Complexity	5	1.23	1.23	0.81-0.88	0.90	0.71
Techno-Insecurity	4	1.24	1.29	0.78-0.86	0.83	0.66
Techno-Invasion	3	1.28	1.35	0.75-0.90	0.80	0.72

Construct	**No. of Items**	**Mean**	**Standard Deviation**	**Loadings**	**Cronbach's α**	**AVE**
Techno-Overload	4	1.63	1.30	0.79-0.90	0.88	0.74
Techno-Uncertainty	4	1.81	1.23	0.81-0.88	0.87	0.72

Table 3.2-2 Statistical quality of the measures used in the study: descriptive statistics, item reliabilities, internal consistency, and AVE

All loadings of the items on their respective latent factors in the CFA were above the value of 0.71, which indicates that more than 50 % of the variance of this item is explained by the underlying construct. Only for the intangibility of results, lower loadings were observed. However, since the average variance extracted (AVE) of intangibility of results (and for all other constructs) was above 0.50, we did not consider it critical and retained the indicators. Cronbach's Alpha showed values of at least 0.80 for all scales indicating internal consistency.

In the next step, we assessed discriminant validity based on the Fornell-Larcker criterion (Fornell and Larcker 1981) as Cronbach's Alpha relies on correlations of the items and, thus, does not account for dimensionality of constructs. The Fornell-Larcker criterion compares the size of the correlations of the latent constructs to the AVE. The square root of each construct‘s AVE was higher than the correlations with the other constructs (see Table 3.2-12 in Supplemental Material F). Another, newer criterion to asses discriminant validity is the heterotrait-monotrait ratio introduced by Henseler et al. (2015). It sets the average correlation of items measuring different constructs (heterotrait-heteromethod) in relation to the average correlations of items measuring the same construct (monotrait-heteromethod). If the indicators of one construct correlate higher with each other than with the indicators of different constructs, the ratios should be small. Ratios close to 1 indicate a lack of discriminant validity. The ratios were obtained for the characteristics of digital technologies and the technostress creators as they are used in the model to analyze for our second research question. All ratios were below 0.85, indicating that discriminant validity is good. For more detailed information on the results, see Table 3.2-13 in Supplemental Material F. Overall, we consider discriminant validity as given.

In the last step of validating our measurement instrument, we evaluated the fit of our model to gain further information about our assumptions on the data structure. The fit was judged according to the following guidelines: The root mean square error of approximation (RMSEA) indicates good model fit at values smaller than 0.6. The square root mean residual (SRMR) should show values smaller than 0.05. Comparative fit index (CFI) and Tucker-Lewis index (TLI) indicate a satisfactory model fit if they are higher than 0.90 and good fit at values above 0.95. We did not consider chi-square for the evaluation of the model fit, because the indicator has shown to be sensible to sample size in simulation studies (Boomsma 1982). For our model, CFI (0.956) and TLI (0.951) were above 0.95, indicating good fit of the initial model with ten latent, correlating characteristics. Both SRMR (0.036) and RMSEA (0.044) showed only small deviations of the estimated from the expected covariance matrix with values below 0.05 and/or 0.06, respectively. Therefore, we argue that we finally validated our measurement model. To sum up, we now have validated measurement scales for the identified characteristics of digital technologies that — according to literature and qualitative empirical research — relate to technostress.

To confirm this ten-factor structure, a nested model comparison was conducted. The simpler model comprised nine latent factors (interim result from the first EFA in pre-test, reapplied to data from the main study) where all items of the two factors simplicity of use and reliability loaded on the same, common construct. A chi-square difference test revealed significant better fit (χ2Model1 = 5277.18, χ2Model2 = 3327.98, dfModel1 = 651, dfModel2 = 657, $\Delta\chi$2 = -1949.20) of the model with ten latent factors. The fit indices are displayed in Table 3.2-3.

Model	**CFI**	**TLI**	**RMSEA**	**SRMR**
Nine Factors – Model 1	0.924	0.914	0.059	0.041
Ten Factors – Model 2	0.956	0.951	0.044	0.036

Table 3.2-3 Nested-model comparison of the measurement model for the technology characteristics

3.2.4.3 Profiles of Digital Technologies based on their Characteristics

To get a better understanding of the differences between technologies with respect to their characteristics, we created a profile for each of the 40 digital technologies from our list. Each profile line consists of the means of all ten characteristics that were evaluated for this one specific technology. We argue that the characteristic of a digital technology that is used more frequently has a higher impact on the overall perceived characteristics of digital technologies. Therefore, we only regarded the responses of persons that used this specific technology at least once a day. We then calculated a mean score for the ten characteristics. See Table 3.2-4 for examples.

From the overall list of 40 technologies, some had to be excluded for the profiles. Due to the randomized choice which technology the respondent was asked to evaluate, group sizes were in some cases below 30. These were considered too small to provide unbiased information. For example, 86 used augmented, virtual and mixed reality daily, but only ten respondents were asked to evaluate its characteristics due to the randomized sampling. All profiles with means and standard deviations are provided in Table 3.2-4. The table shows how different technologies are perceived by users. It is important to note that these perceptions are from users, that is, they are conditional on the respondent working in a job where the employer assumes a task-technology fit and, thus, provides the technology. Cash systems have a higher perceived usefulness than statistics software to pick just one example. Likely, only few people use both types of systems. The perceptions originate from different people in different jobs. Five profiles are visually displayed in Figure 3.2-2 to highlight similarities and differences. For example, smartphones enable mobile working represented by high values of mobility. The same applies to e-mails because usually, these can be checked on the run with the smartphone. However, in contrast to smartphones, e-mails have a rather low pace of change. A new smartphone is released almost every other week by different companies, whereas the functionality of the e-mail program remains the same as ten years ago (Figure 3.2-2).

To sum up, we now have profiles of the 26 most important (i.e., common and frequently used) workplace technologies along with the characteristics that — according to literature and qualitative empirical research — relate to technostress. This answers RQ3.2-2.

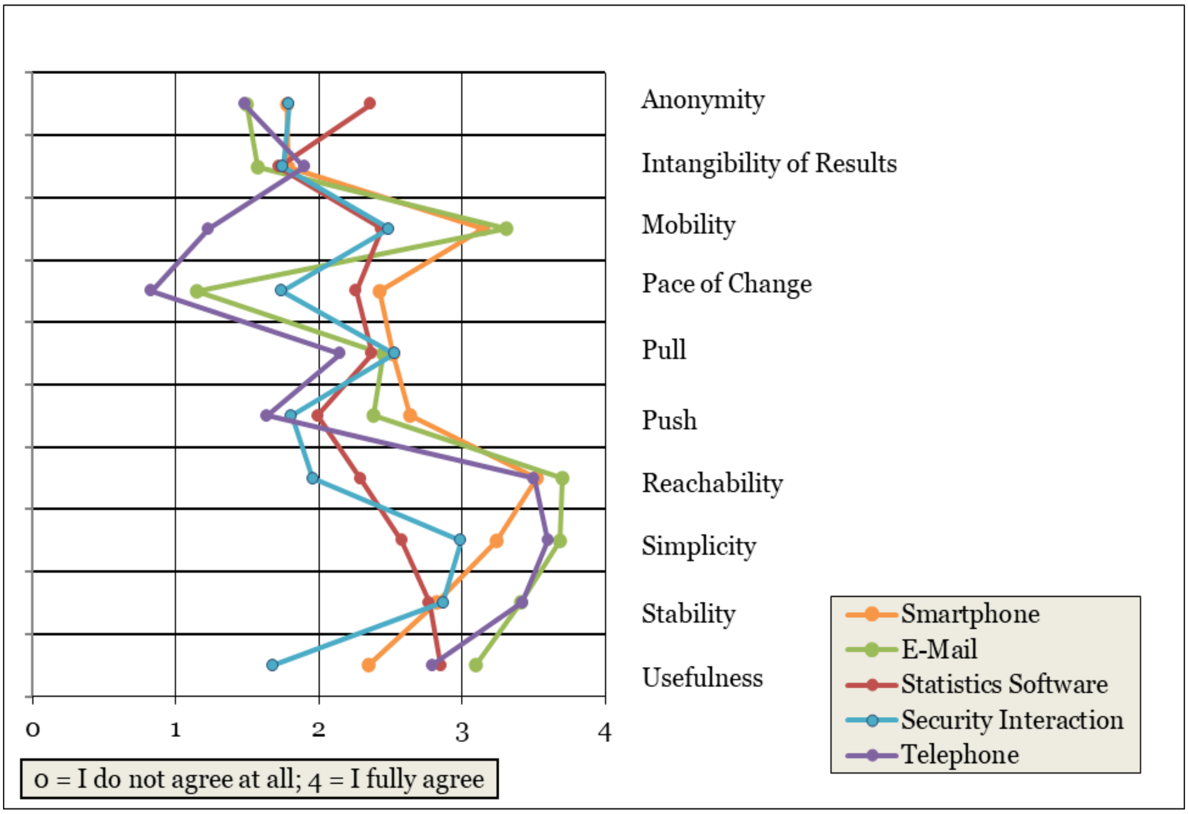

Figure 3.2-2 Profiles of five different digital technologies based on their characteristics

Technology	n	Useful-ness		Simplicity of Use		Reliabi-lity		Anony-mity		Mobility		Reach-abil-ity		Pace of Change		Pull		Push		Intangi-bility	
		M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Administrative Software	69	3.02	0.98	2.79	1.00	2.82	0.89	1.50	1.15	2.18	1.39	2.19	1.34	1.90	1.01	2.47	1.20	1.71	1.15	1.38	1.13
Cash System	41	3.08	1.10	3.49	0.73	3.19	0.73	1.80	1.39	2.14	1.68	1.37	1.57	1.53	1.38	2.46	1.37	1.69	1.53	1.64	1.50
Cloud Computing	54	2.60	1.04	2.73	1.01	2.44	1.03	1.64	1.13	2.88	1.16	2.53	1.25	2.16	0.96	2.49	1.16	1.97	1.22	1.66	1.17
Database	134	2.86	1.05	2.60	1.04	2.71	0.96	1.61	1.16	2.15	1.37	1.92	1.32	1.88	1.09	2.44	1.18	1.92	1.29	1.46	1.22
E-Mail	311	3.10	1.07	3.68	0.68	3.41	0.72	1.50	1.27	3.31	1.21	3.70	0.62	1.15	1.14	2.45	1.31	2.38	1.38	1.57	1.32
Headset	69	2.89	1.17	3.35	0.98	3.16	1.00	1.78	1.45	2.32	1.48	2.97	1.18	1.18	1.28	1.75	1.41	1.69	1.39	1.83	1.35
Internet	220	3.10	0.97	3.42	0.76	2.88	0.84	1.86	1.22	3.25	1.06	3.22	0.95	2.10	1.07	2.61	1.10	2.10	1.20	1.65	1.12
Knowledge Management	91	2.86	1.07	2.92	1.05	2.70	1.00	1.91	1.28	2.55	1.33	2.36	1.25	2.21	1.08	2.54	1.12	1.86	1.22	1.68	1.19
Laptop	125	3.07	1.15	3.55	0.74	3.29	0.78	1.79	1.28	3.23	1.15	3.03	1.07	1.73	1.18	2.65	1.10	2.06	1.30	1.23	1.23
Logistics System	33	3.05	0.91	2.94	0.95	2.65	1.00	1.92	1.23	1.96	1.45	1.86	1.42	2.04	1.28	2.60	1.09	1.99	1.31	1.45	1.33
Management Information Software	42	2.66	0.99	2.60	0.88	2.62	0.89	1.69	1.36	2.53	1.25	2.53	1.29	2.40	1.06	2.64	1.12	1.91	1.38	1.65	1.40
Mobile Phone	62	2.35	1.37	3.46	0.97	2.98	1.18	1.75	1.35	2.79	1.46	3.54	0.80	1.15	1.20	2.23	1.24	1.88	1.39	2.10	1.13
Network Hardware	82	2.78	1.07	2.69	0.95	2.56	0.94	1.58	1.16	2.55	1.29	3.01	1.03	2.07	1.07	2.35	1.12	1.93	1.26	1.58	1.13
Office Software	188	3.33	0.85	3.09	0.91	3.12	0.86	1.95	1.21	2.98	1.22	1.83	1.37	1.64	1.15	2.13	1.23	1.45	1.30	1.21	1.27
PC	301	3.17	1.04	3.27	0.85	3.01	0.85	1.51	1.23	1.48	1.52	2.92	1.13	1.80	1.20	2.64	1.10	1.98	1.32	1.33	1.20
Printer	303	3.25	0.96	3.57	0.70	3.24	0.82	1.74	1.35	1.87	1.57	2.39	1.47	1.27	1.19	2.20	1.34	1.72	1.44	1.07	1.21
Production Planning	30	2.77	1.14	2.46	0.98	2.46	1.09	1.75	1.26	1.91	1.43	1.73	1.30	1.70	1.28	2.34	1.30	1.71	1.37	1.81	1.24
Realtime Communication	50	2.89	1.11	3.19	1.00	2.84	1.08	1.81	1.38	2.68	1.44	3.22	0.89	2.05	1.15	2.46	1.16	2.41	1.30	1.94	1.18
Security Background	94	2.18	1.28	2.55	1.02	2.79	0.94	2.00	1.11	2.93	1.18	2.13	1.27	1.94	1.19	2.39	1.16	2.12	1.24	2.08	1.27
Security Interaction	150	1.68	1.30	2.99	1.00	2.87	0.91	1.79	1.23	2.49	1.37	1.96	1.36	1.74	1.29	2.53	1.14	1.81	1.29	1.75	1.25
Smartphone	151	2.56	1.26	3.25	0.92	2.91	0.95	1.74	1.14	3.16	1.13	3.55	0.81	2.37	1.08	2.56	1.15	2.32	1.26	1.78	1.24
Social Collaboration	71	2.46	1.14	2.77	0.92	2.27	1.00	1.63	1.12	2.93	1.09	3.19	0.87	2.19	0.99	2.38	1.05	2.32	1.15	2.03	1.06
Statistics Software	32	2.85	0.96	2.58	0.99	2.77	1.00	2.36	1.23	2.44	1.32	2.29	1.35	2.26	1.08	2.37	0.98	1.99	1.29	1.72	1.42
Tablet	58	2.68	1.29	3.47	0.87	2.81	1.14	1.73	1.25	3.09	1.21	2.76	1.32	1.83	1.27	2.64	1.24	2.15	1.40	1.69	1.40
Telephone	246	2.79	1.14	3.60	0.75	3.42	0.81	1.48	1.40	1.23	1.53	3.50	0.82	0.83	1.16	2.15	1.38	1.64	1.45	1.90	1.37
Wireless Network	164	2.94	1.13	3.21	0.90	2.74	0.92	1.91	1.22	2.85	1.23	3.34	0.85	2.01	1.17	2.49	1.17	2.29	1.23	1.64	1.26

Table 3.2-4 Profiles of digital technologies: mean and standard deviation for each characteristic for each digital technology

3.2.5 The Influence of Technology Profiles on Technostress

Technostress at work arises from a workers' interaction with typically a range of digital technologies. It does not depend on a single digital technology but on the portfolio of digital technologies at the workplace and their characteristics profiles. Thus, in order to investigate the influence of technology profiles on technostress, we aggregated the profiles of the digital technologies to digital workplace portfolios. For example, for a respondent who uses a smartphone, laptop, e-mails, social collaboration software, and wireless networks for work, we took the characteristic profiles of these five digital technologies and averaged them to build one mean "portfolio" score across the five digital technologies for each of the ten characteristics.

We set up a covariance-based structural equation model (SEM) to measure the influence of the ten characteristics of the digital technology portfolio at the workplace on the five technostress creators techno-overload, techno-invasion, techno-complexity, techno-insecurity, and techno-uncertainty (Ragu-Nathan et al., 2008; Tarafdar et al., 2007). We conducted Harman‘s single factor test, which showed that about 11 % is the highest proportion of variance attributed to one factor, which suggests that common-method bias is not a problem. Next, we statistically controlled for common-method bias by modeling a method factor (Podsakoff et al. 2003). The comparison of the results of the structural model with and without the method factor showed no substantial differences (ΔCFI = 0,029). Researchers (Cheung & Rensvold 2002; Little 1997) have suggested that differences in the CFI less than .05 are acceptable and indicate the equivalence of measurement models. Thus, common-method bias seems not to be a major concern for our data. The model showed good fit to the data (CFI = 0.972, TLI = 0.962, SRMR = 0.031, RMSEA = 0.036).

Hypotheses were tested two-tailed because we did not have specific directional hypotheses about the influence of the characteristics of the digital workplace on technostress. Table 3.2-5 displays the results. For a detailed list of all paths and their respective t-statistics, including the p-values see Supplemental Material G (Table 3.2-14).

In this final step of the analysis, we answer RQ3.2-3, which asked how the profiles of digital technologies used at the workplace influence technostress. Results of the structural model reveal that not all portfolios of characteristics at the digital workplace influence technostress in the same manner, but each of the characteristics is significantly linked to at least one technostress creator.

Characteristic \ TS Creator	Techno-Complexity	Techno-Insecurity	Techno-Invasion	Techno-Overload	Techno-Uncertainty
Anonymity	-0.16**	-0.27**	-0.40***	-0.10	-0.17
Intangibility of Results	+0.16**	+0.34***	+0.31***	+0.25***	+0.30***
Mobility	+0.08	+0.18***	+0.28***	+0.12**	+0.14**
Pace of Change	-0.04	+0.04	+0.31***	+0.10	+0.07
Pull	-0.16	-0.18	-0.40**	-0.23	-0.17
Push	+0.11	-0.08	-0.28**	-0.14	+0.03
Reachability	-0.20*	-0.16	-0.18*	-0.13	-0.17*
Reliability	-0.18	-0.25	-0.46**	-0.07	+0.11
Simplicity	+0.08	-0.19	+0.40*	-0.18	-0.50**
Usefulness	+0.00	+0.22**	+ 0.14	+0.11	+0.07
R^2	0.11	0.20	0.22	0.12	0.16

Table 3.2-5 Digital workplace portfolio
*(The influence of the characteristic profiles of digital technologies on the five technostress creators; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; '+' indicates that a higher value of the characteristic within the digital workplace portfolio is associated with a higher level of the technostress creator and '-' is vice versa.)*

3.2.6 Discussion and Conclusion

We investigated the characteristics of digital technologies that are related to technostress. Therefore, we did a literature search and qualitative interviews in order to expand the understanding of characteristics that have previously been presented in the literature. To validate the characteristics as well as their relationship with technostress, we conducted a quantitative survey study. We used structural equation modelling to reveal the characteristics' relationship with technostress creators. The results answer our three research questions by showing the existence of ten characteristics of digital technologies related to technostress, profiling 26 common workplace technologies along the ten characteristics, and relating the digital workplace portfolio with technostress creators.

In terms of revealing characteristics of digital technologies with relation to technostress creators, we found evidence for ten different characteristics. Each technology characteristic relates to at least one technostress creator and each technostress creator to at least two characteristics.

In this dense web of relationships, we found that anonymity is negatively related to complexity, insecurity, and invasion. For insecurity, for example, this means that if the users may use their technologies anonymously without leaving traces of their usage behavior, employees fear to lose their jobs less as they less feel their work activities to be monitored. Intangibility of results is positively associated with all five technostress creators. Again, for insecurity, this relationship is understandable as employees experience more fear of losing their jobs if they do not see the results of their work and thereby feel no progress in accomplishing their tasks. Regarding these two results concerning insecurity in combination this could be interpreted in the following way: With high intangibility of results, employees might experience a lack of productivity and they fear losing their job because this seemingly poor performance could be controlled or traced, for example by the supervisor, if a system does not allow anonymous usage. For mobility, we found positive relations with insecurity, invasion, overload, and uncertainty. With regard to invasion, this may be because mobile workplaces allow individuals for more flexibility in doing their tasks. Therefore, they may experience a stronger feeling of blurring boundaries between job and private life, resulting in higher levels of perceived invasion. Pace of change is only related to invasion and the relationship is positive, meaning that a high pace of change increases the feeling of one's life being invaded with digital technologies. This may be because employees have to use their non-work times (e.g. weekends) in order to deal with the newly changed digital technologies and learn how to use them and, thus, feel their private lives as being invaded by digital technologies. In contrast to pace of change, pull as well as push is negatively linked with invasion. For pull, this relationship may be because individuals actively have to access information via their digital workplace portfolio and, thus, are more in control of when they want to do so. For push, however, in the first sense, one would expect a positive link to invasion. But we argue that, if individuals know that their digital technologies will notify the individuals about important work issues, they do not have to constantly check their smartphone or other digital technologies for important updates and, thus, can mentally disconnect from their job when being with their family. Reachability is negatively associated with complexity, invasion, and uncertainty. One possible interpretation of the decreasing uncertainty could be that people who are well reachable (i.e. due to their position) will inevitably interact and deal with the technology permanently, which means that they have little uncertainty in using it. For reliability, we only found a negative relation to invasion. Simplicity is linked with invasion and uncertainty. For invasion, the relation is positive, whereas, for uncertainty, it is negative. Interestingly, simplicity does not affect complexity. Lastly and unexpectedly, usefulness is positively related to insecurity. At this point, further research is needed to better understand and interpret the relationship.

Our paper contributes to theory in several ways. Our first contribution is the identification and definition of further characteristics of digital technologies that affect technostress at an individual’s workplace, including measurement scales for the newly added characteristics. Placing these newly identified characteristics side by side with the ones from extant literature (esp.

from Ayyagari et al., 2011), our paper presents the most holistic set of technology characteristics related to technostress. Further, to the best of our knowledge, we are the first to combine the characteristics of Ayyagari et al. (2011) with the technostress creators of Ragu-Nathan et al. (2008) and thereby can show their relationships. With this broader understanding of characteristics, future research can investigate the influence of digitalization on technostress in more detail.

Second, we show that it is important to investigate the workplace as a whole based on the portfolio of technologies at the workplace. Prior research either investigates individual technologies (e.g. Hung et al., 2015; Maier et al., 2015; Salo et al., 2019) or the entire digital workplace without considering the individual technologies at work (e.g. Ragu-Nathan et al. 2008; Tarafdar et al. 2007). We take an intermediate way considering all major individual digital technologies at the workplace. We build technology profiles on the individuals' perception of characteristics and not by asking technology experts. Stress is a construct that builds on the perception of a situation and the individual's own ability to cope with a certain situation. Therefore, from the individual's point of view, the perceived characteristics of digital technologies at the workplace are key because stress is neither solely anchored in the environment and its demands nor solely in the person's characteristics (Folkman and Lazarus 1984). Asking users rather than design experts seems appropriate according to adaptive structuration theory (DeSanctis and Poole 1994). Outcomes of the use of advanced information technology do not only depend on the structure of the technology but also the social interaction of the user with the technology (which can be different than intended by the designer also depending on the organizational practices and norms). These profiles were put together to an individual portfolio consisting the mean characteristics of the different technologies each employee uses at his/her own workplace. This provides a more holistic picture than looking at only a single technology; further, it allows to trace the effects on technostress back to characteristics and from there to individual technologies rather than considering technologies at the workplace as monolithic.

Third and last, we give evidence on the relationship of the characteristics with different technostress creators instead of technostress in general. This more detailed understanding can help future research to develop specific preventive measures and coping strategies for concrete technostress creators at concrete workplaces. In sum, the identification and measurement of characteristics of digital technologies along with knowledge on their effect on technostress enable future research to cluster technologies and evaluate different technologies and workplaces based on their impact on technostress. Future research could consider whether the technology profiles prove to be consistent among demographic and cultural differences. Also, the size of the technology profile combined with the intensity of usage or additional moderating characteristics influencing technostress can be analyzed.

The results of this study also provide implications for practice. Since prior research has shown the negative effects of technostress, including lower productivity and lower job satisfaction, organizations should aim to prevent and lower the level of technostress of their employees. Based on our developed items for characteristics of digital technologies, digital workplaces can be evaluated on their possible susceptibility to technostress, by for example identifying technologies that outshine the positive characteristics of other digital technologies in terms of technostress. This is important as we were able to show that the combination of technologies and their aggregated mean characteristics are associated with technostress creators. The combination of technologies matters as one technology with its' characteristics can distort the overall sensation and lead to technostress.

Workplace designers should focus on usability features, including usefulness, simplicity of use, and reliability, but also on technologies that enable mobility and pull configurations. When individual technostress creators are of specific concern for a given workplace or company, the guidance becomes more nuanced on which characteristics to look out for and which technologies have a favorable profile regarding these characteristics. Besides, individuals can affect their levels of technostress by adjusting their workplace technologies. Therefore, employers also should give their employees the flexibility of configuring their digital technologies in a way that is most beneficial for each individual.

However, there are limitations to our research. Each respondent to the survey assessed only the characteristics of one digital technology and not the characteristics of the digital technologies at her or his entire workplace. However, since our sample is of a high number, we were able to assign the perception of the characteristics between subjects.

Despite these limitations, our results add to a broader understanding of characteristics of digital technologies at an individual's workplace, not only by extending the number of characteristics that were already known but also by revealing the structure among them as well as their effect on technostress creators.

Acknowledgements

The authors acknowledge the financial support and funding by the German Federal Ministry of Education and Research – BMBF (funding agreement numbers: 02L16D035 and 02L16D030) for the project PräDiTec – Prävention für gesundes und sicheres Arbeiten mit digitalen Technologien.

3.2.7 References

Ayyagari, R., Grover, V., & Purvis, R. (2011). Technostress: technological antecedents and implications. *MIS Quarterly, 35(4),* 831. https://doi.org/10.2307/41409963

Berger, S., Denner, M.-S., & Roeglinger, M. (2018). The nature of digital technologies: Development of a multi-layer taxonomy. In *Proceedings at the 26th European Conference on Information Systems (ECIS 2018), Portsmounth*.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. *MIS Quarterly*, *37*(2), 471–482. https://doi.org/10.25300/MISQ/2013/37:2.3

Bharadwaj, A. S. (2000). A resource-based perspective on information technology capability and firm performance: An empirical investigation. *MIS Quarterly*, *24*(1), 169. https://doi.org/10.2307/3250983

Boomsma, A. (1982). The robustness of LISREL against small sample sizes in factor analysis models. *Systems Under Indirect Observation: Causality, Structure, Prediction*.

Brod, C. (1984). *Technostress: The Human Cost of the Computer Revolution*. Addison-Wesley.

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, *9*(2), 233–255. https://doi.org/10.1207/S15328007SEM0902_5

Dahlan, M. K. M., Abdullah, N., & Suhaimi, A. I. H. (2018). A study on supporting factors of digital workplace diffusion in public sector. In *Proceedings of the International Conference on User Science and Engineering* (pp. 327–335). Springer.

Dery, K., Sebastian, I. M., & van der Meulen, N. (2017). The digital workplace is key to digital innovation. *MIS Quarterly Executive, 16*(2).

DeSanctis, G., & Poole, M. S. (1994). Capturing the complexity in advanced technology use: Adaptive structuration theory. *Organization Science*, *5*(2), 121–147.

Fitzgerald, M., Kruschwitz, N., Bonnet, D., & Welch, M. (2013). Embracing digital technology: A new strategic imperative. *MIT Sloan Management Review*, *55*(2), 1–12. https://sloanreview.mit.edu/projects/embracing-digital-technology/

Folkman, S., & Lazarus, R. S. (1984). *Stress, appraisal, and coping*. Springer Publishing Company.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.2307/3151312

Gartner. (2020). *Gartner IT Glossary > Digital Workplace*. http://www.gartner.com/it-glossary/digital-workplace

Gimpel, H [H.], Lanzl, J [J.], Manner-Romberg, T., & Nüske, N. (2018). *Digitaler Stress in Deutschland: Eine Befragung von Erwerbstätigen zu Belastung und Beanspruchung durch Arbeit mit digitalen Technologien.*

Gimpel, H [Henner], Hosseini, S., Huber, R., Probst, L., Röglinger, M., & Faisst, U. (2018). Structuring digital transformation: A framework of action fields and its application at ZEISS. *Journal of Information Technology Theory and Application*, *19*(1), 31–54.

Gimpel, H [Henner], Lanzl, J [Julia], Regal, C., Urbach, N., Wischniewski, S., Tegtmeier, P., Kreilos, M., Kühlmann, T. M., Becker, J., Eimecke, J., & Derra, N. D. (2019). *Gesund digital arbeiten?! Eine Studie zu digitalem Stress in Deutschland*. Augsburg. https://doi.org/10.24406/fit-n-562039

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hung, W.-H., Chen, K., & Lin, C.-P. (2015). Does the proactive personality mitigate the adverse effect of technostress on productivity in the mobile environment? *Telematics and Informatics*, *32*(1), 143–157. https://doi.org/10.1016/j.tele.2014.06.002

Köffer, S. (2015). Designing the digital workplace of the future - What scholars recommend to practitioners. In *Proceedings of the 36th International Conference on Information Systems (ICIS).*

Little, T. D. (1997). Mean and covariance structures (MACS) analyses of cross-cultural data: Practical and theoretical issues. *Multivariate Behavioral Research*, *32*(1), 53–76. https://doi.org/10.1207/s15327906mbr3201_3

MacKenzie, S., Podsakoff, P., & Podsakoff, N. (2011). Construct measurement and validation procedures in MIS and behavioral research: Integrating new and existing techniques. *MIS Quarterly*, *35*(2), 293. https://doi.org/10.2307/23044045

Mahapatra, M., & Pati, S. P. (2018). Technostress creators and burnout. In *Proceedings of the 2018 ACM SIGMIS Conference on Computers and People Research*, Buffalo-Niagara Falls, NY, USA.

Maier, C., Laumer, S., & Weinert, C. (2015). Enterprise resource planning systems induced stress: A comparative empirical analysis with young and elderly SAP users. In *Proceedings of the 12th International Conference on Wirtschaftsinformatik.* https://aisel.aisnet.org/wi2015/93

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job burnout. *Annual Review of Psychology*, *52*, 397–422. https://doi.org/10.1146/annurev.psych.52.1.397

Melville, N., Kraemer, K., & Gurbaxani, V. (2004). Review: Information technology and organizational performance: An integrative model of IT business value. *MIS Quarterly*, *28*(2), 283–322. https://doi.org/10.2307/25148636

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192–222. https://doi.org/10.1287/isre.2.3.192

Nüske, N., Bayer, S., & Lanzl, J [J.]. (2019). *Digitization of the German Workplace: Typical Technologies and Who Uses Them.* Research in Process.

Pirkkalainen, H., Salo, M., Tarafdar, M., & Makkonen, M. (2019). Deliberate or instinctive? Proactive and reactive coping for technostress. *Journal of Management Information Systems*, *36*(4), 1179–1212. https://doi.org/10.1080/07421222.2019.1661092

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *The Journal of Applied Psychology*, *88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Ragu-Nathan, T. S., Tarafdar, M., Ragu-Nathan, B. S., & Tu, Q. (2008). The consequences of technostress for end users in organizations: Conceptual development and empirical validation. *Information Systems Research*, *19*(4), 417–433. https://doi.org/10.1287/isre.1070.0165

Salo, M., Pirkkalainen, H., & Koskelainen, T. (2019). Technostress and social networking services:: Explaining users' concentration, sleep, identity, and social relation problems. *Information Systems Journal*, *29*(2), 408–435. https://doi.org/10.1111/isj.12213

Sarabadani, J., Cater, M., & Compeau, D. (2018). 10 Years of research on technostress creators and inhibitors: Synthesis and critique. In *Twenty-fourth Americas Conference on Information Systems (AMCIS 2018).*

Sebastian, I., Ross, J., Beath, C., Mocker, M., Moloney, K., & Fonstad, N. (2017). How big old companies navigate digital transformation. *MIS Quarterly Executive*, *16*(3), 197–213.

Tan, B., Pan, S. L., Lu, X., & Huang, L. (2015). The role of IS capabilities in the development of multi-sided platforms: The digital ecosystem strategy of alibaba.com. *Journal of the Association for Information Systems*, *16*(4), 2.

Tarafdar, M., Cooper, C. L., & Stich, J.-F. (2019). The technostress trifecta - Techno eustress, techno distress and design: Theoretical directions and an agenda for research. *Information Systems Journal*, *29*(1), 6–42. https://doi.org/10.1111/isj.12169

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., & Ragu-Nathan, T. S. (2007). The impact of technostress on role stress and productivity. *Journal of Management Information Systems*, *24*(1), 301–328. https://doi.org/10.2753/MIS0742-1222240109

Tarafdar, M., Tu, Q., Ragu-Nathan, T. S., & Ragu-Nathan, B. S. (2011). Crossing to the dark side: Examining creators, outcomes and inhibitors of technostress. *Communications of the ACM*, *54*(9), 113. https://doi.org/10.1145/1995376.1995403

Tiwana, A., Konsynski, B., & Bush, A. A. (2010). Research commentary - Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, *21*(4), 675–687.

Tu, Q., Wang, K., & Shu, Q. (2005). Computer-related technostress in China. *Communications of the ACM*, *48*(4), 77–81. https://doi.org/10.1145/1053291.1053323

Venkatesh, V., Brown, S. A., & Bala, H. (2013). Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems. *MIS Quarterly*, *37*(1), 21–54. https://doi.org/10.25300/MISQ/2013/37.1.02

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Westermann, T., Möller, S., & Wechsung, I. (2015). Assessing the relationship between technical affinity, stress and notifications on smartphones. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct.* https://doi.org/10.1145/2786567.2793684

Williams, S. P., & Schubert, P. (2018). Designs for the digital workplace. *Procedia Computer Science*, *138*, 478–485. https://doi.org/10.1016/j.procs.2018.10.066

Yalina, N. (2019). Digital workplace implementation to promote gender equality. In *Proceedings of the International Conference on Research and Academic Community Services (ICRACOS 2019).* https://doi.org/10.2991/icracos-19.2020.1

Zuppo, C. M. (2012). Defining ICT in a boundaryless world: The development of a working hierarchy. *International Journal of Managing Information Technology*, *4*(3), 13–22. https://doi.org/10.5121/ijmit.2012.4302

3.2.8 Appendix

Construct	Item	Mean	SD	Est	Source
Usefulness	Use of {selected technology} enables me to accomplish tasks more quickly.	2.97	1.14	0.82	Ayyagari et al. 2011
	Use of {selected technology} improves the quality of my work.	2.65	1.18	0.83	
	Use of {selected technology} makes it easier to do my job.	2.88	1.13	0.90	
	Use of {selected technology} enhances my effectiveness on the job.	2.75	1.16	0.89	
Simplicity of Use (Complexity)	Learning to use {selected technology} is easy for me.	3.21	0.95	0.87	Ayyagari et al. 2011
	{selected technology} is easy to use.	3.20	0.95	0.92	
	It is easy to get results that I desire from {selected technology}.	3.01	0.99	0.80	
Reliability	The features provided by {selected technology} are dependable.	2.93	0.95	0.91	Ayyagari et al. 2011
	The capabilities provided by {selected technology} are reliable.	2.93	0.94	0.93	
	{selected technology} behaves in a highly consistent way.	2.92	0.96	0.86	
Anonymity	It is easy for me to hide how I use {selected technology}.	1.85	1.22	0.80	Ayyagari et al. 2011
	I can remain anonymous when using {selected technology}.	1.79	1.29	0.80	
	It is easy for me to hide my {selected technology} usage.	1.72	1.23	0.92	
	It is difficult for others to identify my use of {selected technology}.	1.75	1.22	0.76	
Mobility	The use of {selected technology} is not limited to the workplace.	2.68	1.42	0.76	Self-developed with input from Tarafdar et al. 2017
	The use of {selected technology} is not restricted to a certain location.	2.61	1.44	0.86	
	It is possible to use {selected technology} on the go.	2.53	1.50	0.93	
	{selected technology} is accessible from anywhere.	2.51	1.43	0.89	
	{selected technology} enables me to work anywhere.	2.40	1.41	0.80	
Reachability (Presenteeism)	The use of {selected technology} enables others to have access to me.	2.69	1.31	0.92	Ayyagari et al. 2011
	{selected technology} makes me accessible to others.	2.67	1.32	0.95	
	The use of {selected technology} enables me to be in touch with others.	2.74	1.29	0.95	
	{selected technology} enables me to access others.	2.77	1.28	0.95	
Pace of Change	I feel that there are frequent changes in the features of {selected technology}.	1.82	1.24	0.92	Ayyagari et al. 2011
	I feel that characteristics of {selected technology} change frequently.	1.74	1.20	0.94	
	I feel that the capabilities of {selected technology} change often.	1.78	1.22	0.94	
	I feel that the way {selected technology} works changes often.	1.70	1.21	0.92	
Pull	{selected technology} displays information only when I actively interact with it.	2.04	1.29	0.75	Self-developed
	To receive information through {selected technology} I need to actively request it.	2.03	1.35	0.83	
	Information is provided by {selected technology} only on request.	2.11	1.33	0.85	
Push	{selected technology} displays information. whilst I am otherwise engaged.	2.36	1.18	0.75	Self-developed
	I automatically receive news / through information {selected technology} when I use it.	2.48	1.13	0.89	
	{selected technology} uses push notifications to provide information.	2.59	1.15	0.74	
Intangibility of Results	The result of my work with {selected technology} is not tangible.	1.53	1.27	0.89	Self-developed
	The result of my work with {selected technology} is not clearly visible.	1.55	1.25	0.90	
	{selected technology} creates products that are not tangible.	1.56	1.26	0.84	
	The result of working with {selected technology} is not noticeable.	1.46	1.24	0.88	
	Results from the use of {selected technology} are not visible to third parties.	1.69	1.27	0.65	
	Third parties can not immediately see changes caused by using {selected technology}.	1.89	1.26	0.60	

Table 3.2-6 Item means, standard deviation and factor loadings of the finale scales used in the main study (N = 4,560)

3.2.9 Supplemental Material

3.2.9.1 Material A

Area	Specification	Search String
1 Technologies		(reality NEAR/4 (augmented OR virtual OR artificial) OR "Artificial Intelligence" OR "virtual environment") OR (digital NEAR/4 (device OR technology OR system OR machine OR assistant)) OR (technology NEAR/4 (new OR information OR communication) OR "ICT" OR robot* OR (crowd OR click OR smart) AND worker) OR (device NEAR/4 (wearable OR mobile OR smart) OR wearables OR (head NEAR/2 mounted NEAR/2 display) OR "hmd") OR (smartwatch OR smart NEAR/4 (watch OR phone OR glass*) OR mobile NEAR/4 (phone OR computing OR "based solution" OR business OR service) OR "pda") OR (tablet NEAR/2 (computer OR PC) OR touchscreen OR laptop OR notebook OR computer)
2 NOT		child* OR smoking OR smoke* OR animal OR electromagnetic OR radiation OR base-station OR "base station" OR drug* OR electrosmog OR economic OR *oscopy* OR incontinence OR elastomer* OR polymer* OR *fiber* OR fabrication OR treatment OR therap* OR "PTSD" OR war OR trier OR financial OR "mechanic* stress*" OR "deformation* stress*" OR chemical* OR crystal* OR temperatur* NEAR/3 (high* OR low*) OR arthroplast* OR piezoelect* OR metal OR transistor* OR corrosion* OR microstructur* OR biomechanic* OR oxid* OR genom* OR composit* OR bone* OR diabet* OR road
3 Context		(work* OR occupation* OR job OR employ*)
A Outcome: Stress and Strain	General and Symptoms of Illness	strain OR stress OR complaint OR affliction OR distress OR irritation OR irritability OR discomfort OR disorder NEAR/4 (mood OR psychiatric OR sleep OR affect*) OR (mental NEAR/4 (illness OR symptom* OR satiation OR health OR tension OR disorder))
	Fatigue	fatigue OR exhaustion OR satiation
	Well-Being	affect* NEAR/4 (negative OR positive OR symptom* OR tension)) OR "well being" OR "well-being" OR wellbeing OR "irritable mood"
	Technostress Creators	(techno* NEAR/4 (invasion OR uncertainty OR overload OR unreliability OR complexity OR insecurity OR stress)) OR technostress OR Technikstress
	Stress Prevention	coping OR „Boundary Management“ OR „online intervention“ OR care OR mhealth OR "mobile health" OR mHealth OR therapy OR rehabilitation OR treatment OR screening OR "monitoring") und/oder Lernaspekte ("mobile learning" or mlearning or m-learni
B Outcome: Detachment	Usage Behavior	"phantom ringing" OR "phantom vibration" OR "internet dependency" OR "mobile dependency" OR "phone dependency" OR "technology dependency" OR "internet addiction" OR "mobile addiction" OR "phone addiction" OR "technology addiction" OR “daily interruptions” OR ringxiety OR “ringing syndrome” OR “impulsive use” OR “obsessive use” OR "invasion of privacy" OR "privacy invasion" OR "role ambiguity"
	Work-Life-Conflict	“work-home interference” OR “work-home segmentation” OR "work home conflict" OR "work-home conflict" OR

Area	Specification	Search String
		"work-life balance" OR "work life balance" OR “work-life conflict” OR “life-to-work-conflict” OR “life to work conflict” OR “work-to-life-conflict” OR “work to life conflict” OR “work-family-conflict” OR “work family conflict”
C Outcome: Surveillance		(surveillance NEAR/2 (performance OR computer* OR e- OR electronic*)) OR (monitoring NEAR/2 (performance OR computer* OR e- OR electronic*)) OR "performance observation"
D Outcome: Cultural Diversity in the Workplace		((backround NEAR/2 (cultural OR ethical OR national OR management)) OR (intercultural NEAR/2 (communication OR competence OR awareness)) OR (cultural NEAR/2 (differences OR distance OR norms OR habits OR values OR customs OR gap)) OR (work NEAR/4 (migration OR migrants OR immigrants OR refugees OR discrimination OR acculturation)) OR (diversity NEAR/2 (workforce OR management OR cultural)) OR "intercultural management")
E Outcome: Cognition		((cognit* OR mental* OR informat*) NEAR/2 (load OR overload OR workload)) OR overus* OR “over-us*” OR ((cognit* OR mental*) NEAR/2 (speed OR perform* OR attent* OR inattent* OR distract* OR judg* OR evaluat* OR reason* OR comput* OR (problem NEAR/2 solv*) or (deci* NEAR/2 mak*) OR comprehend* OR alert* OR aware* OR multitask*)) OR ((cognit* OR mental*) NEAR/4 (know* OR memor* OR forget* OR interrupt* OR "executive function*" OR concentrat*))
F Outcome: Acceptance		(acceptance OR satisfaction OR willingness OR trust OR reliability OR accessibility OR preference OR compliance) AND (*stress OR strain)

Table 3.2-7 Search strings for the literature research in the qualitative part of the study to identify technology characteristics which relate to technostress and its’ outcomes. Please note that for some databases operators were adjusted due to different logic

3.2.9.2 Material B

Name of the interviewer:	Date of the interview:	Position and expertise of interviewee:
______________________	______________________	______________________

(Relevant items to be marked by interviewer) Yes No

Did interviewee sign data protection sheet? _____ _____

Did interviewee sign declaration of consent? _____ _____

Didi interviewee approve documentation (if “yes” turn on audio recording device)? _____ _____

ID:

	I. Introduction	**Notes**
Introduction	Thank you very much for taking the time to participate in this interview concerning healthy work with digital technologies. You are in expert in the field and we are kindly interested in your opinion and hearing your experiences regarding this topic.	
Anonymity	The interview solely serves research purposes. None of your statements are traced back to you as a person, your employees or business partners.	
Documentation	Do you approve that the interview will be recorded for the purpose of documentation? Please sign the declaration of consent and the data protection declaration before the interview begins.	
	II. Research Questions	**Notes**
General	Can you think of examples of digital technologies and media which were introduced in German companies and small and medium sized enterprises (SME) in the last couples of years? What effect did the introduction have? *(Background information)* *There are different definitions and models of stress. Stress is basically a normal and adaptive response to challenges. Stress is caused by certain triggers (stressors), e.g., excessive demands, conflicts, shift work, perfectionism. In addition, stress is associated with various reactions, such as feelings (e.g. fear, anger), behaviors (e.g. increased consumption of al-*	

	cohol / nicotine, social withdrawal) and physical reactions (e.g. sweating, breathlessness), but also cognitive impairments (e.g. concentration, memory).
	However, people differ in which stressors are experienced as stressful. Whether a person experiences a situation as stressful depends heavily on how the person evaluates it, whether, for example, he sees it as personally relevant or threatening, and what "tools" or resources the person has at hand to deal with the situation. Stress does not necessarily have to be negative but can, to a certain extent, also be experienced as positive and improve performance. Stress is therefore a very individual process. In everyday language, stress often refers to the negative consequences that stressors have. (Based on the transactional model by Lazarus & Folkman, 1984)
	Technostress (respectively digital stress) refers to stress that is triggered by digital technologies and is associated with certain reactions and consequences on the physical, emotional, cognitive, and behavioral level.
	Digital technologies (also information technology (IT), information and communication technology (ICT), information systems (IS) or just called computers) enable the storage and processing of data, the transfer of information and different types of electronically mediated communication (based on Zuppo, 2012). Digital technologies can be divided into hardware, software and networks. Hardware includes, for example, workstations, laptops, tablets, projectors or smartphones. Software includes, for example, Skype for Business, Microsoft Office, Google Drive or Dropbox. Intranet or social networks belong to the generic term of networks.
Causes	In your opinion, what causes technostress among employees?
	Which technologies and media may cause stress?
	Which characteristics or use cases of digital technologies may cause stress? (*Examples are that a technology often evolves or that the technology can be used in a flexible manner away from the workplace or outside of working hours.)*
	Which occupational groups are particularly affected?
	Do employees differ with respect to what causes technostress for example persons with different age, gender, full-time/half-time employment, care of elderly persons/children?
	Do employees differ with respect to what causes technostress due to their cultural background?
Consequences	In your opinion, what are the consequences of technostress for employees?
	How do these consequences manifest?
Coping	In your experience, how do employees and the company / SME handle technostress. It means how do they cope?
	Do employees differ with respect to how they cope with technostress for example persons with different

	age, gender, full-time/half-time employment, care of elderly persons/children?	
	Do employees differ with respect to how they cope with technostress due to their cultural background?	
	Does coping differ between different digital technologies and media which are sued, are they handled differently?	
	Does the handling of technostress differ from other forms of stress and if so in what way?	
Coping Success	How successful do you think are those strategies to cope with technostress?	
	What do you believe is an effective way and what is a less effective way to cope?	
	Is this way of coping more successful/less successful than dealing with other forms of stress? In what way?	
Resources	By what means or resources, e.g. features, abilities and characteristics can the assessment of technostress and the effective handling of it be supported?	
	(Possible areas)	
	Organizational characteristics (autonomy, social support etc.)	
	Personal characteristics (IT-skills, self-efficacy, resilience, etc.)	
	III. Structuring Variables	**Notes**
Areas of Expertise	In your opinion, which areas of expertise are relevant in the examination of technostress?	
Occupational Groups	In your opinion, which occupational groups should eb included in focus groups investigating technostress? Are different hierarchy levels of relevance?	
Cultural Background	In your opinion, should employees with different cultural backgrounds be regarded separately in focus groups?	
	IV. Conclusion	**Notes**
Further Information	With this question we conclude our interview. Is there anything that comes to your mind which seems important in this context which we have not talked about yet?	
End Note	Thank you very much for taking the time to support the research in our project!	

Table 3.2-8 Guideline for the expert interviews in the qualitative part of the study for a conceptual under-standing of technostress

3.2.9.3 Material C

Time: 1.5-2h

Execution: 1 moderator, 1 person to record workshop

	I. Introduction	**Actions and Comments**
Introduction	Today, we would like to talk about your usage of digital technologies for work. Thank you for in participating in this group session. We are kindly interested in your opinions and hearing your experiences.	Keep it general Don't name specific technologies, stressors, or consequences to avoid priming
Digital Technologies	Which digital technologies do you use for work? *(Background information)* *Digital technologies (also information technology (IT), information and communication technology (ICT), information systems (IS) or just called computers) enable the storage and processing of data, the transfer of information and different types of electronically mediated communication (based on Zuppo, 2012). Digital technologies can be divided into hardware, software and networks. Hardware includes, for example, workstations, laptops, tablets, projectors or smartphones. Software includes, for example, Skype for Business, Microsoft Office, Google Drive or Dropbox. Intranet or social networks belong to the generic term of networks.*	Individual work (5 mins) Avoid "at the workplace" use "work" Participants write down what comes to their mind without evaluation or judgement of importance, relevance, or frequency Collect cards, spread them out on the floor and stack duplicates on top of each other (3 mins)
	II. Research Questions	**Actions and Comments**
Stress	How much do(es) the named technology(ies) stress you out?	Scale from "*not at all*" to "*totally*" Each participant gets sticky points for the rating to glue them on the pin board (10 mins)
Causes	What usage and/or characteristics of this specific technology stresses you out exactly?	Group discussion Comparison of triads: 2 "less stressful" technologies vs. 1 "highly stressful" technology 3 heterogeneously stressful technologies Other interesting combinations Moderator puts characteristics on pin board
Stress, Potential Characteristics	How strongly do these specific aspects stress you out? How strongly does this aspect stress you compared to the others?	Template with the results from the afore steps is put on pin board Moderators explains already known techno stressors Group discussion (15 mins) Participants get sticky points to glue them behind the characteristics on the pin board Moderators lets participants prioritize the characteristics according to the rating
Consequences	What triggers this in you and your environment? (besides feeling stressed) What can you observe in your	Participants write on cards for each characteristic

	colleagues? How does it manifest itself in behavior (at work, at home, among friends...)? *(Additional Question)* *Are there positive aspects?*	Show matrix afterwards (short/long term consequences, psychological/physiological…) Leave room for group discussion (15 mins) Moderator should ask to be more precise and specific if necessary
Coping	What can you personally do about it (meaning cope with it)? What can the organization/environment do about it? What can be done about it from a technological point of view? What are your experiences / wishes here?	Do not skip! Essential part for the participants and company's' motivation that their employees take part in the focus group Group discussion (15 mins)
	III. Conclusion	**Actions and Comments**
Further Information	With this question we conclude our workshop. Is there anything that comes to your mind which seems important in this context which we have not talked about yet?	
End Note	Thank you very much for taking the time to support the research in our project!	

Table 3.2-9 Guideline for the focus groups in the qualitative part of the study for a conceptual under-standing of technostress

3.2.9.4 Material D

Category	Technology	Category	Technology
Standard Technologies	Laptop PC Telephone Mobile Smartphone Tablet Printer Headset	Subject-Specific Applications	Product Development Design Software Simulation Software Statistics Software Medical Software Database
		Management- and enterprise-Applications	Management Information Software Decision Support Systems Administrative Software
New Technologies	Artificial Intelligence Augmented Reality Language Interaction	Payment Transaction and E-Commerce	Cash Systems Digital Cash E-Commerce
Standard Applications	Office Software Knowledge Management Internet CMS	Networks	Wireless Network Network Hardware
		Production and Logistics	Production Planning Manufacturing System Logistics System
Communication, Interaction and Collaboration	E-Mail Realtime Communication Social Collaboration Cloud Computing	Environmental Recognition	Sensor Systems Localization
Security	Security Background Security Interaction		

Table 3.2-10 Taxonomy of digital technologies

3.2.9.5 Material E

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(1)0
I1	0.81									
I2	0.84									
I3	0.90									
I4	0.90									
I5		0.91								
I6		0.89								
I7		0.61								
I8			0.89							
I9			0.95							
I10			0.80							
I11				0.75						
I12				0.86						
I13				0.94						
I14				0.73						
I15					0.77					
I16					0.91					
I17					0.93					
I18					0.86					
I19					0.71					
I20										
I21						0.93				
I22						0.96				
I23						0.94				
I24						0.94				
I25							0.92			
I26							0.95			
I27							0.91			
I28							0.91			
I29								0.67		
I30										
I31								0.75		
I32								0.91		
I33									0.65	
I34									0.92	
I35									0.72	
I36										0.85
I37										0.87
I38										0.81
I39										0.86
I40										0.75
I41										0.68

Table 3.2-11 Rotated components matrix from the split sample of the main study. N = 2,280. Extraction method: Principal Axis Factoring (PAF) with oblimin rotation

3.2.9.6 Material F

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Anonymity	**0.82**														
Intangibility	0.30	**0.80**													
Mobility	0.26	0.08	**0.85**												
Pace of Change	0.40	0.36	0.30	**0.93**											
Pull	0.17	0.11	0.20	0.25	**0.80**										
Push	0.29	0.28	0.42	0.44	0.13	**0.81**									
Reachability	0.12	0.12	0.32	0.19	0.13	0.49	**0.94**								
Reliability	0.19	-0.14	0.18	-0.13	0.24	0.12	0.28	**0.90**							
Simplicity of Use	0.10	-0.14	0.21	-0.15	0.20	0.12	0.35	0.67	**0.87**						
Usefulness	0.21	-0.09	0.18	0.10	0.22	0.23	0.33	0.52	0.44	**0.86**					
Techno-Complexity	0.11	0.38	0.00	0.29	0.02	0.14	-0.03	-0.24	-0.35	-0.12	**0.81**				
Techno-Insecurity	0.22	0.34	0.09	0.34	0.06	0.25	0.03	-0.12	-0.25	-0.02	0.65	**0.76**			
Techno-Invasion	0.24	0.39	0.13	0.36	0.04	0.27	0.03	-0.14	-0.22	-0.02	0.62	0.72	**0.78**		
Techno-Overload	0.07	0.31	0.04	0.28	0.06	0.15	-0.01	-0.17	-0.25	-0.11	0.67	0.73	0.66	**0.82**	
Techno-Uncertainty	0.21	0.22	0.12	0.37	0.09	0.25	0.08	-0.05	-0.15	0.03	0.42	0.63	0.47	0.56	**0.80**

Table 3.2-12 Latent correlations of the constructs in the study obtained from confirmatory factor analysis of the constructs. Square root of the AVE printed in the diagonal (N = 4,560)

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	(13)	(14)	(15)
Anonymity															
Intangibility	0.34														
Mobility	0.29	0.07													
Pace of Change	0.39	0.37	0.28												
Pull	0.21	0.14	0.18	0.26											
Push	0.30	0.32	0.44	0.43	0.17										
Reachability	0.09	0.12	0.32	0.15	0.17	0.48									
Reliability	0.20	0.12	0.18	0.16	0.25	0.12	0.29								
Simplicity of Use	0.12	0.13	0.21	0.15	0.24	0.14	0.38	0.71							
Usefulness	0.20	0.09	0.20	0.12	0.24	0.22	0.30	0.50	0.47						
Techno-Complexity	0.11	0.36	0.02	0.24	0.03	0.13	0.04	0.21	0.30	0.12					
Techno-Insecurity	0.25	0.32	0.09	0.34	0.07	0.24	0.03	0.14	0.22	0.04	0.61				
Techno-Invasion	0.20	0.37	0.16	0.32	0.04	0.26	0.04	0.16	0.19	0.04	0.58	0.73			
Techno-Overload	0.07	0.27	0.05	0.24	0.05	0.15	0.02	0.17	0.21	0.09	0.60	0.70	0.67		
Techno-Uncertainty	0.17	0.21	0.10	0.35	0.07	0.24	0.08	0.08	0.12	0.03	0.39	0.62	0.49	0.57	

Table 3.2-13 Heterotrait-monotrait ratios (HTMT) of the constructs in the study.
Calculations done with the corrected formula of the HTMT which uses the absolute values of the item correlations (N = 4,560)

3.2.9.7 Material G

TS Creator	Techno-Complexity			Techno-Insecurity			Techno-Invasion			Techno-Overload			Techno-Uncertainty		
Characteristic	**Est**	***t***	***p***	**Est**	***t***	***p***	**Est**	***t***	***p***	**Est**	***t***	***p***	**Est**	***t***	***p***
Anonymity	-0.16	-1.56	.12	-0.27	-2.62	.01	-0.40	-3.84	.00	-0.10	-0.98	.33	-0.17	-1.63	.10
Intangibility	0.16	2.78	.01	0.34	5.97	.00	0.31	5.55	.00	0.25	4.41	.00	0.30	5.26	.00
Mobility	0.08	1.80	.07	0.18	4.15	.00	0.28	6.50	.00	0.12	2.76	.01	0.14	3.12	.00
Pace of Change	-0.04	-0.52	.60	0.04	0.50	.61	0.31	3.80	.00	0.10	1.23	.22	0.07	0.89	.37
Pull	-0.16	-1.24	.21	-0.18	-1.39	.17	-0.40	-3.10	.00	-0.23	-1.73	.08	-0.17	-1.29	.20
Push	0.11	1.03	.30	-0.08	-0.80	.42	-0.28	-2.66	.01	-0.14	-1.35	.18	0.03	0.27	.79
Reachability	-0.20	-2.33	.02	-0.16	-1.91	.06	-0.18	-2.12	.03	-0.13	-1.58	.11	-0.17	-2.08	.04
Reliability	-0.18	-1.12	.26	-0.25	-1.55	.12	-0.46	-2.87	.00	-0.07	-0.40	.68	0.11	0.72	.47
Simplicity of Use	0.08	0.49	.63	-0.19	-1.10	.27	0.40	2.33	.02	-0.18	-1.05	.30	-0.50	-2.87	.00
Usefulness	0.00	0.00	1.00	0.22	2.60	.01	0.14	1.67	.09	0.11	1.35	.18	0.07	0.80	.42

Table 3.2-14 Standardized regression weights, test statistics and p-values of the structural model: evaluating the influence of profiles of digital technologies on technostress (N = 4,560)

3.3 Gamifying Digital Work: An Empirical Investigation How Gamification Affects IS Use Appraisal

Abstract: Information systems (IS) and their healthy use are becoming increasingly important in the digital work environment. The cognitive appraisal of an IS-enabled demand is decisive for if IS use leads to positive or negative outcomes. This work investigates how gamification integrated into IS can support challenge appraisal and reduce threat appraisal of IS-enabled demands. We conducted an online experiment to examine the impact of gamification on appraisal. We simulated time urgency in a gamified IS and examined how challenge and threat appraisal developed among participants during the experiment. We examined the panel data with a Latent Growth Model and find that gamified IS does not initially reduce threat appraisal but reduces it over time. Challenge appraisal is not significantly higher among users working in gamified IS. That this hypothesized effect does not show in the data might require further research. Our paper contributes to a better understanding of the cognitive appraisal process in IS use research and identifies gamification as a valuable tool to positively influence the cognitive appraisal process.

Keywords: IS Use, Gamification, Appraisal, Latent Growth Models

Authors: Michelle Berger, Carolin Jung, Manfred Schoch

Status: This article will be published in the proceedings of the 56th Hawaii International Conference on System Sciences (HICSS), in Lāhainā, USA, 2023.

3.3.1 Introduction

Modern information systems (IS) have become ubiquitous in private and business lives, enabling many benefits such as facilitated work routines, higher performance, or new ways of working (Dittes & Smolnik, 2019). During the COVID-19 pandemic, IS for communication and collaboration supported the transformation of many workplaces towards telework and enabled sustained social contacts (Ketter et al., 2020). Yet, previous research indicates that the use of IS might also lead to adverse psychological effects among employees, such as increased psychological exhaustion (Tarafdar et al., 2007). Such negative outcomes can be triggered by IS-enabled demands, which are "objective demands that are enabled by IS and [may] stress individuals" (Galluch et al., 2015, p. 3). Further, research findings support that users may also perceive IS-enabled demands as a challenge that may provide opportunities for personal growth and empowerment when successfully overcome (Benlian, 2020; Le Fevre et al., 2003). Congruently, literature considers IS use as a dual phenomenon with bright and dark sides (Tarafdar et al., 2019). The cognitive appraisal offers an explanation of different reactions in objectively identical situations (Krohne, 2001). Influencing the individual's appraisal towards appraising the IS-enabled demand as challenging instead of threatening can potentially decrease the adverse consequences of using IS. Designing IS in a way that gives users the impression that they can successfully deal with IS-enabled demands is considered a possible approach to positively influence the individual's cognitive appraisal (Johnson & Wiles, 2003; Tarafdar et al., 2019). Therefore, IS design features might have the potential to positively impact the perception of stress. For example, IS design features that empower users and encourage them could help diminish negative experiences by increasing user motivation and enjoyment (Tarafdar et al., 2019).

The gamification domain indicates that gamification elements can motivate users, for example, by giving them feedback about their performance (Zichermann & Cunningham, 2011). Therefore, a promising approach to positively influence IS use appraisal could be the integration and application of gamification (Tarafdar et al., 2019). Gamification refers to "the use of game design elements in non-game contexts" (Deterding et al., 2011, p. 2). Previous research suggests its effectiveness in supporting engagement, motivation, and promoting the users' well-being by generating positive experiences and emotions, or satisfying basic needs (Hamari et al., 2014; McGonigal, 2011). However, research has not yet investigated the potential of gamification to influence the cognitive appraisal process. Thus, in this study we assess its ability to support challenge appraisal and reduce threat appraisal concerning IS-enabled demands. Congruently, we follow the research question:

RQ3.3-1: *Does the influence of gamification on cognitive appraisal reduce threat appraisal and support challenge appraisal of an IS-enabled demand?*

To answer the question, we conducted an online experiment in which we simulated an environment where users must process an unknown number of work tasks under time urgency. Previous research suggests that such situations can create both challenge and threat appraisals (Benlian 2020). We collected data at different points in time during the experiment and analyzed them with a Latent Growth Model (LGM). We contribute to existing research by considering the positive impact of gamification on cognitive appraisal. We show how gamification might help to influence the appraisal of an IS-enabled demand as a challenge and reduce threat appraisal. Besides the benefits for research, managers, and software developers can profit by adapting their IS accordingly.

3.3.2 Theoretical Background

3.3.2.1 Stress Appraisal Leading to a Bright and Dark Side of IS Use

From the transactional-based approach, stress comprises an ongoing procedure that entails an exchange between the individual and the environment (Lazarus & Folkman, 1984). When encountering an environmental demand, individuals determine whether it is relevant and considerably strenuous for their resources. Next, individuals make appraisals to classify the personal implications of the encounter (Lazarus & Folkman, 1984). The person assesses the degree to which the transaction between the individual and the environmental demand is positive, irrelevant, or stressful (primary appraisal) and whether they have the required resources to deal with this demand (secondary appraisal) (Lazarus & Folkman, 1984). The appraisal can be categorized as a threat which indicates the possibility of future harm, or as a challenge that indicates a potential for mastery, growth, or benefit (Lazarus & Folkman, 1984). Several different paths to a positive perception of the environment are described in stress research, e.g.: overcoming hardship, successfully overcoming stressful situations, opportunities to grow, or inherently enjoyable activities (e.g., Edwards & Cooper, 1988). In this paper, we follow a more positive definition of challenge as an opportunity for mastery and growth (c.f., LePine et al., 2016). It must be considered that challenge and threat appraisal are not mutually exclusive but can coincide to varying degrees (Schwarzer, 1992). Thus, stress is a dualistic phenomenon and can be harmful and positive for an individual (Selye, 1976).

This conceptual understanding of the stress process also applies to technostress (Tarafdar et al., 2019). Technostress is a phenomenon triggered by the use of IS and has been conceptualized as a process in the context of numerous studies (e.g., Ragu-Nathan et al., 2008). While previous research has focused on the negative side of IS use and its implications, recent literature shows that IS-enabled demands can also have positive effects that may primarily result from challenge appraisals rather than threat appraisals (Tarafdar et al., 2019). Depending on the appraisal of IS-enabled demands, previous research indicates that IS use can lead to both desirable (e.g., satisfaction, higher productivity) and avoidable (e.g., poor health, strain) outcomes (Gimpel et al., 2019).

IS-enabled demands are the “objective demands that are enabled by IS and [may] stress individuals” (Galluch et al., 2015, p. 3). Based on a literature review, Benlian (2020) identified, for example, time urgency as a challenging work stressor and has placed it in an IS-related context. Benlian (2020) identified some conceptual overlap between time urgency and techno-overload. On the one hand, and related to time urgency, IS use can be considered a leverage that helps users handle and accomplish more work (challenge appraisal), on the other hand, IS can be appraised as forcing users to work more and faster than they can (threat appraisal) (Benlian, 2020). Therefore, working in a demanding IS environment is not always seen as a challenge (bright side of IS use) but can also be seen as a burden and lead to adverse effects (dark side of IS use) (Benlian, 2020). Similar results were found by Califf et al. (2020) who substantiate that not all currently recognized techno-stressors are associated with threat appraisals.

To date, IS literature lacks knowledge about what influences cognitive appraisal. There has been little research on IS design features influencing the appraisal process and their possibility to support challenge appraisal of an IS-enabled demand (Tarafdar et al., 2019). Promising IS design features in that regard are game design elements.

3.3.2.2 Theoretical Foundations of Gamification

The motivational mechanism of gamification can be used to support long-term behavior changes by making applications more exciting and enjoyable (Hamari et al., 2014). Gamification is about incorporating elements that are characteristic and typical for games into a real-world context (Deterding et al., 2011). Examples of game design elements include *badges*, *progress bars*, *points*, or *notifications* (Koivisto & Hamari, 2019). *Badges* are symbolic honors users can obtain within a game (Sailer et al., 2013). The users can determine their progress on a *progress bar* and receive information about whether they are approaching their goals (Sailer et al., 2013). Users can collect *points* for specific activities within the gamified environment (Sailer et al., 2013). Lastly, *notifications* provide users with motivational and informative feedback based on their performance (Buchem et al., 2019). The application areas, among others, include contexts in work, teaching, and health (Arai et al., 2014; Johnson et al., 2016; Koivisto & Hamari, 2018). Studies show, for example, that the integration of game design elements in stress management applications is perceived positively by users and increases their commitment (Dennis & O'Toole, 2014; Hoffmann et al., 2019). Additionally, game design elements can instantly lead to wellbeing. Gamification can support the emergence of positive experiences by fulfilling fundamental psychological needs and other aspects of wellbeing such as positive feelings, accomplishment, giving sense, and engagement (Johnson et al., 2016; McGonigal, 2011; Pereira et al., 2014). There are several studies on the influence of gamification on flow experience, which show mainly positive results (Oliveira et al., 2021). Flow is defined as a condition of pleasure, inspiration, total engagement and an uplifting sense of transcendence (Csikszentmihalyi, 1998).

Concerning mental health, studies have examined the effect of gamification in detail. Research results indicate that gamification can positively affect mental wellbeing, personal growth, and flourishing while reducing anxiety (Dennis & O'Toole, 2014; Hall et al., 2013). The high number of studies examining the influence of gamification on mental health have found positive or mixed results (Johnson et al., 2016).

3.3.2.3 Impact of Gamification on Stress

Few studies focus on the negative (e.g., Hammedi et al., 2021; Yang & Li, 2021) or positive influences (Fajri et al., 2021; Paniagua et al., 2019; e.g., Tennakoon & Wanninayake, 2020) of gamification on the experience of stress. Regarding the adverse effects, for example, Hammedi et al. (2021) found that employees can feel stressed about whether or not to pass a challenge delivered via gamification (Hammedi et al., 2021). Nevertheless, Paniagua et al. (2019) found a positive relationship between chemical engineering students using a gamified learning platform and reducing their stress levels. Furthermore, Tennakoon & Wanninayake (2020) confirmed the moderating effect of gamification in the workplace regarding its impact on work stress and employee performance. Finally, Fajri et al. (2021) found that gamification can increase the playfulness of digital learning management systems and reduce technostress.

3.3.3 Hypothesis Development

A gamified IS can make a user's performance visible, for example, through points or badges received for completed work (Sailer et al., 2013). This reward mechanism provides the user with motivating feedback and immediate reinforcement and thereby reaffirms the user's abilities (Hamari & Eranti, 2011; Rigby & Ryan, 2011; Sailer et al., 2013). This way, users receive recognition and praise for their performance in the gamified IS (Antin & Churchill, 2011).

Hence, users feel confident that working in a gamified IS will positively affect them and is a chance to demonstrate their abilities. Subsequently, users perceive the IS-enabled demand as a challenge to keep up their good performance and further develop their skills to earn additional rewards (Csikszentmihalyi, 1998; Hamari et al., 2014). At the same time, motivational feedback, for example through the receipt of notifications and changes in a progress bar, can help users to better assess their performance in an IS and give them clarity about the situation (Waldersee & Luthans, 1994). For instance, users who receive a praising notification and take a step in a progress bar after accomplishing a work task know they have completed it correctly and are assured about their abilities. This feedback can reduce users' feelings of insecurity and fear that the work results will have negative consequences for them (Levy et al., 1995). The playful design of IS and encouraging feedback may make an IS-enabled demand less threatening for the user. Thus, a gamified IS has several capabilities to help promote challenge appraisal and reduce threat appraisal of an IS-enabled demand, leading to the following hypotheses:

H1: Users of a gamified IS have an initially lower (H1a) and stronger decreasing (H1b) threat appraisal in association with an IS-enabled demand than users of a non-gamified IS.

H2: Users of a gamified IS have an initially higher (H2a) and stronger increasing (H2b) challenge appraisal in association with an IS-enabled demand than users of a non-gamified IS.

3.3.4 Methodology

3.3.4.1 Design and Realization of the Experiment

We conducted an online experiment to evaluate the research model by simulating an IS-enabled demand related to time urgency. It is considered a stress factor that users can appraise as both a threat (i.e., the perception of IS as a force to work faster) (Tarafdar et al., 2007) and a challenge (i.e., the perception of IS as a support to work faster) (Benlian, 2020). Hence, it is well suited to analyze the cognitive appraisal process. As a means to an end, we designed a digital assessment system (DAS) containing gamification elements. We generated the IS-enabled demand in which participants must process work tasks provided via email in an inbox under time urgency. It is assumed that participants are familiar with the use of email inboxes. Using LabVanced, we created a DAS interface that corresponds to the design and functionalities of an email inbox. We chose different intelligence test exercises as tasks embedded in an email frame, e.g., completing missing numbers or abstract figures in a series of them, solving arithmetic problems, drawing logical conclusions from given assertions, or memory exercises. The difficulty level of the tasks was easy to medium in order to avoid that the difficulty of the tasks would cause stress, which might distort the result. The participants had four minutes for each round so that they could complete them just under the allotted time but dosed them so that participants experienced some time urgency.

We integrated gamification into the DAS to manipulate the appraisal of the IS-enabled demand in the intervention group. For that, we included a *point system*, *notifications*, *progress bars*, and *badges* in the DAS. Participants received points for completed tasks and for correct answers which were displayed immediately on the screen. Collected points were summarized in a point bar which was always visible. The notifications contained motivating and informative messages like "You have successfully solved the task, keep it up!". They also appeared after finishing a task. During each round, a progress bar showed participants how many tasks had been completed and how many still needed to be completed within the time, allowing participants to manage their time. Note: not all messages in the inbox contained tasks. The badges were displayed after each round to reward the overall success of a round (e.g., Promising Candidate Level 1).

The online experiment was separated into a pre-experimental, experimental, and post-experimental stage (see Figure 3.3-1). In advance, we carried out pilot tests to improve the experimental stages. Following the advice of Cook et al. (1970), we chose a purpose that prevents participants from identifying the true purpose of the experiment to avoid demand characteristics bias. In the pre-experimental stage, participants are briefed that they serve as test persons to examine a DAS for employee recruitment. Participants were informed about the study procedure, the number of rounds, and data protection aspects. Next, participants were asked to imagine that they applied for a job they were willing to be hired for and were invited to participate in a DAS to demonstrate their skills. Participants were introduced to the DAS and the expected tasks in detail. After the introduction, participants had to fill out the first survey, which assessed *self-efficacy* and *stress mindset*.

Treatment Group	Preexperimental Stage	Experimental Stage								Postexperimental Stage
Gamification Group	Introduction and Survey 1	Task block 1 Gamification	Survey 2	Task block 2 Gamification	Survey 3	Task block 3 Gamification	Survey 4	Task block 4 Gamification	Survey 5	Survey 6
Control Group	Introduction and Survey 1	Task block 1	Survey 2	Task block 2	Survey 3	Task block 3	Survey 4	Task block 4	Survey 5	Survey 6

Figure 3.3-1 Experimental procedure

The experimental stage began with participants entering the email inbox interface. They could start opening emails and working on the tasks. Continuously, new emails arrived. A round in the DAS contained seven to eight emails with five to six exercises. If participants completed all tasks before the end of the four minutes, they could finish early. After each round, participants had to complete a survey. The surveys during the experimental stage asked participants for their perceived *threat appraisal* and *challenge appraisal* regarding their personal use of the DAS.

The post-experimental stage started after participants completed the four rounds in the DAS. We collected demographic data on age, gender, and education level. Finally, we thanked the participants for completing the experiment and explained the actual goal of the study.

We recruited participants via Amazon Mechanical Turk (MTurk). The experiment lasted 30 minutes. Participation was voluntary and was paid $4.10. 120 runs were conducted. The final sample included 89 subjects, as we excluded participants based on missed attention checks. Most are between 30 and 39 years old (29.2%), followed by 40 to 49 (25.8%). 57.3% of the participants are men, and 42.7% are women. Most completed vocational training (47.2%). The remaining have a lower school leaving certificate (29.2%), high school diploma or equivalent (16.9%), or a bachelor's degree (6.7%). Participants were randomly assigned to one of the two groups.

3.3.4.2 Measurements

Threat appraisal was assessed by applying four items for perceived threat (adapted from Bala & Venkatesh (2015) and Major et al. (1998)). *Challenge appraisal* was measured using four items for perceived opportunity (adapted from Bala & Venkatesh (2015), Major et al. (1998), and Drach-Zahayy & Erez (2002)). As mentioned, there are several interpretations of challenge appraisal in the literature ranging from overcoming hardship, to successfully overcoming stressful situations and opportunities to grow. This is a rather positive operationalization. We adjusted the items by applying them to the context of the DAS and the simulated stressor time urgency. Thus, for example, we changed "the system" from the original item to "digital assessment system": "I am confident that the system will have positive consequences for me." (Bala & Venkatesh, 2015, p. 170) was adjusted to "I am confident that the digital assessment system will have positive consequences for me." Additionally, we changed and specified "the situations caused by the system" to "the number of tasks, information and time pressure" (e.g., "I personally have what it takes to deal with the number of tasks, information and time pressure"). The remaining items have been adjusted similarly.

Various studies identified differences in the perception of IS use between individual characteristics of users: *gender*, *age*, *stress mindset*, *self-efficacy*, and *educational level* (Ayyagari et al., 2011; Ragu-Nathan et al., 2008). For this reason, we controlled that the two groups do not differ in these variables. *Self-efficacy* was measured using the generalized self-efficacy scale from Schwarzer & Jerusalem (1995). *Stress mindset* was determined with items adapted from Crum et al. (2013). We measured all constructs with a 7-point Likert scale (strongly disagree to strongly agree).

3.3.4.3 Data analysis: Latent Growth Modeling

We applied a data analytic approach to study our assumptions and used an LGM analysis to test the hypotheses. An LGM enables the investigation of a construct's initial value and trajectory over time. It allows a broad class of statistical methods that offer several advantages in analyzing longitudinal data (Diallo & Morin, 2015). First, LGMs provide improved statistical power, and second, LGMs allow the study of intraindividual changes over time (i.e., changes within individuals over time) as well as the study of interindividual variability in intraindividual changes (i.e., individual differences in changes over time; Diallo & Morin, 2015; Felt et al., 2017). For these reasons, this method is very suitable for analyzing our data. In the first step, LGMs were investigated separately for the intervention and control group for threat appraisal and challenge appraisal. We applied the functional form of a linear growth model. The following quality criteria were considered and analyzed for each LGM: root mean squared error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and standardized root mean square residual (SRMSR).

The data sets of the two treatment groups were merged to determine whether there were significant differences between the intervention and control group in slopes and intercepts for threat appraisal and challenge appraisal. We calculated the LGM of the combined dataset. We integrated a dummy variable that measured the group membership. The dummy variable displayed a time-invariant covariate and measured the additional effect (i.e., the difference between the treatment groups) of gamification in the intervention group on slope and intercept. The values of the control group represented the base (dummy variable = 0, intervention group =1). The difference in the height of slope and intercept between the treatment groups was tested for its significance. For the analyses, we used Microsoft Excel and the statistics software R.

3.3.5 Results

In the following, we describe the results for the threat appraisal of the control group (Figure 3.3-2 and Figure 3.3-3). A linear growth model is assumed here, which fits quite well to the data (CFI = 0.99, TLI = 0.99, SRMR = 0.08, RMSEA = 0.08). The initial level is 2.934 and significant (p = 0.00). The linear slope is 0.041 but not significant (p = 0.38). Next, the LGM for threat appraisal of the intervention group is presented. The quality criteria indicate that the fit of a linear growth model is very good (CFI = 1.00, TLI = 1.00, SRMR = 0.02, RMSEA = 0.00). The initial level is 2.554 and significant (p = 0.00). The trajectory value for the linear slope is -0.108 and indicates a significant (p = 0.00) slight decrease in perceived threat at each measurement time. The investigation of group differences shows that there are no significant differences in the initial value between the treatment groups and that there is a significant difference between the linear slopes of the treatment groups (estimated markups in the intervention group: Intercept: -0.380, p = 0.22; Slope: -0.154, p = 0.00). Thus, the hypothesis (H1a) that users of a gamified IS have an initially lower perception of threat associated with the IS-enabled demand than users of a non-gamified IS must be rejected. The hypothesis (H1b) that users of a gamified IS have an over time stronger decreasing perception of threat in association with the IS-enabled demand to users of a non-gamified IS can be supported.

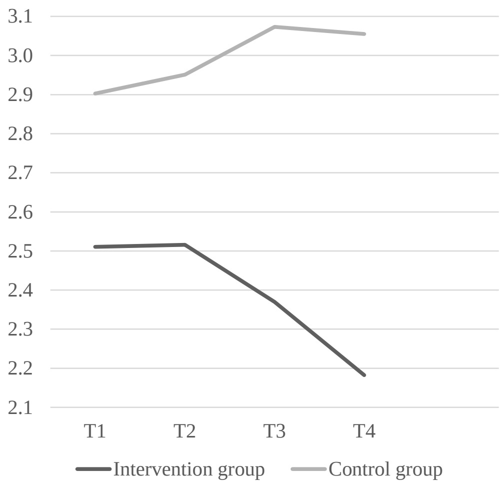

Figure 3.3-2 Trajectories of threat appraisal

The next LGMs considered are for challenge appraisal (Figure 3.3-4 and Figure 3.3-5), starting with the control group. The quality criteria show an acceptable fit of the linear model (CFI = 0.91, TLI = 0.89, SRMR = 0.14, RMSEA = 0.32). The initial level is 5.110 and significant (p = 0.00). The value for the linear slope is 0.012 and not significant (p = 0.71). Finally, the LGM of the intervention group for challenge appraisal is examined. The quality criteria indicate that the fit of the used linear model is very good (CFI = 0.98, TLI = 0.98, SRMR = 0.05, RMSEA = 0.14). The initial level is 5.651 and significant (p = 0.00). The trajectory value for the linear slope is 0.033 and not significant (p = 0.23). The study of group differences indicates no significant differences in the intercepts of the two treatment groups. Furthermore, there are no significant differences in the slopes between the two treatment groups (estimated markups in the treatment group: Intercept: 0.409, p = 0.09; Linear slope: 0.077, p = 0.09). Hence, the hypothesis (H2) that users of a gamified IS have an initially higher and over time stronger increasing challenge appraisal in association with the IS-enabled demand to users of a non-gamified IS, must be rejected. Yet, given the low sample size of this study and the relatively low p-values (p=0.09), these results should be taken with a grain of salt.

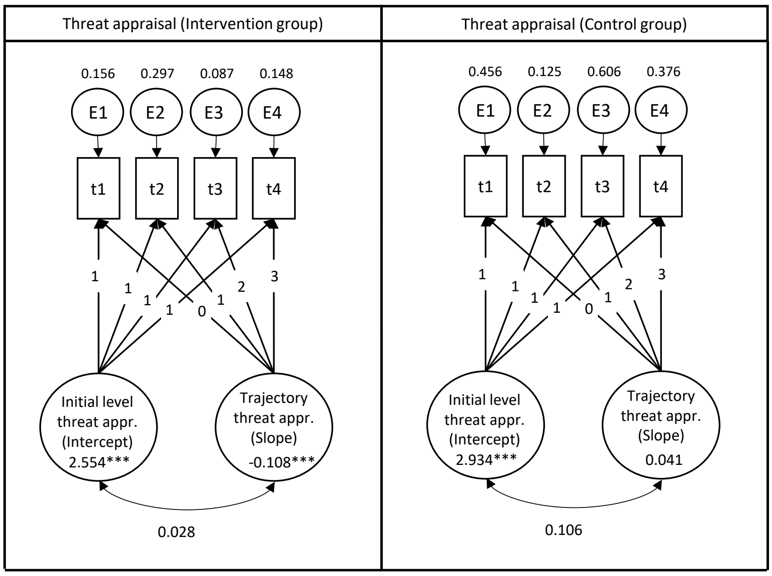

Figure 3.3-3 Latent Growth Model results for threat appraisal
*(Note: p > 0.05, p** < 0.05, p*** < 0.01, E = error variance, t# = time point, ↔ = covariance, numbers on arrows represent the factor loadings of a linear growth model; appr. = appraisal)*

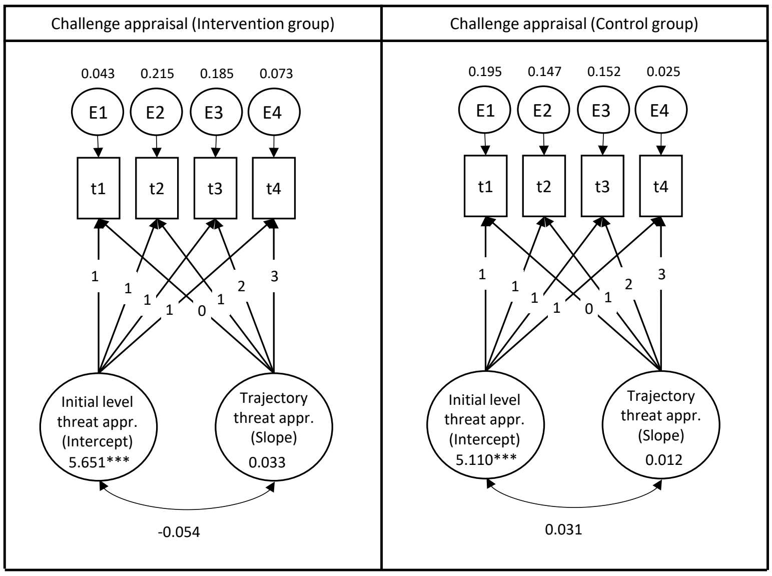

Figure 3.3-4 Latent Growth Model results for challenge appraisal
*(Note: p > 0.05, p** < 0.05, p*** < 0.01, E = error variance, t# = time point, ↔ = covariance, numbers on arrows represent the factor loadings of a linear growth model; appr. = appraisal)*

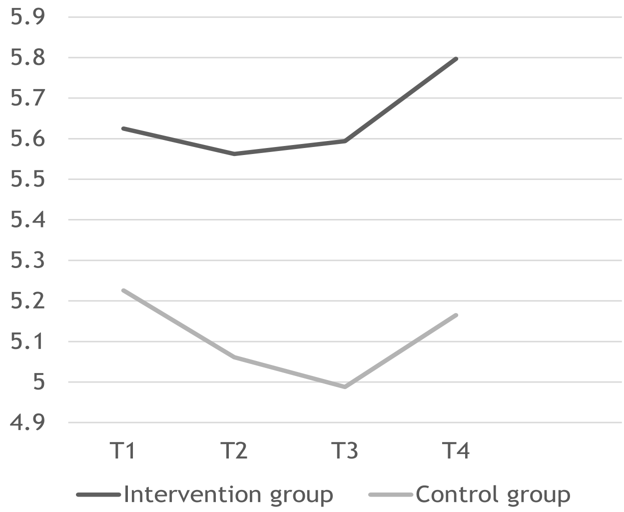

Figure 3.3-5 Trajectories of challenge appraisal

3.3.6 Discussion

This study focuses on investigating the cognitive appraisal process when using IS. We analyze if gamification can contribute to challenge appraisal and decreases threat appraisal. First, we hypothesized that the initial value and the slope for threat appraisal were lower in the intervention group than in the control group throughout the experiment (H1). After the first round of the experiment, the treatment group did not appraise the IS-enabled demand as a threat significantly differently from the control group (H1a: rejected). Retrospectively, this result might be explained by the increased complexity of the gamified user interface and the additional information users must process in the treatment group. The complexity might initially offset the positive effects of gamification. Our result is congruent with Yang & Li (2021). They provide evidence that gamification can be associated with the stressor techno-overload, which is inherently appraised as a threat (Tarafdar et al., 2019). However, after some time working with the gamified IS, participants of the intervention group appraised the IS-enabled demand as significantly less threatening than the control group, as evidenced by a significantly negative slope (H1b: supported). This shows gamification's positive effect. Gamification has been shown to motivate and support IS users (Johnson et al., 2016; Sailer et al., 2013). Those two factors have been associated with the appraisal of IS (Tarafdar et al., 2019). In our experiment, the gamified IS was designed to make users feel that their work with the IS would have no adverse effect on their performance (badges) and made it easier for them to assess the demands (progress bar). Evidently, that made them perceive less threat appraisal. Hence, we conclude that a gamified IS can significantly reduce perceived threats over time. This finding is enabled by our longitudinal research design.

Second, we examine whether a gamified IS can help increase the appraisal of an IS-enabled demand as a challenge. We hypothesized that the initial intercept and the slope for challenge appraisal were both higher in the intervention group than in the control group (H2) – mainly because users are encouraged by the motivating effect of gamification (Sailer et al., 2013). This effect is primarily driven by badges that set goals for users and provide positive feedback upon their reception. Contrary to our hypothesis, challenge appraisal is not significantly higher in the intervention group than in the control group after the first round of the experiment (H2a: rejected). Yet, the mean value is higher for the gamification group and given the relatively small sample size as well as the p-value of 0.09, this may encourage further research into the issue. During the experiment, participants in the intervention group appraised the IS-enabled demand as constantly higher as a challenge than the participants in the control group, yet the difference is again not significant. Results from research on the effect of gamification on flow indicate that gamification has the power to create positive engagement and psychological reactions by setting goals and providing feedback or rewards (Oliveira et al., 2021). Roh et al. (2016) show that gamification is a valuable way to increase employees' motivation and positive experience by generating flow through playful goals and feedback.

Further analysis of challenge appraisal reveals that the participants in both treatment groups do not experience a significant change over time. The trajectories of the slopes are quite similar for both treatment groups and do not differ significantly. This is against our expectations (H2b: rejected). Previous research suggests that after the first interaction in a gamified interface, users initially seek feedback to maximize positive affective states (Hamari et al., 2014; Levy et al., 1995). However, this perception decreases over time, which Hamari et al. (2014) call the novelty effect. Csikszentmihalyi (1998) argues that a positive form of stress appears when an individual is fully involved in facing a challenge that is barely manageable. If users are not challenged further, they become increasingly bored (Przybylski et al., 2010). We did not implement an increase in difficulty, so participants may not have been challenged enough to experience the hypothesized increasing effect.

Several studies show that gamification can contribute to stress reduction and are in line with our research results (e.g., Fajri et al., 2021; Tennakoon & Wanninayake, 2020). Fajri et al. (2021) show in the context of technostress and e-learning that gamification can provide pleasure, lowering the users' negative stress levels (threat). Our results confirm this and shed light on how threat appraisal changes over time – an intra-situational view that has scarcely been investigated. These results indicate that gamification reduces users' resistance to work and increases the effectiveness of IS implementation (Fajri et al., 2021).

Our empirical results do not support our hypotheses regarding the positive side of stress (challenge appraisal). While there is a difference between the control and gamification groups, it is not significant. Hussain et al.'s (2018) results show that a gamified work environment increases employee engagement, commitment, and motivation while positively impacting employees' mental health and stress perception. Thus, we encourage future research to investigate the subject from an intra-situational longitudinal perspective.

3.3.6.1 Theoretical and Practical Contribution

The positive side of IS use in demanding situations and the underlying mechanisms are still unexplored (Tarafdar et al., 2019). Recent literature suggested that a motivating gamified IS design could help individuals appraise an IS-enabled demand as a challenge rather than a threat (Tarafdar et al., 2019). We find empirical support for its ability to reduce threat appraisal, yet our results stop short of showing a significant positive effect on challenge appraisal. Our results imply several theoretical contributions.

First, we address the call for research by Tarafdar et al. (2019) to explore the role of cognitive appraisal in the context of the technostress process more comprehensively. Our results show whether IS-enabled demands related to time urgency are appraised as a threat or a challenge that can be affected through IS design elements. We provide insights that a gamified IS using the elements of progress bars and badges can reduce threat appraisal. Second, we show how this effect develops over time. Stress is a process, and previous research has indicated that appraisal may vary over time (e.g., Schwarzer, 1992). Our results show that gamification gradually helps individuals in reducing their threat appraisal over time (as indicated by a negative slope in the intervention group). Per our design, this may be due to feedback received. Third, this work contributes to the gamification literature by increasing the knowledge about its influence on the perception of IS use. Gamification researchers have primarily studied the context of flow which they consider a separate construct and research stream than stress (for a literature review: Oliveira et al., 2021). Our work addresses the effect of gamification on challenge and threat appraisal of IS-enabled demands. To the best of our knowledge, it is the first to do so following an intra-situational perspective over time. It provides first insights that gamification is a meaningful tool to positively influence the appraisal of IS-enabled demand by reducing threat appraisal.

Our work also provides practical implications on how threat and challenge appraisal of an IS user can be influenced. Building on our findings, we recommend that organizations and software providers gamify IS to affect their users' perception of stress. Our experiment shows one possible implementation that offers progress bars, feedback, and badges. For example, Microsoft Outlook offers the possibility to create tasks from emails that could be utilized to implement such a design. However, gamification can also be implemented into other work systems and in other forms. Through gamification, users perceive working with an IS as less threatening, which can reduce several adverse outcomes. Nevertheless, our study shows that the effect of gamification does not set in immediately but only after a certain period in which users become accustomed to the gamified IS.

3.3.6.2 Limitations and Future Research

Like all studies, this study has limitations that allow for additional research. First, our empirical results regarding challenge appraisal could not support the hypotheses theoretically derived from literature. We attribute this to an experimental design that did not increase the difficulty to counteract the novelty effect (Hamari et al., 2014) and a limited sample size. Second, our experimental design was intended to simulate an IS-enabled demand related to time urgency that can be appraised both as a challenge and a threat (Benlian, 2020). Transferability and generalizability of our findings to other IS-enabled demands need to be established. Also, our design is limited in creating an actual work situation involving aspects like workforce, working in multiple IS simultaneous, task complexity, and external interruptions. Yet, by recruiting MTurks for this task, we aimed to simulate a real work scenario in our experiment. Third, this study focuses on achievement-related gamification elements (e.g., points). Future research might consider investigating immersion-related elements (e.g., avatars, storytelling) and social-related elements (e.g., interactions) (Xi & Hamari, 2019) and their effect on appraisal. Lastly, we required multiple data points to analyze the perception of the different constructs as a trajectory over time (Kline, 2015). Therefore, participants interrupted the work in the experimental interface after each round by answering surveys. This procedure was necessary to collect data at four points in time. However, the interruptions could have led to distractions.

3.3.7 Conclusion

This work aims to understand better how gamified IS can positively influence the cognitive appraisal process toward supporting challenge appraisal and reducing threat appraisal. We developed a research model and measured the impact of gamification on the challenge and threat appraisal in an online experiment. We created a work situation that simulated IS-enabled demands related to time urgency. The interface of the intervention group contained various gamification design elements aimed at affecting appraisal. We analyzed appraisal from an intra-situational perspective and collected data at four different times during the experiment. The data was analyzed using LGMs. We find that after a familiarization phase, users of a gamified IS found the situation to be continuously less threatening than users of a non-gamified IS. Contrary to our hypotheses, it did not significantly affect the users' challenge appraisal. Further research should consider the novelty effect and use larger sample sizes. We contribute to a broader understanding of the cognitive appraisal process in IS use research and provide insights into how gamification can support challenge appraisal and reduce threat appraisal.

Funding: This paper presents and discusses results of the Bavarian Research Association on Healthy Use of Digital Technologies and Media (ForDigitHealth), funded by the Bavarian Ministry of Science and Arts.

3.3.8 References

Antin, J., & Churchill, E. (2011). Badges in social media: A social psychological perspective. In *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems.*

Arai, S., Sakamoto, K., Washizaki, H., & Fukazawa, Y. (2014). A gamified tool for motivating developers to remove warnings of bug pattern tools. In *Proceedings of the 6th International Workshop on Empirical Software Engineering in Practice*.

Ayyagari, Grover, & Purvis (2011). Technostress: Technological antecedents and implications. *MIS Quarterly*, *35*(4), 831. https://doi.org/10.2307/41409963

Bala, H., & Venkatesh, V. (2015). Adaptation to information technology: A holistic nomological network from implementation to job outcomes. *Management Science, 62*(1), 156-179. https://doi.org/10.1287/mnsc.2014.2111

Benlian, A. (2020). A daily field investigation of technology-driven spillovers from work to home. *MIS Quarterly*, *44*(3), 1259–1300. https://doi.org/10.25300/MISQ/2020/14911

Buchem, I., Klamma, R., & Wild, F. (Eds.). (2019). *Springer eBook Collection*. *Perspectives on Wearable Enhanced Learning (WELL): Current Trends, Research, and Practice* (1st ed. 2019). Springer. https://doi.org/10.1007/978-3-319-64301-4

Califf, C., Sarker, S [Saonee], & Sarker, S [Suprateek] (2020). The bright and dark sides of technostress: A mixed-methods study involving healthcare IT. *MIS Quarterly, 44*(2). https://doi.org/10.25300/MISQ/2020/14818

Cook, T. D., & al, e. (1970). Demand characteristics and three conceptions of the frequently deceived subject. *Journal of Personality and Social Psychology*, *14(3),* 185–194. https://doi.org/10.1037/H0028849

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104(4),* 716–733. https://doi.org/10.1037/a0031201

Csikszentmihalyi, M. (1998). *Finding flow: The psychology of engagement with everyday Life.* Basic Books.

Dennis, T. A., & O'Toole, L. (2014). Mental health on the go: Effects of a gamified attention bias modification mobile application in trait anxious adults. *Clinical Psychological Science: A Journal of the Association for Psychological Science*, *2(5),* 576–590. https://doi.org/10.1177/2167702614522228

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). Gamification: Toward a definition. In *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems*.

Diallo, T. M. O., & Morin, A. J. S. (2015). Power of latent growth curve models to detect piecewise linear trajectories. *Structural Equation Modeling: A Multidisciplinary Journal, 22(3),* 449–460. https://doi.org/10.1080/10705511.2014.935678

Dittes, S., & Smolnik, S. (2019). Towards a digital work environment: the influence of collaboration and networking on employee performance within an enterprise social media platform. *Journal of Business Economics, 89(8-9),* 1215–1243. https://doi.org/10.1007/s11573-019-00951-4

Drach-Zahavy, A., & Erez, M. (2002). Challenge versus threat effects on the goal–performance relationship. *Organizational Behavior and Human Decision Processes, 88(2),* 667–682. https://doi.org/10.1016/S0749-5978(02)00004-3

Edwards, J. R., & Cooper, C. L. (1988). The impacts of positive psychological states on physical health: A review and theoretical framework. *Social Science & Medicine*, *27*(12), 1447–1459. https://doi.org/10.1016/0277-9536(88)90212-2

Fajri, F. A., Haribowo P., R. K., Amalia, N., & Natasari, D. (2021). Gamification in e-learning: The mitigation role in technostress. *International Journal of Evaluation and Research in Education (IJERE)*, *10*(2), 606. https://doi.org/10.11591/ijere.v10i2.21199

Felt, J. M., Depaoli, S., & Tiemensma, J. (2017). Latent growth curve models for biomarkers of the stress response. *Frontiers in Neuroscience*, *11*, 315. https://doi.org/10.3389/fnins.2017.00315

Galluch, P., Grover, V., & Thatcher, J. (2015). Interrupting the workplace: Examining stressors in an information technology context. *Journal of the Association for Information Systems*, *16*(1), 1–47. https://doi.org/10.17705/1jais.00387

Gimpel, H., Lanzl, J., Regal, C., Urbach, N., Wischniewski, S., Tegtmeier, P., Kreilos, M., Kühlmann, T., Becker, J., Eimecke, J., & Derra, N. D. (2019). *Gesund digital arbeiten?!* Projektgruppe Wirtschaftsinformatik des Fraunhofer FIT. https://doi.org/10.24406/fit-n-562039

Hall, M., Glanz, S., Caton, S., & Weinhardt, C. (2013). Measuring your best you: A gamification framework for well-being measurement. In *Proceedings of the International Conference on Cloud and Green Computing.*

Hamari, J., & Eranti, V. (2011). Framework for designing and evaluating game achievements. In *Proceedings of DiGRA 2011 Conference: Think Design Play*.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? - A literature review of Empirical Studies on Gamification. In *2014 47th Hawaii International Conference on System Sciences (HICSS).*

Hammedi, W., Leclercq, T., Poncin, I., & Alkire, L. (2021). Uncovering the dark side of gamification at work: Impacts on engagement and well-being. *Journal of Business Research*, *122*, 256–269. https://doi.org/10.1016/j.jbusres.2020.08.032

Hoffmann, A., Faust-Christmann, C. A., Zolynski, G., & Bleser, G. (2019). Gamification of a stress management app: Results of a user study. In A. Marcus & W. Wang (Eds.), *Lecture Notes in Computer Science. Design, User Experience, and Usability. Application Domains.*

Hussain, S., Qazi, S., Ahmed, R., Streimikiene, D., & Vveinhardt, J. (2018). Employees management: Evidence from gamification techniques. *Montenegrin Journal of Economics*, *14*(4), 97–107. https://doi.org/10.14254/1800-5845/2018.14-4.7

Johnson, D., Deterding, S., Kuhn, K.-A., Staneva, A., Stoyanov, S., & Hides, L. (2016). Gamification for health and wellbeing: A systematic review of the literature. *Internet Interventions*, *6*, 89–106. https://doi.org/10.1016/j.invent.2016.10.002

Johnson, D., & Wiles, J. (2003). Effective affective user interface design in games. *Ergonomics*, *46*(13-14), 1332–1345. https://doi.org/10.1080/00140130310001610865

Ketter, W., Padmanabhan, B., Pant, G., & Raghu, T. S. (2020). Special issue editorial: Addressing societal challenges through analytics: An ESG ICE framework and research agenda. *Journal of the Association for Information Systems*, *21*(5), 1115–1127. https://doi.org/10.17705/1jais.00631

Kline, R. (2015). *Principles and Practice of Structural Equation Modeling: Fourth Edition (Methodology in the Social Sciences)*. Guilford Press.

Koivisto, J., & Hamari, J. (2018). Gamification of education and learning: A review of empirical literature. In *Proceedings of the 2nd International GamiFIN Conference*.

Krohne, H. W. (2001). Stress and coping theories. In *International Encyclopedia of the Social & Behavioral Sciences*. Elsevier. https://doi.org/10.1016/B0-08-043076-7/03817-1

Lazarus, R., & Folkman, S. (1984). *Stress, Appraisal, and Coping.* Springer .

Le Fevre, M., Matheny, J., & Kolt, G. S. (2003). Eustress, distress, and interpretation in occupational stress. *Journal of Managerial Psychology*, *18*(7), 726–744. https://doi.org/10.1108/02683940310502412

LePine, M. A., Zhang, Y., Crawford, E. R., & Rich, B. L. (2016). Turning their pain to gain: charismatic leader influence on follower stress appraisal and job performance. *Academy of Management Journal*, *59*(3), 1036–1059. https://doi.org/10.5465/amj.2013.0778

Levy, P. E., Albright, M. D., Cawley, B. D., & Williams, J. R. (1995). Situational and individual determinants of feedback seeking: A closer look at the process. *Organizational Behavior and Human Decision Processes*, *62*(1), 23–37. https://doi.org/10.1006/OBHD.1995.1028

Major, B., Richards, C., Cooper, M. L., Cozzarelli, C., & Zubek, J. (1998). Personal resilience, cognitive appraisals, and coping: An integrative model of adjustment to abortion. *Journal of Personality and Social Psychology*, *74*(3), 735–752. https://doi.org/10.1037/0022-3514.74.3.735

McGonigal, J. (2011). *Reality is Broken. Why Games make us Better and How They can change the World*, Penguin Books. https://doi.org/10.4000/questionsdecommunication.8846

Oliveira, W., Pastushenko, O., Rodrigues, L., Toda, A. M., Palomino, P. T., Hamari, J., & Isotani, S. (2021). Does gamification affect flow experience? A systematic literature review. In *Proceedings of the 5th International GamiFIN Conference 2021, Finland.*

Paniagua, S., Herrero, R., García-Pérez, A. I., & Calvo, L. F. (2019). Study of Binqui. An application for smartphones based on the problems without data methodology to reduce stress levels and improve academic performance of chemical engineering students. *Education for Chemical Engineers*, *27*, 61–70. https://doi.org/10.1016/j.ece.2019.03.003

Pereira, P., Duarte, E., Rebelo, F., & Noriega, P. (2014). A Review of Gamification for Health-Related Contexts. In A. Marcus (Ed.), *Lecture Notes in Computer Science. Design, User Experience, and Usability. User Experience Design for Diverse Interaction Platforms and Environments*. https://doi.org/10.1007/978-3-319-07626-3_70

Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology*, *14*(2), 154–166. https://doi.org/10.1037/a0019440

Ragu-Nathan, T. S., Tarafdar, M., Ragu-Nathan, B. S., & Tu, Q. (2008). The consequences of technostress for end users in organizations: Conceptual development and empirical validation. *Information Systems Research*, *19*(4), 417–433. https://doi.org/10.1287/isre.1070.0165

Rigby, S., & Ryan, R. (2011). *Glued to games : how video games draw us in and hold us spellbound*. Praeger.

Roh, S., Seo, K., Lee, J., Kim, J., Ryu, H. B., Jung, C., Lee, H., & Shin, J. (2016). Goal-based manufacturing gamification: Bolt tightening work redesign in the automotive assembly line. In C. Schlick & S. Trzcieliński (Eds.), *Advances in Intelligent Systems and Computing. Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future*. Springer. https://doi.org/10.1007/978-3-319-41697-7_26

Sailer, M., Mandl, H., & Klevers, M. (2013). Psychological perspectives on motivation through gamification. *Interaction Design and Architecture(S) Journal*(19), 28–37.

Schwarzer, R. (1992). Self-efficacy as a resource factor in stress appraisal processes. *Self-Efficacy: Thought Control of Action. Hemisphere*, 195–213.

Schwarzer, R., & Jerusalem, M. (1995). Generalized selfefficacy scale. *In Measures in Health Psychology: A User's Portfolio. Causal and Control Beliefs*, 35–37.

Selye, H. (1976). Stress without distress. In G. Serban (Ed.), *Psychopathology of Human Adaptation* (pp. 137–146). https://doi.org/10.1007/978-1-4684-2238-2_9

Tarafdar, M., Cooper, C. L., & Stich, J.-F. (2019). The technostress trifecta - techno eustress, techno distress and design: Theoretical directions and an agenda for research. *Information Systems Journal*, *29*(1), 6–42. https://doi.org/10.1111/isj.12169

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., & Ragu-Nathan, T. S. (2007). The impact of technostress on role stress and productivity. *Journal of Management Information Systems*, *24*(1), 301–328. https://doi.org/10.2753/MIS0742-1222240109

Tennakoon, W. D. N. S. M., & Wanninayake, W. M. S. M. (2020). Where play become effective: The moderating effect of gamification on the relationship between work stress and employee performance. *Sri Lanka Journal of Economic Research*, *7*(2), 63.

Waldersee, R., & Luthans, F. (1994). The impact of positive and corrective feedback on customer service performance. *Journal of Organizational Behavior*, *15*(1), 83–95. https://doi.org/10.1002/job.4030150109

Xi, N., & Hamari, J. (2019). Does gamification satisfy needs? A study on the relationship between gamification features and intrinsic need satisfaction. *International Journal of Information Management*, *46*, 210–221. https://doi.org/10.1016/j.ijinfomgt.2018.12.002

Yang, H., & Li, D. (2021). Understanding the dark side of gamification health management: A stress perspective. *Information Processing & Management*, *58(5)*, 102649. https://doi.org/10.1016/j.ipm.2021.102649

Zichermann, G., & Cunningham, C. (2011). Gamification by design: Implementing game mechanics in web and mobile apps. *O´Reilly Media, Inc*.

4 General Discussion and Conclusion

This dissertation aims to support current efforts to promote sustainability in everyday behavior by focusing on the potential of the ubiquity of digital technologies in a wide variety of everyday contexts. Specifically, it intends to advance the understanding of the sustainable interaction of individuals with digital technologies. While, on the one hand, the dissertation aims at *fostering pro-environmental behavior* when interacting with digital technologies, it also aims at mitigating adverse outcomes associated with the interaction, hence *maintaining mental health*. It includes the analysis of selected aspects of the three Human-Computer-Interaction (HCI) perspectives *context*, *technology*, and *human* to promote the two different outcomes of *fostering pro-environmental behavior* (Chapter 2) and *maintaining mental health* (Chapter 3). This Chapter first illustrates the key findings of this dissertation and their contributions in Chapter 4.1. Next, Chapter 4.2 lists its limitations and opportunities for future research. Lastly, Chapter 4.3 concludes the dissertation.

4.1 Summary of Results and Implications

This Chapter summarizes the findings, theoretical contributions, and practical implications of each of the seven research articles, structured along the HCI framework presented in Chapter 1. For each of the two addressed outcomes of pro-environmental behavior and mental health when interacting with digital technologies, the framework is applied as a guiding structure. Chapter 4.1.1 summarizes the key results of Chapter 2, which addresses the outcome of pro-environmental behavior. Chapter 4.1.2 focuses on the outcome of maintaining mental health and hence summarizes the findings of the three research articles in Chapter 3. Lastly, meta-inferences are provided at the end of this Chapter for an integrated view (Chapter 4.1.3).

4.1.1 Results and Implications of Chapter 2: Fostering Pro-environmental Behavior when Interacting with Digital Technologies

Four research articles in Chapter 2 of this dissertation deal with the outcome of fostering pro-environmental behavior when interacting with digital technologies using Digital Nudging Elements (DNEs). Chapter 2.1 covers the HCI perspective context by analyzing the effectiveness of DNEs in certain behavioral contexts, in which the individual makes decisions that have an impact on their environmentally sustainable behavior (e.g., in the contexts of “food” or “energy”). The developed framework of Chapter 2.1 helps to better assess the effectiveness of DNEs in their underlying contexts by structuring the highly fragmented research area of DNEs to promote pro-environmental behavior using an IS lens. Thus, Chapter 2.1 bridges the gap between research-driven from the context domain and works focusing on DNEs from other fields (e.g., psychology). The contribution of Chapter 2.1 is threefold: (1) It derives meta-inferences of context-specific DNEs, that go beyond the information provided within the individual studies that focus on specific DNEs in their underlying context. These meta-inferences include, for example, that “default rules” seem to be the most promising DNE to promote pro-environmental behavior in all contexts. (2) The article hypothesizes underlying mechanisms that influence the effectiveness of DNEs in different contexts. These mechanisms refer to possible trade-offs between costs and pro-environmental behaviors. When pro-environmental behavior is associated with reduced consumption (e.g., in contexts like “energy”), the users associate pro-environmental behavior with lower costs (e.g., saving energy). This conclusively means that in “consumption-related contexts,” there is a congruence between individuals’ economic motivations and pro-environmental behavior. In contrast, in “shopping-related contexts” (e.g., the contexts such as “food”), pro-environmental behavior is rather associated with higher costs (e.g., organic, and regional products), therefore presenting a trade-off. This underlying mechanism seems to influence the utilization and effectiveness of DNEs, which requires further study to verify (for further illustration regarding future research opportunities see Chapter 4.1.1). (3) Last, by covering an extensive range of representative research articles, Chapter 2.1 assists fellow researchers who can now quickly assess the diverse configuration and application of DNEs to promote pro-environmental behavior in one paper rather than roam through numerous articles. For practice, the developed framework provides an applicable tool to select effective DNEs for the respective context. The chapter assists practitioners from different domains in selecting and designing effective DNEs to promote pro-environmental behavior. Second, by summarizing existing knowledge and deriving meta-inferences, the article makes the previously distributed knowledge usable for practitioners.

Changing to the HCI perspective technology, Chapter 2.2 presents findings regarding the design and effectiveness of implementing promising DNEs in online grocery stores to address the outcome of pro-environmental behavior when shopping for groceries online. Chapter 2.2, therefore, represents one of the matrix fields of the framework developed in Chapter 2.1. Chapter 2.2 first analyzes existing literature on nudging elements to promote pro-environmental grocery shopping behavior. Next, it transfers the three promising elements “default rules”, “simplification”, and “social norms” into a digital choice environment, hence providing an implementation in a fictitious online grocery store. Afterward, the effect of the DNEs is examined by observing the buying behavior of 291 experiment participants, who had to complete a task in an online grocery store. The results of regression analysis show that “default rules” are moderately effective for the entire sample of customers when controlling for individual food choice motives and food consumption preferences. A further cluster analysis shows that "simplification" is effective for customers who are especially concerned about the environment. Chapter 2.2 contributes to prior research, which mostly focuses on physical choice environments, by transferring, implementing, and evaluating the DNEs "default rules", "simplifications", and "social norms" into a digital choice environment, here an online grocery store. Therefore, the research article offers important insights on how to influence customers' consumer behavior in favor of becoming more environmentally friendly as well as how the effectiveness of the assessed DNEs varies across different DNEs and individual characteristics. The investigation of different customer groups and the resulting difference in the DNEs effectiveness in promoting pro-environmental shopping behavior highlights the potential of using online consumer data to provide individualized online shops with different DNEs based on personal characteristics and preferences. For practitioners, especially for the online grocery stores, delivery, or subscription services currently on the rise, the results indicate that implementing pre-selection of pro-environmental options but also providing condensed information about the sustainability of products can positively influence the consumers' food choices and help environmentally-conscious customers to transfer their good intentions into concrete choices. This might lead to rising sales of ecologically sustainable products, and thereby could be used for marketing campaigns. Finally, consumers can profit from time savings and perhaps even receive health benefits that ecologically sustainable products might bring along.

Chapter 2.3 switches to the context of energy conservation, and thus implements and analyses DNEs in a smart home app (HCI perspective *technology*). Based on insights from prior studies in the field of DNEs to promote pro-environmental behavior (as pointed out in Chapter 2.1), Chapter 2.3 derives five hypotheses addressing the effectiveness of "default rules", "framing", and their combination in promoting more energy-conserving selections in a smart home app. The chapter provides a complete set of screen designs simulating a smart home app with the implemented DNEs. Next, the article tests their effectiveness by conducting an online experiment in which 231 participants were asked to control four smart home devices (i.e., light, washing machine, dishwasher, and heater) through the app. The results of a parametric ANOVA reveal large positive effects of "framing", and medium effects of the combination of both DNEs compared to the single usage of "default rules". Chapter 2.3 contributes by extending prior research to test DNEs in the rising technology of a smart home app, hence investigating DNEs to promote daily energy conservation behavior in a digital behavior environment. It surprisingly finds larger effects for "framing" compared to "default rules," even though "default rules" seemed much more promising in prior literature and have been investigated several more times and in various contexts (e.g., e-commerce, mobility, food, etc.) compared to "framing" (also findings of Chapter 2.1). The article finds the largest effects of the combination of both DNEs. It, thus, contributes by pointing out the assumption that "framing" might help to increase the users' comprehensibility of the option pre-selected by the "default rules". While prior studies predominantly focus on single DNEs, through the investigation of the combination of two DNEs, the article contributes by showing that "default rules" achieve better results if combined with an additional nudge. For practice, this chapter sheds light on important design and feature decisions companies and software developers should consider when creating smart home apps, which are currently becoming more common.

While the effectiveness of DNEs is of great interest to promote pro-environmental behavior, the users' satisfaction with the specific design and function of the DNE included in the technology is equally important. User satisfaction determines the user's continuing usage of the given technology in which DNEs are implemented. Therefore, Chapter 2.4 focuses on the HCI perspective *human* and complements the traditional focus on the effectiveness of DNEs with a perspective on user satisfaction. Chapter 2.4 analyzes the users' satisfaction with specific features of the well-researched and promising DNE "feedback" in a smart home app to promote energy conservation behavior (as pointed out in Chapter 2.1). By consolidating existing knowledge on different feedback nudge features (FNFs) that have been investigated to promote energy conservation behavior, Chapter 2.4 contributes by providing an overview of 25 FNFs structured in six dimensions (e.g., dimension "update frequency" includes the features "near real-time" and "periodically"). These dimensions with features can be regarded when investigating "feedback nudges" in smart home apps. Next, using the Kano model, a survey is performed to evaluate users' perception of the implementation or non-implementation of the 25 FNFs. A key result is the identification of "must-be" features, as their omission leads to user dissatisfaction – which should be avoided by implementing these features. Interestingly, these features proved less effective in promoting energy conservation behavior in prior studies. Chapter 2.4, therefore, sheds light on the importance of not only focusing on features that are efficient in promoting pro-environmental behavior but also including features whose non-implementation can risk user dissatisfaction, hence the continued usage of the smart home app. As a second key result, the article finds that most of the features belonging to the dimension "social comparison" are seen as "indifferent" to the user, which emphasizes that for these features, future research is needed to evaluate their effectiveness in promoting energy conservation. If these features prove to be effective, they should be included in smart home apps as they do not impact user satisfaction but can potentially promote energy conservation behavior. Lastly, Chapter 2.4 offers possibilities to integrate personalization and individualization in a smart home app by pointing out features that can be added optionally by each user as the effect can only be positive on user satisfaction. For practitioners, the chapter provides an overview of features that can be included in smart home apps to promote energy conservation behavior. Especially for features that have a large implementation overhead, it is helpful to know which features contribute to user satisfaction. Additionally, the findings help to select features that are best implemented optionally in a personalized area.

4.1.2 Results and Implications of Chapter 3: Maintaining Mental Health when Interacting with Digital Technologies

In Chapter 3, the focus of the research articles switches to a second important part of sustainable interaction with digital technologies: maintaining mental, specifically avoiding technostress. Chapter 3.1 sets the *context* and focuses on how organizations can prevent technostress among their employees. It conceptualizes the Theory of Stress Prevention in the specific context of technostress, introducing the concepts of primary, secondary, and tertiary technostress prevention measures. Chapter 3.1 presents a list of 24 primary and secondary prevention measures an organization can implement to address their moral and legal responsibility to prevent employees' technostress. The measures are characterized in terms of their basic approach to technostress prevention (primary vs. secondary technostress prevention), their applicability (i.e., concerning their entity of change, organizational size, target group, duration of implementation, realization duration, and effect duration), and their relevance in targeting technostress creators. This thus serves as a common starting ground for addressing technostress prevention from an organizational view. The implications for research of Chapter 3.1 are threefold: The article advances existing knowledge on technostress inhibitors by introducing the concept of primary, secondary, and tertiary prevention. It, thus, sheds light on how and at which stage of the technostress process, specific measures can prevent the emergence of it. Researchers working on analyzing or designing technostress inhibitors can use the prevention framing to obtain further theoretical grounding for their technostress research. Second, through characterizing the measures, the article offers the possibility to describe measures or groups of measures on a shared set of characteristics. This possibility is important to better compare and classify similar measures in future research. Also, the article finds that applying primary measures represents a long-term approach to preventing technostress, which requires high initial efforts. In comparison, secondary technostress prevention measures rather represent a short- and mid-term approach to preventing technostress and require lower initial efforts. Last, Chapter 3.1 contributes to research by shedding light on the relevance of primary technostress prevention measures to reduce technostressors. It finds that primary technostress prevention measures differ in their relevance of either reducing single or several technostress creators. For practice, the chapter offers valuable and actionable support for organizations to fulfill their moral, legal, and economic responsibility to reduce technostress among their employees by offering a list of 24 relevant and characterized primary and secondary prevention measures an organization can introduce.

Chapters 3.2 and 3.3 dive into two specific primary technostress prevention measures from the HCI perspective *technology* (Chapter 3.2) and the HCI perspective *human* (3.3) that both aim at reducing the frequency, duration, and/or intensity of technostress creators. Chapter 3.2 addresses the primary prevention measure "adopt a stress-sensitive digital workplace design", by investigating the characteristics of digital technologies used in a digital workplace. Being a mixed-methods study, the research methods applied in Chapter 3.2 consist of a structured literature analysis, qualitative interviews, and a quantitative survey of 4,560 employees that use digital technologies. The findings include a list of ten characteristics of digital technologies that are related to technostress, for each of which a measurement instrument is developed through explorative and confirmative structure analysis. This instrument is of importance for future research to investigate the sources of technostress. Next, Chapter 3.2 develops profiles on the perception of ten characteristics of 26 digital technologies used in a digital workplace and determines their influence on technostress creators using structural equation modeling. Overall, the contributions of Chapter 3.2 are threefold: first, it identifies additional characteristics of digital technologies and provides a measurement instrument for each. Second, Chapter 3.2 highlights the importance of investigating entire digital workplaces instead of focusing on single digital technologies only. Third, for practitioners, by providing insights on the influence of each characteristic on different technostress creators, the article highlights different design opportunities for health-oriented workplaces that alleviate technostress. Specifically, it recommends that workplace designers should focus on usability features, including usefulness, simplicity of use, and reliability, but also on technologies that enable mobility and pull configurations.

Lastly, Chapter 3.3 addresses another primary technostress prevention measure: the use of gamification. Chapter 3.3 changes the HCI perspective from *technology* to *human* and focuses on reducing the technostress creator through a change in the individual’s appraisal when interacting with digital technologies. The individual’s appraisal of a given situation is important as it determines if the situation leads to negative outcomes in terms of technostress (i.e., a negatively appraised situation poses a technostress creator, and thus should be avoided). The article considers the positive impact of gamification on cognitive appraisal and shows how gamification might help to influence the appraisal of a demand – enabled by digital technology – to be seen more as a challenge and less as a threat. Through examining data from an online experiment with analyses of the Latent Growth Model, Chapter 3.3 finds that the integration of gamification elements (i.e., point system, notifications, progress bars, and badges) can reduce the individual’s threat appraisal. No significant increase in challenge appraisal among panel participants working in the gamified environment of the online experiment is found. Still, the chapter contributes to a better understanding of the cognitive appraisal process and identifies gamification as a valuable tool to positively influence the appraisal process by reducing threat appraisal. For practitioners, the article shows how managers or software developers can positively influence the individual’s appraisal when interacting with digital technologies, thus preventing technostress by reducing the chance of the emergence of a technostress creator at the beginning of the technostress process.

4.1.3 Integrated Perspective on Results and Implications

Four overarching contributions to pro-environmental behavior when interacting with digital technologies using DNEs emerge when taking an integrated perspective on the results and implications of Chapter 2. First, the overview of the effectiveness of DNEs based on the underlying behavioral context (framework of Chapter 2.1) uncovers differences and similarities between DNEs and contexts that go beyond the information provided in single studies. It, therefore, highlights the importance of investigating every single DNE in the underlying context with its specific configuration, but also sheds light on possible underlying mechanisms between contexts, offering explanations for similarities. Second, with a deep dive into the context of grocery shopping with a focus on the technology, a design for an online grocery store that includes the DNEs “social norms”, “default rules”, and “simplification” is tested and presented to promote ecologically sustainable grocery shopping behavior. The last two mentioned proved to be effective. By including individual customer differences, the article uncovers differences in the effectiveness of DNEs among different customer groups. This highlights the potential of using online individual consumer data to provide individualized online shops based on personal characteristics and preferences. Third, focusing on advancing smart home technology, a design for a smart home app is evaluated including the DNEs "default rules" and "framing". Both designs proved to be effective in promoting energy conservation behavior, especially the combination of both, leading to the assumption that users appreciate an explanation (through "framing") of the pre-selected option. Fourth, the traditional focus on the effectiveness of DNEs is complemented by investigating user satisfaction with single FNFs in a smart home app. Thereby, a list of features that must be included to avoid user dissatisfaction is given, which differs from prior findings regarding the effectiveness to promote energy conservation behavior and thus sheds light on the importance of user satisfaction when designing a technology that aims to promote pro-environmental behavior.

Overall, the findings of Chapter 2 emphasize the importance of investigating the perspectives of *context*, *technology*, and *human* when interacting with digital technologies to promote pro-environmental behavior. While Chapter 2.1 provides insights into DNEs' effectiveness in a specific behavioral context, Chapters 2.2 and 2.3 zoom in on the technological implementation of specific DNEs, and Chapter 2.4 sheds light on the importance of investigating user satisfaction when implementing (as proposed in Chapters 2.2 and 2.3) specific well-researched and promising DNEs (as pointed out in Chapter 2.1) in digital technologies that aim to promote pro-environmental behavior. It becomes clear, that when implementing DNEs in digital technologies, the effectiveness of the underlying context (Chapter 2.1), its concrete design (Chapters 2.2 and 2.3), and also the user preference (Chapter 2.4) are important to consider.

Consolidating the implications of Chapter 3, which focus on maintaining mental health when interacting with digital technologies in professional life, a deepened understanding of how technostress can be prevented, especially through the detailed investigation of two primary prevention measures (Chapters 3.2 and 3.3) emerges. Chapter 3.1 sheds light on the large variety of prevention measures an organization can undertake to prevent technostress among their employees. By developing a list of 24 primary and secondary prevention measures, that either aim to reduce the frequency, duration, and/or intensity of the technostress creator (primary) or aim at changing and optimizing the individuals' technostress response (secondary), the article assists researchers and practitioners to maintain mental health by preventing technostress. Chapter 3.2 zooms in on one specific primary prevention measure addressing the technology itself to reduce the frequency, duration, and/or intensity of the technostress creator. It identifies ten characteristics of digital technologies at a digital workplace and how they influence technostress creators when investigated in a digital workplace portfolio consisting of several digital technologies. It, thus, helps to design digital workplaces to maintain mental health by targeting the technostress creator. Chapter 3.3 also addresses a primary technostress prevention measure ("use gamification") through the human perspective by finding that the integration of gamification in digital technologies can reduce the individual's threat appraisal of the demand caused by interacting with digital technologies. It contributes to a better understanding and importance of the cognitive appraisal process, as it determines whether a given situation is appraised as a technostress creator.

To sum up, the findings of Chapter 3 also emphasize the importance of investigating all three HCI perspectives to promote mental health when interacting with digital technologies. By introducing 24 technostress prevention measures an organization can introduce to reduce technostress among employees who need to interact with digital technologies in the professional context, Chapter 3.1 focuses on the perspective *context*. Chapters 3.2 and 3.3 zoom in on two specific technostress prevention measures that aim at reducing the technostress creators by taking two different perspectives: Chapter 3.2 focuses on characteristics of digital technologies at a digital workplace and their influence on technostress creators, thus the *technology* perspective. Chapter 3.3 analyses the potential of gamification to positively influence *human* appraisal when working with digital technologies, so to prevent the emergence of technostress creators through a decrease in threat appraisal.

The results presented are summarized in Table 4.1-1. It compiles the separate results emerging from the seven research articles regarding the analysis of sustainable interaction with digital technologies. Table 4.1-1 further aggregates the findings over the two outcomes of pro-environmental behavior and mental health for a holistic overview of the three HCI perspectives. Thereby, it becomes clear that, as aimed by the utilized HCI framework, the different research perspectives of *context*, *technology*, and *human* informs and builds on each other to create a comprehensive view of sustainable interaction with digital technologies to promote pro-environmental behavior and maintain mental health. The consideration of all perspectives is needed to reach the intended outcomes. The *context* perspective helps to bring together the individual pieces of the mosaic and to create an overview, be it individual studies focusing on the implementation of DNEs or the design of individual technostress prevention measures. The *technological* perspective helps to better understand the design and characteristics of digital technologies while the *human* perspective has shown in both chapters that human perception plays an important role that must be considered in order to reach the preferred outcome when interacting with digital technologies

Outcome		Human-Computer-Interaction Perspective			Overall Findings
		Context	**Technology**	**Human**	
Outcome	**Pro-environmental Behavior** *(Chapters 2.1, 2.2, 2.3, and 2.4)*	• Derivation of meta-inferences of the effectiveness of DNEs in specific behavioral contexts that impact the individuals' pro-environmental behavior (Chapter 2.1) • Calling for grant theory to verify the expected underlying mechanism that influences the effectiveness of DNE in specific contexts (Chapter 2.1) • Providing an applicable tool and overview to quickly access the effectiveness of DNEs in a specific behavioral context (Chapter 2.1)	• Design and implementation of different DNEs in an online grocery store and a smart home app to promote pro-environmental behavior (Chapters 2.2 and 2.3) • Observation of a moderate positive effect of "default rules" for all surveyed customers and a positive effect of "simplification" among environmentally conscious customers on pro-environmental grocery shopping behavior (Chapter 2.2) • Observation of a surprisingly larger effect for "framing" compared to "default rules" leading to the assumption that "framing" helps to increase smart home app user's comprehensibility of the preselected option (Chapter 2.3)	• Evaluation of the impact of the implementation of the 25 FNFs on user satisfaction in smart home apps (Chapter 2.4) • Realization that user satisfaction is of importance when designing digital technologies that include DNEs to promote pro-environmental behavior (Chapter 2.4)	• Understanding of how the effectiveness of DNEs differ among behavioral contexts in which the individual uses digital technologies to complete tasks • Insights on how DNEs in a digital technology must be designed in online grocery stores and a smart home app to promote pro-environmental behavior • Shedding light on the importance of user satisfaction when designing a DNE and how these results can differ from results focusing on effectiveness only
	Mental Health *(Chapters 3.1, 3.2, and 3.3)*	• Introduction of primary, secondary, and tertiary technostress prevention based on the Theory of Preventive Stress Management (Chapter 3.1) • Presentation of 24 characterized prevention measures an organization can implement to address their moral and legal responsibility to prevent employees' technostress (Chapter 3.1) • Shedding light on the relevance of primary measures to reduce technostress creators (Chapter 3.1)	• Identification of ten characteristics of digital technologies that are related to technostress (Chapter 3.2) • Profiling 26 common digital workplace technologies along the ten characteristics (Chapter 3.2) • Recommendation for digital workplace designers to focus on usability features and technologies that enable mobility and pull configurations (Chapter 3.2)	• Better understanding of the cognitive appraisal process (Chapter 3.3) • Observation of a positive effect of gamification elements in reducing the individual's threat appraisal when interacting with digital technologies (Chapter 3.3)	• Introduction of the Theory of Preventive Stress Management in the context of technostress • Derivation of 24 technostress prevention measures categorized into primary and secondary prevention measures • Indications of how-to best design digital workplaces focusing on digital technology characteristics and indications for gamification as a valuable tool to positively influence an individual's appraisal process, both to prevent technostress and promote mental health

Table 4.1-1 Summary of the findings of the included research articles

4.2 Limitations and Future Research

Each research article comes with limitations, which are discussed here. Furthermore, based on the results of the seven research articles included in this dissertation, new questions and opportunities for future research emerge. The most beneficial areas are discussed in this chapter.

4.2.1 Limitations and Future Research of Chapter 2: Fostering Pro-environmental Behavior when Interacting with Digital Technologies

Like any research article, the articles of Chapter 2 have limitations that should be considered and can be addressed in further research. Although Chapter 2.1 covers a wide area of essential contexts around pro-environmental behavior, the scope must not be defined as exhaustive and leaves room for further research in other parts of sustainability (e.g., focusing on social sustainability instead). Also, it seems appropriate to investigate further contexts that are relevant for pro-environmental behavior (e.g., waste management), which have not yet been the focus of previous DNE research. Second, the developed framework represents the status quo of research around DNEs to promote pro-environmental behavior. But the research area is rapidly changing, thus it may be worthwhile to re-run this study to keep up with the research progress.

Next to addressing the limitations of Chapter 2.1, the research article sheds light on several possible future research directions by pointing out missing research in the framework and by hypothesizing possible underlying mechanisms across context, that need to be verified in the future (trade-off vs. congruence of pro-environmental behavior and costs in shopping- vs. consumption-related contexts, see Chapter 4.1.1). Regarding the identified blank spots, an example for future research includes the investigation of DNEs in the context of "durable goods" (e.g., cars) that influence the decision before the action ("priming", "social norms", "goal setting"), instead of during the action ("default rules", "simplification"), which are currently studied only. Hypothesizing that decisions in these contexts are rather long-term decisions (e.g., buying a new car), the influence of DNEs might be more effective before the action to influence these long-term decisions.

The second example of future research opportunities identified in the framework of Chapter 2.1 includes the investigation of DNEs in digital environments to promote pro-environmental behavior in the contexts of "energy" and "water". Currently, studies in these contexts mainly focus on DNEs in physically targeted environments (e.g., the DNE implemented in an app reminds301 you to turn down the heating when opening the window, but the heating must be managed physically). But through the rise of smart home technologies, these insights should be transferred and tested in a digital target environment (e.g., the heating is managed in the same app in which the DNE is implemented). Chapters 2.3 and 2.4 partly address this research opportunity by investigating the DNEs “default rules,” “framing,” and “feedback” in a smart home app (i.e., digital target environment), but allow room and offer inspiration for further studies in this field. Finally, Chapter 2.4 also partly addresses one further future research opportunity pointed out in Chapter 2.1, which is the analysis of design principles or meta-analysis for areas in which several studies have been performed (e.g., “feedback” in the context of “energy”). Chapter 2.4 addresses this opportunity by investigating users’ preferences for features of the DNE “feedback” in the context of “energy”, but still offers room for further research in this promising area.

Chapters 2.2, 2.3, and 2.4 are subject to similar limitations due to their experimental and survey-based approaches, which lack real-world consequences. Instead of fictional shopping and household tasks, the DNEs can be implemented in real-world online settings, in which customer behavior can be observed in more natural contexts with real-world consequences (e.g., waiting longer for the dishwasher to finish or paying high prices with “real money” for organic products). Especially for Chapter 2.4, which is based on the Kano questionnaire, the length of the survey of functional and dysfunctional questions for each of the 25 features might have negatively influenced the concentration of the participants. Due to the structured literature review, Chapter 2.4 relies on prior research conducted in the field of feedback nudges to promote energy conservation behavior. While the findings of the 25 FNFs were discussed with an industry expert, future research could further complement the list with practical insights to ensure completeness. In addition, Chapter 2.4 measures aggregated user satisfaction, but does not consider individual differences between the users. As the results indicate that individual perceptions differ, future research could look at different user subgroups (e.g., by analyzing the impact of environmental attitude or technological affinity of the user).

Focusing on further future research possibilities besides the ones that resulted from Chapter 2.1, more DNEs as well as different configurations and designs could additionally expand the knowledge of which DNEs are effective in promoting ecologically sustainable shopping behavior (Chapter 2.2) and energy consumption behavior (Chapter 2.3). These possible future research opportunities are also pointed out in the framework of Chapter 2.1 (e.g., DNEs in digital environments to promote pro-environmental behavior in the contexts of “energy” and “water”).

4.2.2 Limitations and Future Research of Chapter 3: Maintaining Mental Health when Interacting with Digital Technologies

The three research articles of Chapter 3 also come with some limitations and future research propositions. First, the results of Chapter 3.1 are based on a structured literature review, 17 experts in focus groups, and the expertise of 13 Delphi panelists. While the focus group and Delphi panel are diverse, no formal claim about the representativeness can be made, thus presenting a limitation. Second, the findings regarding the measures' relevance and expected effectiveness need more extensive quantitative empirical research in the future to make definitive claims on the measures' effectiveness in preventing single technostress creators. Third, to offer a first overview of organizational prevention, the scope to industries or company sizes were kept broad. However, some of the results might depend on the respective industry. Future research can therefore address the quantitative analysis of the relevance relation, and overall conduct targeted empirical studies on the implementation, use, and efficacy of technostress prevention measure. As a starting point, three propositions are formulated in the research article, that can be tested empirically in future quantitative studies. Second, the developed overview of technostress prevention measures is important for researchers to design and investigate technostress prevention measures in detail in the future, similar to Chapters 3.2 and 3.3. The results and implications of Chapters 3.2 and 3.3 emphasize the importance of a deeper investigation from different perspectives. Next, while the list of prevention measures and their expected effectiveness on technostress creators of Chapter 3.1 is valuable, in real-life scenarios, organizations will probably apply sets of such measures. Therefore, future research could investigate sets and portfolios of prevention measures and create a quantification of the effect of different portfolios and a guideline on how to develop and implement such a prevention measure portfolio.

For Chapter 3.2 which focuses on the characteristics of digital technologies, the following limitations should be considered. First, participants were asked to evaluate ten characteristics of certain digital technologies that they use frequently. However, they did not assess the characteristics of all technologies they use at their digital workplace. Nevertheless, due to the large size of our dataset, we were able to assign the perception of the characteristics of the digital technologies at her or his entire workplace among participants. Second, we asked general users of digital technologies instead of IT experts. Hence, the evaluation of the characteristics is not objective and should be seen as perceived characteristics of digital technologies. With a view to future research potential, an investigation of the objective characteristics and a comparison with the perceived characteristics could provide valuable insights. Besides these limitations, Chapter 3.2 adds to a better understanding of sources of technostress and provides a measurement model for each identified characteristic, which is of importance for future research when further analyzing the sources of technostress. Last but not least, Chapters 3.1 and 3.2 both examine nine (Chapter 3.1) and five (Chapter 3.2) technostress creators, that are known as the most frequently studied sources of technostress. But literature holds further technostress creators, which could be included in future studies.

The main limitation of Chapter 3.3 is the missing empirical results regarding the increase in challenge appraisal in the gamified environment, which can be attributed to the experimental design and the size of the dataset. Therefore, future research should improve the experiment in terms of difficulty and sample size. Second, the experiment focused on only one demanding situation when working with digital technologies (time urgency); hence transferability and generalizability to other situations need to be established.

4.3 Conclusion

Due to the ubiquity of digital technologies in daily life and the increasing human-induced environmental deterioration, the dissertation focused on the potential of fostering pro-environmental behavior when interacting with digital technologies. As the increased interaction with digital technologies can cause adverse effects on the individuals' health, the dissertation also focuses on maintaining mental health when interacting with digital technologies, therefore mitigating technostress. The seven included research articles are structured along the three Human-Computer-Interaction perspectives context, technology, and human and contribute insights to the two addressed sustainable outcomes. The first four articles provide indications on how Digital Nudging Elements must be selected, implemented, and designed to effectively influence the user towards pro-environmental behavior. The remaining three articles demonstrate possible technostress avoidance efforts to maintain mental health when interacting with digital technology. Overall, this dissertation supports current efforts in both research and practice to promote sustainable interaction with digital technologies – one that is both environmentally friendly and healthy, especially for the mind.