Designing Behavior Change Support Systems in the Context of Knowledge Documentation:

Development of Theory and Practical Implementation

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"Quality is not an act, it is a habit."

Aristotle

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Note: All essays in this dissertation have been slightly modified compared to their published version to facilitate readability. Modifications include a continuous page count, adapted references to other sections, and a central list of references at the end of this dissertation.

List of Essays

This dissertation is based on multiple scientific essays. In case of essays already published, the corresponding outlet will be shown alongside its current ranking in the "WI-Orientierungslisten der Wissenschaftlichen Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft e.V. (WKWI) und des Fachbereichs Wirtschaftsinformatik der Gesellschaft für Informatik (GI-FB WI)" as well as the "VHB-JOURQUAL 3 des Verbands der Hochschullehrer für Betriebswirtschaft e.V. (VHB)". The research highlights of each essay are presented, and for essays with multiple authors, the share contributed by the author of this dissertation is mentioned.

In order as mentioned in the thesis:

1. Hosseini, Sabiölla; Merz, Marieluise; Röglinger, Maximilian; Wenninger, Annette (2018). Mindfully Going Omni-channel: An Economic Decision Model for Evaluating Omni-channel Strategies. Decision Support Systems, 109, pp. 74-88.

   Highlights:
   - We propose a decision model for determining an appropriate omni-channel strategy for value-based management.
   - The decision model is the first to capture non-sequential customer journeys.
   - We evaluate the decision model based on real-world data from a German bank, which demonstrates the applicability and usefulness of our decision model in real-world settings.

   Ranking (Share: 25%):
   WI-Orientierungslisten: Ranked A
   VHB-JOURQUAL 3: Ranked B

   https://doi.org/10.1016/j.dss.2018.01.010   *urn:nbn:de:bvb:384-opus4-645349*

2. Schermann, Michael; Merz, Marieluise (2018). User Participation in Information Systems Projects: Necessary But Not Sufficient. In: 26th European Conference on Information Systems (ECIS). Portsmouth, UK, June 23-28, pp. 103 -117.

   Highlights:
   - We instantiate the theoretical framework for user participation proposed by Markus and Mao (2004) to unveil the relationship between modes of user participation and performance of information systems projects.
   - We perform a quantitative meta-analysis adopting a two-stage structural equation modeling approach using 226 studies with a total of 42,330 information systems projects.
   - Our results emphasize the different effects of functional and managerial user participation and show the direct relationship of change agent capabilities to project performance.

   Ranking (Share: 50%):
   WI-Orientierungslisten: Ranked A
   VHB-JOURQUAL 3: Ranked B

   https://aisel.aisnet.org/ecis2018_rp/103/ *urn:nbn:de:bvb:384-opus4-649573*

3. Merz, Marieluise; Ackermann, Lena (2021). Design Principles of Persuasive Systems – Review and Discussion of the Persuasive Systems Design Model. In: 27th Americas Conference on Information Systems (AMCIS). Montreal, Canada/Virtual Conference, August 9-13.

   Highlights:
   - We provide an overview of the application of design principles in theoretical and practical studies about persuasive systems.
   - We identify and analyze 42 studies with 633 applications of the design principles of the Persuasive Systems Design model of Oinas-Kukkonen and Harjumaa (2009) and 62 additional concepts used as design principles.
   - Our results show the current lack of transparence in design principles formulation and usage, as well as provide a base for developing enhanced models.

   Ranking (Share: 70%):
   WI-Orientierungslisten: Ranked B
   VHB-JOURQUAL 3: Ranked D

   https://aisel.aisnet.org/amcis2021/sig_hci/sig_hci/3/
   urn:nbn:de:bvb:384-opus4-961735

4. Merz, Marieluise; Steinherr, Vanessa (2022). Process-based Guidance for Designing Behavior Change Support Systems - Marrying the Persuasive Systems Design Model to the Transtheoretical Model of Behavior Change. Communications of the Association for Information Systems, 50, pp. 337-357.

   Highlights:

   - We develop a model that specifies the Persuasive Systems Design model and provides a guideline to select effective design principles for BCSS.
   - Based on theory and a systematic literature review, we identify 11 design principles as basic requirements and categorize 17 design principles into four levels of recommendation for the transitions along the stages of behavior change.
   - By specifying 85 links between the design principles of the Persuasive Systems Design model and the stages of change, the model merges technical and psychological views for designing persuasive systems.

   Ranking (Share: 50%):
   WI-Orientierungslisten: Ranked B
   VHB-JOURQUAL 3: Ranked C

   https://doi.org/10.17705/1CAIS.05014   *urn:nbn:de:bvb:384-opus4-961688*

5. Merz, Marieluise; Steinherr, Vanessa. Design Principles for Persuasive Systems – Towards Designing Behavior Change Support Systems. Revise and resubmit in: Business & Information Systems Engineering.

   Highlights:

   - We synthesize existing design knowledge from theoretical and practical studies to systematically derive design principles for Behavior Change Support Systems.
   - Following the process of design principle development of Möller et al. (2020b) and the design principles schema of Gregor et al. (2020), we aggregate 125 concepts of design knowledge to 14 design principles.
   - Our design principles provide researchers and developers with explicitly formulated prescriptive knowledge on how to design, evaluate, and develop Behavior Change Support Systems.

   Ranking (Share: 50%):
   WI-Orientierungslisten: Ranked A
   VHB-JOURQUAL 3: Ranked B

6. Merz, Marieluise (2020). Gestaltung eines Behavior Change Support Systems für nachhaltige Wissensdokumentation. Research-in-Progress. In: 15. Internationale Tagung Wirtschaftsinformatik (WI). Potsdam, March 9-11, pp. 480-486.

   Highlights:
   - We present a design for developing a Behavior Change Support System for knowledge management along the five stages of change of Prochaska and DiClemente (1983).
   - Based on literature reviews with 56 results about behavior change and 130 results about knowledge management systems, this proposes the first Behavior Change Support System in the context of knowledge management.
   - While most Behavior Change Support Systems presume problem awareness, we introduce the combination of scenarios and reflection questions to raise problem awareness.

   Ranking:
   WI-Orientierungslisten: Ranked A
   VHB-JOURQUAL 3: Ranked C

   https://doi.org/10.30844/wi_2020_d8-merz *urn:nbn:de:bvb:384-opus4-891164*

7. Merz, Marieluise (2022). Bewusstseinsbildung und Verhaltensänderung für Wissensdokumentation. In: 17. Internationale Tagung Wirtschaftsinformatik (WI). Prototype-Track. Virtual Conference / Nürnberg, Germany, February 21-23.

   Highlights:
   - We present the prototype *wissensguide* as a Behavior Change Support System that guides users through the stages of behavior change towards sustainable knowledge documentation.
   - The prototype offers high rigor and shows practical implementation of the design. It is published as a web-app, Android- and iOS/Testflight app.
   - The evaluation emphasizes users' acceptance and the potential of the artifact to raise awareness for knowledge documentation.

   Nominated for Best Prototype Award: 2nd Runner-Up.

   Ranking:
   WI-Orientierungslisten: Ranked A
   VHB-JOURQUAL 3: Ranked C

   https://aisel.aisnet.org/wi2022/prototype_track/prototype_track/33
   urn:nbn:de:bvb:384-opus4-961672

8. Merz, Marieluise; Hurm, Max (2022). Goal-Setting for Knowledge Documentation using Persuasive Systems Design. In: 55th Hawaii International Conference on System Sciences (HICSS). Virtual Conference, January 3-7.

   Highlights:
   - We investigate goal-setting in persuasive systems and derive 17 design principles from literature and theories.
   - Based on a systematic literature review with 51 studies and two design iterations, we first realize the design principles in a specific goal-setting process and, second, implement them as a persuasive system.
   - We evaluate the persuasive system using semi-structured interviews involving 20 users with different levels of experience.

   Ranking (Share: 85%):
   WI-Orientierungslisten: Ranked B
   VHB-JOURQUAL 3: Ranked C

   https://doi.org/10.24251/HICSS.2022.680 *urn:nbn:de:bvb:384-opus4-961719*

9. Merz, Marieluise. Persuasive Systems in the Context of Knowledge Documentation: A Human-centered Approach to Derive Design Principles. Under review in: Business & Information Systems Engineering.

   Highlights:
   - We extract design principles for persuasive systems in the context of knowledge documentation with a reflective, human-centered approach.
   - The analysis combines knowledge management preferences of 101 users in seven scenarios with design aspects that are identified from 342 qualitative statements of 57 users using a state-of-the-art topic modeling approach.
   - The resulting 14 mechanisms specify design principles and emphasize aspects of knowledge management that should be considered important aspects and aspects for development.

   Ranking:
   WI-Orientierungslisten: Ranked A
   VHB-JOURQUAL 3: Ranked B

1 Introduction

The actions of employees and their knowledge shape developments and future growth (Alt et al. 2021). Although innovation and operating efficiently require creating, transferring, and applying knowledge (Alavi and Leidner 2001), successful knowledge documentation remains a challenge for organizations (Pereira et al. 2021; Aboelmaged 2018). While knowledge management systems support knowledge management activities (Alavi and Leidner 2001), the missing link to applying knowledge management relies on human actions and their behaviors (Davenport 1994; AlShamsi and Ajmal 2018).

Supplementing functional knowledge management systems, persuasive systems that focus on addressing the behavior of their users combine the technical features with aspects that influence users' actions and application of the systems. While persuasive technology generally denotes technology that influences users through persuasion (Fogg 2003), a behavior change support system (BCSS) is a key construct for research in persuasive technology (Oinas-Kukkonen 2010a, 2010b) and "designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception" (Oinas-Kukkonen 2010a, p. 6). Therefore, a well-designed BCSS in the context of knowledge documentation has the potential to enhance knowledge management activities that prevent knowledge loss and thus foster innovation (Merz 2022).

According to a systematic literature analysis (Merz 2020) and to the best of our knowledge, this dissertation is the first to investigate the design of BCSS in the context of knowledge documentation. We raise the superordinate question: *How should a BCSS be designed to persuade users to change their behavior towards knowledge documentation?*

This dissertation answers this question with a design science research (DSR) approach that combines essays about 1) the environment, which is investigated for addressing and involving users to participate in information systems projects, 2) the knowledge base developing theories of designing BCSS, and 3) the specific design of a BCSS towards knowledge documentation. This supports both, users to adopt knowledge documentation as well as researchers and developers to design meaningful BCSS.

Each essay of this dissertation is grounded on both, practical relevance as well as scientific rigor. In particular, investigating the research question in the essays contributes with theory on how to design BCSS and practical implementation of a BCSS in the context of knowledge documentation. Further, they contribute in a descriptive way by describing the current state-of-the-art and creating novel design knowledge. As design-oriented information systems research according to Österle et al. (2011), the essays comply with the principles of abstraction, originality, justification, and benefit. Inspired by the DSR cycles of Hevner (2007) and Drechsler and Hevner (2016), Figure 1 depicts an overview of the essays.

Environment Addressing and Involving Users	**Information Systems Design** BCSS for Knowledge Documentation	**Knowledge Base** Theory of Designing BCSS
Essay 1: Mindfully Going Omni-channel: An Economic Decision Model for Evaluating Omni-channel Strategies **Essay 2:** User Participation in Information Systems Projects: Necessary but not Sufficient	**Essay 6:** Gestaltung eines Behavior Change Support Systems für nachhaltige Wissensdokumentation **Essay 7:** Bewusstseinsbildung und Verhaltensänderung für Wissensdokumentation **Essay 8:** Goal-Setting for Knowledge Documentation using Persuasive Systems Design **Essay 9:** Persuasive Systems in the Context of Knowledge Documentation: A Human-centered Approach to Derive Design Principles	**Essay 3:** Design Principles of Persuasive Systems – Review and Discussion of the Persuasive Systems Design Model **Essay 4:** Process-based Guidance for Designing Behavior Change Support Systems – Marrying the PSD Model to the Transtheoretical Model of Behavior Change **Essay 5:** Design Principles for Persuasive Systems – Towards Designing Behavior Change Support Systems

Figure 1: Overview of essays, inspired by the DSR cycles of Hevner (2007)

The first two essays investigate addressing and involving users for participating in information system projects. This is important because users are critical actors for information systems (Schermann and Merz 2018; Gregor et al. 2020) and especially for systems that focus on supporting and guiding their users. Thus, we argue that it is relevant to investigate how to implement channel strategies to address customers as future users of the BCSS (Essay 1) and to synthesize existing findings on the role of user participation to the performance of information system projects (Essay 2). In particular, **Essay 1** focuses on communication and interaction channels (Hosseini et al. 2018). While earlier studies predominantly take a descriptive perspective and require sequential customer journeys, we propose a decision model for determining an appropriate omni-channel strategy that allows non-sequential customer journeys and is highly adaptable to the organization's situation (e.g., online and offline channels, opening and closing of channels, customers' channel preferences). As opposed to multi-channel management, which considers different channels as separate and independent (Nüesch et al. 2015), omni-channel management applies synergetic management and considers interactions across different channels (Verhoef et al. 2015). The decision model analyses the potential of different channel strategies and, drawing on value-based management, recommends the omni-channel strategy with the highest contribution to an organization's long-term firm value. Our evaluation of the model based on real-world data from a German bank demonstrates its applicability and usefulness in a real-world setting. In the context of this dissertation, the study contributes insights into channel strategies for user interaction and provides a decision model to choose the appropriate channel strategy for the long-term implementation on how to address customers (i.e., users) in an organizational setting.

In addition to addressing users, **Essay 2** examines the role of user participation to the performance of information systems projects and explores the effects of different modes of user interaction on project performance (Schermann and Merz 2018). In this essay, we perform a meta-analytic structural equation modeling based on 226 studies with a total of 42,330 information systems projects. Our model instantiates and specifies the theoretical framework by Markus and Mao (2004). Differentiating between capacities and capabilities of stakeholders to include users and between formal and informal modes of user participation, the results show how user participation is necessary to improve but not sufficient to ensure project outcomes. As this dissertation addresses how to persuade users to change their behavior, we emphasize users' attitudes and participation to design meaningful BCSS. In this context, Essay 2 provides detailed insights into the role of user participation to the performance of information systems projects, in particular by highlighting to include users during systems design and ensuring high stakeholder capacities (i.e., abilities of stakeholders to contribute to the success of the project) (Schermann and Merz 2018).

The following essays (Essays 3 - 5) are on the theory of designing BCSS. When communicating design knowledge, design principles provide "prescriptive statements that include how to do something to achieve a goal" (Gregor et al. 2020, p. 1622). For designing BCSS, the Persuasive Systems Design (PSD) model of Oinas-Kukkonen and Harjumaa (2009) is the most referenced model (Merz and Ackermann 2021; Otyepka 2018) and, besides a general development process, suggests 28 design principles in four categories. However, the PSD model does not specify the selection of its design principles (Oinas-Kukkonen and Harjumaa 2009; Wiafe et al. 2014) and, developed in 2009, could not build on recent design knowledge. In particular, recent research on design principles reveals the unclear and ambiguous use of design principles and defines a design principles schema with important aspects that design principles should specify (e.g., aim, mechanism, rationale) (Gregor et al. 2020). Essays 3 - 5 contribute by determining the state of the art of design principles in persuasive systems, specifying the selection of design principles based on the targeted stage of behavior change, and aggregating design knowledge to a set of explicitly formulated design principles.

Considering the progression of persuasive systems and their design principles, **Essay 3** reviews the PSD model to identify to what extent the design principles of the PSD model reflect the current research insights (Merz and Ackermann 2021). Conducting a systematic literature review of 42 studies with 633 applications of design principles of the PSD model and 62 additional concepts named design principles, we provide researchers and developers of BCSS with a detailed overview of the selection of design principles in persuasive systems (Merz and Ackermann 2021). Our results indicate that the PSD model covers most aspects of design principles of BCSS but lacks explicit formulation and specification. We reveal scope for extensions and specifications and provide a base for developing enhanced models.

Essay 4 provides recommendations for selecting design principles of the PSD model for the specific stages of behavior change targeted by the BCSS (Merz and Steinherr 2022). Combining technical and psychological views, we combine the PSD model with the transtheoretical model of Prochaska and DiClemente (1983). The transtheoretical model suggests stages of change that are transitioned when changing behavior: precontemplation, contemplation, preparation, action, and maintenance (maintenance further leads to termination or relapse) (Prochaska and Norcross 2001). Based on an independent mapping and a systematic literature review, we reveal 11 design principles as basic requirements and categorize 17 design principles into four levels of recommendation for the transitions along the stages of behavior change. The results provide a specification of the PSD model and a guideline to select effective design principles for developing BCSS (Merz and Steinherr 2022).

Aggregating and synthesizing design knowledge from theory and practical studies, **Essay 5** presents how we systematically derive design principles for BCSS that provide explicitly formulated prescriptive knowledge on how to design, evaluate, and develop BCSS. Möller et al. (2020b) present a reflective and supportive approach to systematically derive design principles. Considering the wide existing background for design principles of BCSS, we select the supportive approach and aggregate 125 concepts to 14 design principles. The formulation of our design principles follows the design principles schema of Gregor et al. (2020). Those design principles include, for example, specifications of design principles of the PSD model, such as praise and rewards, but also introduce additional concepts such as goal-setting as a persuasive design principle. This study directly utilizes the results of the state-of-the-art analysis of Essay 3; the reflective approach for design principle development (as opposed to the supportive approach in Essay 5) is selected in Essay 9 to derive design principles in the context of knowledge documentation. In sum, the essays contribute to the theoretical background for designing BCSS by analyzing and providing design principles that allow to systematically create and evaluate BCSS with a high rigor, as well as communicate obtained design knowledge.

Following the environment and theoretical knowledge base, Essays 6 - 9 address the practical implementation of a BCSS in the context of knowledge documentation. Knowledge documentation can be described using the SECI model of Nonaka (1991): Knowledge creation is accomplished through forming tacit and explicit knowledge with socialization, externalization, combination, and internalization (Figure 2). Knowledge documentation captures externalization and combination of knowledge so that knowledge is explicitly specified and available independent of other employees. As explicit knowledge is limited to codifiable knowledge (Hedlund 1994), it is most meaningful for tasks that combine transformations of routine situations, extensions of routines, or mix routines with external factors as specified by Wiig (2003). Figure 3 specifies the different levels of task complexity and depicts where knowledge documentation is most meaningful (no. (2) to (4)).

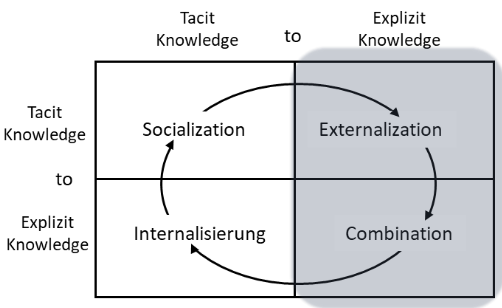

Figure 2: Knowledge documentation in the SECI model of Nonaka (1991)

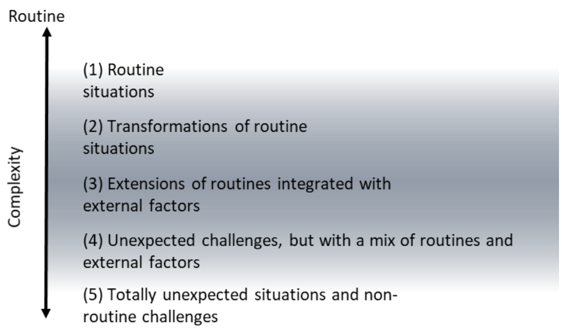

Figure 3: Meaningful knowledge documentation in the context of task complexity according to Wiig (2003)

In this context, it is notable that knowledge documentation involves an organization and its culture as a whole but is acted out by the individual employees (Al Saifi 2015). Therefore, the BCSS addresses the behavior of individual employees in addition to other efforts such as adopting company culture and offering technical means (Aboelmaged 2018; Shanshan 2014; King 2007). Focusing on reinforcing, forming, or altering compliance, behavior, and attitude (Oinas-Kukkonen 2013), a BCSS is able to target the specific needs of the employees rather than determining norms. Thus, BCSS confers the goal and meaning of knowledge documentation to the employee as norms and procedures require appropriate actions.

Based on this background, **Essay 6** suggests an approach of designing a BCSS in the context of knowledge documentation based on the stages of behavior change of Prochaska and DiClemente (1983) (Merz 2020). This research-in-progress essay elaborates that it is the first to propose a BCSS in the context of knowledge documentation. It further suggests implementing a measure to raise problem awareness using a combination of scenarios and reflections based on the knowledge elements of Probst and Romhardt (1997) and the reflective cycle of Gibbs (1988).

Essay 7 describes an implementation and evaluation of the BCSS that is proposed in Essay 6 (Merz 2022). We evaluate the acceptance of the artifact with 15 users using the technology acceptance model (TAM) of Davis (1989). The TAM measures the concepts intention to use, perceived ease of use, and perceived usefulness to determine system acceptance, which should be examined early in system development (Kim 2015). The results indicate acceptance of the system and show that the strength of the prototype is to raise awareness for knowledge documentation.

The second stage of behavior change, after raising awareness in the stage of contemplation, is the stage of preparation (Prochaska and Norcross 2001), which can be achieved using goal-setting. Consequently, **Essay 8** focuses on goal-setting for knowledge documentation using persuasive systems design (Merz and Hurm 2022). In this essay, we derive 17 design principles for goal-setting in persuasive systems and apply them in a process that guides users to set goals for knowledge documentation. The evaluation of the goal-setting process as well as the evaluation of the BCSS implementing this process emphasize that the guidance is perceived as useful and valuable. The essay contributes by selecting design principles from literature and showing their implementation into a process and BCSS.

While Essays 5 and 8 derive design principles from literature (Essay 5 as a general model for persuasive systems design, and Essay 8 specific for the design of goal-setting for knowledge documentation in BCSS), **Essay 9** presents design principles that are extracted from an existing BCSS. This approach applies the reflective approach of design principle development of Möller et al. (2020b) that allows creating design knowledge from insights of implemented artifacts. The reflective approach of Möller et al. (2020b) is instantiated by combining users' preferences for knowledge documentation and perceptions of design aspects to derive design principles. We measure users' preferences using the reflection questions of the artifact (Essay 7) and identify the design aspects using topic modeling of feedback based on the TAM of Davis (1989). The findings contribute by presenting new insights into the perception of knowledge documentation, exploring a human-centered approach to derive design principles based on users' perceptions and feedback, and introducing design principles for designing BCSS in the context of knowledge documentation.

In the following, each essay included in this dissertation is presented in detail. As mentioned earlier, please note that all essays have been slightly modified compared to their published version to facilitate readability. Modifications include a continuous page count, adapted references to other sections, and a central list of references at the end of this dissertation.

2 Essays on Addressing and Involving Users

2.1 Essay 1: Mindfully Going Omni-channel: An Economic Decision Model for Evaluating Omni-channel Strategies

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2.1.1 Abstract

In the digital age, customers want to define on their own how to interact with organizations during their customer journeys. Thus, many organizations struggle to implement an omni-channel strategy (OCS) that meets their customers' channel preferences and can be operated efficiently. Despite this high practical need, research on omni-channel management predominantly takes a descriptive perspective. What is missing is prescriptive knowledge that guides organizations in the valuation and selection of an appropriate OCS. Most existing studies investigate single facets of omni-channel management in detail while neglecting the big picture. They also require customer journeys to follow sequential and organization-defined purchase decision processes. To address this research gap, we propose an economic decision model that considers online and offline channels, the opening and closing of channels, non-sequential customer journeys, and customers' channel preferences. Drawing from the principles of value-based management, the decision model recommends choosing the OCS with the highest contribution

to an organization's long-term firm value. We applied and validated the decision model based on real-world data from a German bank.

2.1.2 Introduction

Digital technologies such as mobile devices or social media fundamentally change omni-channel business (Choudhury and Karahanna 2008; Mirsch et al. 2016). For instance, today’s customers have access to comparison portals and reviews from online communities, and they seek information in traditional, online, and mobile channels simultaneously (Schoenbachler and Gordon 2002; Rapp et al. 2015). In the digital age, customers want to decide on their own how to interact with organizations during their customer journeys (CJs) (Schoenbachler and Gordon 2002). Further, new channels and an increasing number of channels affect customers’ channel preferences (Nunes and Cespedes 2003). In the banking industry, for example, 20% of customers use digital channels for information seeking and purchases, whereas 58% use mobile devices for service requests (Accenture Strategy). Thus, a key challenge of omni-channel management (OCM) is the management of customer behavior across channels by implementing an appropriate omni-channel strategy (OCS) (Neslin et al. 2006).

The academic literature on OCM is mature and encompasses descriptive as well as prescriptive work. Researchers studied topics such as cross-channel customer behavior, channel adoption, channel choice, and channel usage as well as the effects on organizational performance. To name a few examples, insights include the effects of online and offline channels (Cao and Li 2015; Lui and Piccoli 2016; Pauwels et al. 2011), the duration of channel adoption (Venkatesan et al. 2007), customers’ information search and purchase behavior (Balasubramanian et al. 2005; Verhoef et al. 2007), and the willingness to pay for various channels (Wang et al. 2015). Beyond these descriptive studies, very few prescriptive works offer actionable strategies and decision support. For example, attribute models such as “last-click wins” help allocate budgets to channels (Anderl et al. 2014) or Markov-chain-based models assist in determining the impact of digital channels to CJs (Anderl et al. 2016). In addition, Hosseini et al. (2015) offer a decision model that requires CJs to follow sequential and organization-defined purchase decision processes (PDPs). Finally, Thomas and Sullivan (2005) recommend strategies for targeting and communicating with customers in line with their channel preferences.

In sum, most OCM-related studies consider single facets in detail, but neglect the big picture. Further, there is mature descriptive knowledge, but hardly any prescriptive study that guides organizations in determining an appropriate OCS. Extant work rarely considers online and offline channels in an integrated manner, a simplification disregarding a constitutive feature of omni-channel environment (Holland and Flocke 2014). Further, the circumstance that CJs are required to follow sequential and organization-defined PDPs neglects emerging customer channel preferences that become manifest in non-sequential CJs. In fact, customers' willingness to comply with organization-defined PDPs has substantially dropped in omni-channel environments (Barwitz and Maas 2016; Nüesch et al. 2015). Against this background, we investigate the following research question: *How can organizations determine which channels they should offer for various PDP steps when considering non-sequential CJs in an omni-channel environment?*

To address this research question, we propose an economic decision model that assists organizations in the valuation and selection of an appropriate OCS. The decision model caters for non-sequential CJs that cover pre-sales, purchase, and post-sales PDP steps as well as omni-channel environments with online and offline channels. To do so, the decision model builds on Markov chains for modelling CJs and the principles value-based management (VBM), which is rooted in investment theory and an accepted paradigm of corporate decision-making, for modelling the value contribution of OCSs. Accordingly, the decision model recommends choosing the OCS with the highest contribution to an organization's long-term firm value. When specifying the decision model, we followed established guidelines of normative analytical modelling (Meredith et al. 1989).

The remainder of this paper is organized as follows: Section 2.1.3 introduces relevant theoretical background on OCM, CJs, Markov chains, and customers' channel preferences to set the scene for the decision model presented in section 2.1.4. In section 2.1.5, we apply the decision model to real-world data from a German bank. We conclude in section 2.1.6 by summarizing key results and outlining limitations together with avenues for future research.

2.1.3 Theoretical Background

The availability of ever more channels and customers' emancipation from organization-defined PDPs implies substantial challenges for managing the interaction between customers and organizations (Cao and Li 2015; Pauwels and Neslin 2015). This development makes organizations rethink their channel strategies, i.e. how they interact with their customers in line with customers' channel preferences and which channels support the steps of the PDP for individual product and service offerings and/or customer segments including pre-sales, purchase, and after-sales activities (Choudhury and Karahanna 2008). Common PDP steps are information search, evaluation of product options, purchase decision, and post-purchase support (Gupta et al. 2004). Channels are an organization's media for interacting with customers (Lewis et al. 2014; Neslin et al. 2006). They can be split into online (e.g. websites or mobile apps), offline (e.g. agencies or stores), and traditional direct-marketing channels (e.g. catalogs or magazine advertisements) (Verhoef et al. 2015). Channel strategies can be formalized as matrices with a PDP and a channel dimension, indicating which channels supports which PDP steps (Anderl et al. 2016; Hosseini et al. 2015). Thereby, channel strategies define the boundary conditions for CJs as organizations and customers can only interact via open channels. In case of an inappropriate channel strategy, which means that open and closed channels are misaligned with customers' channel preferences, organizations run the risk of not tapping the potential of customer relationships as customers buy less, churn, or spread negative word of mouth (Sweetwood 2016; Verhoef et al. 2007).

Against this backdrop, multi-channel management (MCM) has evolved into an established discipline for managing an organization's interactions with customers via multiple channels. In the MCM context, however, channels are typically treated as independent silos and optimized separately (Nüesch et al. 2015). With each channel pursuing individual goals, organizations do not tap the economic potential of customer relationships by design (Piotrowicz and Cuthbertson 2014; Pophal 2015). Coping with the drawbacks of MCM, OCM focuses on customers' channel preferences and channel dependencies (Nüesch et al. 2015). Verhoef et al. (2015) define OCM as "the synergetic management of the numerous available channels […] in such a way that the customer experience across channels and the performance over channels is optimized" (p.176). Thus, OCM reflects an integrated design and management of multiple channels (Melero et al. 2016; Nunes and Cespedes 2003; van Bruggen et al. 2010). This feature is vital as customers are changing the way they collect and evaluate information, how they make decisions, and how they interact with organizations in the digital age (Brynjolfsson et al. 2013; Payne and Frow 2004).

CJs capture the interactions between customers and an organization along the PDP from a customer perspective for a distinct product or service offering and/or customer segment (Anderl et al. 2014; Zomerdijk and Voss 2010). As mentioned, channel strategies define the boundary conditions for CJs. CJs are an important concept of OCM as, on an aggregated level, they provide insights into customers' current and future channel usage

(Nenonen et al. 2008). As customers conduct different PDP steps via different channels to achieve a specific goal such as the purchase of a product or use of a service, CJs reflect customers' channel preferences (Sanz 2014). The number of channels, their characteristics, and customers' channels preferences increase the complexity of today's CJs (Crawford-Browne 2016). For instance, customers may prefer the personal service at physical stores and the broad product range of online stores. Although PDPs are typically modelled as a sequence of pre-sales, sales, and post-sales activities, CJs also must reflect non-sequential behavior. That is, customers move forward and backward the PDP or temporarily leave the PDP instead of following an organization-defined sequence of PDP steps (Barwitz and Maas 2016; Choudhury and Karahanna 2008; van Nierop et al. 2011).

For decision-making purposes, CJs must be captured mathematically (Zomerdijk and Voss 2010). In the literature, Markov chains have evolved into an established tool for modelling, analyzing, and optimizing customer relationships and CJs (Anderl et al. 2016; Homburg et al. 2009; Pfeifer and Carraway 2000). Markov chains are defined by states and a matrix that contains transition probabilities among states. Major advantages of Markov chains are their well-developed mathematical foundation, which is rooted in stochastic processes and probability theory, as well as their flexibility that enables them to deal with customer migration or retention over time (Pfeifer and Carraway 2000). The mathematical foundation of Markov chains also enables accounting for dependencies among states, predicting future customer behavior, and estimating expected values of relevant characteristics, e.g. the number of customers who access a distinct PDP step via a distinct channel (Styan and Smith 1964). Although Markov chains have so far only been used for modelling sequential CJs, they can handle non-sequential CJs and comply with the matrix conceptualization of channel strategies introduced above. Markov chains are differentiated by their order. First-order Markov chains indicate that customer decisions are memoryless, i.e. the next state of a CJ depends on the current state as reflected in the current PDP step/channel constellation, customers' channel preferences, and the OCS in focus (Ferschl 1970; Sperandio and Coelho 2006). This phenomenon has already been substantially covered in the literature. For instance, Hoyer (1984) found that customers tend toward simple rules that allow for fast and effortless decisions. Lysonski et al. (1996) as well as Kacen and Lee (2002) found that impulsiveness, which refers to unplanned and fast purchase decisions, is a central characteristic of customer decision-making. Further, Edelman and Singer (2015) explain the shift from traditional CJs, characterized by long consideration and evaluation phases, to more spontaneous CJs, characterized by fast decision-making. The difference between first-order and higher-order Markov chains is that the simple transition probabilities between states turn into conditional probabilities as the next state also depends on one or more past states. Anderl et al. (2016) analyzed CJs modelled via Markov chains of different orders, showing that the number of required input parameters increases exponentially with a Markov chain's order and that models quickly becomes too large to be handled efficiently. At the same time, higher-order Markov chains tend to be less significant than first- or second-order chains. Thus, lower-order Markov chains are appropriate for modelling CJs as they feature high real-world fidelity based on a reasonable amount of input data.

CJs strongly depend on customers' channel preferences, particularly their channel switching behavior if channels are opened or closed for specific PDP steps (Sonderegger-Wakolbinger and Stummer 2015). Thus, knowledge about customers' channel switching behavior enables anticipating how CJs look like for different OCSs. This is important task in omni-channel decision-making (Payne and Frow 2004). In general, customers traverse the PDP along those channels that create the highest subjective utility relative to costs (Reardon and McCorkle 2002). On a more detailed level, channel switching behavior depends four factors: customer attributes, customer goals, product and service characteristics, and channel attributes (Sousa and Voss 2012). In addition, the literature names experience, spillover effects, and channel similarity as determinants of channel switching behavior (Gensler et al. 2012; Gupta et al. 2004; Verhoef et al. 2007). Spillover effects capture to which extent the likelihood of using a channel for a distinct PDP step affects the likelihood of using the same channel for other steps. (Gupta et al. 2004) found that particularly the similarity between channels determines customers' switching behavior. The reason is that similar channels cause low (cognitive) opportunity costs and have similar attributes. Thus, channel similarity partly covers the factors introduced above. Hosseini et al. (2015) already used channel similarity as a proxy for customers' channel switching behavior in the context of sequential CJs. In sum, channel similarity is a central driver of customers' channel switching behavior (Barwitz and Maas 2016; Neslin et al. 2006; Sousa and Voss 2012).

2.1.4 Decision Model

2.1.4.1 Basic Idea

In line with the principles of VBM, the decision model aims to identify the OCS with the highest impact on the long-term firm value of the organization in focus (Martin and Petty 2000; Ittner and Larcker 2001). To do so, the decision model valuates OCSs by analyzing the CJs, which occur if a distinct OCS is implemented, as well as the opening and closing of channels for specific PDP steps in terms of recurring, investment, and configuration cash flows. Thus, the decision model comprises two central components: a CJ analysis and an investment analysis component (Figure 4). In the CJ analysis, the decision model analyzes CJs based on input parameters such as available channels, PDP steps, and customers' channel preferences using first-order Markov chains. Regarding the investment analysis, the decision model determines the value contribution of OCSs based on the output of the CJ analysis and information on customer demand and cash flows. Thereby, the decision model takes a differential investment perspective, i.e. the value contribution of an OCS reflects the increased or decreased economic effect compared to the organization's current OCS. Below, we provide details on the general setting and both components of the decision model.

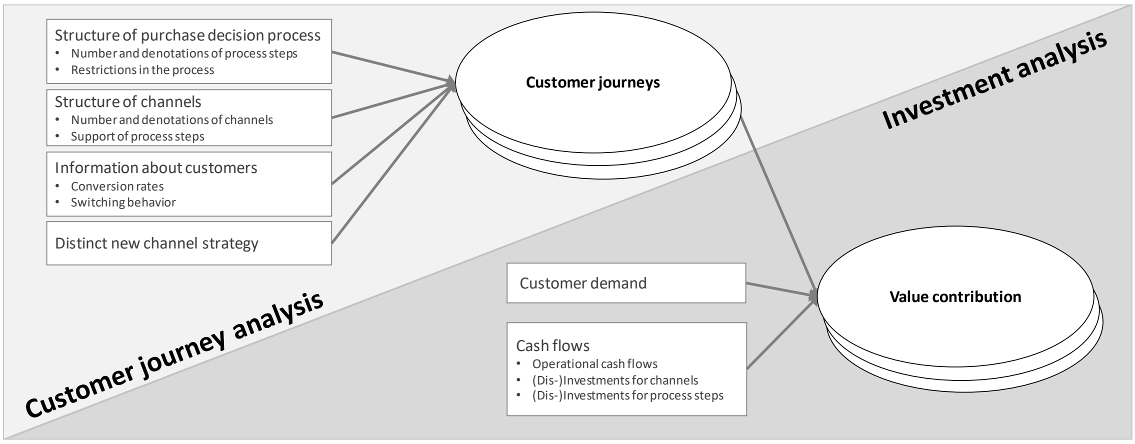

Figure 4: Structure of the decision model for a distinct new OCS

2.1.4.2 General Setting

In this section, we introduce the foundational concepts of the decision model, i.e. CJs, OCSs, and conversion rates that hold for the organization's current OCS. To model modifications of CJs and conversion rates caused by the opening and closing of channels, we also introduce a restriction matrix and a switching matrix.

The unit of analysis of our decision model is the OCS of an organization for a specific product or service offering. To analyze CJs, we model CJs as an absorbing first-order Markov chain, a frequently used approach for modelling customer relationships and CJs (Anderl et al. 2016; Homburg et al. 2009; Pfeifer and Carraway 2000). Although Markov chains have so far only been used for modelling sequential CJs, they are capable of dealing with complex customer behavior that becomes manifest in non-sequential CJs (Tseng et al. 1999). This makes Markov chains particularly suitable for our purposes.

Markov chains consist of states and probabilities. In our case, states reflect admissible combinations of channels and PDP steps that customers traverse with specific probabilities during their CJs. Probabilities are expressed as conversion rates from one state to others and captured in terms of a conversion matrix. The absorbing Markov chain property enables the modelling of states that, once entered, cannot be exited. Such states characterize the end of CJs, if a customer has bought an offering or left. First-order Markov chains assume that the next state of a CJ only depends on the conversion rates associated with the current state, not on further past states (Ferschl 1970; Sperandio and Coelho 2006). Of course, the next state also depends on the OCS under consideration that determines which channels are open or closed and whether customers can continue their CJ in line with their preferences. Using first-order Markov chains is sensible as customers are known to traverse PDPs based on spontaneous decision (Lysonski et al. 1996; Kacen and Lee 2002; Edelman and Singer 2015). Such customer behavior can also be captured via higher-order Markov chains. However, the real-world fidelity of our decision model would increase only slightly, while its applicability would suffer greatly, as conditional probabilities are much harder to estimate (Anderl et al. 2016). Thus, we assume:

(A1) *The next state of a CJ only depends on the conversion rates associated with the current state of the CJ and the boundary conditions set by the OCS under consideration.*

An OCS determines which channels support the PDP steps of a specific product or service offering (Figure 5). This is why OCSs define the boundary conditions for CJs. PDP steps have a logical and sequential order (Anderl et al. 2016). We define a PDP as a sequence of steps p_j, with $j = 0, \dots, N$ $(N \geq 1)$. A channel c_i, with $i = 0, \dots, M$ $(M \geq 1)$, supports at least one PDP step. For technical reasons, we supplement the channels offered by the organization with an 'Auxiliary' channel to include an 'Indefinite' and a 'Termination point' step. We use the 'Indefinite' step to model customers outside the organization's PDP and to cover the possibility that customers can temporarily leave the part of the CJ visible for the organization. For example, a customer leaves the visible part of a CJ if he visits a comparison portal to verify product information obtained by the organization, before he may return to buy the product or not. The 'Termination point' covers the absorbing Markov chain property as a terminal point with no outgoing edges, where customers conclude their journeys by buying an offering or not. The PDP steps 'Indefinite' and 'Termination point' appear only in the 'Auxiliary' channel, but are technically treated as regular states in the OCS. As shown in Eq. (1), we model OCSs as matrices (Hosseini et al. 2015). Referring to a distinct state, the binary variable $x_{i,j}$ specifies whether channel c_i supports PDP step p_j. The variable $x_{0,0}$ represents the 'Indefinite' state, while $x_{0,N}$ represents the 'Termination point'. The states $x_{1,0}, \dots, x_{M,0}$ and $x_{0,1}, \dots, x_{0,N-1}$ and $x_{1,N}, \dots, x_{M,N}$ are 0, as they are technical components.

$$X = \begin{pmatrix} x_{0,0} & \cdots & x_{0,N} \\ \vdots & \ddots & \vdots \\ x_{M,0} & \cdots & x_{M,N} \end{pmatrix} \qquad x_{i,j} = \begin{cases} 1 & \text{if channel } c_i \text{ supports process step } p_j \\ 0 & \text{else} \end{cases} \tag{1}$$

The customers' preferences to stay within the same channel or to switch channels along the PDP are captured in terms of the conversion matrix R, shown in Eq. (2). This matrix covers all conversion rates that reflect the organization's current OCS. Each conversion rate $r_{i,j,k,l}$ depicts the fraction of customers in channel c_i and process step p_j (state $x_{i,j}$) who continue their CJ via channel c_k to proceed to step p_l (state $x_{k,l}$).

$$R = \begin{pmatrix} r_{0,0,0,0} & \cdots & r_{0,0,M,N} \\ \vdots & \ddots & \vdots \\ r_{M,N,0,0} & \cdots & r_{M,N,M,N} \end{pmatrix} \text{with } r_{i,j,k,l} \in [0;1] \; \forall i,k \in \{0,\dots,M\} \wedge j,l \in \{0,\dots,N\} \tag{2}$$

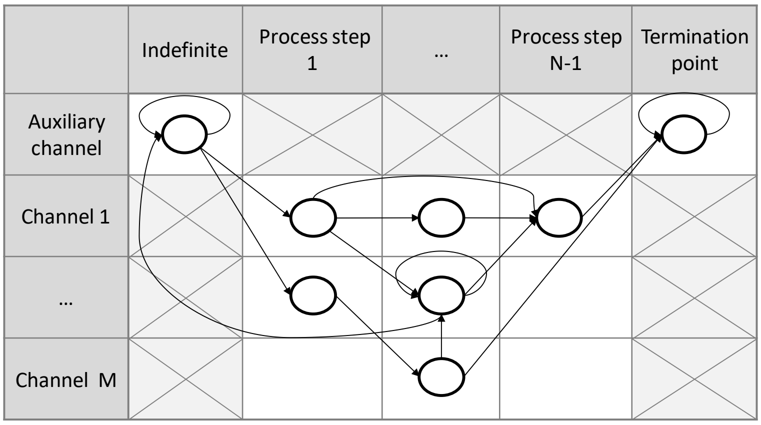

Figure 5: Representation of channels, process steps, and non-sequential CJs in the PDP

Although customers want to determine on their own how to interact with organizations, CJs are subject to restrictions, for logical or legal reasons. For instance, a logical restriction is that a customer cannot have a meeting without scheduling it beforehand. A legal reason is that customers must have an obligatory consultation before signing the contract of a complex product or service. To account for such restrictions, we use a restriction matrix Q, as shown in Eq. (3), which determines whether it is possible to proceed from one PDP step to another. Thereby, the restriction matrix supports sequential, non-sequential, and hybrid CJs depending on the underlying PDP and limitations of first-order Markov chains. As the 'Termination point' describes the final state of a CJ, and there is no possibility of leaving this state, the variables $q_{N,0}$, …, $q_{N,N-1}$ are 0.

$$Q = \begin{pmatrix} q_{0,0} & \cdots & q_{0,N} \\ \vdots & \ddots & \vdots \\ q_{N,0} & \cdots & q_{N,N} \end{pmatrix}, \tag{3}$$

$$\text{with } q_{j,l} = \begin{cases} 1 & \text{if the conversion from step } p_j \text{ to } p_l \text{ is allowed} \\ 0 & \text{else} \end{cases} \quad \forall \boldsymbol{j}, \boldsymbol{l} \in \{\boldsymbol{0}, \dots, \boldsymbol{N}\}$$

The organization can change its current OCS by opening or closing channels either completely or for specific PDP steps. In the case of closing a channel for a specific PDP step, customers may no longer be able to traverse the PDP in line with their channel preferences. Instead, they must choose other channels and/or PDP steps to proceed or decide to leave (Sonderegger-Wakolbinger and Stummer 2015; Reardon and McCorkle 2002). This phenomenon is also known as enforced channel switching (Hosseini et al. 2015). In the banking industry, for instance, organizations tend to close branch offices for financial reasons, which means customers must shift to online channels. The opposite holds if new channels are opened. Customers then have more interaction possibilities. They may even get the possibility to follow the PDP in line with their channel preferences, which may not have been possible for the organization's current OCS. To account for the effects of opening and closing channels, it is necessary to modify conversation rates, which reflect the customer behavior in the status quo. To do so, we use channel switching rates $s_{i,k}$ that denote the rate at which customers are willing to switch from channel c_i to another channel c_k. Switching rates are compiled in the switching matrix S, as shown in Eq. (4). To facilitate data collection, we designed the switching matrix such that it does not need normalized input values that add up to 1, as switching rates can be set in relation to one another.

$$S = \begin{pmatrix} s_{0,0} & \cdots & s_{0,M} \\ \vdots & \ddots & \vdots \\ s_{M,0} & \cdots & s_{M,M} \end{pmatrix} \text{with } s_{i,k} \in [0;1] \; \forall i,k \in \{0,\dots,M\} \tag{4}$$

The switching matrix comes into play if the organization changes its OCS, i.e. channels are opened or closed. In this case, customers prefer to switch to similar channels (Gupta et al. 2004). Channel similarity is a key driver of customers' switching behavior as is partly covers factors such as customer attributes and goals as well as channel attributes (Sousa and Voss 2012). As our decision model focuses on the OCS for a distinct offering, product and service characteristics, which also drive customers' switching behavior, are covered implicitly by conversion rates. Further, the involved PDP steps have a moderating effect as the decision model ensures that, in line with empirically observed behavior, customers maintain the original direction of their CJ even if the OCS is changed (Melero et al. 2016). For example, if a customer is interested in buying a product and has already negotiated contract conditions, he is likely to proceed with the purchase step instead of continuing his CJ at early PDP steps. The restriction matrix ensures that CJs do not include forbidden or illogical transitions. In sum, the similarity-based switching matrix and the moderating effect of the PDP steps involved ensure the process/channel fit of customer behavior (Gensler et al. 2012). We assume:

(A2) *The switching rates, which are used to modify conversion rates in case channels are opened or closed, only depend on channel similarity.*

2.1.4.3 Customer Journey Analysis

We now show how the decision model uses the foundational concepts introduced above to calculate modified conversion rates. Thereby, we refer to modified conversion rates as $r_{i,j,k,l}^{\text{mod}}$, representing the conversion of customers between state $x_{i,j}$ and state $x_{k,l}$ in a changed OCS.

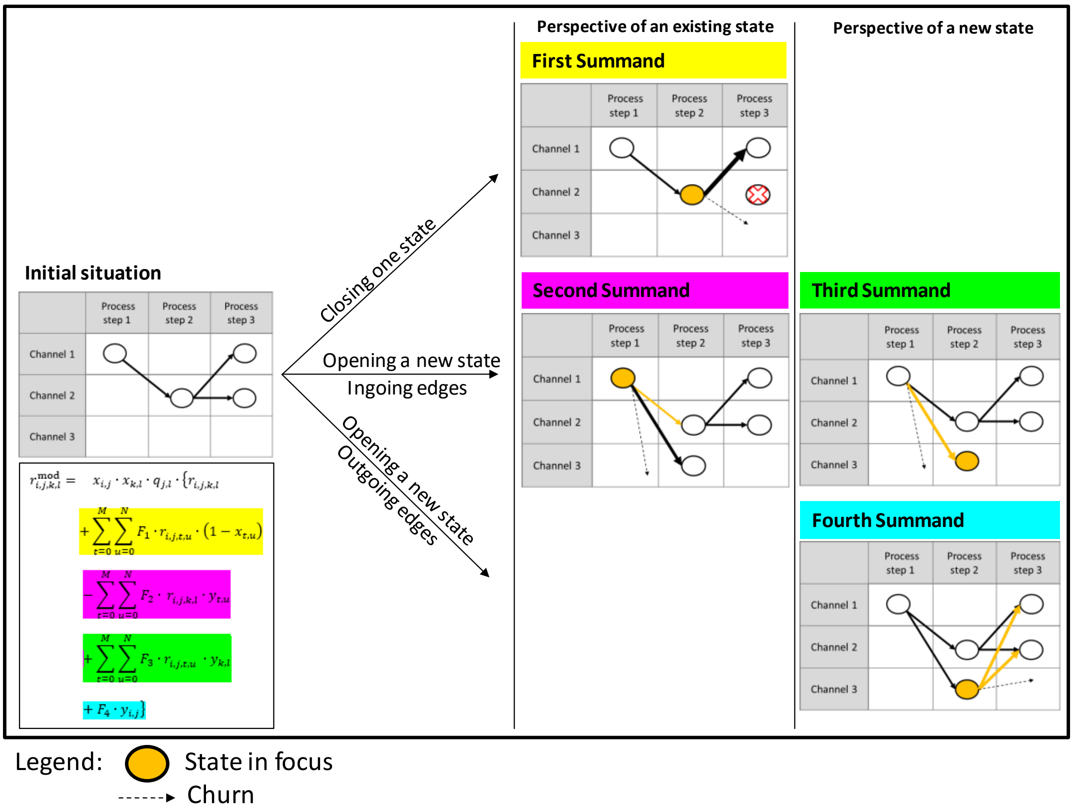

Figure 6: Possibilities to change an OCS

The effects of changed OCSs on conversion rates and CJs can be split into four effect categories. Figure 6 represents these categories graphically, while Eq. (11) offers a mathematical specification. Every summand of Eq. (11) covers one effect category, using a fraction as auxiliary quantity for calculating its effect size. These auxiliary quantities are shown in Eq. (5), Eq. (6), Eq. (9), and Eq. (10). The first summand of Eq. (11) accounts for enforced channel switching, i.e. if a channel no longer supports a PDP step that has been supported in the organization's current OCS. Consequently, customers switch to other states or leave. For example, an organization may cancel its catalog offerings, which means that customers must obtain information via other channels. The second summand captures the negative effects on conversion rates if a channel supports additional PDP steps. Customers may then use newly opened instead of existing channels. For instance, if an organization introduces a new mobile app, some customers refrain from visiting agencies or the organization's website. The third summand considers the same effect, but from the perspective of newly opened states. As such states did not exist in the current OCS, they draw customers from established states. Finally, once a new state has been opened, it is important to know which states customers use subsequently. This is covered by the fourth summand. For instance, if customers use a new mobile app, they must decide via which channel they want to proceed to the next PDP step.

Before presenting Eq. (11) in detail, we introduce its components and their meaning. As mentioned, each summand includes a fraction $F_1, \dots, F_4$ as auxiliary quantity that reflects the relative number of customers by which the conversion rates of the status quo must be increased or decreased, respectively.

Fraction F_1, which is used in the first summand of Eq. (11), determines the fraction of customers who switch to another state due to enforced channel switching. F_1 is shown in Eq. (5). We define F_1 as the ratio of the switching rate $s_{t,k}$ to the switching rates from state $x_{t,u}$ (depicting a closed state) to all open states that have a conversion from state $x_{i,j}$. Thus, we check whether there exists an outgoing edge (if $r_{i,j,a,b}$ is greater than 0) and whether the referring state $x_{a,b}$, where the edge points to, still exists in the new OCS (if $x_{a,b}$ equals 1). For this fraction, and for all following divisions, it is reasonable to define that, if the denominator of a division equals 0, the result of the division equals 0. Customers who wanted to move forward in the PDP will keep their attitude of moving forward, and customers who wanted to move backward in the PDP will keep their attitude of moving backward (Melero et al. 2016). Thus, we divided F_1 in two cases to calculate the ratio of the switching rates to only those states that lie in the same direction along the PDP as that of the closed state (first case: backward direction, second case: forward direction). The "else" case occurs if the closed state $x_{t,u}$ lies in the opposite direction than the currently observed conversion rate $r_{i,j,k,l}$ is pointing to. As the 'Indefinite' state is not integrated in the process sequence, the switch to the 'Indefinite' state is included in both cases (see addition of $s_{t,0}$ and $r_{i,j,0,0}$ in the denominators) and thus independent from the customers' attitude of moving forward or backward along the PDP.

$$F_1 = \begin{cases} \frac{s_{t,k}}{\sum_{a=1}^{M} \sum_{b=1}^{j} s_{t,a} \cdot x_{a,b} \cdot \operatorname{sgn}\left(r_{i,j,a,b}\right) + s_{t,0} \cdot \operatorname{sgn}\left(r_{i,j,0,0}\right)} & \text{if } u - j < 0 \land l - j < 0 \\ \frac{s_{t,k}}{\sum_{a=1}^{M} \sum_{\substack{b=j \\ b \neq 0}}^{N} s_{t,a} \cdot x_{a,b} \cdot \operatorname{sgn}\left(r_{i,j,a,b}\right) + s_{t,0} \cdot \operatorname{sgn}\left(r_{i,j,0,0}\right)} & \text{if } u - j > 0 \land l - j > 0 \\ 0 & \text{else} \end{cases} \tag{5}$$

Fraction F_2, which is used in the second summand of Eq. (11), determines the relative number of customers moving from their planned state to a newly opened state. F_2 is shown in Eq. (6). Specifically, F_2 equals the ratio of switching rate $s_{k,t}$ to the switching rates between state $x_{t,u}$ (depicting a newly opened state now) and all open states with a conversion from state $x_{i,j}$. The variable $count_j$ used in Eq. (7) ensures an appropriate allocation to all new states. It displays the number of new states that customers can possibly move to starting from PDP step p_j. As such new states can change the customers' attitude of moving forward or backward, we did not divide the fraction F_2 into different cases, as we did for F_1. Thereby, the variable $y_{t,u}$ shown in Eq. (8) equals 1 if the referring state $x_{t,u}$ is a newly opened state and 0 in all other cases.

$$F_2 = \frac{s_{k,t}}{count_j \cdot \sum_{a=0}^{M} \sum_{b=0}^{N} s_{a,t} \cdot x_{a,b} \cdot \mathrm{sgn}\left(r_{i,j,a,b}\right)} \tag{6}$$

$$count_j = \sum_{a=0}^{M} \sum_{b=0}^{N} y_{a,b} \cdot q_{j,b} \tag{7}$$

$$y_{t,u} = 1 + \mathrm{sgn}\left(x_{t,u} - x_{t,u}^{\mathrm{old}} - 1\right) = \begin{cases} \text{if } x_{t,u} \text{ is a new state} \\ \text{else} \end{cases} \tag{8}$$

In the third summand of Eq. (11), the fraction F_3 considers the same effect as F_2 but from the perspective of a newly opened state. Fraction F_3, which is shown in Eq. (9), is the ratio of switching rate $s_{t,k}$ to the switching rates between states $x_{k,l}$ and all open states that have a conversion from $x_{i,j}$, including the number of new states to which the customer can move from process step p_j.

$$F_3 = \frac{s_{t,k}}{count_j \cdot \sum_{a=0}^{M} \sum_{b=0}^{N} s_{a,k} \cdot x_{a,b} \cdot \mathrm{sgn}\left(r_{i,j,a,b}\right)} \tag{9}$$

Finally, F_4 shown in Eq. (10) determines the relative number of customers leaving a newly opened state to another state to continue their journey. Thereby, F_4 constitutes the ratio of the switching rate $s_{i,k}$ to the switching rates between state $x_{i,j}$ and all other open states.

$$F_4 = \frac{s_{i,k}}{\sum_{a=0}^{M} \sum_{b=0}^{N} s_{i,a} \cdot x_{a,b}} \tag{10}$$

As all auxiliary fractions have been defined, we now focus on how these fractions are integrated in Eq. (11) to model the modified conversion rates.

$$\begin{aligned} r_{i,j,k,l}^{\text{mod}} = \quad & x_{i,j} \cdot x_{k,l} \cdot q_{j,l} \cdot \{ r_{i,j,k,l} \\ & + \sum_{t=0}^{M} \sum_{u=0}^{N} F_1 \cdot r_{i,j,t,u} \cdot (1 - x_{t,u}) \\ & - \sum_{t=0}^{M} \sum_{u=0}^{N} F_2 \cdot r_{i,j,k,l} \cdot y_{t,u} \\ & + \sum_{t=0}^{M} \sum_{u=0}^{N} F_3 \cdot r_{i,j,t,u} \cdot y_{k,l} \\ & + F_4 \cdot y_{i,j} \} \end{aligned} \tag{11}$$

where:

$r_{i,j,k,l}$	Original conversion rate from state $x_{i,j}$ to state $x_{k,l}$ (as valid in the current OCS)
$r_{i,j,k,l}^{\text{mod}}$	Modified conversion rate from state $x_{i,j}$ to state $x_{k,l}$
$x_{i,j}$	Indicator showing whether state $x_{i,j}$ is open in a changed OCS
$y_{i,j}$	Indicator showing whether state $x_{i,j}$ is newly opened
$q_{j,l}$	Indicator showing whether a conversion from PDP step p_j to p_l is possible
M	Number of channels
N	Number of PDP steps, including the 'Termination point'
F_1	Fraction consisting of switching rate from a closed channel to switching rates regarding all other relevant states
F_2	Fraction consisting of switching rate to a specific new state to switching rates regarding all other relevant states (from the perspective of an existing state)
F_3	Fraction consisting of switching rate from a specific new state to switching rates regarding all other relevant states (from the perspective of a new state)
F_4	Fraction consisting of switching rate from a state in a new channel to switching rates regarding all other relevant states

Below, we explain the meaning of Eq. (11). The conversion rate $r_{i,j,k,l}$ can only be applied in a changed OCS if states $x_{i,j}$ and $x_{k,l}$ are open and the conversion between both states is not restricted. The multiplication of the three binary variables $x_{i,j}$, $x_{k,l}$, and $q_{j,l}$ captures this condition by assigning the value 0 to the conversion rate if the condition is violated. If both states are open and the conversion is not restricted, Eq. (11) modifies the original conversation rate by accounting for the effects categories outlined above and based on the fractions F_1 to F_4.

The first summand accounts for enforced channel switching. It adds the rate of customers who switch to state $x_{k,l}$ in the new OCS if some outgoing edges of state $x_{i,j}$ are no longer supported. The product $r_{i,j,t,u} \cdot (1 - x_{t,u})$ checks whether the considered state $x_{t,u}$ is a newly closed state. In this regard, the product equals 0 if $x_{t,u}$ is an open state, or if the conversion rate $r_{i,j,t,u}$ is 0 as the state $x_{t,u}$ was already closed in the current OCS. It is greater than 0 if state $x_{t,u}$ is a closed state and if there was originally some conversion from state $x_{i,j}$ to the now closed state $x_{t,u}$. The second summand subtracts the rate of customers who choose to switch to newly opened states. Hereby, the $y_{t,u}$ indicates all new states that can cause a loss of customers from existing states. The third summand defines the conversion to state $x_{k,l}$ if $x_{k,l}$ is a newly opened state. Graphically, this summand creates the ingoing edges into a new state. The variable $y_{k,l}$ checks whether the state $x_{k,l}$ is a newly opened state. Finally, the fourth summand calculates the conversion rates of the outgoing edges of $x_{i,j}$ if $x_{i,j}$ is a new state. This case occurs if the variable $y_{i,j}$ signals that state $x_{i,j}$ is a new state.

After calculating the modified conversion rate $r_{i,j,k,l}^{\mathrm{mod}}$ for all states in the OCS, we normalize the conversion rates in Eq. (12). This step is necessary as Markov chains are based on probabilities. The conversion rates of outgoing edges represent the probability of customers moving on to the next state. All probabilities of the outgoing edges of a single state must thus accumulate to 1 or 0 in case of no outgoing edges. If this is not the case, two issues arise. On the one hand, the decision model would not record all customers, e.g. after a state is closed. Generally, customers using a specific state are then forced to switch or leave. If the conversion rates of the outgoing edges do not accumulate to 1, there is no information how some customers might proceed with their CJ after the OCS has been changed. On the other hand, if the accumulated conversion rates of the outgoing edges are greater than 1, e.g. after a state is closed, more customers would be distributed to other states or leave than the number of customers who used the closed state before. The modified and normalized conversion rates $r_{i,j,k,l}^{\text{res}}$, which are shown in Eq. (12), are the result of all previous calculations, and build the final modified conversion rate matrix R^{res} for a distinct changed OCS.

$$r_{i,j,k,l}^{\text{res}} = \frac{r_{i,j,k,l}^{\text{mod}}}{\sum_{a=0}^{M} \sum_{b=0}^{N} r_{i,j,a,b}^{\text{mod}}} \forall i \in \{0, \dots, N\}; j \in \{0, \dots, M\} \quad (12)$$

2.1.4.4 Investment Analysis

Finally, we show how the decision model determines the value contribution of an OCS, using the modified and normalized conversion rate matrix as well as additional information on customer demand, time measurements, and cash flows as input. Complying with the principles of VBM, the decision model recommends choosing the OCS with the highest positive value contribution. The principles of VBM require that decisions are based on cash flows, take a long-term perspective in terms of a multi-period planning horizon (time value of money), and account for the involved decision-makers' risk attitude (Damodaran 2012).

Customer demand is an essential input parameter for omni-channel decision-making, as it indicates how many customers use a state at a distinct point in time. As the principles of VBM require considering each period of a multi-period planning horizon explicitly, customer demand is not static, but must be forecasted. Appropriate forecasts can be achieved if seasonality and/or trend effects are included (Fitzsimmons et al. 2008). Thus, the decision model accounts for changes in customer demand via growth rates. Hereby, we distinguish between a $NewCustomerRate_{\tau}$, which reflects a proportional increase of customer demand in period τ, and a $ChurnRate_{\tau}$, which captures a proportional decrease of customer demand. The demand vector D_{τ} contains all states as entries (starting with all process steps of the first channel and so on) and depicts the average number of customers for every possible state as the starting point of CJs at the beginning of a period τ (Eq. 13). That is, the demand vector indicates how many and in which state customers start their journey. As the demand vector does not only contain the demand of existing states, but also of potentially new states, it can be used to reflect the number of new customers attracted by new states.

$$D_{\tau+1} = D_{\tau} \cdot (1 + NewCustomerRate_{\tau} - ChurnRate_{\tau}) \quad (13)$$

Below, we elaborate on the time parameters and their relationships needed to capture the time value of money in line with the principles of VBM. The time parameters and their relationships are shown in Figure 7. The planning horizon T indicates how many periods τ are considered to determine the value contribution of an OCS. The length of a period is characterized by the variable θ, which can be measured in, for instance, days or months. A period characterizes a planning period for recurring cash flows as well as the time basis for estimating the number of customers traversing the PDP. Further, the variable η describes the length of a PDP step, quantified in the same measurement unit as θ. Thus, every PDP step has a duration of θ. Nevertheless, customers can take more time for PDP steps, a circumstance that is represented via loops in CJs. For example, some customers require more time to decide on a product or may favor a second appointment. Such behavior can be modelled as loops in the Markov chain, representing a self-directed conversion from a state to itself. The last parameter for measuring time is the number of PDP steps H, which is the maximum number of steps to complete a PDP. Thus, the $H \cdot \theta$ measures the length of a PDP, and $\theta/(H \cdot \eta)$ measures the number of PDPs in one period τ.

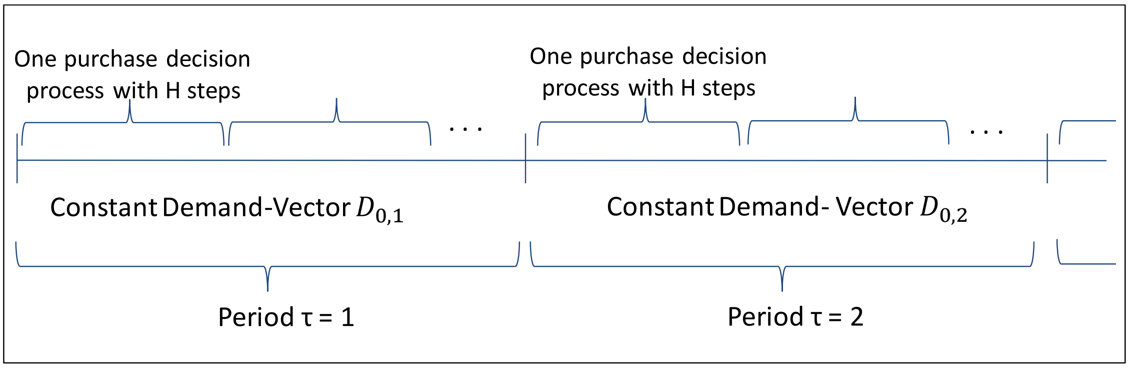

Figure 7: Relationship between time parameter

As for the cash flow effects of omni-channel decisions, the decision model accounts for three components of cash in- and outflows: recurring, investment, and configuration cash flows. These cash flow components are modelled in Eq. (14), Eq. (16), and Eq. (17), respectively. Recurring cash flows I^{rec} accrue in each period for maintaining open channels according to the OCS under consideration. Investment cash flows I^{inv} result from the opening and closing of channels, and configuration cash flows I^{conf} accrue if the PDP steps supported by a channel change. The recurring cash flows consist of variable outflows μ^{var} (e.g. outflows for verifying a credit application), variable inflows π (e.g. the sales price of products or services), and channel-specific outflows μ^{cs} (e.g. the labor expenses for an offline channel or IT maintenance expenses for an online channel). For our purposes, we define every cash outflow $\mu_{.}$ as a positive vector. We assume:

(A3) *The organization adopts the principles of VBM. All considered cash flows as well as the time parameters are constant and deterministic during the planning horizon.*

Below, we show how the cash flow components are calculated, starting with the recurring cash flows in Eq. (14).

$$I^{\text{rec}} = \sum_{\tau=1}^{T} \left(\frac{\frac{\theta}{H \cdot \eta} \sum_{h=1}^{H} \left[\left(D_{\tau}^{\text{mod}} \cdot (R^{\text{res}})^{h} - D_{\tau} \cdot R^{h} \right) \cdot (\pi - \mu^{\text{var}}) \right]}{(1+r)^{\tau}} \right) - \mu^{\text{cs}} \cdot \begin{pmatrix} Z_0 \\ \vdots \\ Z_N \end{pmatrix} \cdot \frac{(1+r)^{T} - 1}{(1+r)^{T} \cdot r} \tag{14}$$

where:

R	Conversion rates of original OCS
R^{res}	Conversion rates of new OCS
π	Variable inflows per state
μ^{var}	Variable outflows per state
μ^{cs}	Channel-specific outflows
D_{τ}	Demand vector in the original OCS in period τ
D_{τ}^{mod}	Demand vector in a changed OCS in period τ
T	Number of periods τ (planning horizon)
H	Maximum number of steps to complete a PDP
θ	Length of a period
η	Length of one PDP step
r	Risk-adjusted interest rate
Z_i	Indicator showing whether channel i is newly opened

The first term of Eq. (14) calculates the variable cash flows for one period τ. The multiplication of the customer demand vector D_{τ}^{mod} by $(R^{\text{res}})^{h}$ determines the states of the customers after h PDP steps, based on the properties of the Markov chain (Ferschl 1970). Thereby, the decision model calculates different CJs and respective variable cash flows. This expression is then summed up for each PDP step in the CJs and multiplied by the number of PDPs to calculate the cash flows of one period τ.

The second term of Eq. (14) reflects the channel-specific outflows accruing for maintaining open channels. Thus, we add channel-specific outflows in our differential investment perspective if a channel is opened, and subtract channel-specific outflows if a channel is closed. Here, the variable Z_i shown in Eq. (15) is equal to 1 if channel c_i is new, –1 if channel c_i (with all corresponding steps) is closed, and 0 in all other cases.

$$Z_i = \operatorname{sgn}\left(\sum_{n=0}^{N} x_{i,n}\right) - \operatorname{sgn}\left(\sum_{n=0}^{N} x_{i,n}^{\text{old}}\right) = \begin{cases} 1 & \text{if } c_i \text{ is a new channel} \\ 0 & \text{else} \end{cases} \tag{15}$$

Further, the investment cash flows depend on the changes in the OCS that result from establishing or closing a complete channel compared with the original OCS. To calculate the investment and disinvestment outflows across all channels, we cumulate channel investment outflows for all newly opened channels and the channel disinvestment outflows for all newly closed channels, as shown in Eq. (16).

$$I^{\text{inv}} = -\sum_{i=0}^{M} \mu_i^{\text{inv,open}} \cdot [\operatorname{sgn}(Z_i - 1) + 1] - \sum_{i=0}^{M} \mu_i^{\text{inv,close}} \cdot [1 - \operatorname{sgn}(Z_i + 1)] \tag{16}$$

where:

$\mu_i^{\text{inv,open}}$	Investment outflows for establishing channel i
$\mu_i^{\text{inv,close}}$	Disinvestment outflows for closing channel i completely
Z_i	Indicator showing whether channel i is newly opened

When an OCS changes, the organization must invest or disinvest configuration cash flows I^{conf} for opened or closed states. The configuration cash flows are only taken into account for channels that already existed before the channel changes and still exist afterwards. Accordingly, Eq. (17) shows how the configuration cash flows are calculated:

$$I^{\text{conf}} = -\sum_{i=0}^{M}\sum_{j=0}^{N}\mu_{i,j}^{\text{conf,open}} \cdot y_{i,j} \cdot \text{sgn}\left(\sum_{n=0}^{N} x_{i,n}^{\text{old}}\right) - \sum_{i=0}^{M}\sum_{j=0}^{N}\mu_{i,j}^{\text{conf,close}} \cdot z_{i,j} \cdot \text{sgn}\left(\sum_{n=0}^{N} x_{i,n}^{\text{old}} + \sum_{n=0}^{N} y_{i,j} - \sum_{n=0}^{N} z_{i,n}\right) \quad (17)$$

where:

$\mu_{i,j}^{\text{conf,open}}$	Configuration outflows if channel i supports a new PDP step
$\mu_{i,j}^{\text{conf,close}}$	Configuration outflows if channel i no longer supports an established PDP step
$x_{i,j}^{\text{old}}$	Indicator showing whether state $x_{i,j}$ is open in the current OCS
$y_{i,j}$	Indicator showing whether state $x_{i,j}$ is newly opened
$z_{i,j}$	Indicator showing whether state $x_{i,j}$ is newly closed

The computation of the configuration cash flows follows the same logic as the calculation of the investment cash flows. Conversely, $z_{i,j}$ is an indicator variable equal to 1 if state $x_{i,j}$ is closed, and 0 in all other cases, as shown in Eq. (18). Based on the introduced cash flow components, Eq. (19) allows for identifying the optimal OCS X, which has the highest value contribution base on recurring, investment, and configuration cash flows.

$$z_{i,j} = -\text{sgn}\left(x_{i,j} - x_{i,j}^{\text{old}} + 1\right) - 1 = \begin{cases} 1 & \text{if } x_{i,j} \text{ is a closed state} \\ 0 & \text{else} \end{cases} \quad (18)$$

$$X^{*} = \arg\max_{X} \left(I^{\text{rec}} + I^{\text{inv}} + I^{\text{conf}}\right) \quad (19)$$

2.1.5 Real-world Application at a German Bank

2.1.5.1 Case Description

To demonstrate the applicability and usefulness of our decision model in real-world settings, we applied it to the omni-channel environment of a German bank. Thereby, we specifically investigated the bank's OCS for its construction financing service. The bank is a German cooperative bank with a tradition of more than 200 years. It has about 600 employees in 40 branches and total assets of more than EUR 2 billion. To reach as many customers as possible, the bank offers diverse channels. As requested by the bank's management, we thus refrained from changing or closing existing channels. Instead, the application of our decision model focused on new channels. Below, we outline the case context and provide information on the bank's current OCS. After that, we explain how we collected and prepared required input data. Finally, we report the optimization results, before concluding with an analysis and interpretation.

The PDP of the construction financing service encompasses the following steps: 'Need/Interest,' 'First contact,' 'Schedule of appointment,' 'Information,' 'Consulting,' 'Negotiation,' and 'Conclusion of contract.' These steps are not mandatory in all CJs. Customers may skip 'Need/Interest' and 'First contact' as both steps can occur in any form, i.e. via the bank's channels or word of mouth. In addition, the step 'First contact' is not mandatory as regular customers are already known to the bank. For prospects, however, the 'First contact' step is mandatory. The steps 'Schedule of appointment,' 'Information,' and 'Negotiation' are mandatory in all CJs. Some customers repeat these steps by rescheduling appointments, reconsidering provided information, or requiring several appointments to negotiate contract conditions. The PDP of the construction financing service ends with the conclusion of a contract or with customers leaving the PDP.

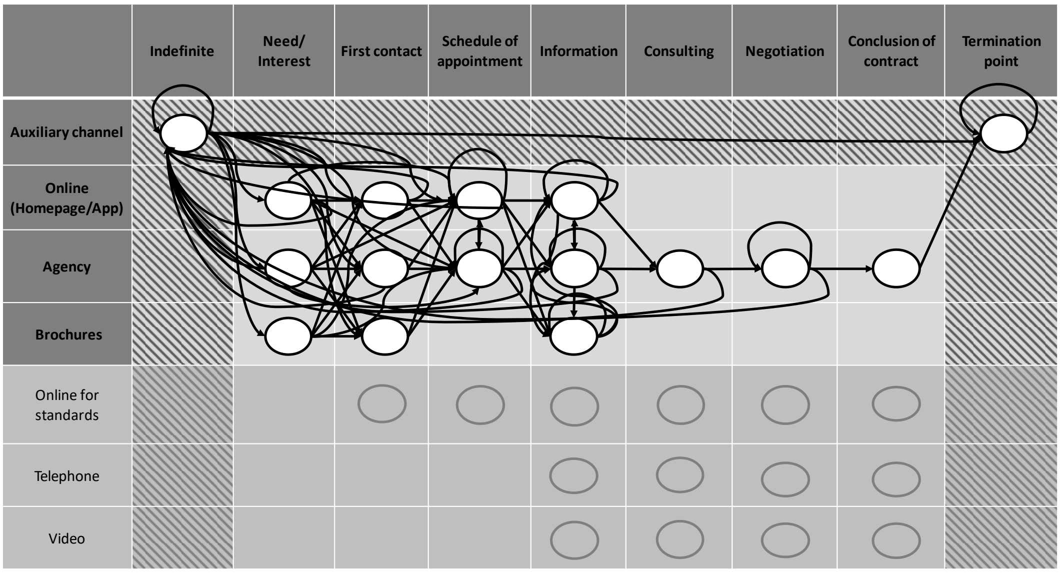

Figure 8: Current omni-channel environment at the case company

To enable interactions between the bank and its customers, the bank's current OCS features three channels (Figure 8): an 'Agency' channel, an 'Online' channel via a website and mobile app, which the bank considers as a single integrated channel, and a 'Brochures' channel for traditional marketing activities. In the future, with a planning horizon of three years, the bank plans to extend its OCS with an 'Online for standards' channel where standardized contracts and contract sections are processed automatically. Further, 'Telephone' and 'Video' channels shall offer customers new ways of contacting bank employees. The bank's current OCS is the starting position for the application of our decision model. Currently, only the 'Agency' channel supports the PDP steps 'Consulting,' 'Negotiation,' and 'Conclusion of contract.' The new channels have different properties, depending on whether customers conclude contracts personally with an agency, whether an interaction is IT-supported, and whether an interaction is one- or bi-directional. For example, the 'Agency,' 'Telephone,' and 'Video' channels support bi-directional personal contact between bank employees and customers. The response to customers using online channels is IT-supported. The 'Brochures' channel is one-directional, providing customers with company and product information. Owing to these channel properties, not all channels support all PDP steps. To illustrate the complexity of the bank's current omni-channel environment, Figure 8 does not only visualize the bank's current OCS, but also all CJs, depending on channel properties and mandatory PDP steps as specified in the restriction matrix. As can be seen, customer behavior can only be captured appropriately via non-sequential CJs. The more non-mandatory

PDP steps and the more options for customers to choose between channels an OCS includes, the more complex the CJs.

2.1.5.2 Data Collection and Preparation

To apply the decision model to the bank's omni-channel environment, we first presented our idea to the head of global bank management, the head of the sales department, and the department head for private and commercial customers. We then collected and validated required input data in an iterative process. Our primary informant was an employee of the bank's sales department, who consulted and involved members of other departments wherever needed. If necessary, we also used additional information from the literature to prepare collected data and validate estimated values. In the case at hand, our primary data source is an in-depth analysis that the bank's sales department had recently conducted of the construction financing service's PDP with a focus on customers' channel usage. We were also granted access to anonymized data from the bank's customer relationship management system. Below, we provide information on our data sources, structured along the components of the decision model (i.e. CJ analysis and investment analysis). Table 1 summarizes input data that resulted from interviews and workshops with the bank's employees, except for the conversion rates that are displayed in the Appendix Table 1 due to the high number of conversion rates.

As for the CJ analysis component, the decision model requires input data about the structure of the PDP and relevant restrictions, available and potential channels, and information about customers including conversion and switching rates. The bank's omni-channel environment and possible CJs could be identified easily based on an interview with a member from the bank's sales department, as channels and PDP steps are the sales department's daily business. Likewise, we quickly reached consensus on the restriction matrix based on logical considerations and legal regulations when discussing CJs with the bank's employees.

Conversion rates were tracked by the bank only in some cases. For example, the bank knew how many customers are leaving the PDP such that we could easily quantify the conversion rates for the 'Auxiliary' channel. We then estimated the remaining conversion rates by considering that the weights of a state's outgoing edges must sum up to 1. Starting with known conversion rates from the bank's channel usage analysis, we allocated the remaining fractions of the conversion rates based on the fraction of customers who used the involved channels.

The switching rates, which capture customer's channel switching preferences if channels are opened or closed steps and which are used to modify conversion rates, were the most difficult to estimate. With the modelling of customer behavior in terms of Markov chains and channel switching rates, as proposed in this study, being a novel approach, organizations do not have such data readily available. To estimate switching rates, we made use of the fact that the switching matrix does not need to be filled with absolute values. Instead, relative values are sufficient, a feature that simplified the collection of required input data. In agreement with the bank's experts, we distinguished 'low,' 'medium,' 'high,' and 'very high' channel switching preferences, with values of 0.25, 0.5, 0.75, and 1, respectively. With channel similarity being a central drive of customer's channel switching preferences, we based the classification just presented on channel similarity and customers' channel usage trends identified by the bank (Gupta et al. 2004). We assigned high switching rates to similar channels and vice versa. By definition, the diagonal of the switching matrix refers to the category 'very high'. Further, we applied the category 'high' between the 'Online' and the 'Online channel for standards' channels as well as the category 'low' between the 'Online' and 'Agency' channels. Switching to the 'Auxiliary' channel was based on the bank's knowledge and the literature, suggesting that personal contact leads to higher preferences than brochures (Frambach et al. 2007). Further, we accounted for the general trend that customers in the digital age tend to prefer online channels over offline channels (Gupta et al. 2004; Verhoef et al. 2015). Thus, we increased the switching rates from the 'Agency' to the 'Online' channel. We did the same when determining the switching rates starting from the 'Auxiliary' channel. The remaining part of the switching matrix was symmetric due to the channels' similarity properties.

As for the investment analysis component, we needed information about the time horizon, customer demand, and cash flow effects. Relevant data on time (i.e. the planning horizon, the length of a period, and the length of PDP steps), customer demand, and how often the PDP steps of the construction financing service are executed, were provided by the bank's sales management department and did not need to be estimated.

Table 1: Real-world input data for the demonstration example

Current OCS

Channels/ Process steps	Indefinite	Need/ Interest	First contact	Schedule of appointment	Information	Consulting	Negotiation	Conclusion of contract	Termination point
Established channels									
Auxiliary channel	1	0	0	0	0	0	0	0	1
Online	0	1	1	1	1	1	0	0	0
Agency	0	1	1	1	1	1	1	1	0
Brochures	0	1	1	0	1	0	0	0	0
Newly considered channels									
Online (std.)	0	0	0	0	0	0	0	0	0
Telephone	0	0	0	0	0	0	0	0	0
Video	0	0	0	0	0	0	0	0	0

Restriction matrix

Process steps/ Process steps	Indefinite	Need/ Interest	First contact	Schedule of appointment	Information	Consulting	Negotiation	Conclusion of contract	Termination point
Indefinite	1	1	1	1	0	0	0	0	1
Need/Interest	1	0	1	1	0	0	0	0	0
First contact	1	0	0	1	0	0	0	0	0
Schedule of appointment	1	0	0	1	1	0	0	0	0
Information	1	0	0	0	1	1	0	0	0
Consulting	1	0	0	0	0	0	1	0	0
Negotiation	1	0	0	0	0	0	1	1	0
Conclusion of contract	0	0	0	0	0	0	0	0	1
Termination point	0	0	0	0	0	0	0	0	1

Initial demand for two months ($\eta \cdot H$)

Channels/ Process steps	Indefinite	Need/ Interest	First contact	Schedule of appointment	Information	Consulting	Negotiation	Conclusion of contract	Termination point
Established channels									
Auxiliary channel	15	0	0	0	0	0	0	0	0
Online	0	15	20	0	0	0	0	0	0
Agency	0	7	36	0	0	0	0	0	0
Brochures	0	4	3	0	0	0	0	0	0
Newly considered channels									
Online (std.)	0	0	0	0	0	0	0	0	0
Telephone	0	0	0	0	0	0	0	0	0
Video	0	0	0	0	0	0	0	0	0

Switching matrix

Channels/ Channels	Auxiliary channel	Online	Agency	Brochures	Online (std.)	Telephone	Video
Auxiliary channel	1	0.75	0.5	0.25	0.75	0.5	0.5
Online	0.25	1	0.25	0.25	0.75	0.5	0.5
Agency	0.25	0.5	1	0.25	0.5	0.75	0.75
Brochures	0.75	0.25	0.25	1	0.25	0.25	0.25
Online (std.)	0.25	0.75	0.25	0.25	1	0.5	0.5
Telephone	0.25	0.5	0.5	0.25	0.5	1	0.75
Video	0.25	0.5	0.5	0.25	0.5	0.75	1

Time

H: Number of process steps for a PDP	12
η: Length of one process step	5 days
Θ: Length of one period	1 year
T: Planning horizon	3 years
$\eta \cdot H$: Length of one PDP	60 days

Variable outflows per customer

Channels/ Process steps	First contact	Schedule of appointment	Information	Consulting	Negotiation	Conclusion of contract	Investment outflows	Operational outflows	Inflows for conclusion of contract
Auxiliary channel	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	1,430.00 €
Online	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	18,416.67 €	**New customer rate**
Agency	0.00 €	0.75 €	2.00 €	123.59 €	40.00 €	19.48 €	0.00 €	33,450.00 €	2.30%
Brochures	0.20 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	833.33 €	**Churn rate**
Online (std.)	0.00 €	0.00 €	0.00 €	81.85 €	9.00 €	2.87 €	40,000.00 €	18,416.67 €	0%
Telephone	0.00 €	0.75 €	2.00 €	123.59 €	40.00 €	19.48 €	40,000.00 €	28,666.67 €	**Interest rate**
Video	0.00 €	0.75 €	2.00 €	123.59 €	40.00 €	19.48 €	40,000.00 €	33,000.00 €	5%

The bank's controlling department provided us with data for monetary input parameters, particularly for variable cash flows, inter alia the sales prices of the construction financing service, investments outflows, and channel-specific outflows. We discussed these input data with experts from the bank's sales department to ensure mutual comprehension of the different concepts used to describe monetary data and to break recurring cash outflows down to individual time periods if needed. Variable cash outflows per customer are based on the monetized average time consumption of an employee, which was known from the bank's recent PDP analysis. The channel-specific outflows for established channels were directly provided by the sales department, whereas for new channels, where no historical data was available, we estimated channel-specific outflows using comparable data from existing channels and challenged the results in semi-structured interviews with experts from the bank's private and commercial customers department. Further, we could use estimations of the sales department for investment outflows, which the bank had already made to prepare the introduction of the new channels. The configuration cash flows capture outflows for changing which PDP steps are supported by a distinct channel. As it is difficult to allocate some cash outflows to individual PDP steps, most organizations – including the bank – do not have detailed data on configuration outflows per state. We thus discussed these outflows in semi-structured interviews with employees from the bank's sales department. Thereby, we assumed that the configuration outflows are equally high for the PDP steps within a distinct channel, but vary between channels. Regarding the cash outflows for the complete or partial closing of channels, neither historical data were available nor could we find reliable estimations in external sources. Thus, we agreed with the bank to refrain from analyzing OCSs that include the closing of channels to maintain the quality of our results. Although our primary focus was on the opening of new channels in line with the bank's strategy, such analyses would have been interesting to find out whether there are favorable OCSs with a reduced number of existing channels.

2.1.5.3 Optimization Results

In line with the bank's strategy and the objective function of our decision model, we aimed to identify the OCS with the highest value contribution, i.e. the highest contribution to the bank's long-term firm value. In our case, the optimal OCS yielded a value contribution of 877,212 EUR. To realize this value contribution, the bank is advised to open the 'Online for standards' channel completely except for the 'Negotiation' step, which is not needed for standard products as indicated in expert interviews. In addition, the bank should open the 'Telephone' channel for the PDP steps 'Information' and 'Conclusion of contract'.

Table 2: OCSs and corresponding value contributions

ID	OVERVIEW OF NEW STATES TO BE OPENED		VALUE CONTRIBUTION	COMMENT
	Considered channel(s)	Considered process step(s)		
1	-	1 2 3 4 5 6 7	0 €	As-is OCS
2	'Online for standards'	1 2 3 4 5 6 7	-68.304 €	Sequential introduction of a new channel (using the example of the channel 'Online for standards')
3	'Online for standards'	1 2 3 4 5 6 7	-92.199 €	
4	'Online for standards'	1 2 3 4 5 6 7	-187.082 €	
5	'Online for standards'	1 2 3 4 5 6 7	-112.920 €	
6	'Online for standards'	1 2 3 4 5 6 7	-763.930 €	
7	'Online for standards'	1 2 3 4 5 6 7	796.693 €	
8	'Telephone'	1 2 3 4 5 6 7	79.161 €	Complete introduction of a new channel
9	'Telephone'	1 2 3 4 5 6 7	446.338 €	Channel-specific local optimum
10	'Video'	1 2 3 4 5 6 7	66.768 €	Complete introduction of a new channel
11	'Online for standards' & 'Telephone'	1 2 3 4 5 6 7	378.513 €	Combined complete introduction of two new channels
12	'Online for standards' & 'Video'	1 2 3 4 5 6 7	366.120 €	
13	'Telephone' & 'Video'	1 2 3 4 5 6 7	2.227 €	
14	'Online for standards', 'Telephone', &'Video'	1 2 3 4 5 6 7	110.719 €	Combined complete introduction of three new channels
15	'Online for standards', 'Telephone', &'Video'	1 2 3 4 5 6 7	270.541 €	FSP's initially preferred OCS
16	'Online for standards' & 'Telephone'	1 2 3 4 5 6 7	877.212 €	Optimal OCS

LEGEND

- N — CHANNEL DOES NOT SUPPORT PROCESS STEP *N*
- N — CHANNEL SUPPORTS PROCESS STEP *N*
- N — Channel cannot support process step *N*
- N — Some channels support process step *N*

The problem of determining the optimal OCS is complex as it requires a full enumeration of all possible OCSs. In case at hand, we had to calculate the value contribution of 16,384 OCSs, a task for which we implemented a software prototype. Due to the high number of candidate OCS, we only present parts of the results, i.e. the most interesting

OCSs from our perspective. Table 2 shows the bank's current OCS, the stepwise opening of a channel to determine a channel-specific local optimum using the 'Online for standards' channel as example, and all combinations of introducing one, two, or all discussed channels. We further highlight the OCS that the bank would have implemented before gaining insights from the application of our decision model. We also compare this OCS with the optimal OCS determined by our decision model.

2.1.5.4 Interpretation and Discussion

As outlined, the bank aims to offer a broad range of channels to reach as much customers as possible. Thus, we deliberately refrained from changing or closing channels of the bank's current omni-channel environment. Instead, we focused on the three new channels the bank was currently considering. The results presented in Table 2 support that the decision model can be applied in real-world settings. Its input parameters can be collected or estimated with reasonable effort. Below, we discuss the various OCSs and their effects.

OCS 1 captures the bank's current OCS. Keeping this OCS leads to a value contribution of 0, a reasonable result that is rooted in the differential investment perspective underlying our decision model. Further, OCSs 2 to 7 capture the stepwise opening of the 'Online for standards' channel structured along the PDP of the construction financing service. Due to complex and non-sequential customer behavior, the opening of this channel only yields a positive value contribution if it supports all PDP steps. From OCSs 8 and 9, which refer to the 'Telephone' channel, we can infer that there are channel-specific local optima. For instance, in the 'Telephone' channel, it is more reasonable to support the last process steps 'Negotiation' (step 6) and 'Conclusion of contract' (step 7) than all process steps. Up to OCS 14, we list all combinations of the new channels. For every channel, OCSs 7, 9, and 10 reflect the respective local optima. Notably, the combination of locally optimized channel strategies does generally not lead to a globally optimal OCS in terms of value contribution. This phenomenon is again rooted in non-sequential CJs (Katz and Shapiro 1994).

The bank initially aimed to implement an OCS that includes all three discussed channels. This OCS is included as OCS 15 in Table 2, and has a rather low, but positive value contribution. Thus far, the complete opening of the 'Online for standards' channel (OCS 7) had the highest value contribution (i.e. 796,693 EUR). The process step 'Negotiation' (step 6) causes considerable variable outflows as we modelled a loop for this step, catering for the fact that most customers need more time than planned. The effect on the bank's omni-channel environment is that the decision model avoids the PDP step 'Negotiation' (step 6) if possible. OCS 16 accounts for this circumstance, showing that the optimal OCS includes a combination of the 'Online for standards' and 'Telephone' channels. This optimal OCS leads to a value contribution of 877,212 EUR, a value more than three times higher than the bank's initially preferred OCS (OCS 15).

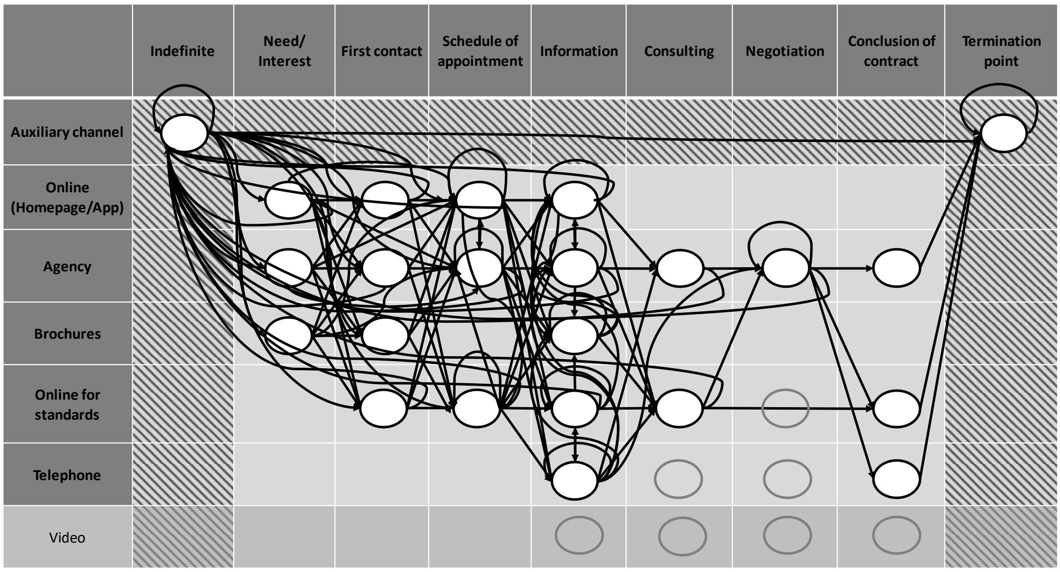

Figure 9: Omni-channel environment at the case company after implementing the optimal OCS 16

In the case at hand, we detected that it is not useful to ignore or open all new channels. The appropriate OCS depends on channel properties and customer's preferences captured in terms of conversion and switching rates as well as on the economic effects associated with the opening, closing, and operations of channels for PDP steps. In the case at hand, the 'Telephone' and 'Video' channels are very similar compared to established channels in terms of their properties and cash flow effects. Thus, it is not reasonable to implement both channels as customers perceive them as substitutable. According to the collected data, the 'Telephone' channel causes lower cash outflows, but similar cash inflows as the 'Video' channel. Thus, it should was preferred. In addition, the investigated OCSs tended to yield higher value contributions if newly opened channels support every PDP step. Finally, our analysis revealed that time-intensive PDP steps of non-standardized products, such as the 'Negotiation' step, are realized by the 'Agency' channel, even if the bank introduces new channels. The reason was that customers prefer the personalized contact with agencies on matters concerning construction financing. Figure 9 shows the bank's omni-channel environment, including anticipated CJs after implementing the optimal OCS. Customers then have more possibilities to interact with the bank. Thus, the structure of CJs becomes even more complex. The 'Agency' channel is relieved by additional channels for the first four process steps and the 'Conclusion of contract' step.

To challenge the optimization results, we presented and discussed the optimal OCS (OCS 16) with a leading employee of the bank. According to the bank's assessment, the PDP of the construction financing service was captured completely and accurately. The optimal OCS eliminates the so far preferred option of using the 'Video' channel for the reasons mentioned above (OCS 15). The leading employee indicated that the optimal OCS is a feasible design option for the bank. One reason was that the optimal OCS leads to less investment outflows than the initially preferred OCS because one channel less must be opened. Further, the bank confirmed that the most important tasks of the construction financing service's PDP are still planned to be conducted by agencies, a property covered by the optimal OCS. Finally, the bank stated that our mathematical analysis of its OCS did not only yield interpretable and actionable results, but also advanced the management team's thinking about complex customer behavior in terms of non-sequential CJs, channel dependencies that influence customers' switching behavior, and the manifold cash flow effects associated with changing an organization's OCS.

2.1.6 Conclusion

2.1.6.1 Summary and Contribution

To account for the increasing importance of OCM and the lack of related prescriptive knowledge, we investigated how organizations can determine which channels they should offer for various PDP steps when considering non-sequential CJs in an omni-channel environment. To do so, we proposed an economic decision model that compares OCSs in terms of their contribution to an organization's long-term firm value. For our purposes, we modeled OCSs as matrices with a channel and a PDP dimension, while capturing CJs via first-order Markov chains. This design enabled us to include online and offline channels, the opening and closing of channels for distinct PDP steps, customer churn due to enforced channel switching, and non-sequential customer behavior. With non-sequential customer behavior and synchronized interaction via multiple channels being essential in the digital age, we considered both phenomena in our decision model. We validated the decision model's applicability using real-world data from a German bank, finding that the required input data can be gathered with reasonable effort and that the results are useful for subject matter experts.

Providing well-founded guidance on how to determine an appropriate OCS for a distinct organization, our decision model adds to the prescriptive knowledge on OCM. Compared to extant prescriptive works, our decision model takes a holistic perspective and is the first to combine non-sequential CJs modelled as first-order Markov chains with decision-making in line with the principles of VBM. Nevertheless, it difficult to infer general recommendations for the selection of OCSs based on the decision model per se due to the high number of input parameters. Such recommendations require a substantial amount of real-world case studies and computational experiments. However, organizations can still benefit from insights based on our decision model when deciding about different OCS without determining all input parameters and applying the model directly. For example, changing one's OCS is not an either-or decision about opening or closing one or more channels. Rather, it implies a conscious deliberation of how customers will behave in case of adjustments. In some cases, closing a single state or opening a channel for specific PDP steps only is more reasonable than closing or opening a channel for the entire PDP. The real-world semantics of the components F_1 to F_4 provide further guidance for omni-channel decision-making. If an organization bears these semantics in mind, it can account for how the diverse effects of omni-channel decision-making and related dependencies. For example, if a channel or state is closed, an organization must propose an alternative with similar characteristics to redirect CJs and avoid churn. Generally, organizations must be aware of their channel offering, the steps of the PDP, and consistently take a customer as well as an investment perspective. The decision model builds on relevant theoretical concepts from the literature and is able to handle manifold situations that occur in real-world settings. Thus, it can be applied in multiple organizational contexts.

2.1.6.2 Limitations and Future Research

Our decision model is beset with limitations that stimulate future research. Below, we present these limitations and related directions for future research, structured into model- and application-specific limitations.

As for model-specific limitations, the decision model makes some simplifying assumptions. First, we assume that most input parameters are constant and deterministic throughout the planning horizon. In real-world settings, however, cash flows and customer behavior are uncertain. As stochastic parameters require information about probability distributions, we deliberately restricted our decision model to deterministic parameters to keep its complexity and the amount of input data manageable. Second, we modeled CJs using first-order Markov chains, acting on the assumption that future customer behavior only depends on a customer's current channel and PDP step combination. Although customers are known to traverse PDPs based on spontaneous decisions, second-order Markov chains would slightly increase the real-world fidelity of our decision model by covering experiences made in previous steps. From a mathematical modelling perspective, the decision model can be extended easily, but its applicability would suffer greatly due to the increased data collection effort. Third, the switching matrix used in the decision model only covers switching rates from one channel to another. Based on the restriction matrix, the decision model also covers the moderating effect of the involved PDP as customers tend to keep their original direction through the PDP. Nevertheless, switching probabilities may differ per PDP step as well as for product or service offerings such that a more fine-grained conceptualization of the switching matrix would increase the real-world fidelity of our decision model. We accepted these limitations to keep the decision model applicable, focusing on those parameters with the highest effects as highlighted in the literature. Nevertheless, future research should challenge which assumptions can be purposefully relaxed. Thereby, one must keep in mind that the decision model aims to purposefully abstract from the real world, not to capture all its complexity. It is imperative to deliberate carefully whether an increase in real-world fidelity gained by relaxing assumptions outvalues corresponding increases in model complexity and data collection effort.

When applying the decision model to the case of a German bank, we determined the most appropriate OCS for a single offering, namely the construction financing service. In general, organizations have several product or service offerings, which differ in terms of their monetary effects and CJs. As channels can be used for all product and service offerings of an organization once they have been established, it is important to consider all offerings to ensure an integrated perspective on an organization's omni-channel environment. However, analyzing CJs for one offering is already very complex. For this reason, our application focused on one service offering to validate how the decision model behaves in a real-world setting. Nevertheless, the decision model can be easily extended to account for several product or service offerings, e.g. by adding PDP steps. The main difficulty of applying our decision model is the estimation of required input parameters such as conversion or switching rates. However, with the conception and implementation of a novel OCS being a rather seldom and irreversible decision associated with long-term effects and huge investments, we are convinced that organizations should make the effort to determine all input parameters, apply the decision model accordingly, and calculate scenarios to mitigate potential estimation inaccuracies. We are convinced that this effort is justified given the enormous consequences of omni-channel decisions. In addition, in the digital age, data about channel preferences and CJs can be collected more easily as ever more data will become available in organizations. Although our real-world application demonstrated that data can be collected with reasonable effort, we recommend conducting additional case studies in different contexts to get a better understanding of realistic value ranges and to establish a knowledge base. Additional case studies and computational experiments will also lead to generalizable insights into the mechanics of omni-channel decision-making. Finally, when applying our decision model, we implemented a software prototype, which is fit for research purposes, but not user-friendly enough to be applied in manifold industry-scale settings. When conducting multiple case studies, the prototype should be enhanced by means of more sophisticated analysis functionality and a convenient user interface.

Appendix Table 1: Conversion rates of the real-world case

From	To	Value	From	To	Value	From	To	Value	From	To	Value	From	To	Value
c0p0	c0p0	0.1	c1p1	c2p3	13/80	c1p4	c3p4	0.01	c2p3	c3p4	0.184	c3p1	c2p2	0.125
c0p0	c0p8	0.5	c1p1	c3p2	0.05	c2p1	c0p0	0.1	c2p4	c0p0	0.02	c3p1	c2p3	0.125
c0p0	c1p1	0.03	c1p2	c0p0	0.1	c2p1	c1p2	17/80	c2p4	c1p4	0.01	c3p1	c3p2	0.05
c0p0	c1p2	1/12	c1p2	c1p3	0.4	c2p1	c1p3	17/80	c2p4	c2p4	0.01	c3p2	c0p0	0.25
c0p0	c1p3	0.03	c1p2	c2p3	0.5	c2p1	c2p2	17/80	c2p4	c2p5	0.95	c3p2	c1p3	0.375
c0p0	c2p1	0.03	c1p3	c0p0	0.05	c2p1	c2p3	17/80	c2p4	c3p4	0.01	c3p2	c2p3	0.375
c0p0	c2p2	1/12	c1p3	c1p3	0.01	c2p1	c3p2	0.05	c2p5	c0p0	0.05	c3p4	c0p0	0.02
c0p0	c2p3	0.03	c1p3	c1p4	0.276	c2p2	c0p0	0.05	c2p5	c2p6	0.95	c3p4	c1p4	0.01
c0p0	c3p1	0.03	c1p3	c2p3	0.01	c2p2	c1p3	19/80	c2p6	c0p0	0.175	c3p4	c2p4	0.01
c0p0	c3p2	1/12	c1p3	c2p4	0.47	c2p2	c2p3	19/80	c2p6	c2p6	0.55	c3p4	c2p5	0.95
c0p0	c0p8	1	c1p3	c3p4	0.184	c2p3	c0p0	0.05	c2p6	c2p7	0.275	c3p4	c3p4	0.01
c1p1	c0p0	0.3	c1p4	c0p0	0.02	c2p3	c1p3	0.01	c2p7	c0p8	1			
c1p1	c1p2	13/80	c1p4	c1p4	0.01	c2p3	c1p4	0.276	c3p1	c0p0	0.45			
c1p1	c1p3	13/80	c1p4	c2p4	0.01	c2p3	c2p3	0.01	c3p1	c1p2	0.125			
c1p1	c2p2	13/80	c1p4	c2p5	0.95	c2p3	c2p4	0.47	c3p1	c1p3	0.125			

c0: Auxiliary channel, c1: Online channel, c2: Agency, c3: Brochures, c4: Online for standards, c5: Telephone, c6: Video. p0: Indefinite, p1: Need/Interest, p2: First contact, p3: Schedule of appointment, p4: Information, p5: Consulting, p6: Negotiation, p7: Conclusion of contract, p8: Termination point.

2.2 Essay 2: User Participation in Information Systems Projects: Necessary but not Sufficient

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2.2.1 Abstract

The information systems literature frequently models project performance of information systems projects as a function of user participation. Markus and Mao (2004) consolidate the literature on user participation in a theoretical framework and call for its instantiation and empirical investigation. In this study, we answer this call by using meta-analytic structural equation modeling to fit the framework to a meta-analytic sample of 226 studies with a total of 42,330 information systems projects. We instantiate the original framework in three important ways. First, we differentiate between capacities and capabilities of project stakeholders to include users. Second, we differentiate between formal and informal mode of user participation. Third, we include residual risk as an important factor in the relationship between user participation and project performance. Our results offer support but also a nuanced perspective on the theoretical framework by Markus and Mao (2004) of user participation and suggest new directions for future research. User participation is necessary to improve project outcomes but not sufficient to ensure project outcomes.

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2.2.2 Introduction

The relationship between modes of user participation and project performance is a frequent unit of analysis in the information systems literature. Early research explores antecedents of user participation and its relationship to the intention to use and the actual use of information systems (See, for instance, Hartwick and Barki 1994; Barki and

Hartwick 1994). Later research conceptualizes the lack of user participation as user risk and investigates its impact on project management practices and project performance (Hung et al. 2014; Liu and Wang 2014; Wallace et al. 2004). A large body of research investigates contingencies such as task complexity, different modes of user participation, and even negative consequences of user participation (McKeen et al. 1994; Saleem 1996; Heinbokel et al. 1996). In their seminal paper, Markus and Mao (2004) consolidate this diverse and complex body of knowledge on user participation in a theoretical framework and call for its instantiation and empirical examination.

While individual constructs and relationships of the theoretical framework by Markus and Mao (2004) have been adopted, questioned, or substantiated in the information systems literature, an empirical examination of the overall framework is still missing. Markus and Mao (2004) develop their framework in the "spirit [of a] complex adaptive systems theory" (p. 538) and argue that the relationships between the constructs should not necessarily be interpreted as representation of variance or processes but rather as "merely influential" (p. 538). An empirical examination of the overall framework would enable us to augment this systems perspective with a variance perspective.

Other studies offer critical perspective on the role of user participation in information systems projects (e.g., Heinbokel et al. 1996). In particular, meta-analytic results by He and King (2008) suggest a weak to moderate effect of user participation on project outcomes. However, these studies investigate direct effects and do not consider the complex interactions proposed by Markus and Mao (2004). An empirical aggregation of the literature on user participation would enable us to offer direction for future research on the role of user participation.

We adopt meta-analytic structural equation modeling to explore the theoretical framework of user participation by Markus and Mao (2004) in the context of information systems projects. Meta-analytic techniques allow us to review the empirical literature and estimate effect sizes by aggregating quantitative empirical results across individual studies (Wowak et al. 2013). Building on the results by He and King (2008), meta-analytic structural equation modeling allows us to treat individual studies on user participation as empirical manifestations of the complex adaptive system of user participation proposed by Markus and Mao (2004). Following Burton-Jones et al. (2015), this would allow us to assess the ecological validity of the theoretical framework, which means in the context of this study, assessing the extent to which the complex adaptive systems theory of user participation by Markus and Mao (2004) can be generalized to the empirical settings investigated by information systems researchers.

Meta-analysis is a well-established research methodology in information systems discipline's reference disciplines, including management science, marketing, and finance (Filippin and Crosetto 2016; Fernandes et al. 2014). Increasingly, meta-analysis is also adopted in the information systems (See, for example, Sharma and Yetton 2007; He and King 2008; Schermann et al. 2016). Thus, we extend this research and explore whether the theoretical framework of user participation by Markus and Mao (2004) is a "coherent and useful form" (Hunter and Schmidt 2004, p. xxvii) to capture the complex nature of user participation in information systems projects.

Our results from instantiating the theoretical framework by Markus and Mao (2004) and fitting it to a meta-analytic sample of 226 empirical research studies with a total sample size of 42,330 information systems projects support the fundamental structure and logic of the theoretical framework by Markus and Mao (2004). Furthermore, our results also offer support for the critical perspective on user participation in information systems projects by He and King (2008). User participation has a weak to moderate relationship on project performance. More specifically, user participation is independent of propensities to design, offer, and execute opportunities for user participation. User participation appears to be a necessary but not sufficient project management practice.

We organized the remainder of the paper as follows. In the next section, we introduce and review the theoretical framework by Markus and Mao (2004). Additionally, we propose adaptation to the framework, which we derive from the literature. Then, we introduce and justify our approach to locating, coding, and aggregating empirical data from individual studies. Next, we present the result the meta-analytic structural equation modeling. Subsequently, we discuss implications for theory and practice. We close with an assessment of limitations and outline potentially fruitful avenues for future research.

2.2.3 Theoretical Background

The information systems literature offers heterogeneous perspectives on a variety of modes of user participation in a broad range of contexts. For instance, early research on user participation focuses on the relationship of user participation and adoption of information systems (See for example, Hartwick and Barki 1994). Other studies investigate the role of user participation in the context of information security risk management (See for example, Spears and Barki 2010). However, the predominant stream of research investigates user participation in information systems projects. This literature investigates the role of user participation in a variety of project tasks such as requirements engineering, testing, user training, and system adoption (Hsu et al. 2008; Coughlan and Macredie 2002; Nidumolu 1996).

A broad range of methodological approaches combined with mixed results on the effect of user participation impede the ability of the information systems discipline to offer sound guidance on whether and how to include users in information systems projects. He and King (2008) argue that this becomes particularly problematic as "[m]any academics and consultants recommend user participation […] as an effective practice to achieve various favorable outcomes" (He and King 2008, p. 302).

Two studies are particularly important to consider for advancing the understanding of the role of user participation in information systems projects. One, Markus and Mao (2004), develop a theoretical framework of user participation, which describes core concepts and relationships among the concepts. The authors position the theoretical framework as a complex adaptive systems theory and posit a set of propositions on the relationship of user participation and project performance.

The other study by He and King (2008), a meta-analysis, offers a more critical perspective on user participation. By estimating the effect of user participation on a set of outcome measures, He and King (2008) conclude that user participation has a weak to moderate effect of user participation on project performance. However, the study only measures the direct effects of user participation on outcome measures and thus (by design) ignores the complex relationship between antecedents of user participation, different modes of user participation, and project performance suggested by Markus and Mao (2004). Here, we attempt to apply the meta-analytic perspective adopted by He and King (2008) to the theoretical framework of user participation developed by Markus and Mao (2004) using a meta-analytic structural equation modeling approach. We develop our structural equation model in three steps. First, we define the independent and dependent concepts in our model.

Here, we extend the theoretical framework by Markus and Mao (2004) and include important elements discussed by He and King (2008). Second, we review the literature to understand important modes of user participation not explicitly covered by either of the two studies. Third, we develop the relationships between the concepts as hypotheses by interpreting the propositions offered by Markus and Mao (2004).

2.2.3.1 Independent and Dependent Concepts

In line with Markus and Mao (2004), we differentiate between two set of actors that are relevant in the context of user participation. Stakeholders are organizational members, who are either directly or indirectly affected by information systems projects. Markus and Mao (2004) assign the label *stakeholder* instead of *user* to highlight the fact that not just the intended users of the information system should or could participate but also other actors such as executives or consultants. In line with the literature, we posit that user participation activities require effort, time, and commitment from stakeholders, which may not be available to the extent required by information systems projects (Markus and Mao 2004). Thus, we conceptualize the role of stakeholders as **stakeholder capacity**, which combines the psychological and practical ability to contribute to the success of an information system project.

The other set of actors are change agents. Change agents are actors, who are responsible for the progress and outcomes of information systems projects. Similar to the broad definition of stakeholders, this group not only includes the technical specialists that develop the information system but also consultants and IT vendors (Markus and Mao 2004). We capture the role of change agents in two concepts. One concept captures the change agent capabilities. **Change agent capabilities** refer to the knowledge and experience of the change agents to conduct information systems projects. The change agent capabilities include the ability of change agents to design, offer, and execute opportunities for user participation. The other concept captures critical perspectives on user participation, which suggest that user participation should be used only selectively to improve outcomes (Heinbokel et al. 1996; He and King 2008). We capture such perspectives using the concept of **change agent propensity**.

We conceptualize the consequences of user participation with two concepts: residual risk and project performance. Residual risk refers to the perceived risk "remaining in the project" (Nidumolu 1995, p. 195) despite interventions including functional and managerial user participation. While neither Markus and Mao (2004) nor He and King (2008) introduce residual risk as a consequence of user participation, our review of the project literature indicates that the lack of user participation is frequently used as control variable (Liu and Wang 2014). Furthermore, a dominant objective of user participation is to mitigate requirements uncertainty (Coughlan and Macredie 2002; Hsu et al. 2008). Thus, we follow (Nidumolu 1995) and include **residual risk** as consequence of user participation.

Finally, we conceptualize the functional outcomes of information system projects using the concept of **project performance**. Although Markus and Mao (2004) offer a more fine-grained conceptualization of project performance, we adopt a broader perspective for two reasons. One is that the information systems literature offers a plethora of definitions for project performance, which are frequently used interchangeably across studies. The other reason is that Markus and Mao (2004) suggest emergent relationships between concepts of project performance. Initial explorations of our meta-analytic sample indicated that the information systems literature does not provide enough empirical data to investigate such relationships. Thus, we opted for a composite measurement of project performance.

2.2.3.2 Modes of User Participation

The concept of user participation refers to activities designed by change agents to include stakeholders in specific tasks of information systems projects (Barki and Hartwick 1994). We differentiate between functional and managerial participation as two important modes of user participation. Predominantly, the literature on user participation investigates functional modes of user participation. For instance, stakeholders provide domain knowledge to improve requirements engineering phases during the project (Coughlan and Macredie 2002). The literature on functional modes of user participation frequently differentiates between a psychological perspective of user involvement and behavioral perspective of user participation, with user involvement as an antecedent to user participation (Hartwick and Barki 1994; Barki and Hartwick 1994). In line with He and King (2008), our empirical data suggests that both perspectives are used interchangeably in the information systems literature. Thus, we conceptualize both perspectives as **functional user participation**.

Additionally, the literature on project control suggests managerial modes of user participation (Wiener et al. 2016). Stakeholders, particularly when following the broad definition of Markus and Mao (2004), participate in the design, operation, and evaluation of project control systems. The purpose of project control is to regulate the behavior of stakeholders and change agents and to align potentially incongruent objectives ofstakeholders and change agents (Ouchi 1979). For instance, stakeholders may use outcome control modes to specify and control the attainment of desired target states of projects (Eisenhardt 1985; Gopal and Gosain 2010). Alternatively, the literature on behavior control investigates control modes where the change agents define desired behavior with stakeholder participation (Henderson and Lee 1992; Kirsch 1997). We conceptualize such forms of user participation as **managerial user participation**.

2.2.3.3 Hypotheses

We develop hypotheses by instantiating propositions offered by Markus and Mao (2004). It is important to note that it is not our intent to test the theoretical framework by Markus and Mao (2004). Instead, we opt for an exploratory approach to investigate a broad set of hypotheses and their manifestations in the empirical literature. We explore three independent concepts: stakeholder capacity, change agent capacity, and change agent propensity. Figure 10 summarizes our hypotheses as a conceptual model of user participation in information systems projects.

Markus and Mao (2004) propose that stakeholders "differ in their ability to contribute by their participation" (p. 530). Higher limits to stakeholders' effort, time, and commitment offer more opportunities for change agents to include stakeholders in functional and managerial modes of user participation. More formally:

H1: Stakeholder capacity is positively related to functional user participation.

H2: Stakeholder capacity is positively related to managerial user participation.

Similarly, Markus and Mao (2004) propose that "the quality of change agents' efforts in designing and executing participating activities is related to (…) success" (p. 530). The capabilities of change agents and their organizations limit their ability to include stakeholders. More formally:

H3: Change agent capabilities are positively related to functional user participation.

H4: Change agent capabilities are positively related to managerial user participation.

The change agent propensity captures the inclination of the change agent to offer opportunities for user participation. While Markus and Mao (2004) do not offer specific propositions, we include the change agent propensity to capture important beneficial or detrimental antecedents to user participation. More formally:

H5: Change agent propensity is positively related to functional user participation.

H6: Change agent propensity is positively related to managerial user participation.

Furthermore, Markus and Mao (2004) state that the actors should focus on developing "effective relationships" and "work effectively together to design opportunities" (p. 531). We hypothesize that managerial user participation aligns the objectives of the involved actors and thus increase the likelihood for opportunities of functional user participation. More formally:

H7: Managerial user participation is positively related to functional user participation.

The fundamental assumption of the user participation literature is that user participation improves project outcomes (He and King 2008). An important objective of functional user participation is to reduce uncertainty about the desired target of the information systems projects.

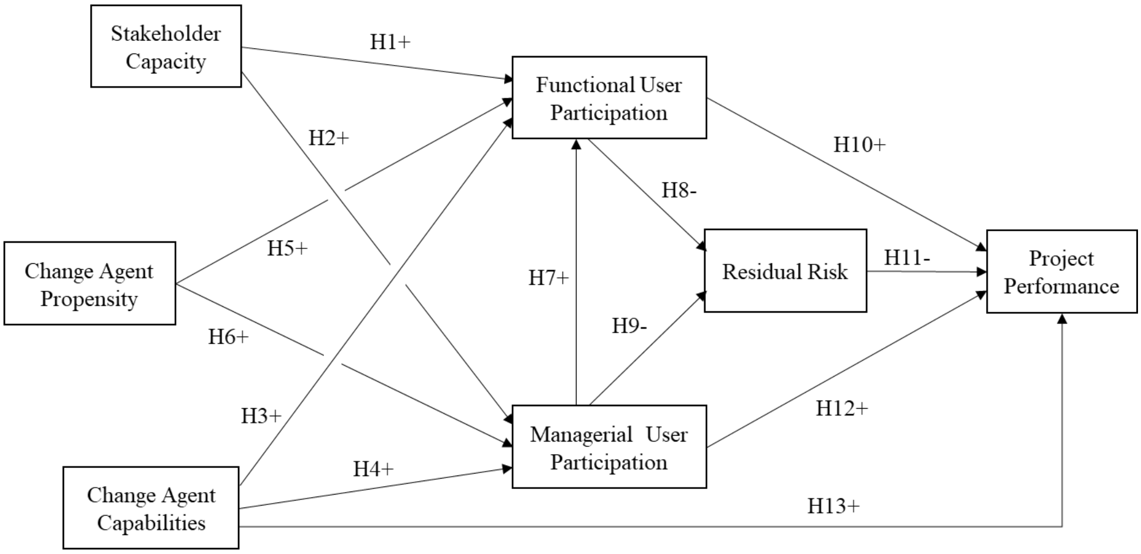

Figure 10: Conceptual Model of User Participation in Information Systems Projects

Similarly, managerial user participation reduces the likelihood of actors pursuing egocentric objectives (Kirsch 1997). Additionally, Nidumolu (1995) shows that higher levels of residual risk are associated with lower levels of project performance. More formally:

H8: Functional user participation is negatively related to residual risk.

H9: Managerial user participation is negatively related to residual risk.

H10: Functional user participation is positively related to project performance.

H11: Managerial user participation is positively related to project performance.

H12: Residual risk is negatively related to project performance.

The core argument of He and King (2008) is that user participation is just one of the measures to improve project performance. Following this argument would indicate that the change agent capabilities should not just affect modes of user participation but also project performance. As we do not investigate measures other than user participation in our model, we state more formally:

H13: Change agent capabilities are positively related to project performance.

2.2.4 Method

We adopt meta-analytic structural equation modeling to review the literature on user participation. Metaanalytic structural equation modeling enables us to investigate structural relationships using effect sizes synthesized from literature. In their meta-analysis, He and King (2008) suggest marginal to moderate direct relationships between user participation and project performance. Markus and Mao (2004), however, suggest more complex relationships between antecedents, modes, and consequences of user participation. Combining meta-analysis and structural equation modeling allows us to investigate both arguments relationships simultaneously.

We follow established guidelines to locate, code, and aggregate empirical findings in a structural equation model (Lipsey and Wilson 2001; Cheung and Chan 2005a; Jak 2015). A robust literature search protocol guides the process of locating and selecting empirical studies. Given the diverse nature of the information systems literature, a coding protocol ensures a systematic categorization of empirical findings. Finally, we use two-stage structural equation modeling to aggregate the empirical findings and fit them to the model developed above (Cheung and Chan 2005a).

2.2.4.1 Literature Search Protocol

The objective of the literature search protocol is to locate, assess, and select robust empirical findings for inclusion in the meta-analytic sample. We adopt an exhaustive literature search strategy to mitigate the threat of publication bias (Rosenthal 1979). Thus, the literature search protocol consists of two phases: an initial systematic keyword search in databases, an initial search for unpublished studies. Both phases follow a backward and forward search strategy (Webster and Watson 2002).

The systematic keyword search used the following databases: ScienceDirect, EBSCOhost, Institute of Electrical and Electronics Engineers (IEEE) Xplore, The Association for Information System Electronic Library (AISeL), and the Association for Computing Machinery (ACM) Digital Library. We located studies published in conference proceedings and journals that examined factors of performance or success in IS projects using one or more of the following keywords: “information system”, “information technology", "software", "project*", "performance", "success", "outcome", "qualit*", and "risk*". We did not specifically search for user participation to ensure a broad perspective of potentially interesting modes of user participation. Additionally, user participation is often measures in control variables (e.g., Liu and Wang 2014). We complemented this search with a search for unpublished studies in Google, Google Scholar, dissertation repositories, and the Social Science Research Network (SSRN). Using backward and forward search strategies, our initial meta-analytic sample includes 421 publications. We collected quantitative empirical studies only.

Each study must pass the following checks to be included in the final meta-analytic sample. First, the study must investigate constructs at the project level. Second, the study must provide Pearson product-moment correlation coefficients. Third, the study must not raise any quality concerns. Fourth, and most importantly, each study must report on a unique empirical sample. Including studies that report on various perspective on the same empirical sample would introduce a bias toward this sample. For instance, the search protocol yielded working papers, conference publications, journal publications using the same samples. In such cases, we selected either the publication with the most reputation (e.g., the journal publication over the conference proceeding) or the most recent publication. The final meta-analytic sample includes 226 studies with a total sample size of 42,330 information systems projects.

2.2.4.2 Coding Protocol

The objective of the coding protocol is to ensure a systematic allocation of study variables to the concepts developed above. The meta-analytic sample includes 2,058 variables. Thus, the coding protocol mitigates the risk of "comparing apples and oranges" (He and King 2008, p. 310). The coding protocol consists of three steps: study coding, concept coding, and coding validation.

Study coding involved the extraction of the variables including the definition provided by the authors of the study. Each variable was coded to reflect the authors' definition as close as possible. We coded independently, compared the results, and resolved inconsistencies. In the concept coding, we grouped study codes. Not all codes were grouped. Where appropriate, we reversed codes. For instance, effort overrun was coded as reversed project performance. We ensured high levels of consistency in the groups by visually inspecting forest plots and analyzing sources for heterogeneity in each concept. We resolved inconsistencies by iterating between grouping and forest plot inspections.

Table 3: Result of the Coding Protocol

Concept	Codes	Reversed codes
Functional User Participation	Vertical Coordination, Horizontal Coordination, Integrative Coordination, User Participation, User Involvement, Informal Control, Clan Control	
Managerial User Participation	Administrative Coordination, Internal Coordination, Project Control, Formal Control, Behavior Control, Outcome Control	Autonomy, Self-control
Stakeholder Capacity	User Experience, User Capabilities, Top Management Support, Strategic Importance, Relational Capital	Governance Volatility, Environment Risk, User Risk, Social Subsystem Risk, Organizational Complexity
Change Agent Propensity	Task Complexity, Asset Specificity, Customization, Contract Type (Time and Materials), Reversed Experience with Client	Reversed Asset Specificity, Reversed Task Complexity, Contract Type (Fixed Price), Experience with Client, Knowledge about Client's Industry
Change Agent Capabilities	Project Management Practices, Commitment, Team Familiarity, Project Manager Experience, Project Manager Capabilities, Team Experience, Team Capabilities, Reversed Technical Complexity	Technical Complexity, Technological Uncertainty, Knowledge Resources Risk, Team Risk, Technical Subsystem Risk
Residual Risk	Residual Risk, Requirements Uncertainty, Estimation Uncertainty, Planning & Control Risk, Perceived Performance Risk, Requirement Risk, Target Volatility	Internal Coordination Quality, External Coordination Quality, Teamwork, Learning, Certainty, Conflicts Resolved, Reversed Estimation Uncertainty
Project Performance	Project Performance, Process Performance, System Performance, Team Performance, Time and Budget, User Satisfaction, Profitability	Effort Overrun, Number of Defects, Realized Performance Risk, Conflicts Existing

In a third step, we fitted partial relationships between the groups to available structural equation models (e.g., Nidumolu 1995) to detect potential inconsistencies in our coding and code grouping. Again, identified inconsistencies were resolved in an iterative process. Finally, we combined the groups to match the concepts developed above. Again, to ensure a systematic match, we developed several matches to detect and resolve inconsistencies.

2.2.4.3 Meta-analytic Structural Equation Modeling

We adopted two-stage structural equation modeling to fit the meta-analytic sample to the conceptual model developed above (Cheung and Chan 2005a; Jak 2015). Two-stage structural equation modeling enables us to synthesize effect sizes into a pooled correlation matrix. More importantly, two-stage structural equation modeling uses the full sample size for fitting the model (Cheung and Chan 2005b). Given the heterogeneity in research interests in the information systems discipline, this is a critical property to integrate a diverse set of studies. The pooled correlation matrix is then used to fit the metaanalytic sample to the specified (Cheung and Chan 2005b; Jak 2015).

We used the zero-order Pearson product-moment-correlation coefficients between concepts to estimate effect sizes. We did not apply Fisher's z transformation to avoid an upwards bias (Hunter and Schmidt 2004; Hall and Brannick 2002). We corrected the correlation coefficients for measurement errors using the reliability coefficients provided in the empirical studies (Hunter and Schmidt 2004). If a study does not provide reliability coefficients, we adopted a conservative reliability coefficient of 0.8 (Bommer et al. 1995; Dalton et al. 2003; Jiang et al. 2012).

Additionally, we used the formula for individually corrected correlation coefficients by Hunter and Schmidt (2004) to calculate the standard error of the estimated average correlations. We follow the recommendations by Hunter and Schmidt (2004) to estimate the zero-order Pearson product moment correlation coefficients. This procedure is consistent with recent meta-analyses in the IS literature. In cases, where a study provides two variables for the same concept (e.g., two variables were coded as project performance), we averaged the effect sizes (Hunter and Schmidt 2004).

The corrected correlation coefficients are the input to the stage one of the two-stage structural equation modeling. We pool the corrected correlation coefficients using a random effects model (Cheung and Chan 2005b; Jak 2015). Random effects models assume that the effect sizes vary across studies. Given the diversity and heterogeneity in the information systems literature, random effects models offer conservative estimates because they assume that the effect size is a function of multiple causes including sampling error, variable operationalization, or respondent characteristics. We assess the heterogeneity in the pooled correlation matrix using the Q statistic (Hunter and Schmidt 2004). A significant Q statistic indicates substantial heterogeneity in the meta-analytic sample.

In the second stage, we fit the pooled correlation matrix to the conceptual model developed above. Following the guidelines by Jak (2015), we additionally included relationships between the three independent concepts (i.e., stakeholder capacity, change agent capacity, and change agent intent) to control for co-variance between independent variables.

We use the following goodness-of-fit criteria to assess the fit of the model and the data: The chi-square measure of fit assesses the homogeneity of the meta-analytic sample beyond sampling. A significant chi-square measure of fit indicates that the model does not exactly fit the meta-analytic sample. We do not assume that our model will exactly fit the data. Thus, we also include measures of fit. In particular, we assess the root mean square error of approximation (RMSEA), the standardized root mean square residual (SRMR), and the comparative fit index (CFI) (Schumacker and Lomax 2009; Hooper et al. 2007; Hu and Bentler 1998).

A RMSEA value of less than 0.05 indicates close fit. The confidence interval of the RMSEA should be less than 0.05 for the lower bound and less than 0.08 for the upper bound. A SRMR value of less than 0.08 indicates a good fit (Browne and Cudeck 1992; Hu and Bentler 1998; Schreiber et al. 2006; Schumacker and Lomax 2009). A CFI of more than 0.95 indicates a good fit (Bentler and Bonett 1980; Schreiber et al. 2006).

2.2.5 Results

The two-stage structural equation modeling approach produces two main results. One result is the pooled correlation matrix (See Table 4). The *Q* statistic for the pooled correlation matrix is highly significant ($Q(556) = 8893$, $p < 0.001$), which suggest significant heterogeneity in the meta-analytic sample. Table 4 reports the pooled correlation matrix.

Table 4: Pooled Correlation Matrix

	SC	**CAP**	**CAC**	**RR**	**FUP**	**MUP**	**PP**
SC							
CAP	-0.07						
CAC	0.243	-0.098					
RR	-0.236	0.062	-0.221				
FUP	0.302	0.0158	0.194	-0.285			
MUP	0.246	-0.00072	0.166	-0.270	0.303		
PP	0.350	-0.068	0.354	-0.309	0.329	0.235	

Legend: SC = Stakeholder Capacity, CAP = Change Agent Propensity, CAC = Change Agent Capabilities, RR = Residual Risk, FUP = Functional User Participation, MUP = Managerial User Participation, PP = Project Performance

The second result is the estimated structural equation model. Before interpreting the parameters, Jak (2015) recommends to assess the fit between the model and the data. Table 5 reports the goodness-of-fit measures. The chi-square measure is highly significant (Chi-square = 23.68 (5), $p = 0.00025$), which indicates that the models has to be interpreted as an approximation of the data. The RMSEA value is lower than 0.05, the lower boundary of the confidence interval is less than 0.05 and the upper boundary is less than 0.08, which indicates a good fit (RMSEA = 0.009 [0.006:0.013]). Furthermore, the SRMR value is less than 0.08, which again indicates good fit (SRMR = 0.054). The CFI value is only marginally larger than 0.95, which indicate a satisfactory fit (CFI = 0.957). All goodness-of-fit measures are within the acceptable ranges, which allows us to interpret the parameters of the model.

Table 5: Goodness-of-fit Measures

Chi-square (DF), p-value	RMSEA	CI 95% RMSEA	SRMR	CFI
23.68 (5), p = 0.00025	0.009	0.006:0.013	0.054	0.957

Figure 11 reports the parameter estimates in the context of the hypotheses established above (Viechtbauer 2010). Confidence intervals that include zero indicate non-significant parameters. The parameters for significant relationships range from -0.27 to 0.27.

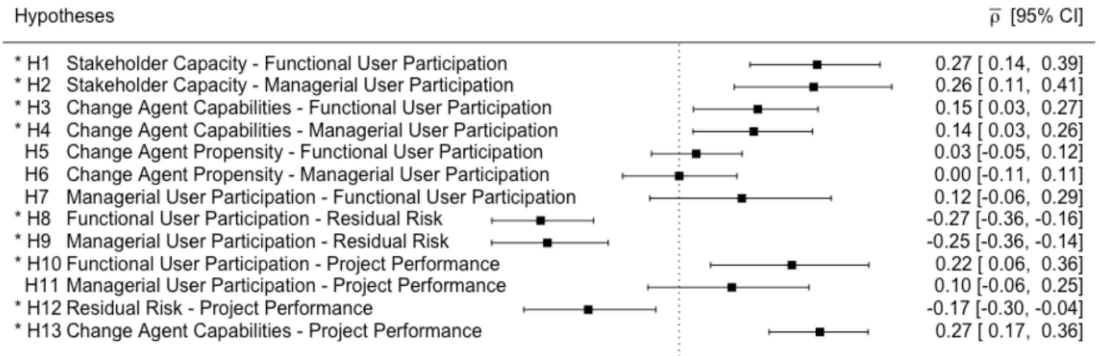

Figure 11: Parameters Estimates for the Hypotheses

Hypothesis H1 posits a positive relationship between stakeholder capacity and functional user participation. Our results support H1 and indicate a positive, significant, but weak relationship between stakeholder capacity and functional user participation ($\bar{\rho}$ = 0.265, CI = [0.136: 0.386]). Hypothesis H2 posits a positive relationship between stakeholder capacity and managerial user participation. Our results support H2 and indicate a positive, significant, but weak relationship between stakeholder capacity and managerial user participation ($\bar{\rho}$ = 0.259, CI = [0.106: 0.409]).

Hypothesis H3 posits a positive relationship between change agent capabilities and functional user participation. Our results support H3 and indicate a positive, significant, but trivial relationship between change agent capabilities and functional user participation ($\bar{\rho}$ = 0.151, CI = [0.027: 0.267]). Hypothesis H4 posits a positive relationship between change agent capabilities and managerial user participation. Our results support

H4 and indicate a positive, significant, but trivial relationship between change agent capabilities and managerial user participation ($\overline{\rho}$ = 0.144, CI = [0.027: 0.256]).

Hypothesis H5 posits a positive relationship between change agent propensity and functional user participation. Our results do not support H5 and indicate a positive, trivial, but non-significant relationship between change agent propensity and functional user participation ($\overline{\rho}$ = 0.033, CI = [-0.053: 0.121]). Hypothesis H6 posits a positive relationship between change agent propensity and managerial user participation. Our results do not support H6 and indicate a positive, trivial, but non-significant relationship between change agent propensity and managerial user participation ($\overline{\rho}$ = 0, CI = [-0.108: 0.111]).

Hypothesis H7 posits a positive relationship between managerial user participation and functional user participation. Our results do not support H7 and indicate a positive, trivial, but non-significant relationship between managerial user participation and functional user participation ($\overline{\rho}$ = 0.121, CI = [- 0.056: 0.292]).

Hypothesis H8 posits a negative relationship between functional user participation and residual risk. Our results support H8 and indicate a negative, weak, but significant relationship between functional user participation and residual risk ($\overline{\rho}$ = -0.266, CI = [-0.36: -0.164]). Hypothesis H9 posits a negative relationship between managerial user participation and residual risk. Our results support H9 and indicate a negative, weak, but significant relationship between change agent propensity and managerial user participation ($\overline{\rho}$ = -0.253, CI = [-0.36: -0.136]).

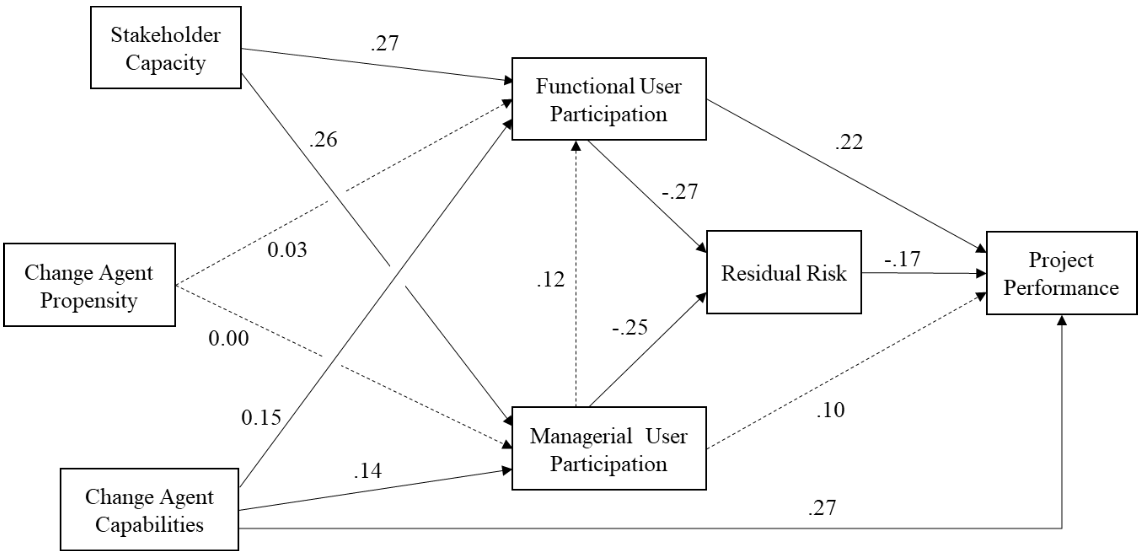

Figure 12: Parameterized Conceptual Model for User Participation in Information Systems Projects

Hypothesis H10 posits a positive relationship between functional user participation and project performance. Our results support H10 and indicate a positive, weak, but significant relationship between functional user participation and project performance ($\overline{\rho}$ = 0.217, CI = [0.061: 0.365]). Hypothesis H11 posits a positive relationship between managerial user participation and project performance. Our results do not support H11 and indicate a positive, trivial, but non-significant relationship between managerial user participation and project performance ($\overline{\rho}$ = 0.101, CI = [-0.06: 0.25]). Hypothesis H12 posits a negative relationship between residual risk and project performance. Our results support H12 and indicate a negative, trivial, but significant relationship between residual risk and project performance ($\overline{\rho}$ = -0.175, CI = [-0.298: -0.045]).

Finally, hypothesis H13 posits a positive relationship between change agent capabilities and project performance. Our results support H13 and indicate a positive, weak, but significant relationship between change agent capabilities and project performance ($\overline{\rho}$ = 0.271, CI = [0.173: 0.363]).

The meta-analytic structural equation model explains 25.8 percent of the variance of project performance. Figure 12 shows the parameterized conceptual model. Solid edges represent significant relationships and dashed edges represent non-significant relationships.

2.2.6 Discussion

We discuss the results in two steps. First, we discuss implications for research in the context of the theoretical framework by Markus and Mao (2004). Second, we review limitations that may impact the validity of our results. These limitations represent implications for future research.

2.2.6.1 Implications for Research

The objective of this research was to instantiate and empirically investigate the theoretical framework by Markus and Mao (2004) using a meta-analytic structural equation modeling approach. Markus and Mao (2004) argue that inconsistent and even conflicting results on the role of user participation are the result of too simple explanations that “leave important conceptual issues unresolved” (p. 514). Thus, they develop a theoretical framework to guide research towards resolving these conceptual issues.

Our results support the fundamental structure and logic of the theoretical framework by Markus and Mao (2004). Stakeholder capacity and change agent capabilities are significant antecedents of user participation. In turn, two modes of user participation activities, functional user participation and managerial user participation, reduce the residual risk in information systems projects. Additionally, functional user participation has a positive impact on project performance. The residual heterogeneity of our results also substantiate the claim by Markus and Mao (2004) that the project context may introduce important moderators of the relationships between the antecedents, modes, and consequences of user participation.

In contrast to Markus and Mao (2004), He and King (2008) use meta-analysis to show that user participation has a weak to moderate effect on project outcomes. He and King (2008) argue that user participation is not a "panacea to guarantee improved [..] outcomes" (p.324). Our results support the arguments by He and King (2008). The direct effect on project performance is weak for functional user participation and even non-significant for managerial user participation. Overall, our model explains just 25.8 percent of the variance of project performance. Additionally, our results show the strongest effect size for the direct relationship between change agent capabilities and project performance. This indicates that user participation is indeed just one of a variety of strategies to improve project outcomes.

In line with Markus and Mao (2004) and He and King (2008), our results indicate that different modes of user participation have differential effects. Functional user participation provides means to reduce risks perceived by stakeholders and change agents during the process of projects. Furthermore, functional user participation improves project performance. Furthermore, our results indicate a role for managerial user participation that is consistent with the original literature on project control (Ouchi 1979; Eisenhardt 1985). Managerial user participation reduces risks perceived by stakeholders and change agents but has a non-significant impact on the outcomes of projects. Finally, the non-significant effect between functional user participation and managerial participation suggest that change agents use different modes of user participation independently.

Beyond the arguments by Markus and Mao (2004) and He and King (2008), our results further indicate that user participation is a necessary but not sufficient strategy to achieve desired project outcomes. More specifically, our results indicate that user participation is independent of the change agents' propensity to design, offer, and execute opportunities for user participation. This suggests that change agents engage in user participation independent of whether they develop a particular propensity for user participation (e.g., due to significant customization efforts). Furthermore, our results indicate that managerial user participation is as important as functional user participation to reduce residual risks in projects.

Our results indicate that practitioners should perceive user participation as a necessary but not sufficient strategy in the set of project management practices. Both modes of user participation help to reduce risks and guide projects toward desired outcomes. In particular, user participation reduces risks in projects. However, the weak effects on residual risk and project performance indicate that user participation is associated with costs that dampen the effect of user participation (He and King 2008). Also, the heterogeneity in stage one of our meta-analysis suggest that the effect of user participation is a function of multiple factors such as the project context or the maturity of the industry. In sum, our results suggest that practitioners should adopt a mindful approach to design, offer, and execute opportunities for users to participate.

2.2.6.2 Limitations

The results of this study are subject to several potential limitations, which originate from the methodological choices outlined above. First, we may have missed empirical studies during our literature search protocol. We are confident that we have not missed a substantial number of studies as our search results are consistent with published meta-analyses (Dongus et al. 2015; He and King 2008).

Second, all literature reviews and meta-analyses are subject to the file drawer problem indicating that unpublished results would differ from the published results (Rosenthal 1979). We mitigated this potential limitation by including a wide variety of publication types including unpublished material, dissertations, and working paper.

Third, our instantiation of the theoretical framework by Markus and Mao (2004) is necessarily subjective. For instance, Markus and Mao (2004) did not conceptualize important characteristics of stakeholders and change agents. Our conceptualization of stakeholder capacity, change agent capabilities, and change agent propensity are an attempt to stay as close to the proposition by Markus and Mao (2004) as possible.

Furthermore, we had to abandon the idea of differentiation categories of project outcome due to heterogeneity in the literature. While previous studies investigate different categories of project outcomes (Basten and Pankratz 2015; He and King 2008; McKeen et al. 1994; Wang et al. 2014), our focus was to fit the full theoretical framework by Markus and Mao (2004) to the data. Similarly, we could not address all propositions by

Markus and Mao (2004) due to a lack of empirical studies. While future research should investigate whether including different categories of project performance or additional concepts significantly changes the results.

Fourth, our coding of the empirical studies is necessarily subjective, too. Although, we followed systematic procedures, our interpretation of empirical studies may have an impact on the results. We are, however, confident that this impact is not substantial as our results are consistent previous studies (He and King 2008). Furthermore, our meta-analytic sample produces results that are consistent with existing structural equation models (Nidumolu 1995).

Fifth, the stage one of the meta-analytic structural equation modeling process reveals significant heterogeneity in the meta-analytic sample. This could be an indicator for moderators that could affect the results. Our results should be interpreted as a first attempt to instantiate the theoretical framework by Markus and Mao (2004). In line with the call by Markus and Mao (2004), future research should investigate potential moderators such as the project context (e.g., difference in the role of user participation in internal and outsourced projects).

2.2.7 Conclusion

In this study, we quantitatively explore the theoretical framework for user participation proposed by Markus and Mao (2004). Based on a meta-analytic structural equation model from 226 with a total of 42,330 information systems projects, our results indicate support for the theoretical framework. User participation has a weak but significant effect on two important project outcomes, residual risks and project performance. This effect is independent of a propensity to include users. Overall, our results suggest that user participation is a necessary strategy to *improve* project outcomes but not sufficient to *ensure* them.

Markus and Mao (2004) argue that their theoretical framework is a complex adaptive systems theory. In this study, we show that meta-analytic approaches help to integrate empirical findings in order to advance and extend such complex adaptive systems theories. We instantiate the original framework by Markus and Mao (2004) in three important ways. First, we differentiate between capacities and capabilities of project stakeholders to include users. Second, we differentiate between formal and informal mode of user participation. Third, we include residual risk as an important factor in the relationship between user participation and project performance.

Our results suggest important directions for future research. First, the substantial heterogeneity in the meta-analytic sample suggest other important factors that influence user participation. Thus, our quantitative results substantiate the call by Markus and Mao (2004) to extend and improve the theoretical framework. Second, we introduced residual risk as an important construct to describe the effect of user participation.

Future research could investigate differential effects of user participation on construct other than project outcomes. Third, coding the empirical findings in the information systems literature reveals a diverse set of measurements. For instance, the conceptualization of project outcomes in Markus and Mao (2004) significantly differs from the one used in He and King (2008). Furthermore, both differ from the conceptualizations used in the studies in our meta-analytic sample. Research on consolidating and improving the constructs and measurement items would ensure cumulative research results as the foundation for sound guidance for practitioners.

3 Essays on the Theory of Designing Behavior Change Support Systems

3.1 Essay 3: Design Principles of Persuasive Systems – Review and Discussion of the Persuasive Systems Design Model

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3.1.1 Abstract

The Persuasive Systems Design (PSD) model by Oinas-Kukkonen and Harjumaa (2009) is the most referenced model for designing Behavior Change Support Systems (BCSS) and proposes 28 design principles in four categories. However, the selection of the design principles is not specified by the PSD model and design principles are used ambiguously in literature. Therefore, we investigate to what extent the design principles proposed by the PSD model reflect the current research and provide researchers and developers of BCSS with a detailed overview of the selection of design principles in persuasive systems. In our systematic literature review, we identify 42 studies with 633 applications of design principles of the PSD model; the studies name 62 additional concepts as design principles. The results indicate that the PSD model covers most aspects of design principles of BCSS, but reveal scope for extensions and specifications to enhance the development of BCSS.

3.1.2 Introduction

Digital technologies contribute to our ability to adapt to changes in our social and work environments. Specifically affecting human cognition and behavioral responses, persuasive systems focus on reinforcing, changing, and shaping attitudes and behaviors without using coercion or deception (Oinas-Kukkonen and Harjumaa 2009). Behavior Change Support Systems (BCSS) are "a key construct for research in persuasive technology" (Oinas-Kukkonen 2010a, pp. 5–6). When developing BCSS, the Persuasive Systems Design (PSD) model of Oinas-Kukkonen and Harjumaa (2009) is the most referenced framework (Otyepka 2018) and introduces 28 design principles to enhance the effectiveness of BCSS (Wiafe et al. 2014; Wildeboer et al. 2016). Design principles serve as prescriptive knowledge of design theory and guide implementers on how to design information systems (Gregor et al. 2020).

While the PSD model allows to build BCSS on a foundation of theoretical knowledge (Berg et al. 2018; Räisänen et al. 2010), the selection of the design principles of the PSD model is not systematically elaborated (Wiafe et al. 2014) and should provide more guidance to designers about how to apply those design principles (Harjumaa and Muuraiskangas 2014) to enable a transparent development and comparability of findings. Gregor et al. (2020) argue that design principles often lack precise formulation and are used inconsistently in literature. More attention should be paid to developing design principles in a well-founded way (Möller et al. 2020b) and to decomposition to gain understanding of the complexity and means of design theory (Gregor et al. 2020). Furthermore, the PSD model is an early framework that was developed in a conceptual way more than ten years ago (Oinas-Kukkonen and Harjumaa 2009) and could not draw on recent research insights. Considering the development and nature of the design principles, we raise the question to what extent the concepts of design principles proposed by the PSD model – despite this model being the most referenced framework for BCSS – still reflect the current research requirements for persuasive systems regarding 1) clear formulation and 2) the coverage of relevant aspects.

Analyzing which design principles have been applied in persuasive systems, we provide a detailed picture of the selection of design principles in BCSS and use of the design principles proposed by the PSD model. Our systematic literature review resulted in 42 studies that apply the design principles of the PSD model in total 633 times. The studies name 62 different concepts as design principles in addition to the 28 design principles proposed by the PSD model. Besides revealing important and missing aspects of design principles of the PSD model, our results indicate that the current formulation of the design principles in the PSD model leads to a lack of differentiation of similar and overlapping aspects.

This study contributes in a descriptive way to understanding the complex relationships of design elements by presenting an overview of the selection of design principles in persuasive systems. It contributes in a pragmatic way by offering researchers and developers of BCSS an overview about which design principles are used to develop BCSS and respective studies. In a theoretical way, it contributes by discussing the fit of the design principles of the PSD model to current research and presenting a knowledge base for further developing the PSD model in order to enhance the effectiveness of future BCSS.

3.1.3 Theoretical Background

Persuasive systems are introduced by Fogg (1998) as "interactive technology that attempts to change attitudes or behaviors". Based on the framework of Fogg (1998), the PSD model by Oinas-Kukkonen and Harjumaa (2009) is, since its development, the most referenced framework for developing BCSS (Otyepka 2018) and provides a guide regarding the analysis, design, and evaluation of persuasive systems (Corbett 2013). The PSD model presents 28 design principles which are intended to support the identification of system requirements for BCSS (Harjumaa and Muuraiskangas 2014) and increase the effectiveness of the systems (Wildeboer et al. 2016). The PSD model classifies the design principles into four categories, each containing seven principles: 1) The category of *Primary Task Support* covers the basic functions of a system (e. g., *self-monitoring* and *simulation*). 2) The design principles of the *Dialogue Support* category provide feedback to the users of the system and help them to achieve their goals through human-computer interaction (e. g., *suggestion, rewards,* and *reminders*). 3) The *System Credibility Support* category is designed to provide trustworthiness and reliability to the system (e. g., *expertise*, *real-world feel*). 4) The fourth category of *Social Support* deals with social influence in various forms, such as *social comparison* and *competition*. (Oinas-Kukkonen and Harjumaa 2009; Harjumaa and Muuraiskangas 2014).

Table 6: Description of the Design Principle *Suggestion* in the PSD Model of Oinas-Kukkonen and Harjumaa (2009)

Principle	Example requirement	Example implementation
Suggestion Systems offering fitting suggestions will have greater persuasive powers.	System should suggest that users carry out behaviors during the system use process.	Application for healthier eating habits suggests that children eat fruits instead of candy at snack time.

As presented in Table 6 on the example of the design principle *suggestion*, Oinas-Kukkonen and Harjumaa (2009) define the 28 design principles of the PSD model using a short description, an example requirement, and an example implementation. While the design principles should be selected based on the persuasion context, the model lacks a specification of how to select and apply them (Harjumaa and Muuraiskangas 2014;

Wiafe et al. 2014). As a result of this high level model, developers often neglect to clearly describe their design (Oduor et al. 2014) which impairs their created design knowledge as design knowledge is codified in the design principles (Möller et al. 2020b; Gregor et al. 2020).

Gregor et al. (2020) address the problem that design principles often lack precise formulation and standardization by suggesting a Design Principles Schema. The Design Principles Schema consists of seven components of a design principle: implementer, context, mechanisms, enactors, aim, user, and rationale. Möller et al. (2020b) provide a taxonomy and method for the development of design principles. In their mapping, design principles are derived from design requirements and result in design features. While Gregor et al. (2020) and Möller et al. (2020b) focus on different aspects – formulation and development of design principles – they highlight the complexity of design principles and provide clear guidelines. Both studies consider design principles in information systems; to provide a specific overview, we focus in this study on design principles of persuasive systems.

3.1.4 Methodology

In order to gain a replicable and transparent overview of design principles in persuasive systems for answering our research question, we identify relevant studies using a systematic literature review (Boell and Cecez-Kecmanovic 2015). In reference to Marrone and Hammerle (2016) and Brendel et al. (2020), our review protocol includes definition of the scope, literature search in selected databases using a keyword search, screening the resulting studies based on predefined criteria, as well as analysis and synthesis of the coding. To mitigate the subjectivity in the coding and analysis of the studies, two researchers independently assessed the studies. This assessment had a high inter-rater reliability and yielded only minor inconsistencies that were easily resolved by a discussion based on the literature.

Because persuasive technology is a multidisciplinary research topic and relevant literature exists in different disciplines, we used databases from a wide multidisciplinary field including economics, technology, health care, social sciences, and psychology: Academic Search Ultimate, Business Source Premier, PubPsych, WISO, and a selection of databases from the ProQuest research platform (ABI/INFORM Collection, Applied Social Sciences Index & Abstracts (ASSIA), ERIC, Social Services Abstracts, Sociological Abstracts, Sociology Database, Sports Medicine & Education Index). Choosing common keywords and synonyms, we identified literature on the design principles used in persuasive technology using the following search string without time restrictions: *Abstract("persuasive system*" OR "persuasive technolog*" OR "Behavior Change Support System" OR "BCSS") AND Abstract("design principle*" OR "persuasive system* design" OR "system feature*" OR "software architecture").* To achieve independent results, we did not include a forward and backward search.

Our search resulted in 66 studies. We screened the results based on the following criteria: First, we excluded 14 duplicates and two dissertations. Second, we excluded eight studies that only described frameworks of persuasion technology or compared them with other socio-technical models without addressing requirements as design principles. This resulted in the final sample of 42 studies on design of persuasive systems, either developing own systems or investigating systems of other studies.

Because it is an important step to consider the persuasion context when developing BCSS (Wiafe et al. 2014; Oinas-Kukkonen and Harjumaa 2009), we further differentiate between contexts of use and categorized the studies into theoretical and practical studies: We categorized studies as practical studies where specific BCSS are the subject of research; studies that are literature reviews or perform a meta-analysis are categorized as theoretical studies. This resulted in two subsets of 20 theoretical and 22 practical studies. We further identified that 29 of the 42 studies investigate persuasive systems in the context of health (13 theoretical studies, 16 practical studies), with six studies specifically focusing on mental health. This is consistent with the findings that persuasive technology is frequently used related to health promotion and disease prevention (Orji et al. 2019). Other contexts include environment and economic applications.

3.1.5 Results

Coding the filtered set of publications, we identified the applied and used design principles in the studies. In sum, we identified 705 applications of design principles. Of those 705 applications, 633 are referring to concepts of design principles suggested by the PSD model; 15 studies describe in sum 71 additional concepts that they name design principles. Removing duplicates, the studies propose 62 different concepts as design principles in addition to the PSD model (Table 7). The results regarding the theoretical studies are presented in Figure 13, the results of the practical studies as well as overall sums are presented in Figure 14.

Because Oduor et al. (2014) indicate that studies often do not clearly describe and explicitly name their design principles, we distinguish between three categories, to consider all design principles used and to present the results transparently. 1) We indicate if a design principle was used and directly named in the study (marked in the Figures by an 'X'). 2) To take into account that some studies do not name the design principles, we indicate if the concept of the design principle is used in the study, but not explicitly named (e.g., Lehto and Oinas-Kukkonen (2013) do not list *self-monitoring* for the design, but its implementation is mentioned by a user in the qualitative evaluation) (marked in the Figures by an '(X)'). 3) We indicate if the design principle is not used by the authors of the study, but was identified in the original study as being missing and useful for the system (e.g., Berg et al. (2018) first exclude *recognition*, but state later on that it "would have been positive") (marked in the Figures by an 'O').

Figure 13, Figure 14, and Table 7 give a detailed overview of the use and application of design principles in BCSS. The results show which design principles and categories of the PSD model are the most and least often applied ones. This overview of the application of the design principles in the identified studies provides further information for researchers and developers of BCSS which design principles were considered important by the authors of the studies.

The results indicate, based on the quantity of mentions, that the category of *Primary Task Support* is highly important (e. g., *self-monitoring*, *personalization*, and *tunneling*). The design principles *suggestion*, *reminders*, and *rewards* were found to be effective especially in connection with *self-monitoring* (Kelders et al. 2016; Räisänen et al. 2010). Regarding the category of *Dialogue Support*, especially feedback that users receive through *praise*, *rewards, reminders*, and *suggestion* raises users' motivation in adopting the target behavior (Mohadis et al. 2016) and contributes to improving the consistency with which users use a system (Berg et al. 2018). The results regarding the design principles of the category *Social Support* are ambiguous: The design principles *social comparison* and *social learning* are used the most; the use quantity of *normative influence* and *recognition* however is similar to the comparably low use of the design principles of the category of *System Credibility Support*. However, three studies that first excluded or neglected the design principles *rewards* and *recognition* later identified them as lost potential (Meedya et al. 2019; Lehto and Oinas-Kukkonen 2013; Berg et al. 2018). This indicates that those design principles should be thoughtfully considered in the design process.

Categories of design principles	Design Principles	Theoretical studies (20)																						
		Oinas-Kukkonen et al. (2009)*	Lehto et al. (2011)*	Mintz et al. (2012)	Oduor et al. (2014)	Wiafe et al. (2014)	Xu et al. (2014)*	Kelders et al. (2016)*	Matthews et al. (2016)*	Wildeboer et al. (2016)*	Sunio et al. (2017)	Wozney et al. (2017)*	Nkwo and Orji (2018a)	Win et al. (2018)*	Asbjornsen et al. (2019)*	Karekla et al. (2019)*	Meedya et al. (2019)*	Radomski et al. (2019)*	Tikka et al. (2019)	Meske et al. (2020)	Parada et al. (2020)*	Design principles used, X and (X)	Sum of design principles per category	Sum of design principles O
Primary Task Support	Reduction	X	X	X		X	X		X	X	X	X	X	X	X	(X)	X	X		X		16		0
	Tunneling	X	X	X		X	X		X	X	X	X		X	X			X		X		13		0
	Tailoring	X	X	X	(X)		X	X	X	X	X	X	X	X	X	X	X	X	X	X		18		0
	Personalization	X	X	X			X	X	X	(X)	X	X	X	X	X	X	X	X	X			16	100	0
	Self-Monitoring	X	X	X	(X)	X	X		X	(X)	X	X	X	X	X		X	X	X		X	17		0
	Simulation	X	X				X			(X)	X	X	O	X	X		X	X				10		1
	Rehearsal	X	X				X			(X)	X	X	X	X	X			X				10		0
Dialogue Support	Praise	X	X	X					X	(X)	X	X	X	X	X	X	O	X		X		13		1
	Rewards	X	X	X	(X)				X	(X)	X	X	X	X	X	X	O	X		(X)	X	15		1
	Reminders	X	X			X	X		X	X	X	X	X	X	X	X	X	X		X	X	16		0
	Suggestion	X	X			X	X		X	(X)	X	X	X	X	X	X	X	X			X	15	93	0
	Similarity	X	X				X			X	X	X		X	X	X	X	X			X	12		0
	Liking	X	X				X		X	(X)	X	X			X	X	X	X			X	12		0
	Social Role	X	X						X	(X)		X	X	X	X	X		X				10		0
System Credibility Support	Trustworthiness	X	X	X		(X)			X			X	X	X		X	X	X			X	12		0
	Expertise	X	X	X		(X)			X			X		X		X	X	X			X	11		0
	Surface-Credibility	X				(X)			X			X	X			X	X	X				8		0
	Real-World Feel	X				(X)							X			X	X	X			X	7	63	0
	Authority	X	X			(X)			X				X	X		X	X	X				9		0
	Third-Party Endorsements	X				(X)			X			X	X	X		X					X	8		0
	Verifiability	X	X			(X)			X				X	X		X	X					8		0
Social Support	Social Learning	X	X		X				X	X	X	X	X	X	X		X	X			X	13		0
	Social Comparison	X	X		X				X	X	X	X	O	X	X		X		X	X		12		1
	Normative Influence	X	X		X				X	(X)	X	X	O	X	X		X					10		1
	Social Facilitation	X	X		X				X	X	X	X	X	X	X							10	72	0
	Cooperation	X	X		X				X	(X)	X	X	X	X	X		X					11		0
	Competition	X	X		X				X	(X)	X		X	X	X							9		0
	Recognition	X	X		X					(X)	X		O	X	X							7		1
	Sum	28	25	9	10	12	11	2	23	21	20	23	24	25	21	17	21	20	4	7	11	**328**		**6**
	Additional design principles			(X)											X	O	O			X		3		2
	New category															O						0		1

X: design principle directly named
(X): design principle used, but not directly named
O: identified in original study as missing
*: study in the context of health

Figure 13: Design Principles in Theoretical Studies

Categories of design principles	Design Principles	Practical studies (22)																									Overall sum (42)		
		Corbett et al. (2013)	Lehto et al. (2013)*	Orji et al. (2013)*	Harjumaa et al. (2014)*	Orji et al. (2014)*	Wohl et al. (2014)	Alkhushayni et al. (2016)*	Karppinen et al. (2016)*	Mohadis et al. (2016)*	Schneider et al. (2016)*	Bartlett et al. (2017)*	Halttu et al. (2017)*	Valk et al. (2017)*	Van Agteren et al. (2018)*	Berg et al. (2018)*	Klaassen et al. (2018)*	Nkwo and Orji (2018b)	Nkwo et al. (2018)	Salvi et al. (2018)*	Yap et al. (2018)*	Orji et al. (2019)	Böckle et al. (2019)	Use of design principles, X and (X)	Sum of design principles per category	Sum of design principles O	Use of design principles, X and (X)	Sum per categories	Sum of design principles O
Primary Task Support	Reduction	X	O	X	(X)				X	X	(X)	X	(X)		X	X	X	X		(X)				13		1	29		
	Tunneling	X		X	(X)		X	X	X	X	(X)	(X)	(X)	X	X		X			(X)	(X)			15		0	28		
	Tailoring	X	O		(X)		X	X	X	X	(X)	X			X	X	X	X		(X)	X			14		1	32		
	Personalization	X	X	X	(X)	X	O	X		X	(X)	(X)		X	X		X	X	X	(X)	(X)	X		17	99	1	33	199	5
	Self-Monitoring	X	(X)	X	(X)	X	X		X	X	(X)	X	X	X	X	X	X	X		X	(X)	X		19		0	36		
	Simulation	X		X	(X)	X		X		X	(X)			X	X		(X)	O		(X)		X		12		1	22		
	Rehearsal	X		(X)	(X)			X		X					X		(X)	X		X				9		0	19		
Dialogue Support	Praise	X	O	X	(X)	X		X	X	X	(X)	(X)	X	X	X		X	X		(X)				15		1	28		
	Rewards	X	O	X	(X)	X		X		X		X	X	X	X	O	X	X		X		X		14		2	29		
	Reminders	X	O		(X)			X	X	X		X	X	X	X	X	X	X		X	(X)			14		1	30		
	Suggestion	X	X	X		X	X	X	X	X	O	(X)		X	X		X	X		X	(X)	X		16	85	1	31	178	7
	Similarity	X						X		X		(X)			X		X						(X)	7		0	19		
	Liking	X			(X)		(X)		X						X	X	(X)						(X)	8		0	20		
	Social Role	X			(X)			X		X	(X)	X			X	X	X	X		(X)				11		0	21		
System Credibility Support	Trustworthiness	X	(X)		(X)								X	X	X	X	(X)			X	(X)			10		0	22		
	Expertise	X			(X)			X		X	(X)		X	X	X	X	(X)			(X)				11		0	22		
	Surface-Credibility	X	(X)		(X)										X	X	(X)			(X)	(X)			8		0	16		
	Real-World Feel	X			(X)			X		X				X	X	X				O				7	55	1	14	118	1
	Authority	X												X	X	X		X					X	6		0	15		
	Third-Party Endorsements	X			(X)	(X)				X					X			X						6		0	14		
	Verifiability	X			(X)				X	X					X		(X)			(X)				7		0	15		
Social Support	Social Learning	X		(X)	(X)				X	X	(X)			X	X	X		X	X					11		0	24		
	Social Comparison	X		X	(X)	X				X	(X)	(X)		X	X	X	(X)	O	X			X		13		1	25		
	Normative Influence	X		X	(X)					X					X			O						5		1	15		
	Social Facilitation	X		X	(X)			X	X	X	O			X	X			X					(X)	10	66	1	20	138	10
	Cooperation	X		X	(X)	X					O	(X)			X			X				X		8		1	19		
	Competition	X		X		X				X	O	X		X	X		(X)	X				X		10		1	19		
	Recognition	X		X	(X)					X	(X)	(X)			X	O	(X)	O	X					9		2	16		
	Sum	28	10	16	24	10	6	14	11	23	16	15	8	16	28	15	21	20	4	17	8	8	4	**305**		**17**	**633**		**23**
	Additional design principles	X		X	O	X		O			O			X		O						X	X	6		4	9		6
	New category	X																						1		0	1		1

Figure 14: Design Principles in Practical Studies and Sums over All Included Studies

Table 7: Identified Additionally Used or Proposed Design Principles

	Study	Category	Design Principles	
Theoretical Studies (5)	Asbjørnsen et al. (2019)	-	Goal-setting Social support	Feedback
	Karekla et al. (2019)	Ethical Issues	Privacy	Confidentiality
		-	Human interaction	
	Meedya et al. (2019)	-	Social networking	
	Meske and Amojo (2020)	-	Anchoring Default setting Framing	Limited time window Pre-commitment Priming
	Mintz and Aagaard (2012)	-	Kairos	
Practical Studies (10)	Alkhushayni and McRoy (2016)	-	Social networking forums	
	Berg et al. (2018)	Social Support	Flagging of new posts	
	Böckle and Yeboah-Antwi (2019)	-	Reciprocity Scarcity Consistency and Commitment	Consensus Liking
	Corbett (2013)	Integration Support	Complementary programs Goal consistency Technological integration Intra-organizational coordination	
		Primary Task Support	Commitment	Personal learning
		Dialogue Support	Social network	
		Social Support	Guilt	
	Harjumaa and Muuraiskangas (2014)	-	Motivational information Guidance	Communication Ability to Adapt
	Orji and Mandryk (2013)	Primary Task Support	Monitoring Feedback Customization Bio feedback Graded task Systematic desensitization	(Increment) Goal setting Role-playing Self-modeling Cognitive restructuring Experiential
		Dialogue Support	Negative reinforcement Punishment Gain/Loss-framed Communication Group contingency	Prompt Persuasive Communication Extinction
		Credibility Support	Group endorsement	Self/Group appraisal
		Social Support	Social role	Vicarious reinforcement
	Orji et al. (2014)	-	Customization	
	Orji et al. (2019)	-	Self-monitoring and feedback Punishment	Goal-setting Customization
	Schneider et al. (2016)	-	Setbacks considered by coach Customizable privacy settings	Formation of groups
	Valk et al. (2017)	-	Goal-setting Sharing Self-logging Notification	Chat Negative reinforcement Economic benefit Game
Sum	**15 studies**		**71 concepts, 62 without duplicates**	

The design principles of *System Credibility Support* are mostly neglected by the studies. Especially, the design principles *real-world feel* and *third-party endorsements* are not only the least used within the *System Credibility Support* category, but also the least used of all 28 design principles of the PSD model. Therefore, one could conclude that those design principles are of less relevance in research than the other design principles of the PSD model. However, it is noteworthy that, compared to the total number, the six studies in the context of mental health use the category *System Credibility Support* comparatively often. Furthermore, when considering the results, one should keep in mind that a high or low use of the design principles does not always indicate a high or low importance, but the effectiveness of a design principle is dependent a more detailed perspective and performance of the system. For example, the design principle *surface-credibility* is considered in seven of the theoretical studies, but only in three of the practical studies. This gap indicates a lack of practical examples and guidelines on how to implement *surface-credibility* into BCSS and does not imply that *surface-credibility* might not be relevant for persuasive systems.

3.1.6 Analysis and Discussion

Regarding the question, if the PSD model still reflects current research requirements for persuasive systems, we identified that only three studies of the 42 identified studies are not referring to the PSD model as a theoretical base (one theoretical study, Meske and Amojo 2020; and two practical studies, Schneider et al. 2016 and Böckle and Yeboah-Antwi 2019). Further, all studies consider and apply design principles that are proposed by the PSD model. This is in accordance with prior literature, that the PSD model is the most referenced model for developing BCSS (Otyepka 2018). The three studies not using the PSD model are published in 2016, 2019, and 2020 (Böckle and Yeboah-Antwi 2019; Schneider et al. 2016; Meske and Amojo 2020). While this could be interpreted to indicate a slight trend, we want to highlight that we identified seven studies of 2019 and 2020 that use the PSD model. The PSD model provides a framework to the studies with a wide range of design principles and categories, and researchers can build on a foundation of practical and theoretical knowledge (Berg et al. 2018).

However, 15 studies list in sum 62 design principles in addition to the design principles proposed by the PSD model. Especially the practical studies (ten studies) reveal a need to supplement the PSD model. Seven of the additional design principles are mentioned by more than one study: *goal-setting*, *customization*, *social networking*, *negative reinforcement*, *punishment*, *feedback*, and *commitment*. Since the studies that mention the same additional design principles do not reference each other in this context, we assume that the need for these strategies of persuasion was identified independently (with exception of Orji et al. 2014; Orji and Mandryk 2013; Orji et al. 2019). The repeated use of design principles with the same properties shows the need for these functionalities in persuasive systems.

However, none of the studies that name additional concepts as design principles follow a clear methodological approach to build and formulate these design principles and the lack of standardization makes it difficult to investigate suitable design possibilities (Kelders et al. 2016). Also, the design principles of the PSD model itself are not developed in a systematic approach or formulated in detail (Oinas-Kukkonen and Harjumaa 2009). For example, *goal-setting* enables users to monitor their progress (Valk et al. 2017; Orji et al. 2019) which is also offered by the design principle *self-monitoring* of the PSD model (which was additionally used by Valk et al. (2017)). Also the design principle *suggestion* supports users to achieve their personalized goals by providing advice for behavioral changes (Wohl et al. 2014) while *self-monitoring* also overlaps with *social role* (of the PSD model) and s*elf-monitoring and feedback* (Orji et al. 2019). Therefore, we identified an overall lack of standardization of the names of identical design principles as well as insufficient or even missing differentiation of similar or overlapping principles. Findings from persuasive systems are difficult to adapt to other BCSS because the studies have no shared understanding of the concept of design principle.

In addition to a shared understanding, the application context of the BCSS needs to be emphasized and considered. For example, as investigated and discussed in studies in the health context, the design principle *competition* has on the one hand the ability to motivate users by leveraging human beings' natural drive to compete (Oinas-Kukkonen and Harjumaa 2009; Bartlett et al. 2017), on the other hand, other participants feared failing and reacted negatively to competition (Bartlett et al. 2017). Especially people who already feel burdened by health problems could be further negatively affected (Karppinen et al. 2016; Mohadis et al. 2016). Health care professionals even "felt that this approach to persuasion was inappropriate" (Bartlett et al. 2017, p. 11) and considered it as "too harsh" (Karppinen et al. 2016, p. 54). Therefore, *competition* may be perceived as contrary to the purpose of a system that is supposed to promote health and strengthen well-being, while being perceived as encouraging and motivating when more closely related to gamification (Bartlett et al. 2017).

Considering that the PSD model is currently the only common framework for developing BCSS, the results indicate that the PSD model provides a fundamental theoretical foundation, but is not fulfilling the recent research requirements regarding coverage and the specification that design principles should be developed and formulated in a systematic and clear form (Gregor et al. 2020; Möller et al. 2020b). To adapt the PSD model to achieve an effective application and comparability of design principles, we infer that researchers should apply the standardized forms and methodology proposed by Gregor et al. (2020) and Möller et al. (2020b) to the foundation provided by the PSD model and extend the model considering the identified additional concepts.

For this procedure, the results reveal which aspects of the PSD model are often applied by current studies (namely, especially the categories of *Primary Task Support* and *Dialogue Support*) and which aspects lack of further context and guidelines (especially the categories of *Social Support* and *System Credibility Support*). Our study further reveals based on the analysis of additionally proposed design principles which aspects should be considered for the extension of the model. This outlines the scope for extensions and specifications when developing BCSS and presents a knowledge base for further developing the PSD model in order to enhance the effectiveness of future BCSS.

3.1.7 Conclusion, Limitations and Future Research

Our analysis of 42 studies with 633 applications of design principles of the PSD model and 62 additional design principles, reveals patterns and research gaps in the adoption of design principles. The PSD model further proved itself to be the most important model for developing BCSS, but the results indicate that the PSD model should be enhanced to provide clear details of standardized design principles and supplemented to cover aspects that were neglected so far (e.g., *goal-setting*). This study contributes by providing researchers and developers with a detailed review of the selection of design principles in BCSS, considering the commonly used PSD model and additional design principles listed by the authors of the identified studies. This serves as an aid when selecting design principles for developing practical BCSS and theoretical models.

Naturally, our analysis is subject to several limitations. First, we may have missed relevant studies during our literature search. To account for a reasonable and replicable analysis, we detailed the literature search protocol. Including various multidisciplinary databases and a wide search string, however, we are confident that we have captured a representative sample of relevant studies. Second, the analysis of the studies is inherently prone to subjectivity. To mitigate this subjectivity and to ensure transparency, we defined criteria for the assessment and disclose our methodology and results in detail. Third, while most studies explicitly name their design principles, some studies do not explicitly name or clearly describe their design principles. Again, this analysis was controlled by two researchers and we openly outline the results by adopting different signs for directly and indirectly mentioned design principles in Figure 13 and Figure 14.

Our results and limitations also contribute by specifying directions for future research. First, future research could further mitigate the mentioned limitations by replicating the study using a different literature search and a higher number of researchers and therefore further reduce the risk of bias. Such research could also investigate more details regarding the context of use. Second, our results highlight a lack of clarity of the implementation of design principles in BCSS. Especially the practical studies often do not clearly describe their design and applied design principles which makes it difficult to compare different BCSS. Further research should therefore emphasize transparency in developing artefacts and persuasive systems. Third, this lack of transparency also occurs due to ambiguous and overlapping definitions of design principles and their implementation. We want to encourage researchers to utilize our study and other current state-of-the-art analyses of design principles to further apply, specify and evolve the PSD model to build an enhanced theoretical foundation for persuasive systems.

3.2 Essay 4: Process-based Guidance for Designing Behavior Change Support Systems – Marrying the Persuasive Systems Design Model to the Transtheoretical Model of Behavior Change

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3.2.1 Abstract

Behavior change is a topic of high relevance and widely studied in the field of psychology. Through the integration of technologies into everyday life, behavior change support systems (BCSS) are gaining attention in the field of information systems. The persuasive systems design (PSD) model of Oinas-Kukkonen and Harjumaa (2009) is a leading framework to provide a generic technical design process including 28 design principles. However, the model is lacking a clear picture regarding which of those design principles should be selected for specific implementations. Consequently, researchers and developers who implement BCSS are missing structured and evidence-based guidance. They need to invest time and cognitive resources in an underlying analysis of different design principles. Because the influence of persuasive systems is strongly linked to the processual state of behavior change, we combine the PSD model with the transtheoretical model (TTM) of Prochaska and DiClemente (1983) and elaborate a model that recommends appropriate design principles for the five transitions along the stages of behavior change. We refined the model using a systematic literature review. The results provide a specification of the PSD model and a guideline to select effective design principles for developing BCSS.

3.2.2 Introduction

People stay in their established way of behavior even though they know that a different way of life would be beneficial. For example, many want to lead a fit and healthy lifestyle, but remain inactive and make poor eating choices. As a result, serious health problems based on unhealthy behavior are on the rise. Despite this discrepancy between desired and actual behavior, it is hard to change established behaviors sustainably. Behavior and how behavior can be influenced is widely studied in the field of psychology. Established behavioral models are, for example, the transtheoretical model (TTM) of Prochaska and DiClemente (1983), the theory of planned behavior by Ajzen (1991), or the health belief model by Siddiqui et al. (2016).

Along with the integration of technology into the individual´s everyday life, Fogg (2003) envisioned the potential of persuasive technologies to support people in changing their attitudes and behaviors. Based on Fogg's (2003) research, Oinas-Kukkonen and Harjumaa (2009) defined the concept of behavior change support systems (BCSS) and introduced BCSS as "a key construct for research in persuasive technology" (Oinas-Kukkonen 2010a, pp. 4–5). BCSS include mobile apps, social media, or interactive websites with the aim to change attitudes or behaviors. BCSS are already successfully used in the context of health (e.g., Langrial et al. 2013) and environmental aspects (e.g., Shevchuk and Oinas-Kukkonen 2016). Additionally, there is further potential to employ BCSS in a working environment supporting behavioral aspects of digital transformation (Merz 2020; Nkwo 2019).

The by far most referenced technical framework in research for developing BCSS is the persuasive systems design (PSD) model by Oinas-Kukkonen and Harjumaa (2009) (Otyepka 2018). The PSD model recommends a generic design process that starts with the analysis of the persuasion context and presents multiple design principles. The PSD model proposes to select context-specific design principles, but a clear picture of how these design principles should be selected is missing (Wiafe et al. 2014). However, it is essential for persuasive systems design to select effective design principles because it is not practical to include a high number of design principles (e.g., studies apply on average only 15 of 28 design principles of the PSD model (Merz and Ackermann 2021)). Moreover, studies highlight the importance of choosing the right design principles instead of implementing as many as possible (Prochaska and Norcross 2001; Wildeboer et al. 2016). Therefore, researchers and developers of BCSS need to invest time and energy conducting a laborious context-related analysis of users' needs and fitting design principles before implementing their projects instead of focusing their cognitive resources on the specific design of BCSS.

The aim of this work is to fill this gap between technical framework and context-related behavioral model. Because the influence of technology-enhanced behavioral interventions is strongly linked to the state in the process of behavior change (Oinas-Kukkonen and Harjumaa 2009; Prochaska and Norcross 2001; Vandelanotte and Bourdeaudhuij 2003), we combine the widely used and frequently validated stages of change of the TTM (Prochaska and DiClemente 1983; Prochaska and Norcross 2001)with the PSD model by Oinas-Kukkonen and Harjumaa (2009). As a result, we take a process perspective on the persuasion context and present a process-based model that recommends appropriate design principles defined by the PSD model. We conduct a systematic literature review to refine our conceptual model in detail and to ensure that the model is in accordance with existing research studies about BCSS.

This work contributes in a descriptive form by presenting researchers and developers of BCSS the role of the design principles of the PSD model along the process of behavior change including examples of implementations. Furthermore, this work contributes in a pragmatic form by concluding implications and guidance for developing BCSS and provides a theoretical specification of the PSD model in order to facilitate the process of designing BCSS.

3.2.3 Theoretical Background

Persuasive technology accompanies and supports the process of behavior change. It is defined as “any interactive computing system designed to change people’s attitudes or behaviors.” (Fogg 2003, p. 1). While persuasive technology is considered as a field of research, BCSS are research objects in this field of research (Oinas-Kukkonen 2010a). According to Oinas-Kukkonen (2013, p. 1225), a BCSS “is a sociotechnical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying without using coercion or deception”. BCSS are developed based on design principles (Oinas-Kukkonen 2010a).

3.2.3.1 Design Principles

Design principles incorporate design knowledge about the design of artifacts and allow to transfer knowledge about how to achieve desired effects to different applications (Möller et al. 2020b). In particular, Fu et al. (2016) derive that “design principles are created to codify and formalize design knowledge so that innovative, archival practices may be communicated and used to advance design science and solve future design problems” (Fu et al. 2016, p. 1). However, design principles are often used ambiguously and are inconsistently formulated in literature (Gregor et al. 2020) which impairs the ability to present design knowledge in an accessible form. To account for that issue, Gregor et al. (2020) suggest a Design Principles Schema for decomposition and classify design principle formulation in three categories regarding the integration of user activity: 1) design principles “about user activity”, when the principle states what users can do with the artifact, 2) design principles “about the artifact”, when the principle is about a feature of the artifact without directly addressing user activity, or 3) “about both”, user activity and artifact, when the principle is combining design knowledge about user activity and a feature of the artifact (Gregor et al. 2020).

Based on the ability of design principles to provide design knowledge about user activities and system features, design principles are the foundation for developing information systems (Fu et al. 2016; Möller et al. 2020b) and thus incorporated in frameworks as, for example, the PSD model by Oinas-Kukkonen and Harjumaa (2009).

3.2.3.2 PSD Model

When developing BCSS, most researchers refer to the PSD model by Oinas-Kukkonen and Harjumaa (2009) (Otyepka 2018). The PSD model acts as a meta-level model and serves as a wide framework including generic steps and design principles for designing BCSS (Räisänen et al. 2010). In order to draw upon the most referenced and established technical framework in research for BCSS development, we build our study on those 28 design principles of the PSD model. Oinas-Kukkonen and Harjumaa (2009) group the design principles into four different categories with seven design principles each: primary task support, dialogue support, system credibility support, and social support. Table 8 shows a list of the design principles as described by Oinas-Kukkonen and Harjumaa (2009). To further specify the nature of the design principles of the PSD model as a strong foundation for our study, we added a classification according to Gregor et al. (2020) into the three categories about artifact, user activity, or both. We coded the classification independently with an interrater reliability of 0.96 (Cohens Kappa).

Table 8: Design Principles of the PSD Model by Oinas-Kukkonen and Harjumaa (2009) including Classification according to Gregor et al. (2020) regarding User Activity

Category	Design Principle	Example Requirement by Oinas-Kukkonen and Harjumaa (2009)	Classification regarding User Activity
Primary Task Support	**Reduction**	System should reduce effort that users expend with regard to performing their target behavior.	artifact
	Tunneling	System should guide users in the attitude change process by providing means for action that brings them closer to the target behavior.	artifact
	Tailoring	System should provide tailored information for its user groups.	artifact
	Personalization	System should offer personalized content and services for its users.	both
	Self-monitoring	System should provide means for users to track their performance or status.	both
	Simulation	System should provide means for observing the link between the cause and effect with regard to users' behavior.	both
	Rehearsal	System should provide means for rehearsing a target behavior.	both
Dialogue Support	**Praise**	System should use praise via words, images, symbols, or sounds as a way to provide user feedback information based on his/her behaviors.	artifact
	Rewards	System should provide virtual rewards for users in order to give credit for performing the target behavior.	artifact
	Reminders	System should remind users of their target behavior during the use of the system.	artifact
	Suggestion	System should suggest that users carry out behaviors during the system use process.	artifact
	Similarity	System should imitate its users in some specific way.	artifact
	Liking	System should have a look and feel that appeals to its users.	artifact
	Social role	System should adopt a social role.	artifact
System Credibility Support	**Trustworthiness**	System should provide information that is truthful, fair and unbiased.	artifact
	Expertise	System should provide information showing knowledge, experience, and competence.	artifact
	Surface credibility	System should have competent look and feel.	artifact
	Real-world feel	System should provide information of the organization and/or actual people behind its content and services.	artifact
	Authority	System should refer to people in the role of authority.	artifact
	Third-party endorsements	System should provide endorsements from respected sources.	artifact
	Verifiability	System should provide means to verify the accuracy of site content via outside sources.	artifact
Social Support	**Social learning**	System should provide means to observe other users who are performing their target behaviors and to see the outcomes of their behavior.	user activity
	Social comparison	System should provide means for comparing performance with the performance of other users.	user activity
	Normative influence	System should provide means for gathering together people who have the same goal and make them feel norms.	user activity
	Social facilitation	System should provide means for discerning other users who are performing the behavior.	user activity
	Cooperation	System should provide means for co-operation.	user activity
	Competition	System should provide means for competing with other users.	user activity
	Recognition	System should provide public recognition for users who perform their target behavior.	artifact

The design principles of the category primary task support “support the carrying out of the user’s primary task” (Oinas-Kukkonen and Harjumaa 2009, p. 492). Applying the classifications of Gregor et al. (2020), we identified that supporting the primary tasks addresses design principles that describe system functionalities (e.g., *reduction* and *tunneling*) and design principles that also enable users to interact with the system (e.g., *self-monitoring* and *simulation*) (Oinas-Kukkonen and Harjumaa 2009). The design principle personalization covers two aspects: Personalized content can be content that is determined by the system for the individual user, but as well determined by preferences that are defined by the individual users themselves.

The category of dialogue support comprises design principles that provide feedback to its users (e.g., by *praise*, *rewards*, and *suggestion*) “potentially via verbal information or other kinds of summaries" (Oinas-Kukkonen and Harjumaa 2009, p. 493). Comprising one-way computer-human-communication, as opposed to human-computer interaction, the design principles describe system features about the artifact according to Gregor et al. (2020).

The category of system credibility support contains design principles that are able to emphasize the credibility and expertise that underlies the system, for example, using *verifiability* and *authority* (Oinas-Kukkonen and Harjumaa 2009). The design principles on credibility support describe system features without user activities (according to Gregor et al. (2020)).

The design principles of the category social support motivate users through social influence and promote exchange of information between different users, for example, using *social comparison* and *cooperation* (Oinas-Kukkonen and Harjumaa 2009). In this category, the design principles aim to provide means to enable user activities, with the exception of the design principle recognition which describes support through system features (according to Gregor et al. (2020)).

Those 28 design principles are integrated in the PSD model (Figure 15) as follows: The first step in the development of persuasive technology is the analysis of the persuasion context and, based on the findings, a selection of persuasive design principles. After selecting design principles, the requirement definition for software qualities and the software implementation follow. While the PSD model provides generic steps and various design principles, it remains unclear how these design principles should be selected according to the context of behavior change (Wiafe et al. 2014). However, the model is designed to be extended by integrating suitable theories to specify certain aspects (Räisänen et al. 2010).

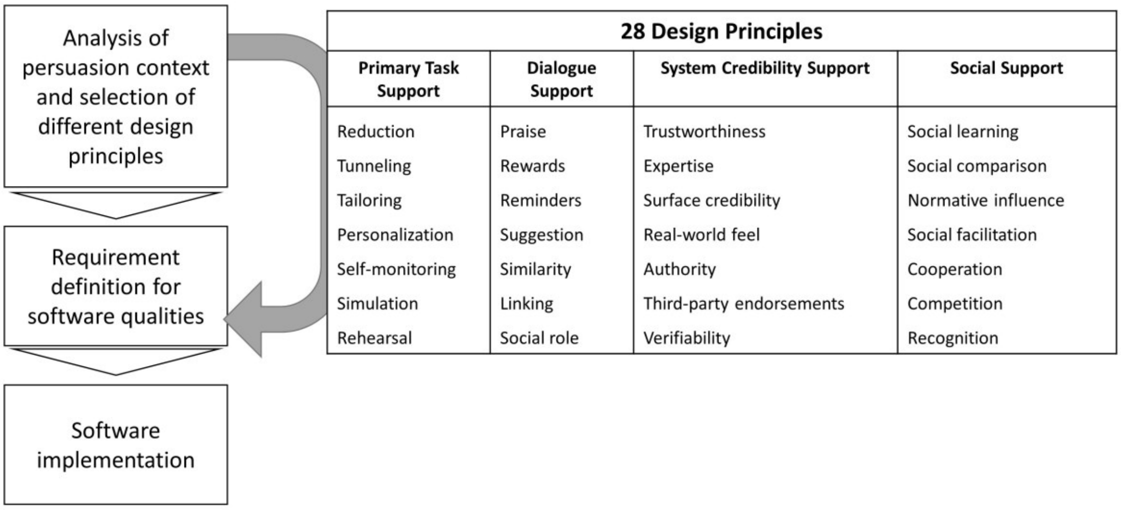


Figure 15: Generic Steps of PSD with Design Principles according to Oinas-Kukkonen and Harjumaa (2009)

3.2.3.3 Transtheoretical Model

A model that specifies the context of behavior change in a structured and procedural form is the TTM of Prochaska and DiClemente (1983). The TTM is widely used in the field of psychology and describes the process of changing behavior in consecutive stages (e.g., Boff et al. 2020; Friman et al. 2017; Hashemzadeh et al. 2019). The six stages of change are precontemplation, contemplation, preparation, action, maintenance, and termination (Prochaska and Norcross 2001). Depending on the stage of behavior change, the addressee of persuasive technology should be supported in the behavior change in a different way (Oinas-Kukkonen and Harjumaa 2009; Prochaska and Norcross 2001; Vandelanotte and Bourdeaudhuij 2003). Therefore, these stages provide guidance and feasible context to select fitting design principles.

3.2.3.3.1 *Stages of Change*

Prochaska and Norcross (2001) describe the stages of change as follows: In the stage of precontemplation, people might wish to change but do not intend or seriously consider changing their behavior patterns. The behavioral problems might be unaware to them but are often known to their families, friends, or employees. In the second stage of behavior change, contemplation, people are aware of their problems and think about working on their behavior. During that second stage, people are "seriously considering changing the problem behavior” (Prochaska and Norcross 2001, 443-444) but do not intend to change their behavior yet. Next, in the stage of preparation, people prepare to take action and are about to bring their intentions to visible behavior in the near future. When people show their intentions in their actions and start to modify their behavior, they have entered the stage of action. This stage is followed by the stage of maintenance where people are continuing their behavioral change and try to prevent a relapse to their problem behavior. In the stage of maintenance, people strive to reach the last stage of termination where the process of behavior change is completed and there is no risk of relapsing into their former behavior (Prochaska and Norcross 2001).

3.2.3.3.2 Transitions

Focusing on the process of behavior change, we address the transition of one stage to the consecutive stage. This results in five transitions, which are depicted in Figure 16.

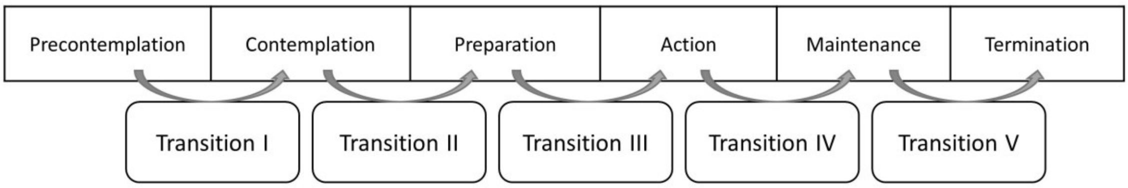


Figure 16: Transitions along the Stages of Change

In order to guide users of BCSS through the process of behavior change, developers should analyze the underlying needs of users to transition from one stage to the next. In accordance with the explanations by Prochaska and Norcross (2001), we identified the following core needs for each transition:

In transition (I) from the stage of precontemplation to contemplation, BCSS need to reveal the problem behavior to users to raise awareness of their problems. In transition (II) from contemplation to preparation, BCSS should further highlight the problem behavior and show the benefits of a changed behavior to form an intent to change. Therefore, BCSS should aim at increasing consciousness and awareness of the problematic behavior. Users in transition (III) from preparation to action need BCSS that get users to start performing the target behavior. BCSS should facilitate the initial approach of its users to adopt their intended behavior. To support users during transition (IV) from action to maintenance, BCSS should reinforce the users’ new behavior and strengthen the users’ will to maintain their changed behavior. For the last transition (V) to the stage of termination, BCSS should help users to form habits and make the changed behavior their regular behavior to prevent relapses.

3.2.3.3.3 *Related Work*

Also, other researchers see the potential in combining persuasive technology and behavioral models. Wiafe et al. (2012) analyze the persuasion context of the PSD model with the three-dimensional relationship model between attitude and behavior (3D-RAB model), which categorizes users' state of cognitive dissonance. While they discuss how researchers can apply the 3D-RAB model to analyze the persuasion context, they do not include information on specific system design in their considerations and the link between persuasion context and the selection of design principles is still missing.

Klein et al. (2011) use the TTM to build sixteen different constructs that include some design principles, but also external factors that do not directly translate to design features (e.g. emotions, self-efficacy). In contrast to Klein et al. (2011), we concentrate on the 28 design principles of the established PSD model that can directly be implemented into BCSS.

Oinas-Kukkonen (2010a) and Oinas-Kukkonen (2013) introduce the "outcome/change design matrix" which presents three behavior outcomes (forming, altering, reinforcing) and three types of behavior change (complying, behavior, attitude). While distinguishing the behavior outcome into forming, altering, or reinforcing extends our approach, both approaches share the understanding that users' awareness of the need for a behavior change is a pre-condition for a sustainable change of behavior. Additionally, both approaches share the same goal of considering targeted forms of behavior change: The matrix shows possible forms of behavior change using the two dimensions of behavior outcomes and types of behavior change, whereas we use a process-based perspective based on the stages of behavior change. Building on the stages of behavior change allows us to examine the specific users' needs and present guidance for referring design principles, while the matrix takes a descriptive point of view. Therefore, the two approaches should not be seen as competing, but as a mutual extension due to their different characters (descriptive vs rather normative).

3.2.4 Method

Our method consists of two steps: First, we developed a model linking the 28 design principles to the stages of the TTM. Second, we refined our resulting model using a systematic literature review of research studies implementing BCSS.

3.2.4.1 Development of Model Based on Theoretical Background

In the first step, we carefully studied the original literature of the PSD model and the TTM to ensure that our model reflects the underlying models as close as possible. Two researchers independently mapped the 28 design principles to the transitions weighted by the ability of the design principle to address the users' needs (see chapter 3.2.3.3.2) of each transition. To ensure an unbiased opinion in this initial mapping, the two researchers coded the 28 design principles independently into three categories "slight recommendation" (1), "recommendation" (2), and "strong recommendation" (3). During the mapping, the researchers both identified the fourth category "no recommendation/ not applicable" (0). Table 9 shows the number of assigned categories and where the researchers agreed and diverged. To measure the interrater agreements of two independent coders with more than one exclusive category, the Cohen's Kappa Coefficient is fitting (Cohen 1960; Fleiss et al. 2003). Regarding the mapping of the 28 design principles, the Cohen's Kappa Coefficient κ is 0.445 (with $p_0 = 0.729$, $p_e = 0.361$) indicating a moderate agreement rate (Landis et al. 1977).

Table 9: Results of the independent coding

		Researcher 1				Σ
		0	**1**	**2**	**3**	
Researcher 2	**0**	**24**	6	0	2	32
	1	4	**1**	0	1	6
	2	8	3	**63**	6	80
	3	2	2	4	**14**	22
Σ		38	12	67	23	140

weight
0
1
2
3

category
not applicable/ no recommendation
slight recommendation recommendation
strong recommendation

We discussed the mapping with a third, independent researcher and resolved identified inconsistencies. In sum, we concluded four levels of recommendation as follows: A strong recommendation suggests that the design principles serve the core needs of users (see chapter 3.2.3.3.2) who transition from their current stage in the process of behavior change to the next. Design principles identified as strong recommendation should therefore be considered with high priority for the design of BCSS that support this transition.

If a design principle is indicated as recommended, the corresponding design principle does not directly address users' core needs of a specific transition but supports the transition to a high extent. Slight recommendation indicates that the design principle might have positive effects on users' transition, but does not include an effect directly needed for the transition. Besides these classifications, it is possible that some design principles are not applicable or not recommended in specific transitions because there are no indications for the assumption of positive effects.

For example: The design principle *suggestion* is defined as "system should suggest that users carry out behaviors during the system use process" and that "fitting suggestions will have greater persuasive powers" (Oinas-Kukkonen and Harjumaa 2009, p. 493). Regarding the five transitions, suggestions are not able to reveal problem behavior to users, which is needed for transition (I). Therefore, *suggestion* is not applicable/ not recommended for designing a BCSS targeting transition (I). On contrary, users in the second and third stages of behavior change need to see the benefits of a changed behavior and an approach to take the first steps of their changed behavior. Specific suggestions for behavior and actions address those core needs to transition into the stages of preparation and action (Prochaska and Norcross 2001) and are consequently strongly recommended for transitions (II) and (III). For transition (IV), when users are in the stage of action and strive to reach maintenance, users need to strengthen their will to maintain their changed behavior that they already started performing (Prochaska and Norcross 2001). Here, the design principle *suggestion* does not address the users' core needs of that transition, in contrast to design principles such as *reminders, self-monitoring*, and *competition* (Oinas-Kukkonen and Harjumaa 2009). Therefore, *suggestion* is slightly recommended for the design of transition (IV). Regarding transition (V) where users form a habit and make the changed behavior a regular behavior, the relevance of *suggestion* rises compared to transition (IV) to prevent a relapse. Consecutively, the design principle *suggestion* is recommended for transition (V) into the stage of termination.

In addition, we identified that some design principles, for example, *personalization*, *trustworthiness*, and *expertise*, are recommended for all transitions of the BCSS and address basic needs of users. We incorporate this finding by assigning these design principles to "basic requirements". Our understanding of basic requirement is comparable to the concept of hygiene factors of Herzberg et al. (1959).

3.2.4.2 Refinement of Model Based on Systematic Literature Review

In the second step, we studied the role of the design principles regarding the transition phases in a systematic literature review to ensure that the model is in accordance with existing research studies about BCSS and to refine the conceptual mapping (Figure 17). A systematic literature review mitigates the risk that we disregard studies that could contradict our model, as well as the risk that we use studies that cause a biased model (Boell and Cecez-Kecmanovic 2015). Outlining the approach transparently, we defined a search protocol as suggested by Boell and Cecez-Kecmanovic (2015) and Vom Brocke et al. (2015).

To systematically identify relevant studies that introduce persuasive technologies targeting behavior change in different domains, we conducted a systematic keyword search in the databases ABI/Inform Collection, ACM, AISel, PubPsych, and ebscoHost, using the search string: *("behavior change" OR "behaviour change" OR "persuasive technolog*" OR "persuasive system*") AND abstract:("support system*" OR "assistance system*")* leading to 62 studies. Further admission criteria for the literature review is the description of developed persuasive technology in order to be able to clearly analyze the design elements. We excluded seven duplicates and 31 papers that deal with purely theoretical issues or do not consider persuasive technology in the sense of Fogg (2003) and Oinas-Kukkonen and Harjumaa (2009). Because we include all studies that were not excluded, we did not define specific inclusion criteria. Therefore, in total 24 studies are included in our literature review to refine the model.

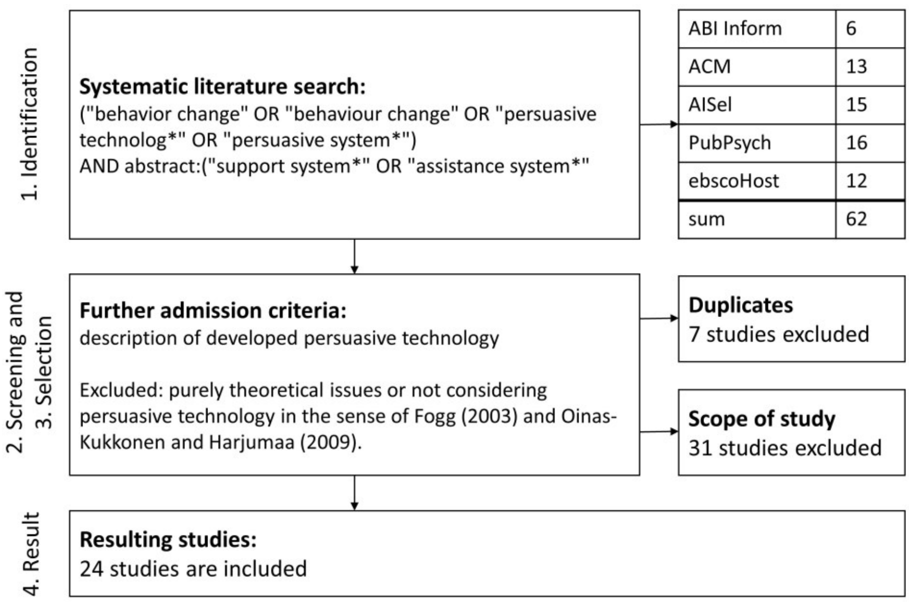


Figure 17: Flow Chart of Literature Review

We compared the findings of the literature review with our conceptual model looking for inconsistencies. Based on this comparison, we refined our model to ensure consistency in practical use, conceptual definitions, and understanding. Where necessary and fitting, examples of implementations were added from additional studies to elaborate the specific design principles along the transitions.

Supplementing our example from step one, based on the theoretical analysis, with insights from the literature review in step two: The design principle *suggestion* is not applicable/ not recommended for designing BCSS targeting transition (I). In fact, our literature review shows that users tend to be averse to advice when they do not experience any problems yet (Phillips and Landon 2016). Regarding transition (II) and (III), Nguyen et al. (2018) and Song et al. (2017) implement suggestions to reveal the benefits of a changed behavior and an approach to take the first steps of their changed behavior. This confirms the strong recommendation of the design principle *suggestion* for transitions (II) and (III). In transition (IV), our literature review shows that *suggestion* can act as a form of feedback and positively affect the alteration of behavior change (Wilson et al. 2017), which is in accordance with a slight recommendation. Because suggestions can help to recall target goals and present new perspectives (Nguyen et al. 2018), *suggestion* has a high impact to prevent a relapse, which indicates a recommendation for transition (V).

3.2.5 Analysis

Table 10 presents the resulting mapping of the different design principles to the five transitions of behavior change and presents the studies that we used for the refinement and our discussion. The table links the 28 design principles of the PSD model (see Figure 15) to the transitions along the stages of change of the TTM (see Figure 16). The design principles are weighted using a scale of four color grades, from white indicating not applicable/ no recommendation to black indicating strong recommendation. A black dot indicates a basic requirement indicating underlying relevance along the whole process of behavior change. The listed studies indicate and substantiate the weighting of the referring design principle.

Table 10: Resulting Mapping of the Design Principles to Transitions of Behavior Change and Referring Studies

Category	Principle	I	II	III	IV	V	Studies (cf. chapter 3.2.4.2)
Primary Task Support	Reduction			black	dark grey		Lehto and Oinas-Kukkonen 2013
	Tunneling	light grey	black	light grey			Sunio et al. 2018b
	Tailoring	light grey	black	dark grey	light grey	dark grey	Liang et al. 2006; Schäfer and Willemsen 2019; Sunio et al. 2018b
	Personalization			●			Kelders 2015; Klein et al. 2014; Lehto and Oinas-Kukkonen 2013, 2015a; Nguyen et al. 2018; Oinas-Kukkonen and Harjumaa 2009; Schäfer and Willemsen 2019; Wilson et al. 2017
	Self-monitoring				black	black	Harjumaa and Muuraiskangas 2013; Klaassen et al. 2015; Klein et al. 2014; Kulyk et al. 2014; Lehto and Oinas-Kukkonen 2013; Sunio et al. 2018b
	Simulation	dark grey	black	light grey		light grey	Lehto and Oinas-Kukkonen 2015a; Sunio et al. 2018b
	Rehearsal		dark grey	black			Harjumaa and Muuraiskangas 2014; Langrial et al. 2014; Lehto and Oinas-Kukkonen 2015a
Dialogue Support	Praise		light grey	dark grey	black	black	Harjumaa and Muuraiskangas 2014; Lehto and Oinas-Kukkonen 2015a; Toscos et al. 2006
	Rewards				black	black	Nguyen et al. 2018; Wilson et al. 2017
	Reminders				black	black	Harjumaa and Muuraiskangas 2014; Klaassen et al. 2015; Kulyk et al. 2014; Langrial et al. 2013; Langrial et al. 2014; Lehto and Oinas-Kukkonen 2013, 2015a
	Suggestion		black	black	light grey	dark grey	Lehto and Oinas-Kukkonen 2015a; Nguyen et al. 2018; Phillips and Landon 2016; Song et al. 2017
	Similarity			●			Kulyk et al. 2014
	Liking			●			
	Social role			●			
System Credibility Support	Trustworthiness			●			Lehto and Oinas-Kukkonen 2014, 2015a
	Expertise			●			
	Surface credibility			●			
	Real-world feel			●			
	Authority			●			
	Third-party endorsements			●			
	Verifiability			●			
Social Support	Social learning	dark grey	black	dark grey		light grey	Davis 2012; Nkwo 2019
	Social comparison		light grey	light grey	black	black	Davis 2012; Lehto and Oinas-Kukkonen 2015a; Nkwo 2019; Sunio et al. 2018b
	Normative influence	light grey	black	dark grey	light grey	light grey	Kamphorst et al. 2014; Sunio et al. 2018b
	Social facilitation		light grey	light grey	black	dark grey	Nkwo 2019
	Cooperation				black	black	Divjak and Rupel 2018; Minichiello et al. 2019
	Competition			light grey	black	black	Davis 2012; Nkwo 2019
	Recognition				black	black	Davis 2012; Nkwo 2019

white: not applicable/ no recommendation, ligh grey: slight recommendation, dark grey: recommendation, black: strong recommendation, black dot: basic requirement

Of the 28 design principles of the PSD model, 11 design principles are identified as basic requirements and 17 design principles are categorized into the four levels of recommendation. Linking the 17 design principles and the five transitions results in 85 combinations: 31 (36%) show not applicable or not recommended in the referring transition, 17 (20%) show a slight recommendation, 11 (13%) recommendation, and 26 (31%) show a strong recommendation of the design principle in the referring transition. The mapping reveals that the seven design principles of the category system credibility support act as basic requirements (Lehto and Oinas-Kukkonen 2013; Oinas-Kukkonen 2013). Most design principles are linked to the transitions (IV) and (V), from action to maintenance and from maintenance to termination.

We discuss the role of the design principles of the PSD model along the process of behavior change including examples of implementations. We start with the basic requirements that are relevant to the whole transition process following with a discussion of the five transitions.

3.2.5.1 Basic Requirements

According to the analysis, 11 design principles act as basic requirements along the five transitions and should be considered regardless of the specific stage of behavior change. These design principles are *personalization, similarity, liking, social role* as well as the whole category system credibility support with its design principles *trustworthiness*, *expertise, surface credibility, real-world feel, authority, third-party endorsements*, and *verifiability*.

Researchers address *personalization* as a design principle that is relevant along the whole process of behavior change as personalized elements have a high impact to motivate users (Harjumaa and Muuraiskangas 2014) and lead to users feeling more engaged and invested (Wilson et al. 2017). Therefore, *personalization* has the potential to support people in starting their behavior change as well as preventing relapses into old and undesired behavior patterns (Harjumaa and Muuraiskangas 2014; Schäfer and Willemsen 2019). Developers of BCSS integrate *personalization* by allowing users to create their own profile with name and picture (Kelders 2015; Oinas-Kukkonen and Harjumaa 2009) or to select design features (Lehto and Oinas-Kukkonen 2015a). Personalized feedback or advice (Klein et al. 2014; Lehto and Oinas-Kukkonen 2013; Nguyen et al. 2018) as well as *personalization* based on *tailoring*, by leading users to individually set their goals (Schäfer and Willemsen 2019), are additional examples.

Kulyk et al. (2014) emphasize that users of BCSS appreciate *similarity, liking*, and *social role*. Oinas-Kukkonen and Harjumaa (2009) address the relevance of the design principle *similarity* as they state that users of BCSS are more likely to be persuaded through systems that remind them of themselves. The design principle *liking* adds an attractive and appealing look and feel (Oinas-Kukkonen and Harjumaa 2009). Oinas-Kukkonen and Harjumaa (2009) further specify that BCSS that include the design principle *social role* act more persuasive.

Next to these design principles, the category system credibility support also serves as a basic requirement for BCSS. The category system credibility support comprises the design principles *trustworthiness, expertise, surface credibility, real-world feel, authority*, *third-party endorsements*, and *verifiability*. The consideration of these design principles during the design of BCSS does not enable user activities, however, their absence would result in dissatisfaction. *Trustworthiness, expertise*, and *authority* affect the persuasiveness of the BCSS, as they let the system seem truthful, fair, and unbiased as well as demonstrate knowledge, experience, and competence (Oinas-Kukkonen and Harjumaa 2009). *Surface credibility, real-world feel, third-party endorsements* affect perceptions on system credibility because these design principles provide a competent look and feel, information about the people behind the BCSS, endorsements from respected sources, and links to outside sources (Oinas-Kukkonen and Harjumaa 2009). Lehto and Oinas-Kukkonen (2014, 2015) highlight the importance of this category as perceived credibility strengthens the intention to continue.

3.2.5.2 Transition I, Precontemplation to Contemplation

Users in the stage of precontemplation are unaware that the addressed problem exists (Prochaska and Norcross 2001). Due to the unawareness, it is difficult to reach potential users, because they are not actively looking for a behavior change and a transition to the next stage of contemplation. Therefore, only a few design principles are applicable in BCSS for transition (I). To reach users in the stage of precontemplation, other efforts outside BCSS are beneficial, for example, interventions by families, friends, or coworkers, or supplementing measures such as marketing. The most fitting design principles for transition (I) are *simulation* and *social learning* (recommendation), as well as *tunneling* and *normative influence* (slight recommendation). These design principles are able to reveal the problem behavior to users.

Simulation enables users to observe the link between cause and effect (Oinas-Kukkonen and Harjumaa 2009). Sunio et al. (2018b), for example, use *simulation* in a slideshow to present before and after pictures. The effects of certain behavior can also be revealed by *social learning* when users observe others performing the behavior (Oinas-Kukkonen and Harjumaa 2009). *Social learning* is addressed, for example, by including experience reports (Davis 2012) or by enabling the exchange of best practices (Nkwo 2019).

Tunneling guides users along the attitude change process by providing relevant information (Oinas-Kukkonen and Harjumaa 2009). Additionally, *normative influence*, *tailoring*, and *expertise* could be added as design principles in transition (I) to increase the likelihood that a person will adopt a target behavior (Lehto and Oinas-Kukkonen 2015a; Oinas-Kukkonen and Harjumaa 2009; Sunio et al. 2018b).

In transition (I), *reduction, self-monitoring, rehearsal, praise, rewards, reminders, suggestion, social comparison, social facilitation, cooperation, competition*, and *recognition* are design principles that are not able to address users' needs. The design principle *suggestion* is not recommended for transition (I) because it can lead to users' rejection in the stage of precontemplation when they do not have problem awareness yet (Phillips and Landon 2016). Design principles such as *rehearsal, praise,* and *reminders* require a certain awareness of the problem that is not present in this stage, yet. Other design principles such as *rewards, recognition*, and *cooperation* are not applicable because they require the execution of the target behavior (Oinas-Kukkonen and Harjumaa 2009).

3.2.5.3 Transition II, Contemplation to Preparation

In the stage of contemplation, users are aware of an existing problem but do not actively intend to change (Prochaska and Norcross 2001). Transition (II) to the stage of preparation mostly relies on the categories primary task support and social support. In detail, the design principles *tunneling, tailoring, simulation, social learning*, and *normative influence* are strongly recommended for transition (II). These design principles are able to raise awareness for the problem behavior, show benefits of a changed behavior, and therefore to form an intent to change. In this transition (II), *tunneling* guides users and provides means for action (Liang et al. 2006). *Tailoring* refers to ensuring that information is aligned to the context and needs of the targeted user group (Oinas-Kukkonen and Harjumaa 2009). As an example for *tunneling* and *tailoring*, Oinas-Kukkonen and Harjumaa (2009) suggest providing relevant information about the problem behavior and possible treatments and stories of peers, which are referring to different user groups.

Sunio et al. (2018b) apply this by reporting personalized diagnostics including a goal and directing to relevant new elements. *Simulation* is maintaining its purpose as described in transition (I) to highlight the problem behavior and to show results of behavior change (Lehto and Oinas-Kukkonen 2015a). *Social learning* and *normative influence* provide means to behavior change and motivate users by observing the results of other people performing the target behavior and gathering people with the same goal (Oinas-Kukkonen and Harjumaa 2009). *Social learning* can connect people, for example by using a shared fitness journal (Consolvo et al. 2006). *Normative influence* impacts behavior, for example by adding peer pressure (Oinas-Kukkonen and Harjumaa 2009) or by bringing the culture and environment of users into account (Kamphorst et al. 2014).

Besides these strong recommendations, the model indicates *rehearsal* as recommended. *Rehearsal* is able to raise awareness by emphasizing the benefits of changed behavior (Harjumaa and Muuraiskangas 2014) and supports the preparation of real situations (Langrial et al. 2014; Oinas-Kukkonen and Harjumaa 2009). *Rehearsal* can be implemented, for example, in the form of a role-play (Harjumaa and Muuraiskangas 2014) or a video-based exercise builder (Lehto and Oinas-Kukkonen 2015a). Additionally, the model indicates a slight recommendation for *praise, social comparison*, and so*cial facilitation* to raise motivation and strengthen the intent to change (Lehto and Oinas-Kukkonen 2015a; Sunio et al. 2018b).

Design principles that are not applicable for BCSS that address transition (II) are *reduction, self-monitoring, rewards, reminders, cooperation, competition*, and *recognition*. As stated regarding transition (I), these design principles cannot be implemented per definition, as they require the execution of the target behavior (Oinas-Kukkonen and Harjumaa 2009) that is not yet performed during transition (II) (Prochaska and Norcross 2001).

3.2.5.4 Transition III, Preparation to Action

Users in transition (III), from preparation to action, need BCSS that help them with an initial approach ("game plan", Prochaska and Norcross 2001, p. 445) to take first steps and form their intended behavior. Mostly the categories of primary task support and social support are recommended in this transition, providing guidance and means for the change as well as social components emphasizing motivation to change.

The design principles *reduction, suggestion*, and *rehearsal* are strongly recommended for transition (III). *Reduction* breaks down complex behavior into simple tasks or subtasks (Lehto and Oinas-Kukkonen 2013; Oinas-Kukkonen and Harjumaa 2009) and therefore also lowers the barriers to do the first step of the target behavior and increases the willingness that users engage with the BCSS. *Suggestion* offers specific applications of the target behavior, for example, an exercise plan based on preferences and goals (Lehto and Oinas-Kukkonen 2015a). Advice is especially effective when users are experiencing some form of loss or the situation is comprising a low risk (Phillips and Landon 2016). *Rehearsal* explicitly supports the preparation for real situations (Oinas-Kukkonen and Harjumaa 2009) as a training technique (Langrial et al. 2014).

Besides these strong recommendations, the model presents the following design principles as recommendations: *tailoring, praise, social learning, normative influence*. *Tailoring* supports users to make better choices (Schäfer and Willemsen 2019). *Praise* has the ability to strengthen motivation for reaching individual goals (Harjumaa and Muuraiskangas 2014; Toscos et al. 2006). *Social learning* can supplement tailoring by observing the behavior of peers and helps to build an individual goal for intended behavior (Consolvo et al. 2006). *Normative influence* is able to induce active behavior by defaults. Such defaults can appear, for example, as default goals and contribute to *tailoring* by facilitating the decision process of users (Loock et al. 2013). Goal-setting is not explicitly introduced as a design principle by the PSD model. However, goal-setting is a widely studied subject that influences behavior (Locke and Latham 1991, 2002) and should be considered in the process of behavior change. Regarding the design principles of the PSD model, goal-setting may serve as a combination of *suggestion, reduction, tailoring*, and *normative influence*. Therefore, setting an individual goal has strong potential to support the transition (III) from preparation to action.

In transition (III), the design principles *self-monitoring, rewards, reminders, cooperation*, and *recognition* are not applicable, because they are not aiming at supporting an initial approach to the target behavior. As described in transition (I) and (II), the design principles are per definition only applicable when users already perform the target behavior (Oinas-Kukkonen and Harjumaa 2009). This is not the case during transition (III) but in the following stage (Prochaska and Norcross 2001).

3.2.5.5 Transition IV, Action to Maintenance

During transition (IV), from action to maintenance, BCSS should reinforce users' new behavior and strengthen users' will to maintain their changed behavior. Therefore, design principles that analyze the behavior of the users are in focus. Categories that especially address these needs are dialogue support and social support.

Strongly recommended are *self-monitoring*, *praise*, *rewards*, *reminders*, *social comparison*, *social facilitation*, *cooperation*, *competition*, and *recognition*. *Self-monitoring* enables users to keep track of their performance or status and therefore supports users in achieving their goals (Oinas-Kukkonen and Harjumaa 2009). Regarding the intended continual interaction with BCSS, *self-monitoring* has the potential to raise awareness for behavior patterns. Because deviations become recognizable, the appearing links to negative consequences encourage users to make progress (Sunio et al. 2018b) and serve as guidance (Kulyk et al. 2014). Furthermore, *self-monitoring* functions as a reminder, warning, advice, or assessment (Klaassen et al. 2015). Examples for implementation are calculators for own eating habits or medication (Klein et al. 2014; Lehto and Oinas-Kukkonen 2013). Displaying users' behavioral values besides the values of peers serves as a combination of *self-monitoring* and *social comparison*. Praise provides information-based feedback, for example, via words, images, or sounds (Oinas-Kukkonen and Harjumaa 2009), which has positive effects on individuals' motivation (Harjumaa and Muuraiskangas 2014; Toscos et al. 2006). The design principle *rewards* gives credit for performing the target behavior and is able to provide great persuasive powers (Oinas-Kukkonen and Harjumaa 2009). Therefore, *rewards* should be integrated into BCSS as soon as users get into the action phase and perform the desired behavior. *Rewards* can function as a form of positive feedback (Harjumaa and Muuraiskangas 2014), which leads users to recall their target goals (Nguyen et al. 2018) and thus affects alteration and reinforcement of behavior (Wilson et al. 2017). The design principle *reminders* is able to call the target behavior to the users' mind (Oinas-Kukkonen and Harjumaa 2009), make people remember to use the system during the intervention (Langrial et al. 2013; Langrial et al. 2014; Lehto and Oinas-Kukkonen 2013), and keep users motivated (Lehto and Oinas-Kukkonen 2015a). *Reminders* can be implemented as regular text messages (Klaassen et al. 2015; Lehto and Oinas-Kukkonen 2013) or provide impulses at opportune moments (Harjumaa and Muuraiskangas 2014), for example, as soon as the performance of the users is less than a target score (Kulyk et al. 2014).

Additionally, the integration of *competition* can be beneficial and raise social motivation (Davis 2012), however, a healthy level of competitiveness is important (Nkwo 2019). Davis (2012) and Nkwo (2019), for example, implement *competition* through *social comparison*. *Social comparison* and *social facilitation* are able to raise users' motivation and strengthen the intent to change (Sunio et al. 2018b; Lehto and Oinas-Kukkonen 2015a) and are highly relevant to keep users in action. Both go hand in hand, as *social facilitation* can be achieved by *social comparison* (Nkwo 2019). Additionally, *cooperation* can motivate users to adopt a target attitude or behavior as humans have a natural drive to cooperate (Oinas-Kukkonen and Harjumaa 2009). *Cooperation* is typically addressed through tasks that require teamwork (Divjak and Rupel 2018; Minichiello et al. 2019). By offering *recognition* to an individual or a group, BCSS can increase the likelihood of users adopting a target behavior (Oinas-Kukkonen and Harjumaa 2009). *Recognition* is addressed, for example, when users receive appreciative and grateful messages to reward good performance (Davis 2012; Nkwo 2019).

Besides the design principles with strong recommendation, *reduction* is recommended in transition (IV) as it is important to keep the users performing the new behavior. Slight recommendations in transition (IV) are *tailoring, suggestion*, and *normative influence*. *Tailoring* supports users to make better choices (Schäfer and Willemsen 2019) and *suggestion* provides specific applications of the target behavior (Lehto and Oinas-Kukkonen 2015a). Both design principles are slightly recommended in transition (IV) as users already know how to adopt their new behavior. For the same reason, *normative influence* also is slightly recommended.

Design principles that are not able to address users' needs in transition (IV) *are tunneling, simulation, rehearsal*, and *social-learning*. *Simulation, rehearsal*, and *social-learning* are necessary during preparatory transitions but do not explicitly support users during performing the target behavior. This also includes *tunneling*, which guides "users in the attitude change process" (Oinas-Kukkonen and Harjumaa 2009, p. 492), thus the need for this effect ends after the stage of preparation.

3.2.5.6 Transition V, Maintenance to Termination

For the last transition (V), BCSS should help users to form habits and make the changed behavior their regular behavior. Therefore, it is important to continue the integration of design elements of the transition (IV), but also integrate elements of precontemplation to address the importance of keeping up the new behavior. Comparison to users' past status can help to extend and reawake motivation. Looking at the different categories dialogue support and social support are the ones that stand out.

As well as for transition (IV), *self-monitoring, praise, rewards, reminders, social comparison, cooperation, competition*, and *recognition* are strongly recommended for transition (V). *Self-monitoring* tracks users' behavior and makes progress or new behavioral patterns visual. This can keep up motivation (Harjumaa and Muuraiskangas 2013) and visible deviations from the desired behavior remind people of negative consequences to stay on track (Sunio et al. 2018b). Because the design principles *praise, rewards, social comparison, cooperation, competition,* and *recognition* are able to raise or strengthen motivation, they can be implemented in the same way as in transition (IV), but with a different focus. While the focus in transition (IV) is on motivating users to change their behavior, the focus in transition (V) lies on maintaining their motivation for long-term behavior change. Additionally, *reminders* can be used to bind users to the BCSS in the long term.

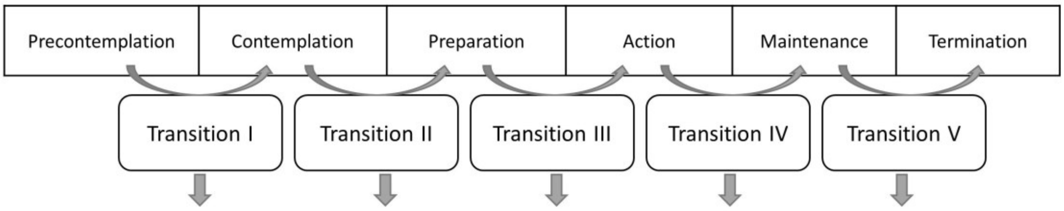
In transition (V), the design principles *tailoring, suggestion, social facilitation* are recommended. *Tailoring* and *suggestion* rise in relevance compared to transition (IV). Both design principles support users in giving advice regarding fitting exercises or impulses to simplify complex tasks of changing behavior (Song et al. 2017). Users in the stage of maintenance are already prepared and rehearsed in their actions, it is a new task to keep up with the changed behavior. Therefore, users need more support through *tailoring* and *suggestion* to facilitate the stage of maintenance. Additionally, *social facilitation* can raise motivation, strengthen the intent to maintenance, and consequently prevent relapses. Additionally, there is a slight recommendation for *normative influence, simulation*, and *social learning*.

Design principles that are not able to address users' needs in transition (V) are *reduction*, *tunneling*, and *rehearsal*. While they facilitate initial steps in earlier transitions, they do not affect the sustainability of behavior change that is needed to achieve the stage of termination. In particular, the definition of *tunneling* highlights the supporting effect for preparatory stages by describing its effect as bringing users "closer to the target behavior" (Oinas-Kukkonen and Harjumaa 2009, p. 492). As soon, as users perform the target behavior, this effect is no longer supporting users' needs (Prochaska and Norcross 2001).

3.2.6 Conclusion

Our model (Figure 18) presents process-based guidance for developing BCSS based on the PSD model by Oinas-Kukkonen and Harjumaa (2009) and the stages of change of the TTM of Prochaska and DiClemente (1983) and Prochaska and Norcross (2001). We introduce a tangible model for implementing fitting and effective design principles according to the targeted stages of behavior change to researchers and developers of BCSS. Figure 18 summarizes the recommendation model in a condensed form filling the gap between the analysis of persuasion context and selection of different design principles for the software implementation of BCSS. The model provides guidance on which design principles should be implemented in BCSS depending on the users' current stage in the process of behavior change, while not restricting individual decisions. The levels of recommendation indicate the priority for implementation differentiating between strong recommendation, recommendation, and slight recommendation; the design principles at the bottom present the basic requirements along all transitions.

The model presents the appropriate design principles regarding each transition along the stages of behavior change. It highlights and depicts in a tangible and applicable form that it is important to choose the fitting design principles according to users' stage of behavior change and the targeted transition.



Strong recommendation			Tunneling, Tailoring, Simulation, Reminders, Social learning	Reduction, Rehearsal, Suggestion	Self-monitoring, Praise, Rewards, Reminders, Social comparison, Social facilitation, Cooperation, Competition, Recognition	Self-monitoring, Praise, Rewards, Reminders, Social comparison, Cooperation, Competition, Recognition
Recommendation		Simulation, Social learning	Rehearsal	Tailoring, Praise, Social learning, Normative influence	Reduction	Tailoring, Suggestion, Social facilitation
Slight recommendation		Tunneling, Tailoring, Normative influence	Praise, Social comparison, Social facilitation	Social comparison, Social facilitation, Competition	Tailoring, Suggestion, Normative influence	Normative influence
Basic requirement	•	Personalization, Similarity, Liking, Social role, Trustworthiness, Expertise, Surface credibility, Real-world feel, Authority, Third-party endorsement, Verifiability				

Figure 18: Model in a Condensed Form Integrated in the Process of the PSD Model

Most existing BCSS focus on users that are in the stages of action and maintenance (i.e. transitions (IV) and (V)) and target users that already have problem awareness and are preparing to change. This is in accordance with the finding that most design principles of the PSD model are categorized in the transitions (IV) and (V) (cf. Figure 18) and that it is a major challenge for BCSS to reach users in the first stage for transition (I) without intent to change behavior. Our model further indicates that BCSS by themselves may not be sufficient enough to persuade users in the first stage of behavior change of pre-contemplation. Other research areas as marketing have the potential to reach users and therefore to supplement BCSS for transition (I).

Addressing all transitions allows to involve a broader target audience, independent of the current stage of behavior change, and to address problem awareness to prevent relapses. When a BCSS supports multiple transitions, we propose to design the BCSS with different sections and corresponding features for each transition. An implementation example is proposed by Merz (2020) where the user passes different levels each addressing a transition in the process of behavior change. Dividing the BCSS into specific sections related to the transitions allows for a focus on selected design principles whose effects and impacts are tailored to the targeted stage of behavior change. In addition to providing guidance on choosing relevant design principles depending on the users' current stage of change, the model emphasizes integrative approaches to design persuasive systems.

Our paper is subject to several potential limitations. First, our resulting model is still quite general, despite our motivation to develop the model because the PSD model is a generic technical framework for developing BCSS. However, we decided consciously not to narrow the focus to maintain the applicability of the model in different fields of research (health, environment, work, etc.), and we still were able to develop a tangible model by specifying and facilitating the recommendation analysis and selection of design principles of the PSD model for developing BCSS. Therefore, this approach provides a starting point for future research in developing more context-specific models. Second, we decided to draw upon the stages of change of the TTM by Prochaska and DiClemente (1983) and Prochaska and Norcross (2001) to fill the gap between technical and behavioral model. The TTM was originally developed for the treatment of people with addictive behavior but has since been applied to various other situations (e.g., stress management (Velicer et al. 1998), academic procrastination (Grant and Franklin 2007), and consumer debt behavior (Xiao et al. 2004)). There are also other behavioral models that address stages of behavior change, such as the 3D-RAB by Wiafe et al.

(2011). The 3D-RAB states 12 transitions (Wiafe et al. 2012). In favor of the applicability of the model, we decided on the less complex TTM with five transitions. It could be subject to further research to specify the model using a narrower focus and a different behavioral model. Third, we may have missed potentially relevant studies in our literature search and the model is partly based on subjective coding. However, following our methodological procedure of the literature search using four interdisciplinary databases with a wide search string, we are confident that we incorporated adequate studies into our analysis for confirmation and were able to minimize potential bias as possible.

While we tried to minimize the subjective bias of our qualitative analysis using our described methodology, it should be subject to further research to validate our model and test the applicability when developing BCSS. Additionally, while we build on the PSD model as the most referenced and established technical framework for developing BCSS, there is a need for further research regarding the consistent understanding of design principles for BCSS (Gregor et al. 2020; Möller et al. 2020b). Our theoretical base for the model was particularly sparse regarding our identified basic requirements, especially the category of system credibility support that is mostly neglected in existing research (Matthews et al. 2016). Therefore, future research should investigate the potentials and possible implementations of these design principles. Also, other design principles should be subject to further research and development: First, a recognizable number of studies and developments of BCSS are adding forms of feedback. For example, Wilson et al. (2017) define the design principles of *praise, rewards, reminder*, and *suggestion* as feedback. In the PSD model, the whole category of dialogue support is stated to provide system feedback. To ensure a consistent use and understanding, the concept of feedback should be elaborated further in the context of BCSS. Second, it is notable that in recent studies since the development of the PSD model the concept of gamification has become increasingly popular. So far, gamification is indirectly incorporated in the PSD model in *competition* or *cooperation*. It should be subject to further research to integrate gamification more explicitly and more elaborated. Third, we propose to integrate goal-setting into the model as an additional design principle that can strongly contribute to the process of behavior change.

3.3 Essay 5: Design Principles for Persuasive Systems – Towards Designing Behavior Change Support Systems

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Revise and resubmit:	Business & Information Systems Engineering.

3.3.1 Abstract

Persuasive technology has become near enough ubiquitous in today's life and influences the attitudes and behaviors of its users. In the form of behavior change support systems (BCSS), persuasive systems aid users, for example, to change habits and pursue healthier lifestyles. While there exists a wide range of design knowledge about BCSS, there is a lack of systematic codification of this design knowledge into precise and unambiguous prescriptive statements that consider current insights of design science. Therefore, this study synthesizes existing design knowledge from theoretical and practical studies to systematically derive a clear and up-to-date set of design principles for BCSS. This adheres to the method for design principle development, as proposed by Möller et al. (2020b) and applies the design principles schema of Gregor et al. (2020). This approach ensures that our methodology observes the best practices on how design principles should be developed and formulated. The value of this study is the aggregation of 125 concepts of design knowledge and the formulation of 14 synthesized design principles. Those design principles provide researchers and developers with explicitly formulated prescriptive knowledge on how to design, evaluate, and develop BCSS.

3.3.2 Introduction

Information systems (IS) and technology have become almost ubiquitous in modern life as digital products surround us in the form of various mobile and ambient technologies (Alt et al. 2021). Against the background that information technologies shape the actions, beliefs, and thoughts of their users (Maedche 2017; Oinas-Kukkonen and Harjumaa 2009), IS researchers of persuasive technology examine and develop meaningful systems that aim to influence their users. Oinas-Kukkonen (2010a) introduce the term Behavior Change Support Systems (BCSS) to describe persuasive systems that aim to "form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements" (Oinas-Kukkonen 2010a). Studies prove that BCSS function as valuable systems helping people to overcome problematic behavior or change their behavior, for example, to lead a healthier life (e.g., Böckle and Yeboah-Antwi 2019; Lehto and Oinas-Kukkonen 2015a; Rieder et al. 2019).

To develop meaningful and effective IS such as BCSS, it is crucial that useful design decisions are not only identified and improved but that any obtained design knowledge is also communicated. Without effective descriptions and communications of design knowledge, avoidable mistakes are repeated and lessons from other artifacts and projects are difficult to learn. This emphasizes the relevance of design principles that codify design knowledge and support the transfer to other artifacts (Gregor et al. 2020; Möller et al. 2020b).

When developing BCSS, most researchers follow the Persuasive Systems Design model (PSD model) of Oinas-Kukkonen and Harjumaa (2009) (Merz and Ackermann 2021), which provides a process for persuasive systems development including 28 design principles. While the PSD model offers a framework for designing BCSS, it offers neither a systematic selection nor a clear presentation of said 28 principles (Wiafe et al. 2014). As also generally identified in the IS literature (Gregor et al. 2020), this leads to ambiguity when applying the design principles, impairs the transfer of design knowledge to other systems, and inhibits the creation of new design knowledge for BCSS based on those design principles (Merz and Ackermann 2021).

Therefore, we address the research gap that the design principles for developing BCSS are currently ambiguous and not clearly formulated, by applying the method of Möller et al. (2020b) and the design principles schema of Gregor et al. (2020) to the existing body of knowledge on persuasive systems. Our goal is to clearly formulate design principles for the development of BCSS that are both meaningful and systematically derived. Thus, we aim to answer the research question: *What are design principles for persuasive systems that provide a clear codification of design knowledge?*

Following Design Science Research (DSR), our approach has an iterative character. This article presents the procedure and findings of the iteration in which we derive the design principles from prior literature on persuasive system research. Our findings provide developers of BCSS with a theory of design and action in terms of Gregor (2006) (theory type five) and allow researchers to apply existing findings as well as to create new design knowledge about persuasive systems.

3.3.3 Theoretical Background

3.3.3.1 Design Principles

Design principles are "prescriptive statements [of design science knowledge] that show how to do something to achieve a goal" (Gregor et al. 2020, p. 1622). They serve as "means of accumulating knowledge and [can be] acted on in real-world situations" (Gregor et al. 2020, p. 1622). Accordingly, clear and comprehensive design principles are required when codifying design knowledge and communicating innovative practices "to advance design science and solve future design problems" (Fu et al. 2016, p. 1).

Aside from guidelines and heuristics, design principles provide an explicit method of expressing knowledge (Fu et al. 2016). They differ from related concepts, however, in that they can be defined as a "fundamental rule or law, derived inductively from extensive experience and/or empirical evidence, which provides design process guidance to increase the chance of reaching a successful solution" (Fu et al. 2016, p. 3). Therefore, design principles aim to provide design knowledge that gives prescriptions for design and actions in terms of Gregor (2006).

To determine a systematic process by which to derive design principles from design knowledge, Möller et al. (2020b) present a method for design principle development in seven dimensions. Within this method, Möller et al. (2020b) map design principles in relation to design requirements and design features according to Rhyn and Blohm (2017): While design principles are derived from design requirements (Rhyn and Blohm 2017), Möller et al. (2020b) design features are considered another layer of specifications that result from design principles (Möller et al. 2020b).

Gregor et al. (2020) discuss a widespread inconsistency in the formulation of design principles. They study the use and anatomy of design principles and present a design principles schema considering 1) aim, 2) actors (comprising implementers, users, and enactors), 3) context, 4) mechanism, and 5) rationale.

3.3.3.2 Persuasive Systems

Persuasive technology describes a research field of computer-based interactive systems designed to purposefully change human behavior through persuasion, without coercion or deception (Fogg 2003). These persuasive systems use either computer-human or computer-mediated persuasion (Oinas-Kukkonen and Harjumaa 2008). According to Fogg (2003), the success of those systems depends on the integration of individual design features that target the motivation, the feasibility, and the trigger of the desired behavioral change (Fogg 2009). BCSS are "a key construct for research in persuasive technology" (Oinas-Kukkonen 2010a, pp. 4–5) and include socio-technical platforms, systems, applications for smartphones, and software designed for persuasion (Oinas-Kukkonen 2010a). Researchers and designers implement BCSS in form of web-based systems, mobile applications, or social networking tools. They investigate the potential of BCSS to enable and support individuals and/or groups (Lehto and Oinas-Kukkonen 2015b).

BCSS are studied in a variety of contexts, whereby applications in the health context predominate (Merz and Ackermann 2021). Health-BCSS are of high practical value as they can address chronic disease risk factors related to lifestyle behaviors, such as diet or exercise (Lehto and Oinas-Kukkonen 2015b). Furthermore, researchers envision great potential for the application of BCSS in educational institutions (Sengupta and Williams 2021; Steinherr 2021) and work environments (Merz 2020; Nkwo 2019). BCSS are also able to contribute to society benefiting from the behavioral changes of their users, for example, by focusing on sustainable behavior (Shevchuk and Oinas-Kukkonen 2016) or waste separation (Lessel et al. 2015).

3.3.3.3 Persuasive Systems Design Model (PSD Model)

The PSD model of Oinas-Kukkonen and Harjumaa (2009) provides a conceptual framework for the development of persuasive systems such as BCSS. It describes the application of design principles in the context of persuasive systems and proposes three development phases: 1) understanding the key issues behind persuasive systems, 2) analyzing the persuasion context, and 3) designing the system qualities. For the design of system qualities (third phase), the PSD model suggests 28 design principles in the four categories of primary task support (e.g., tunneling, tailoring), dialogue support (e.g., praise, reminders), system credibility support (e.g., expertise, verifiability), and social support (e.g., cooperation, competition). Those design principles are based on Fogg (2009) and should be considered as "requirements for software qualities" (Oinas-Kukkonen and Harjumaa 2009, p. 498). The design principles are described using an example requirement and an example implementation (see Table 11).

Table 11: Description of the design principle rehearsal in the PSD model, according to Oinas-Kukkonen and Harjumaa (2009)

Design Principle Rehearsal	Example Requirement	Example Implementation
A system providing means with which to rehearse a behavior can enable people to change their attitudes or behavior in the real world.	System should provide means for rehearsing a target behavior.	A flying simulator to help flight pilots practice for severe weather conditions.

The PSD model of Oinas-Kukkonen and Harjumaa (2009) is the most frequently used model for the development of BCSS (Merz and Ackermann 2021). However, in line with the findings of Gregor et al. (2020), researchers and designers of BCSS identified that the design principles of the PSD model are neither systematically selected (Wiafe et al. 2014) nor do they provide sufficient guidance for designers of BCSS (Harjumaa and Muuraiskangas 2014). As a result, the design principles of BCSS are used inconsistently and ambiguously in literature (Merz and Ackermann 2021). In conclusion, the PSD model provides a general framework for the development of BCSS that considers the role of design principles; however, the suggested design principles were proposed in 2009, so they could account neither for the recent research on design principles nor for the design knowledge that has since been obtained from studying BCSS.

Considering practical studies and literature reviews on BCSS, including our systematic literature review described in section 3.3.5.4, we could not identify other common frameworks or models for the development of persuasive systems that comprise design principles such as the PSD model.

3.3.4 Method

Möller et al. (2020b) present a method for design principle development in seven dimensions. For the purpose of this research project, we instantiate that method in Table 12 and detail them in the following.

1) As we define the design principles ex-ante, we take a supportive perspective to justify future design decisions. 2) The overarching research design is DSR whereby the method in this cycle is qualitative. 3) Within this cycle, the focus is on rigor and the existing knowledge base, as defined by Hevner (2007). Accordingly, our sources of meta-requirements are literature and theory. 4) We derive the meta-requirements from practical studies and existing theories, such as the PSD model, and formulate them as a

response to the identified meta-requirements. 5) The current research study applies a single iteration but encourages further development through additional iterations, as suggested in DSR projects. 6) We evaluate the design principles based on argumentation using demonstration examples. 7) We formulate the design principles based on the design principles schema of Gregor et al. (2020), which comprises the components implementer, aim, user, context, mechanism, enactor, and rationale.

Table 12: Taxonomy of design principle development following Möller et al. (2020b)

	Dimension	Characteristics				
1	Perspective	Supportive	Reflective			
2	Research Design	DSR	A(D)R	Qualitative	Case Study	
3	Source of Meta-Requirements	Literature	Theory	Interviews	Workshops/ Focus Groups	None
4	Design Principles Design	Derived	Extracted	Responsive		
5	Iterations	Single	Multiple			
6	Evaluation	Expert / User Feedback	Instantiation / Field Testing	Argumentation		
7	Formulation	Free	Based on Template			

3.3.5 Design Principle Development

In the following, we specify the seven steps proposed by Möller et al. (2020b) (Figure 19) and then elaborate on them in order to systematically develop clearly formulated design principles for persuasive systems.

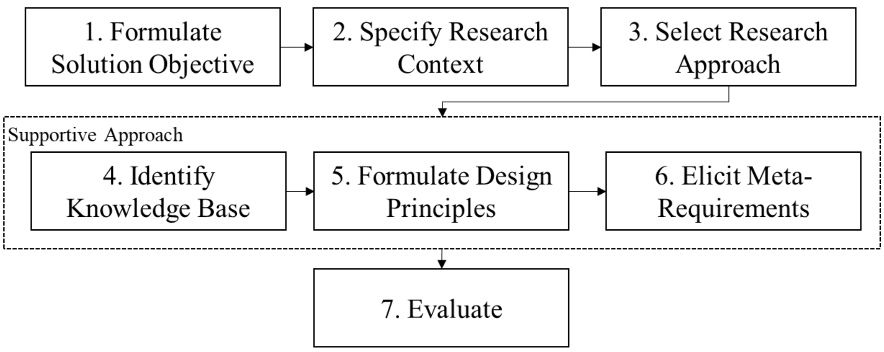

Figure 19: Process of design principle development, instantiated from Möller et al. (2020b)

3.3.5.1 Formulate Solution Objective

The purpose of design principles is to support the successful design of an artifact. Considering the research gap discussed in section 3.3.2 and the definition of design principles presented in section 3.3.3, we specify our solution objective, choosing the form of a question, as follows: *What are design principles for persuasive systems that provide a clear codification of design knowledge?*

In line with the presented theoretical background on persuasive systems and design principles, we consider that design principles provide a *clear codification of design knowledge* if they are prescriptive statements of a formulation by the means of Gregor et al. (2020) that allows for a transfer and application of the design knowledge in different artifacts. Further considering the definition of BCSS, those design principles should allow the systems to "form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements" (Oinas-Kukkonen 2010a, p. 6). Möller et al. (2020b) suggest a method on how to systematically develop design principles that cover a specified research context, which we address in the following.

3.3.5.2 Specify Research Context

To identify and formulate design principles that codify design knowledge in a clear and comprehensive manner, we specify the research context of our study. Our study is embedded in the emerging discipline of persuasive systems with BCSS as artifacts of persuasive systems. The PSD model serves researchers and developers as an initial framework for the design of BCSS, including a list of 28 categorized design principles (Oinas-Kukkonen and Harjumaa 2009). However, the design principles of the PSD model are formulated as a theoretical foundation without major existing knowledge about BCSS. Since the development of the PSD model in 2009, many researchers have created and implemented BCSS, thus, creating design knowledge about persuasive systems and design principles.

Since most researchers have used the PSD model, design knowledge is mostly codified through the design principles of the PSD model (Merz and Ackermann 2021). In addition to using the design principles proposed by the PSD model, researchers also defined their own design principles that are not mentioned in the PSD model (e.g., Asbjørnsen et al. 2019; Orji and Mandryk 2013; Valk et al. 2017).

3.3.5.3 Select Research Approach

Möller et al. (2020b) distinguish between a supportive and a reflective approach: In the reflective approach, design principles are extracted from design projects of developing specific BCSS. In the supportive approach, existing design knowledge is studied and relevant design principles are derived, for example, from literature, and theory. Considering the research context, there is a large body of knowledge that has not yet been incorporated into clearly formulated design principles. Therefore, we aim to aggregate this knowledge from an existing knowledge base and, correspondingly, select the supportive approach.

Considering the research design (dimensions 2 and 5 of Möller et al. (2020b), Table 12), we conduct a qualitative analysis of the existing design knowledge because the identified research gap indicates that we should focus on the formulation of the results. This study is embedded into an iterative DSR project.

3.3.5.4 Identify Knowledge Base

The next step in the systematic development of design principles is to identify a knowledge base from which to extract relevant design principles and meta-requirements (Möller et al. 2020b). Our approach to identify a considerate knowledge base is twofold: First, given the theoretical background, we consider the PSD model of Oinas-Kukkonen and Harjumaa (2009) (described in section 3.3.3.3) to be the appropriate knowledge base from which to derive meta-requirements. According to the authors of the PSD model, its design principles should be understood as "requirements for software qualities" (Oinas-Kukkonen and Harjumaa 2009, p. 498). Furthermore, Condori-Fernandez et al. (2020) suggest using the PSD model to identify requirements for persuasive systems.

For the second part of our twofold approach and in view of the broad research context (section 3.3.5.2), we aim to incorporate design knowledge that was acquired through the development and study of BCSS to cover a wide understanding as well as practical insights and implications. In the interest of a systematic and transparent methodology, we identify relevant studies with a systematic literature review (Boell and Cecez-Kecmanovic 2015). To account for additional concepts not mentioned in the PSD model, Merz and Ackermann (2021) conducted a systematic literature review. They applied the search string *"Abstract("persuasive system*" OR "persuasive technolog*" OR "Behavior Change Support System" OR "BCSS") AND Abstract("design principle*" OR "persuasive system* design" OR "system feature*" OR "software architecture")"* in the databases Academic Search Ultimate, Business Source Premier, PubPsych, WISO, and the ProQuest research platform (Merz and Ackermann 2021). We use the results and insights of this study as the foundation for our systematic literature review but renewed the search to ensure timeliness. We further supplemented the search string with **requirement** as a synonym of design principles to make sure our search also covers BCSS studies that address requirements. Merz and Ackermann (2021) identify 15 studies that suggest concepts as design principles in addition to the design principles of the PSD model. Our supplemented renewal of their literature review yielded three additional studies (Condori-Fernandez et al. 2020; Doumen et al. 2021; Halttu and Oinas-Kukkonen 2021). In total, we identified 18 studies to form our knowledge base in addition to the theoretical foundation provided by the PSD model.

3.3.5.5 Elicit Meta-Requirements

As Möller et al. (2020b) have pointed out, eliciting meta-requirements is the upstream stage prior to formulating design principles, yet „only a few studies employ the concept meta-requirements" (Möller et al. 2020b, p. 214). Therefore, and in accordance with the definition that Oinas-Kukkonen and Harjumaa (2009) provide in the PSD model, we elicit meta-requirements from concepts included in the identified knowledge base, whether these concepts be referred to as design principles or as requirements. We identified 125 such concepts from which to extract certain aspects of meta-requirements; 28 from the PSD model and 97 additional concepts from the studies of the knowledge base. It is worth noting that none of those studies used a specific formulation schema to develop their design principles.

Two researchers with practical experience in developing BCSS (Steinherr 2021 and Merz 2022) further classified the 125 concepts based on the four categories of the PSD model and the aim of each concept (Table 13). As the concepts of the PSD model are not systematically selected (Wiafe et al. 2014), we aggregated them with the additional concepts to form overarching meta-requirements grouped in accordance with their shared aims. For example, because personalization and customization "both aim to achieve the same objective of tailoring systems, although with different approaches" (Orji et al. 2019, p. 327), we assigned them both to the meta-requirement of adoption. Likewise, other high-level concepts, such as tunneling and tailoring, are incorporated in other principles, such as reduction and self-monitoring. Identifying the aspects of those meta-requirements was an iterative process that included the formulation of meaningful design principles (section 3.3.5.6).

Table 13: Categories of the PSD model juxtaposed with their aims and aggregated concepts

Category	Aim of the category	Aggregated aspects of meta-requirements
Primary task support	support behavioral change towards the target behavior	guidance, monitoring, goal-setting, adoption, simulation, and rehearsal
Dialogue support	motivate with feedback	praise, rewards, and trigger
Credibility support	make the design of a system credible	appealing visual design and trustworthiness
Social support	motivate with social influence	formation of groups, interaction, and comparison

3.3.5.6 Formulate Design Principles

Having examined the knowledge base of 125 concepts and the aggregated aspects of meta-requirements, we formulated 14 design principles in the four categories of the PSD model by applying the design principles schema proposed by Gregor et al. (2020). Table 14 presents the components of the design principles schema of Gregor (2006) and the examples that Gregor et al. (2020) used for the purpose of demonstration. Furthermore, it shows how we applied the schema to the example of the design principle rehearsal. See Table 16 for an overview of the sources we used for those design principles.

Table 14: Application of the design principles schema

Components	Example presented by Gregor et al. (2020, p. 1635) (based on Moody 2009)	Example of design principle rehearsal
Aim and **actors** (implementer, user, enactor)	For designers and researchers (implementers) "to design cognitively effective visual notations" (aim) for use by diagram creators and diagram users (users)	For researchers and developers (implementers) to allow BCSS (enactor) to expose users (users) to possible effects of the target behavior and to give users the opportunity to gain experience (aim),
Context	in software engineering	when forming, altering, or reinforcing attitudes behavior, or act of complying without using deception, coercion, or inducements
Mechanism	ensure there is a 1:1 correspondence between semiotic constructs and graphical symbols	introduce the users to increasingly challenging experiences in a training environment
Rationale	because doing so avoids the anomalies of symbol redundancy, symbol overload, symbol excess, and symbol deficit, based on theory, including Goodman's (1968) theory of symbols.	because rehearsing a behavior can enable users to change their attitude or behavior in the real world.

Gregor et al. (2020) suggest five components of design principles: aim, actors (implementers, users, and enactors), context, mechanism, and rationale. In our application, the components actors and context are consistent across all design principles for BCSS. Therefore, the actors (i.e., implementors, users, enactors) are overarching for all suggested design principles for BCSS: we consider the implementers as researchers and developers of BCSS. BCSS themselves are enactors that "perform actions as part of the mechanisms that are used to accomplish the aim" (Gregor et al. 2020, p. 1633). This is in line with Gregor et al. (2020) who specify that enactors themselves can be systems. "Users are those whose aims are to be achieved" (Gregor et al. 2020, p. 1633), which is in this sense of the word that we regard users of BCSS.

The context specifies the "boundary conditions, implementation stetting, further user characteristics" (Gregor et al. 2020, p. 1633). In our case, the context is determined for all design principles by the definition of BCSS as systems that "form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements" (Oinas-Kukkonen 2010a, p. 6).

In addition to the components actor and context, Gregor et al. (2020) emphasize the components aim, mechanism, and rationale in design principle formulation. The mechanisms are activities, actions, processes, or architectures designed to achieve or enable the aim (Gregor et al. 2020). While the design principles within the PSD model describe the mechanism in rather vague terms (e.g., "by providing means for action", (Oinas-Kukkonen and Harjumaa 2009, p. 492), our design principles are detailed and provide tangible mechanisms, such as that to "introduce the users to increasingly challenging experiences in a training environment", Table 14). In order to justify the knowledge inherent in the design principles, the design principles schema demands the formulation of a rationale. Such a rationale may be based on theories or empirical justification of the design principle (Gregor et al. 2020).

The following four tables (Table 16 - Table 19) are assigned to the four categories of the PSD model (primary task support, dialogue support, credibility support, and social support) and present our 14 design principles for BCSS, formulated in accordance with the design principles schema displayed in Table 14.

Since the implementer, enactor, and context presented in Table 14 and Table 15 are overarching for all design principles of BCSS, we did not reiterate them in the presentation. Rather, we decided to render the knowledge base as transparent as possible by listing the references that justify each component of our design principles.

Table 15: Overarching components of our design principles

Implementer	Researchers and developers of BCSS
Enactor	BCSS
Context	when forming, altering, or reinforcing attitudes, behavior, or act of complying without using deception, coercion, or inducements

Table 16: Design principles of the category primary task support

Guidance	
To allow BCSS to reduce the users' effort of performing the target behavior,	Oinas-Kukkonen and Harjumaa 2009
guide users by providing tailored information and tasks	Harjumaa and Muuraiskangas 2014; Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013; Karekla et al. 2019
because guidance reduces barriers to the acquisition of experience and brings users closer to their target behavior step by step.	Harjumaa and Muuraiskangas 2014; Orji and Mandryk 2013
Monitoring	
To allow BCSS to provide users with an assessment of their progress towards the target behavior,	Oinas-Kukkonen and Harjumaa 2009; Valk et al. 2017
track their performance and status, and present information on both past and current states	Orji et al. 2019; Valk et al. 2017; Doumen et al. 2021
because monitoring shows users their adherence to the target behavior and encourages them to 'stay on track'.	Doumen et al. 2021; Karekla et al. 2019
Goal-Setting	
To allow BCSS to direct users to take purposeful actions toward the target behavior,	Asbjørnsen et al. 2019
recommend challenging and specific goals and/or invite users to set challenging and specific goals	Orji et al. 2019; Orji and Mandryk 2013; Valk et al. 2017
because, based on the goal-setting theory, specific and challenging goals lead to higher performance, consistency, and commitment.	Böckle and Yeboah-Antwi 2019; Doumen et al. 2021; Halttu and Oinas-Kukkonen 2021; Locke and Latham 1991, 2002
Adoption	
For BCSS to be tailored to the users' characteristics and preferences to reach the target behavior,	Orji et al. 2019; Schneider et al. 2016
offer personalized content and services and/or provide opportunities to customize content and services	Harjumaa and Muuraiskangas 2014; Karekla et al. 2019
because adoption incorporates the individual needs and choices of users, which makes the system more persuasive.	Corbett 2013; Oinas-Kukkonen and Harjumaa 2009; Orji et al. 2014; Schneider et al. 2016
Simulation	
To allow BCSS to expose users to the benefits of the target behavior,	Oinas-Kukkonen and Harjumaa 2009
simulate the effects of performing a certain behavior	Orji and Mandryk 2013
because a simulation is more persuasive when it lets users observe the link between cause and effect.	Oinas-Kukkonen and Harjumaa 2009

Rehearsal	
To allow BCSS to expose users to possible effects of the target behavior and to give users the opportunity to gain experience,	Oinas-Kukkonen and Harjumaa 2009
introduce the users to increasingly challenging experiences in a training environment	Orji and Mandryk 2013
because rehearsing a behavior can enable users to change their attitude or behavior in the real world.	Oinas-Kukkonen and Harjumaa 2009

Table 17: Design principles of the category dialogue support

Praise	
To allow BCSS to give motivational feedback to users for the purpose of encouraging them to make further progress,	Asbjørnsen et al. 2019
offer praise in the form of words, images, symbols, or sounds	Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013
because a system that offers praise can make users become more open to persuasion.	Oinas-Kukkonen and Harjumaa 2009
Rewards	
To allow BCSS to give credit to users when they perform the target behavior,	Harjumaa and Muuraiskangas 2014
provide virtual rewards, such as badges, special features, or scores (or, on the contrary, remove them as a form of punishment)	Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013
because the prospect of reinforcement (or removement of reinforcement) strengthens the motivation to adhere to the target behavior.	Orji and Mandryk 2013
Trigger	
To allow BCSS to prompt a stimulus that elicits the target behavior from users,	Orji and Mandryk 2013
notify them with messages, reminders, alerts, and suggestions at the right time and place	Doumen et al. 2021; Mintz and Aagaard 2012; Oinas-Kukkonen and Harjumaa 2009; Valk et al. 2017
because "without an appropriate trigger, behavior will not occur even if both motivation and ability are high" (Fogg 2009, p. 3).	Fogg 2009

Table 18: Design principles of the category credibility support

Appealing Visual Design	
To allow BCSS to have a competent and credible look and feel that is pleasing to users,	Condori-Fernandez et al. 2020; Karekla et al. 2019
implement the user interface, Including the language and interaction design, so that it is appealing to users and corresponds to their preferences as well as their familiar environments (highly dependent on the target group)	Halttu and Oinas-Kukkonen 2021; Oinas-Kukkonen and Harjumaa 2009
because visual experience and the attractiveness of the visuals make a persuasive system more usable and likable, which increases the users' willingness to interact with it.	Böckle and Yeboah-Antwi 2019; Halttu and Oinas-Kukkonen 2021
Trustworthiness	
To allow BCSS to be perceived as credible and to provide trustworthy interventions to users,	Karekla et al. 2019; Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013
present information that is truthful, fair, and unbiased, and ensure that this information is based on evidence, experience, and competence by referring to credible sources, such as endorsements by authoritative organizations or experts	Doumen et al. 2021; Karekla et al. 2019; Oinas-Kukkonen and Harjumaa 2009
because trustworthiness firms the persuasiveness of the system more persuasive and the user more likely to comply with the target behavior.	Halttu and Oinas-Kukkonen 2021; Oinas-Kukkonen and Harjumaa 2009

Table 19: Design principles of the category social support

Formation of groups	
To allow BCSS to use elements of social influence on users,	Orji and Mandryk 2013; Schneider et al. 2016
provide the formation of (peer) groups or teams	Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013
because the formation of groups has a normative influence and encourages reciprocity among users, as a result of which the likelihood of adopting a target behavior increases.	Böckle and Yeboah-Antwi 2019; Halttu and Oinas-Kukkonen 2021
Interaction	
To allow BCSS to stimulate social encouragement and social facilitation and cooperation among users,	Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013
provide functions for communication, recognition, and interaction, such as messaging or sharing opportunities	Alkhushayni and McRoy 2016; Asbjørnsen et al. 2019; Harjumaa and Muuraiskangas 2014; Meedya et al. 2019; Oinas-Kukkonen and Harjumaa 2009; Valk et al. 2017
because a greater sense of human contact, appreciation, and sharing of experiences have a positive impact on motivation, accountability, and commitment.	Karekla et al. 2019

Comparison	
To allow BCSS to enable social comparisons among users,	Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013
give them the opportunity to observe and compare the behaviors and achievements of others, for instance, by using competitive elements	Oinas-Kukkonen and Harjumaa 2009; Orji and Mandryk 2013; Valk et al. 2017
because comparison promotes social learning and encourages users to follow the lead of their fellow users.	Böckle and Yeboah-Antwi 2019; Halttu and Oinas-Kukkonen 2021; Oinas-Kukkonen and Harjumaa 2009

3.3.5.7 Evaluation

Considering the iterative and theory-focused nature of this study, we conclude this iteration by evaluating the design principles using existing BCSS as demonstration examples (Aier et al. 2011; Oinas-Kukkonen and Harjumaa 2009). In order to codify design knowledge, it is imperative to first ensure that one's design principles are "correct in form" (Möller et al. 2020b, p. 215) and thus fit to prescribe a specific action. We ensured this by following the design principles schema proposed by Gregor et al. (2020), a tried and tested method of determining prescriptive statements. The second factor to ensure is that the design principles are "adequately general" (Möller et al. 2020b, p. 215), which we deem them to be by virtue of their broad application context and our aggregation of 125 concepts into 14 design principles.

Following Aier et al. (2011) and Oinas-Kukkonen and Harjumaa (2009), we evaluate our formulated design principles by examining their real-world application. While this is not a comprehensive evaluation, it provides a "proof of concept", as suggested by Gregor and Hevner (2013), since it demonstrates that, although our design principles are predicated on theoretical work, they can be applied in a practical system, and usefully so. To ensure their wide application within the field of persuasive systems, we selected three representative BCSS in different domains: The Adidas running app Runtastic (adidas AG 2021) is currently among the most popular and most downloaded apps in the health industry (Mertala 2020), so it serves as a suitable demonstration of how the results of this study can be applied in practice. To adequately reflect the main application area of BCSS, the health context (Merz and Ackermann 2021), we also include the Weight Watchers App (WW International Inc 2021) as one of the best-known apps for healthy nutrition. We complete our evaluation by adding a third BCSS from the application domain of sustainability and environmental protection, Eevie (eevie GmbH 2021). Table 20 describes the context of the three selected BCSS.

Table 20: Context of selected BCSS

Components	Runtastic	Weight Watchers	Eevie
Context	when forming, altering, or reinforcing attitudes, behavior, or act of complying without using deception, coercion, or inducements **towards more exercise**	when forming, altering, or reinforcing attitudes, behavior, or act of complying without using deception, coercion, or inducements **towards healthier eating choices**	when forming, altering, or reinforcing attitudes, behavior, or act of complying without using deception, coercion, or inducements **towards more sustainable behavior**

Following the design principle schema of Gregor et al. (2020) and our formulated design principles, the three selected BCSS represent the enactors. The contexts are determined by the theoretical background of BCSS and specified by the application domain of the individual system. To evaluate the applicability and implementation in real-world design concepts (Gregor et al. 2020), we study whether and how the selected BCSS implement the 14 design principles. Table 21 presents an overview of our formulated design principles and describes the implementation of the corresponding mechanism within the selected BCSS.

For the purpose of demonstration, we chose established and successful BCSS as examples. Our analysis indicates that the design principles are widely used in real-world design contexts. Indeed, they are incorporated by at least two of the BCSS considered here. Most of them are implemented by all three demonstration examples; whereas the design principles interaction, rehearsal, and simulation are implemented by two of the selected BCSS. Furthermore, we observe that the 14 design principles comprise the major persuasive mechanisms of each BCSS. This indicates that our design principles cover a significant number of practical design contexts. Moreover, those design principles convey underlying design knowledge in such a way that they can be generalized for a broad domain of application. Therefore, our evaluation demonstrates that the design principles that we derived from practical studies and theories are applicable in an extensive range of real-world scenarios.

Table 21: Application of design principles as demonstration examples

Design Principle	Runtastic	Weight Watchers	Eevie
Guidance	Different training plans tailored to various skill levels, from beginners to marathon runners	A plan tailored for the individual user based on personal preferences and current lifestyle	Guided questions and tasks introduce users to the topic and functions of the app
Monitoring	Post-run overview of duration, distance, pace, elevation gain, and calories burned	Overview of weekly performance, including the consumed vegetables and water as well as the activities and sleep trends	Carbon dioxide footprint in tons per year, sustainable activities per week
Goal-Setting	Set personal fitness goals (e.g., to run 20 km per week)	Select personal lifestyle goals (e.g., weight reduction and/or healthy habits) and activity goals (e.g., steps per day)	Select from a variety of goals (e.g., upcycling, organic food choices, packaging-free products) including weekly goals
Adoption	Personal profile and option to adjust additional functions, such as reminders	Personal profile, including personal food preferences and functions, such as reminders	Personal profile and selection of habits that users want to change (e.g., save electricity)
Simulation	-	Before and after pictures, discussions in communities	Effects of sustainable habits on personal carbon dioxide footprint
Rehearsal	Recommended training activities increase over time	Adaptive goals and tasks related to personal progress	-
Praise	Weekly push notifications that praise users for completed activities	Praise for users' activities and changes	Encouraging feedback (e.g., well done, you saved energy)
Rewards	Allocation of points for a completed activity	Allocation of points for a completed activity or a healthy food choice	Allocation of points in form of seedlings (e.g., for inviting friends)
Trigger	Push notifications to remind users to go for another run	Push notifications to give users a timely call to action, weekly check-ins	Push notifications with advice, reminders, and hints
Appealing Visual Design	A design that echoes the look and feel of popular apps, such as Instagram and Facebook	A balanced design of images and text elements	A clear design with the familiar app bar at the bottom of the screen to navigate between different pages
Trustworthiness	Health information with reference to research institutions, such as the American Psychological Association	Information refers to research papers	Background information about sustainable projects, including pictures, videos, and FAQs
Formation of Groups	Option to join communities with shared goals (e.g., run 30 km per month), or add friends	Weight loss groups that participants can join to give and receive social support	Option to join communities within organizations, or add friends

Design Principle	Runtastic	Weight Watchers	Eevie
Interaction	Function to comment on completed activities of peers or give them a "like"	Feed page that shows updates of other app users and lets users react	-
Comparison	Feed page and various ranking lists that let users compare their own performances with those of their peers	Voluntary challenges set in communities, chance to share and compare experiences on forums	Comparison of one's own carbon dioxide footprint with those of peers in the user's country and worldwide

3.3.6 Discussion

Gregor et al. (2020) called for fellow researchers to use their design principles schema to formulate functional design principles and to observe how researchers and designers act upon their conceptual schema. To contribute to the discourse of formulating design principles, we describe our point of view: We found the design principles schema to be immediately applicable after we obtained a thorough understanding of its underlying concepts and aspects of the knowledge base upon which we developed our design principles for BCSS. The components of the schema provide a comprehensible structure to ensure that the design principle conveys the detailed information required.

In particular, including the aim of each design principle helps to focus on its essence, whereas the rationale ensures that the design principle is justified. In our review, we found that there is an ambiguous understanding about design principles, and studies often fail to distinguish between their aim, mechanism, and rationale. As a result, concepts based on design knowledge lack standardization and are often governed by design principles with overlapping aims. This is in accordance with the findings of Gregor et al. (2020) as well as Merz and Ackermann (2021). Consequently, we identified 125 concepts, including 28 requirements of the PSD model, and aggregated them into 14 explicit design principles. This aggregation is based on their shared aim according to the components of the design principles schema of Gregor et al. (2020).

In our application of the schema, we found the components of the actors and context to be consistent across all design principles for BCSS: We consider BCSS as the enactors of the mechanism, the implementors as researchers and developers of BCSS, and users as users of those BCSS. While the context of the design principle constitutes an essential aspect of codifying knowledge in design principles, we developed a set of design principles that address the comprehensive context of persuasive systems. However, the design principle schema allows for different levels of abstraction of design principles and specifically encourages to contemplate and contribute by defining that context. We understand that this promotes both transferability and usability of the codified design knowledge.

Möller et al. (2020b) provide a method to extend the body of design knowledge by systematically developing design principles. They differentiate between two approaches: a reflective approach that extracts design principles from the design of an artifact, and a supportive approach that derives design principles from literature by studying meta-requirements. As Möller et al. (2020b) observe, however, „only a few studies employ the concept meta-requirements while extracting design principles" (Möller et al. 2020b, p. 214). Moreover, usually meta-requirements are determined when designing an instantiation of an artifact (Möller et al. 2020b). Therefore, we presume that requirements might be present in a reflective development approach rather than in the supportive development approach we chose for this study (described in section 3.3.5.3). Accordingly, we mainly derived the design principles based on existing concepts of design principles.

Considering the existing knowledge base of design knowledge on persuasive systems, we observed that the literature is ambiguous in formulating design principles, such as that it lacks standardization of names and clear differentiation between similar or overlapping principles. This observation confirms the insights of Gregor et al. (2020) as well as those of Merz and Ackermann (2021). However, when we assembled concepts and compared insights, we found a consensus on the meanings of design principles. It is this consensus on which we proceeded to aggregate all relevant aspects into 14 design principles.

Nonetheless, there are proposed design principles for which the literature presents diverging results. Some studies as well as the PSD model propose the design principle of competition because competition can evoke positive reinforcement in the form of increased motivation, attention, and satisfaction (Mohadis et al. 2016; Oinas-Kukkonen and Harjumaa 2009; Orji et al. 2019). However, competition can also negatively impact users of BCSS when it induces fear or a perception of failure (Bartlett et al. 2017; Mohadis et al. 2016). The same applies to the issue of denying users their accustomed rewards as a form of punishment. While this can induce motivation, it can also have adverse effects, such as frustration or dejection (Orji and Mandryk 2013). Given the lack of consensus on these issues, we did not want to accentuate competition and negative reinforcement as design principles, but we did not want to neglect them either. Hence, we concluded not to formulate specific design principles about those concepts but rather to encase them as mechanisms in the broader terms of comparison and feedback.

3.3.7 Implications

Following a systematic approach, we present 14 design principles for persuasive systems that provide explicitly formulated prescriptive knowledge on how to design BCSS. Those design principles convey actionable mechanisms for persuasive systems in order for them to achieve their aim based on the identified rationales. This allows designers and developers of BCSS to build on our accumulated design knowledge when creating, implementing, and evaluating persuasive systems (Baskerville et al. 2018). The implications are: 1) our findings impact the design of new artifacts as a foundation and provide guidance as to which aspects should be considered and implemented. 2) The design principles can be applied to existing systems where they can serve as an evaluation framework to identify the untapped potential of existing persuasive systems. Comparing the design principles with existing systems might show that the investigated system broadly comprises persuasive mechanisms – or it might reveal further aspects that were not yet considered in the original design. Consequently, 3) the design principles also provide a foundation to advance existing systems, specifically how to extend and supplement support functions in order to increase a system's effectiveness and impact.

Although our attention here is focused on design principles for persuasive systems, we want to encourage and stimulate discussions on how those design principles affect IS in general. Already, Fogg (2003) identifies computers and technology as inherently social actors that impact the decisions and behavior of their users. As of today, this is all the more true as technology is near enough ubiquitous and affecting "human behavior with values and norms" (Maedche 2017, p. 300; Richter et al. 2018). However, other points of view consider that "persuasive systems can be supportive and engaging, but may lead to addiction" (Maedche et al. 2019, p. 540). Considering BCSS in their definition as support systems that aim to "form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements" (Oinas-Kukkonen 2010a, p. 6), we argue for the positive and encouraging role that such systems play when they enable or support users in their desired actions and behaviors. Consequently, while we consider our design principles to be particularly significant to BCSS, we also believe them to be generally applicable to systems designed with the intent to achieve corresponding aims of the formulated design principles.

Supplementing this implication, we emphasize to thoughtfully consider persuasive features of IS in daily life. Even though persuasive systems are usually voluntary and non-coercive, systems that affect human behavior can be found in most areas of modern life

(Alt et al. 2021). These systems have the power to shape many of the beliefs, thoughts, and actions of their users (Alt et al. 2021; Maedche 2017; Oinas-Kukkonen and Harjumaa 2009). Given this impact follows the responsibility to contemplate the actual and potential effects along with their long-term consequences for users and employees. While technology affects human behavior, not every behavioral change is beneficial, nor is it necessarily healthy. Among manifold other risks associated with the use of technology, it can lead to technostress (Ayyagari et al. 2011; Califf et al. 2020), addiction (Maedche 2017), and privacy and security issues (Price and Cohen 2019; Smith et al. 2011). This is true in people's private lives as well as in their working lives (Richter et al. 2018; Spiekermann 2016). Hence, systems with persuasive elements have the potential to support well-being and fitting behavior but users (including employees and managers) should become more aware of underlying persuasive mechanisms that might lead to involuntary, unhealthy, and unintended behavior. These issues are further discussed in research fields regarding responsible and ethical IT innovation (e.g., Alt et al. 2021; Spiekermann 2016).

3.3.8 Conclusion

Persuasive technology in the form of BCSS influences the attitudes and behaviors of its users as well as promotes high practical values, such as personal, social, or organizational benefits. To develop meaningful and effective BCSS, however, it is critical to build on existing design knowledge. The current range of design knowledge about BCSS lacks a systematic codification of this knowledge. We address this research gap by developing explicitly formulated design principles for the domain of persuasive systems that provide a codification of design knowledge. By applying the method for design principle development by Möller et al. (2020b) and the design principles schema of Gregor et al. (2020), we develop 14 design principles. Those design principles provide a specification of the widely used PSD model by Oinas-Kukkonen and Harjumaa (2009) by explicitly elaborating aim, actors, context, mechanism, and rationale regarding each design principle. Our design principles provide developers and implementers of BCSS with guidance in form of an overview and insights into the underlying aims, mechanisms, and rationales of each design principle. Furthermore, researchers can adapt and use our design principles to clearly communicate identified design knowledge as well as to evaluate and extend their designs.

Despite our best efforts to ensure the highest standard of academic rigor, this paper is subject to some inevitable limitations: First, we base our method on a literature review that might miss potentially relevant studies. However, by extending a systematic literature review that incorporates several interdisciplinary databases with a wide search string, we are confident that we cover a sufficiently wide range of articles presenting design knowledge about BCSS. Second, we evaluate the design principles only using a short argumentation and a demonstration example based on popular persuasive systems. This does not claim to meet the standards of a thorough evaluation but rather represents an initial proof of concept, as suggested by Gregor and Hevner (2013). Further, expert interviews, user feedback, and instantiations should augment this study as well as evaluate whether the 14 formulated design principles are understandable and useful for researchers and developers of BCSS (Möller et al. 2020b). By investigating and developing design principles for persuasive systems, we envision extending and codifying current design knowledge about persuasive systems in order to facilitate the creation of meaningful BCSS.

4 Essays on the Design of Behavior Change Support Systems towards Knowledge Documentation

4.1 Essay 6: Gestaltung eines Behavior Change Support Systems für nachhaltige Wissensdokumentation

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4.1.1 Zusammenfassung

Dokumentation ist erforderlich, um Wissen zu bewahren, wenn Mitarbeiter nicht mehr verfügbar sind oder Informationen vergessen werden. Es wurden bereits viele Anwendungssysteme und Methoden entwickelt, um Wissen zu dokumentieren. Diese werden jedoch im Arbeitsalltag nur unzureichend genutzt, sodass Schäden entstehen, die vermeidbar gewesen wären. Um diesem Missstand entgegenzuwirken, soll ein Behavior Change Support System (BCSS) das Bewusstsein und Verhalten von Anwendern adressieren. Einem Design-Science-Research-Ansatz (DSR) folgend gilt es zu untersuchen, wie ein solches BCSS gestaltet sein sollte, um Anwender zu veranlassen, Wissen zweckmäßig und nachhaltig zu dokumentieren. Der Beitrag beschreibt die Grundidee, die derzeitige Gestaltung mit dem Ziel Problembewusstsein zu bilden, und das weitere Vorgehen im laufenden Forschungsprojekt.

4.1.2 Einleitung

Dokumentation von Wissen ist essentiell, um Mitarbeitern Fachwissen und Erfahrungen zugänglich zu machen und damit Arbeitsleistung zu steigern (Fromm 2017; Alavi and Leidner 2001). Informationen und Erfahrungswerte sind häufig an einzelne Menschen gebunden und gehen verloren, wenn Personen, die relevante Erfahrungen gesammelt haben, z. B. wegen Stellenwechsel, hoher Arbeitslast oder Krankheit für einen persönlichen Austausch nicht verfügbar sind oder sich nicht mehr an entscheidende Details erinnern können (Lehmann 2018; Jennex and Bartczak 2013). Folgen eines derartigen

Wissensverlusts sind unter anderem Wiederholung von Fehlern, Kompetenz- und Leistungsverlust, erhöhte Projektkosten sowie Unsicherheit und Stress bei Mitarbeitern mit weiteren negativen, etwa gesundheitlichen, Auswirkungen (Owen et al. 2004; Ferenhof et al. 2016).

Um Wissen zu erfassen, gibt es bereits Werkzeuge und Systeme, wie To-Do-Listen, Wikis und Prozessdokumentationen (Tsui et al. 2006; Olivera 2000; Metzinger 2017) sowie Methoden und Theorien, auf welche Art Wissen dokumentiert werden kann und sollte (Lehmann 2018; Tsui et al. 2006; Nonaka and Takeuchi 1995). Doch trotz dieser Lösungen bestehen in der betrieblichen Praxis Defizite, Wissen zweckmäßig zu dokumentieren (Kautz and Mahnke 2003), weil Anwender Wissensdokumentation durch ihr Verhalten nicht geeignet umsetzen. Ursachen sind unter anderem mangelnde Motivation und unzureichendes Bewusstsein für den zukünftigen Nutzen (Almeida et al. 2016; Chen et al. 2018; Matzler et al. 2011), sodass Wissensdokumentation oft als großer, unattraktiver Aufwand empfunden wird.

Um Wissensdokumentation für Mitarbeiter attraktiv zu machen und Potentiale bestehender Unterstützungssysteme nachhaltig zu nutzen, soll ein Behavior Change Support System (BCSS) als Ausgestaltung von Persuasive Technology das Verhalten von Anwendern adressieren. Da die Gestaltung eines BCSS für Wissensmanagement nach unseren Recherchen[1] bisher nicht explizit untersucht wurde, stellt sich die Frage: *Wie sollte ein BCSS gestaltet sein, um Anwender zu veranlassen, Wissensdokumentation nachhaltig umzusetzen?*

Um diese Frage zu beantworten, wird basierend auf Design Science Research (DSR) nach Hevner et al. (2004), Hevner (2007) und Peffers et al. (2007) ein BCSS als Artefakt entwickelt, welches gemäß den Veränderungsphasen (*Stages of Change*) von Prochaska et al. (1993) hilft, Problembewusstsein zu bilden, Ziele zweckmäßig zu formulieren, Methoden zur Dokumentation von Wissen situationsspezifisch zu wählen und nachhaltige Handlungen aufrechtzuerhalten. Dieses Modell von Prochaska et al. (1993) ist in der Psychologie weitverbreitet und häufig validiert (Sarkin et al. 2001). Da es Problembewusstsein als ersten Schritt und Grundstein von Verhaltensänderung nennt, liegt der Fokus in diesem Research-in-Progress-Beitrag darauf, das BCSS in dieser Phase zu gestalten.

[1] Eine Literaturrecherche in den Datenbanken ABI/INFORM Collection (5), ACM Digital Library (29), AIS eLibrary (13), Business Source Premier (1) und IEEE Xplore (8) mit dem Suchterm *(Titel:"Behavior Change Support System" OR (Titel:"Persuasive Technology" AND Abstract:behavior))* ergab 56 Treffer über Verhaltensänderung.

4.1.3 Theoretischer Hintergrund

Problembewusstsein adressieren Prochaska et al. (1993) in ihrem Modell der Verhaltensänderungsphasen als "the stage in which people are aware that a problem exists and are seriously thinking about overcoming it but have not yet made a commitment to take action." (Prochaska et al. 1993). Bestehende Unterstützungssysteme im Wissensmanagement[2] setzen erst nach dieser Phase ein und fokussieren sich darauf, Anwender bei der Wissenshaltung und -verteilung sowie bei der operativen Arbeit zu unterstützen (z. B. Prozess-Management-Systeme, Electronic Performance Support Systems).

Mit diesen gegebenen Mitteln setzen Vorgesetzte meist auf extrinsische Motivation, um Mitarbeiter zu veranlassen, ihr Wissen zu dokumentieren, ohne sie von dem Nutzen einer zweckmäßigen Dokumentation zu überzeugen (Alavi and Leidner 1999). Erachten Mitarbeiter mit entsprechendem Bewusstsein Wissensaustausch jedoch selbst als wertvoll, statt durch externe Anreize, wie monetäre Entlohnung, motiviert zu sein, geben sie Erfahrungen und Informationen öfter, qualitativ besser (Stenius et al. 2016) und langfristiger (Andriessen 2006) weiter.

Systeme und Untersuchungen zu Verhaltensänderung[1] finden sich bisher überwiegend im Gesundheitsbereich. Die meisten dieser Systeme beruhen auf dem Persuasive System Design Model (PSD-Modell) von Oinas-Kukkonen and Harjumaa (2009). Das Modell definiert einen theoretischen Rahmen zur Entwicklung von BCSS und schlägt Methoden und Gestaltungsmerkmale zur Umsetzung der Verhaltensänderung vor. Solche Merkmale sind unter anderem Selbst-Monitoring, Bereitstellen von Fachwissen, Vorschläge, Gamification und soziale Vergleichbarkeit. Diese Gestaltungsmerkmale nutzend, fördern die Systeme Bewusstseinsbildung beispielsweise, indem sie Anwendern gezielt aufbereitete Informationen, regelmäßige Rückmeldungen über die eigenen Leistungen und die Leistungen anderer, sowie Erfolgserlebnisse geben (z. B. Oyibo 2016; Nguyen et al. 2018).

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[2] Durchgeführt wurde eine Literaturstudie mit 130 Treffern in den Datenbanken ABI/INFORM Collection (61), ACM Digital Library (16), AIS eLibrary (14) und Business Source Premier (39) mit dem Suchterm *Titel:(„Support System" AND knowledge)* und eine unstrukturierte Recherche über Wissensmanagementsysteme mit einer Suchmaschine.

4.1.4 Gestaltung des BCSS zur Bildung von Problembewusstsein

Ziel des BCSS in der hier betrachteten Phase ist es, Problembewusstsein zu wecken und so die Grundlage für eine Verhaltensänderung zu schaffen. Aufbauend auf bestehenden Systemen und den vorgeschlagenen Gestaltungselementen des PSD-Modells verbindet das BCSS Gamification mit strukturierten und gezielten Informationen zu Selbst-Reflexion.

Um für die Bewusstseinsbildung alle Funktionen von Wissensdokumentation abzudecken und eine spielerische Umgebung zu schaffen, wurden Szenarien gemäß der „Bausteine des Wissensmanagements“ von Probst and Romhardt (1997) (z. B. Wissenserwerb, Wissensentwicklung) entwickelt, in denen Wissensdokumentation eine Rolle spielt. Anwender reagieren auf die Szenarien mit der Auswahl aus Antwortmöglichkeiten und identifizieren eine Wunsch-Situation. Der Rückbezug auf die tatsächliche Lage baut auf dem Reflexionszyklus von Gibbs (1988) auf, welcher unter anderem die Phasen Beschreibung, Gefühle, Evaluation und Erstellung eines Handlungsplans umschließt. Diese Reflexionsfragen geben gezielt Impulse, systematisch die derzeitige Wissensdokumentation und ihren Nutzen zu reflektieren.

So können Anwender in kurzer Zeit zielgerichtet und eigenverantwortlich einen Widerspruch zwischen Vorstellungen, gegebener Situation und Handeln identifizieren und damit Problembewusstsein erlangen (gemäß der Theory of Cognitive Dissonance von Festinger 2001). Die Eingaben ermöglichen zudem in den nächsten Phasen der Verhaltensänderung eine Personalisierung des BCSS. Abbildung 1 stellt beispielhaft ein Szenario mit jeweils ersten Reflexionsfragen dar.

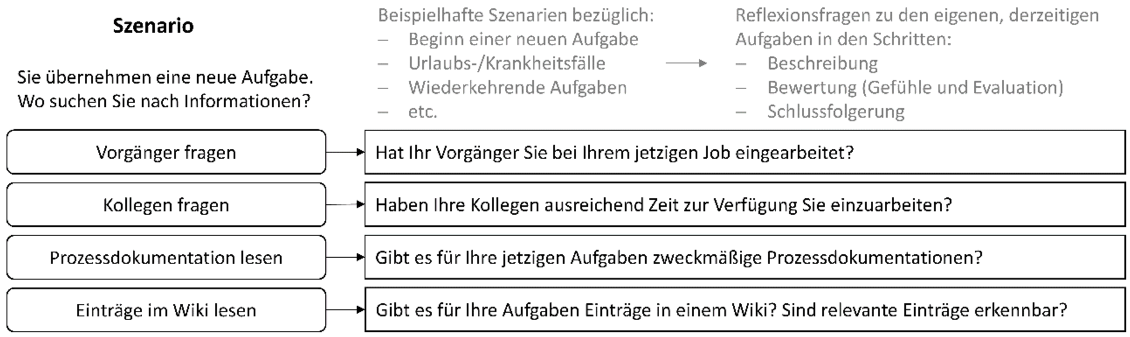

Abbildung 1: Geführte Reflexion als initiales Design der ersten Phase des BCSS

4.1.5 Evaluation und weiteres Vorgehen

Als Vorstudie dienen im weiteren Vorgehen qualitative Befragungen von Führungskräften und Mitarbeitern dazu, die Szenarien und Antworten weiterzu-entwickeln und zweckmäßig auszuwählen. Anforderungen an das BCSS in dieser Phase sind, dass Anwender das BCSS einsetzen und Problembewusstsein entwickeln, indem sie den Nutzen von Wissensdokumentation höher einschätzen als vor Verwendung des BCSS. Da Davis et al. (1989) in ihrem Technology Acceptance Model derartige Konstrukte prüfen, wird das Design in Anlehnung an dieses Modell evaluiert werden. Abbildung 2 skizziert ein mögliches Vorgehen mit einer Test- und einer Kontrollgruppe. Gemäß dem Vorgehen im DSR sind die Ergebnisse der Evaluation Grundlage zu identifizieren, wie das BCSS weiterentwickelt und verbessert werden kann.

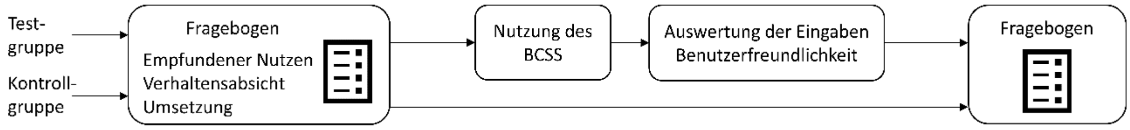

Abbildung 2. Evaluationsdesign mit Test- und Kontrollgruppe im Zeitverlauf

4.1.6 Ausblick

Im Gesamtziel soll das BCSS alle fünf Phasen der Verhaltensänderung von Prochaska et al. (1993) abdecken. Tabelle 1 gibt einen Überblick über die Phasen, Ziele und mögliche Umsetzung durch das BCSS. Das finale BCSS soll keine bestehenden Wissensmanagementsysteme ersetzen, sondern dazu beitragen, dass diese Systeme zweckmäßig und nachhaltig genutzt werden. So soll Wissensverlust entgegengewirkt und Wissensdokumentation attraktiver gemacht werden, indem das BCSS Anwender motiviert und Anhaltspunkte zur Auswahl und Konfiguration zweckmäßiger Systeme und Werkzeuge gibt (Phase 3); in den späteren Phasen soll unter anderem durch adaptive Ziele und Selbst-Monitoring eine regelmäßige und nachhaltige Umsetzung von Wissensdokumentation erzielt werden.

Phase		Ziele des BCSS	Umsetzung
1	Vorbesinnung	Situation ermitteln,	Reflexion im Szenario und eigener Situation
2	Kontemplation	Bewusstsein wecken	
3	Vorbereitung	Ziele festlegen, konkrete Schritte und Handlungen bestimmen	Selbstbestimmtes Auswählen von Zeit und Umfang, Auswählen der Systeme und Werkzeuge
4	Aktion	Schritte und Handlungen unterstützen	Vorschläge bei Tätigkeiten, Erinnerungen, Selbst-Monitoring, Anpassen von Zielen, Gamification
5	Erhalt		

Tabelle 1. Überblick über die fünf Veränderungsphasen und die Umsetzung im BCSS

4.2 Essay 7: Bewusstseinsbildung und Verhaltensänderung für Wissensdokumentation

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4.2.1 Zusammenfassung

Technische Lösungen für die Umsetzung von Wissensmanagement vernachlässigen bislang häufig das Bewusstsein und Verhalten der Nutzer. So werden Aktivitäten zur Dokumentation von Wissen nur unzureichend im Arbeitsalltag integriert und als unattraktiver Aufwand empfunden. Um die individuelle Einstellung und das Verhalten der Nutzer in den Fokus zu stellen und die nachhaltige Umsetzung von Wissensdokumentation zu unterstützen, stellen wir ein Behavior Change Support System (BCSS) für Wissensdokumentation vor. Das Artefakt führt Nutzer durch die Phasen der Verhaltensänderung (Kontemplation, Vorbereitung, Aktion, Erhaltung) und dient dazu, bestehende Wissensmanagementsysteme zu ergänzen. Der vorgestellte Prototyp *wissensguide* ist verfügbar als Web-, Android- und iOS/Testflight-App. Ziel dieses Beitrags ist die Vorstellung des Konzepts und der Implementierung des Designs. Eine initiale Evaluation deutet auf die Akzeptanz bei Nutzern und das Potential des Artefakts hin.

4.2.2 Einleitung

Wissensmanagement ist ein essentieller Baustein innovativer Unternehmen, um sich weiterzuentwickeln und auf bestehende Errungenschaften aufbauen zu können (Buck et al. 2021; Alavi and Leidner 2001). Ohne den Erhalt und die zweckmäßige Weitergabe von Wissen bleiben unter anderem Potentiale und Synergieeffekte ungenutzt, Fehler werden wiederholt und Mitarbeiter sind leistungsschwächer und unzufriedener (Ferenhof et al. 2016; Massingham 2018). Weil Wissen und Erfahrungen häufig an einzelne Mitarbeiter gebunden sind, besteht das Risiko, dass Wissen und Informationen bei Stellenwechsel, Krankheit oder temporärer Arbeitslast oder Abwesenheit nicht verfügbar sind oder entscheidende Details vergessen werden (Lehmann 2018; David 2018). Daher ist die Dokumentation und Weitergabe von Wissen integrativer Teil einer Organisation, um Wissensverlust zu vermeiden (Al Saifi 2015).

Obwohl Unternehmen und Führungskräfte weitreichende organisatorische und technische Maßnahmen ergreifen, bestehen weiterhin Defizite in der praktischen Umsetzung von Wissensdokumentation, da die individuelle Einstellung und das Verhalten der Mitarbeiter häufig vernachlässigt werden (Almeida et al. 2016; Matzler et al. 2011). Auch ausgereifte technische Lösungen (z. B. Wissensmanagement-, Taskmanagementsysteme, Wikis) setzen eine Umsetzung und zweckmäßiges Verhalten der Mitarbeiter voraus (Kautz and Mahnke 2003). Oftmals greifen Führungskräfte auf extrinsische Motivation (z. B. monetäre Vergütung) zurück, um Mitarbeiter zu Handlungen zu bewegen, wodurch jedoch keine nachhaltige Verhaltensänderung erreicht wird (Chen et al. 2018). Ohne den zukünftigen Nutzen von Wissensdokumentation und das individuelle Bewusstsein der Mitarbeiter in den Fokus zu stellen, wird Wissensdokumentation somit als unattraktiver Aufwand empfunden und nicht in das Verhalten und den Arbeitsalltag integriert.

Ziel dieses Prototyps ist es daher, beim Verhalten der Mitarbeiter anzusetzen und zu untersuchen, wie ein Behavior Change Support System (BCSS) Anwender veranlassen könnte, Wissensdokumentation nachhaltig umzusetzen, und ob dieses von Anwendern akzeptiert und genutzt werden würde (Kim 2015). Um das Bewusstsein für Wissensdokumentation zu stärken und eine Verhaltensänderung zu begleiten, führt das BCSS Nutzer durch die Phasen der Verhaltensänderung (Kontemplation, Vorbereitung, Aktion, Erhaltung) (Prochaska and Norcross 2001; Prochaska et al. 1993) und soll so bestehende Wissensmanagementsysteme ergänzen.

Um flexibel einsetzbar zu sein und das Konzept unabhängig untersuchen zu können, haben wir das Artefakt in einem ersten Schritt als Prototyp alleinstehend implementiert, das heißt ohne Integration in ein funktionales Wissensmanagementsystem. Der Prototyp ist als Flutter-Applikation (Google Inc.) *wissensguide* mobil verfügbar als Web[3]-, Android[4]- und Testflight-App für iOS. Die Ergebnisse einer initialen Evaluation mit 15 Anwendern anhand des Technology Acceptance Models (TAM) (Davis 1985) deuten auf Akzeptanz und Potential des Artefakts hin. Dieser Beitrag stellt das Konzept und die Gestaltung des Prototyps vor und soll Wissenschaftlern und Praktikern ermöglichen,

[3] https://wissensguide.web.app/

[4] https://play.google.com/store/apps/details?id=com.wissensguide.wissensguide

Bewusstseins- und Verhaltensbildung für Wissensdokumentation zu erfahren, zu diskutieren und in diesem und anderen Anwendungskontexten weiterzuentwickeln.

4.2.3 Theoretischer Hintergrund

Wissen existiert als implizites Wissen, das inhärent an Personen gebunden ist, und als explizites, kommunizierbares Wissen. Das SECI-Modell (Nonaka and Takeuchi 1995) konzeptualisiert die Zusammenhänge von implizitem und explizitem Wissen. Demnach entsteht explizites Wissen durch Externalisierung und Kombination von Wissen, was unserem Konzept der Wissensdokumentation entspricht. Um den gesamten Umfang des Wissens-managements abzubilden, beschreiben Probst and Romhardt (1997) „Bausteine des Wissensmanagements“, wie beispielsweise Wissensidentifikation, -nutzung, und -bewahrung. Im Modell der Wissenstreppe zeigt North (2021) die Hierarchie im Wissens-management, wie aus Daten Information und Wissen werden, und Wissen durch Handlung und Kompetenz Wettbewerbsfähigkeit schafft. Dieser Entstehungsprozess veranschaulicht die Rolle von Umsetzung und Motivation zu handeln, um eine wissensbasierte Wertschöpfung zu erreichen.

Persuasive Technology unterstützt die freiwillige Veränderung von Verhaltensweisen (Oinas-Kukkonen and Harjumaa 2009) und BCSS sind Instanziierungen von Persuasive Technology (Oinas-Kukkonen 2010a). Die Wirkungen von BCSS beziehen sich auf Compliance, Verhalten und innere Einstellung und können diese sowohl formen, verändern als auch verstärken (Oinas-Kukkonen 2013). Das am häufigsten verwendete theoretische Rahmenwerk für die Entwicklung von BCSS ist das Persuasive Systems Design Modell (PSD-Modell) (Otyepka 2018; Merz and Ackermann 2021).

Für die Umsetzung unseres Artefakts verknüpfen wir die Grundsätze von Persuasive System Design mit den psychologischen Grundlagen des Transtheoretischen Modells (Prochaska and DiClemente 1982) und den Phasen der Verhaltensänderung (*stages of change*, Prochaska and Norcross 2001). Dieses Modell ist in der Psychologie weit verbreitet und validiert (Sarkin et al. 2001) und fasst Verhaltensänderung als Prozess auf, bei dem Phasen der (Prä-)Kontemplation, Vorbereitung, Aktion und Erhaltung durchlaufen werden. Jede dieser Phasen hat bestimmte Anforderungen und profitiert von bestimmten Strategien, die einen Übergang in die nächste Phase fördern (Prochaska and Norcross 2001). So ist es für eine nachhaltige Verhaltensänderung nötig, Problembewusstsein zu bilden, konkrete Schritte und Ziele zu bestimmen, sowie diese initial und langfristig umzusetzen (Abbildung 3).

BCSS werden basierend auf Gestaltungsmerkmalen des PSD-Modells bereits erfolgreich im Gesundheits- und Nachhaltigkeit/Umwelt-Bereich eingesetzt und untersucht (z. B. Salvi et al. 2018; Corbett 2013; Bartlett et al. 2017). Häufig fokussieren BCSS jedoch erst die Phase der Aktion und den Übergang zur Erhaltung von Verhalten (Ludden and Offringa 2015). Unser Konzept, insbesondere die ersten Phasen der Verhaltensänderung miteinzubeziehen, wurde bisher von Franco and Alision (2019) als theoretisches Konzept und von Ludden and Offringa (2015) im Rahmen einer Gesundheits-Studie (Trinken von Wasser) vorgeschlagen. Die Verbindung der Phasen der Verhaltensänderung mit Wissensmanagement ist nach unseren Literaturrecherchen nach dem Vorbild von Merz (2020)[5] bislang nicht untersucht und neuartig. Unser Beitrag ist somit eine Exaptation im Sinne von Gregor and Hevner (2013).

Abbildung 3. Aufbau des BCSS in vier Leveln (in Anlehnung an Merz 2020)

4.2.4 Aufbau und Gestaltung des Artefakts

Um die einzelnen Phasen der Verhaltensänderung zielgerichtet mit den Mitteln von Persuasive Technology unterstützen zu können, stellen wir den Prozess im Artefakt als einzelne Level dar. Jeder Level unterstützt den Nutzer spezifisch darin, die nächste Phase zu erreichen. Abbildung 3 stellt den Aufbau des Artefakts dar. Das Konzept und ins-

[5] Wiederholt und ergänzt wurden Literaturstudien über BCSS und Persuasive Technology und Unterstützungssysteme für Wissensmanagement mit den Suchtermen *(Titel: ("Behavio$r Change Support System" OR "Persuasive Technology" OR "Persuasive System"))* mit 127 Suchergebnissen und *(Titel: ("Support System" AND knowledge)* mit 230 Ergebnissen in den Datenbanken ABI/Inform Collection (18 / 66), ACM Digital Library (47 / 10), AIS eLibrary (28 / 16), Business Source Premier (16 / 42) und IEEE Xplore (18 / 96). Beide systematischen Literaturstudien wurden ergänzt durch unstrukturierte Recherchen mit Google(-Scholar).

besondere das Design des ersten Levels basiert auf den Überlegungen von Merz (2020). Abbildung 4 gibt einen Überblick über die einzelnen Bausteine des Artefakts.

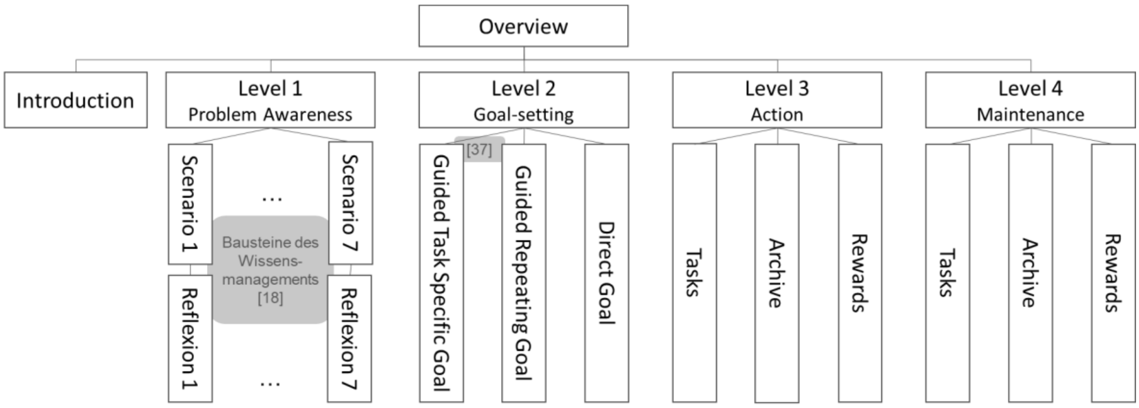

Abbildung 4. Navigationsstruktur des Artefakts (Sitemap)

4.2.4.1 Level 1 – Bildung von Problembewusstsein

Gemäß den Phasen der Verhaltensänderung (Prochaska and Norcross 2001) ist Problembewusstsein der erste Schritt und Grundstein von Verhaltensänderung. Ziel der Bewusstseinsbildung in diesem Level ist es, Bewusstsein für Wissensdokumentation zu fördern und Problembewusstsein zu bilden. Das Artefakt bietet dafür Szenarien, in denen sich der Nutzer durch Antwortmöglichkeiten in Wunsch-Szenarien einordnet, und durch eine geführte Reflexion einen Rückbezug auf die aktuelle Situation herstellt. Um das breite Spektrum von Wissensdokumentation abzudecken, bauen die Szenarien auf den „Bausteinen des Wissensmanagements“ (Probst and Romhardt 1997) auf. Die Reflexionen folgen dem Reflexionszyklus von Gibbs (1988), welcher gezielte Impulse zu Reflexion der Situation (Beschreibung), Gefühle, Analyse und Handlungsplan gibt. Somit können Nutzer gemäß der Cognitiv Dissonance Theory (Festinger 2001) zum Nachdenken und Reflexion über die verschiedenen Facetten von Wissensdokumentation angeregt werden und ein möglicher Widerspruch zwischen Vorstellungen, gegebener Situation und Handeln wird ins Bewusstsein gerufen.

4.2.4.2 Level 2 – Zielsetzung

In der nächsten Phase der Verhaltensänderung werden konkrete Schritte und Ziele gesetzt, welche für das Zielverhalten umgesetzt werden sollen. Um den Nutzer zu unterstützen, selbstständig möglichst spezifische und herausfordernde Ziele zu setzen (Locke and Latham 2002), führt das Artefakt durch einen Prozess, der den Nutzer anleitet, bei der Zielsetzung verschiedene Aspekte wie Unterpunkte, geschätzte Zeit, Dokumentationsform und Deadline zu berücksichtigen (Merz and Hurm 2022). Wir unterscheiden dabei zwischen einmaligen Zielen, die sich auf eine bestimmte Aufgabe beziehen, und sich wiederholenden (bspw. täglichen oder wöchentlichen) Zielen. Nach Erstellung von einem Ziel haben die Nutzer die Möglichkeit, den geführten Zielsetzungsprozess abzukürzen.

4.2.4.3 Level 3 und 4 – Aktion und langfristiges Handeln

Im Weiteren unterscheiden die Phasen der Verhaltensänderung (Prochaska and Norcross 2001) zwischen initialem Umsetzen der Handlungen (Phase der Aktion) und dem Beibehalten und regelmäßigen Wiederholen des Verhaltens (Phase der Erhaltung). Das Artefakt bietet zur Unterstützung beider Phasen Funktionen des Selbst-Monitoring, Erinnerungen und Elemente von Gamification. Schließt der Nutzer drei Wochen hintereinander mindestens je ein Ziel ab, wird Level 4 erreicht. Durch diese gewählte Zeitspanne soll der Übergang in Level 4 herausfordernd, aber nicht zu weit in der Zukunft liegen.

4.2.5 Evaluation

Die Akzeptanz und Nutzungsabsicht eines BCSS ist Grundanforderung an ein innovatives Artefakt und daher sollte dies in einem frühen Schritt untersucht werden (Kim 2015). Um die Akzeptanz und das Potential zu untersuchen, haben wir den Prototyp zur Nutzung zur Verfügung gestellt und anhand des TAM (Davis 1985) die Akzeptanz durch die Konstrukte Nutzungsabsicht, empfundene Nützlichkeit und Benutzerfreundlichkeit und die Relevanz gemäß Venkatesh and Davis (2000) abgefragt. Aufgrund der Verfügbarkeit und des Entwicklungsstands des Artefakts befragten wir in einem ersten Schritt Studierende, welche die Zielgruppe nur unzureichend abbilden, jedoch erste Hinweise aus Sicht von Nutzern geben können. Durch einen Fragebogen nach einem Monat an 77 Nutzer haben wir von 15 Nutzern anonym Feedback erhalten. Abbildung 5 präsentiert die Ergebnisse und Analyse als Strukturgleichungsmodell und die Werte der direkten Einschätzung.

Abbildung 5. Ergebnisse der Evaluation anhand des TAM (Davis 1985) (MW = Mittelwert)

Die Fragen zur Messung der Konstrukte zeigen gute Werte ($\alpha > 0.83$). Die Mittelwerte der Ergebnisse deuten auf eine Akzeptanz und empfundene Relevanz des Artefakts hin und zeigen, dass eine starke Beziehung zwischen empfundener Nützlichkeit und Nutzungsabsicht besteht. Die Beziehung zwischen Benutzerfreundlichkeit und Nutzungsabsicht ist hingegen nicht signifikant. Dies ist in Übereinstimmung mit anderen Untersuchungen von BCSS (Steinherr 2021). Die direkte Einschätzung zeigt, dass die Stärke des Prototyps darin liegt, Bewusstsein für Wissensdokumentation auszubilden. Die niedrigen Werte zur Beeinflussung des Handelns lassen sich durch die fehlende Einbindung in ein Wissensmanagementsystem erklären.

4.2.6 Limitationen und Weiterentwicklung

Das vorgestellte Artefakt setzt beim Verhalten von Anwendern an, um als BCSS Verhaltensänderung bezüglich Wissensdokumentation zu unterstützen und ist als Prototyp unter dem Namen *wissensguide* als mobile App umgesetzt. Mit Elementen von Persuasive Technology werden die Anwender durch die Phasen der Verhaltensänderung begleitet, Bewusstsein zu bilden, zweckmäßige Ziele zu setzen und diese initial und langfristig umzusetzen. Der Prototyp ermöglicht Wissenschaftlern und Praktikern, eine potenzielle Umsetzung und Gestaltung für Wissensdokumentation zu testen, zu untersuchen und als Grundlage für Weiterentwicklungen zu verbessern. Wir haben das Artefakt spezifisch für Wissensdokumentation umgesetzt, jedoch ist die Anwendung von Persuasive Technology grundsätzlich im Arbeitskontext denkbar.

Um das Artefakt zu untersuchen, haben wir als Grundlage für Weiterentwicklungen die Akzeptanz des Prototyps betrachtet (Kim 2015). Ergebnisse einer Evaluation von 15 Studierenden deuten auf grundsätzliche Akzeptanz des Konzepts hin; insbesondere betonen die Ergebnisse, dass die Stärke des Prototyps darin liegt, Besinnung und Bewusstseinsbildung anzuregen, was die Grundlage für Verhalten und Verhaltensänderung ist (Ludden and Offringa 2015; Prochaska and Norcross 2001).

Eine detailliertere Evaluation mit einer größeren Zielgruppe wird weitere Aufschlüsse über positive Aspekte, Nutzen und Gestaltung ermöglichen und durch qualitatives Feedback Hinweise zu zielführenden Gestaltungselementen, Stärken und Verbesserungspotential geben. Um die Benutzerfreundlichkeit zu steigern, wäre beispielsweise die Ergänzung eines Chatbots denkbar (Naim Zierau et al. 2021; Gentner et al. 2020). Zudem gehen wir davon aus, dass alle Nutzer mit dem ersten Level starten. In weiteren Entwicklungen sollte das Potential überprüft werden, Nutzer in ihre aktuelle Phase der Verhaltensänderung einzustufen und entsprechende Funktionen des BCSS daran auszurichten. Entsprechende Untersuchungen zu „Staging-Algorithmen“ gibt es beispielsweise im Gesundheitsbereich (Reed et al. 1997; Guo et al. 2009; Reed et al. 2013).

In der aktuellen Umsetzung wurde das Konzept im Prototyp bisher alleinstehend ohne Einbettung in ein Wissensmanagementsystem umgesetzt, um die theoriebasierte Grundidee unabhängig und initial zu prüfen. Um das BCSS in den Arbeitsalltag einzubinden, müsste das Artefakt in der Weiterentwicklung in ein Wissens-managementsystem integriert oder angebunden werden. Mit der Übertragung der Ziele könnte die Umsetzung dort funktional unterstützt werden. Eine solche Einbindung würde dem Artefakt einen externen Trigger geben (Ludden and Offringa 2015), bestehende Systeme ergänzen und andere Maßnahmen zur Vermeidung von Wissensverlust unterstützen.

Sowohl viele BCSS als auch weitere Systeme im Arbeitsalltag fokussieren sich auf die Unterstützung der Umsetzung und vernachlässigen das Bewusstsein und die Einstellung der Nutzer. Auch wenn Wissensdokumentation nur als Ergänzung anderer Maßnahmen zur Wissensweitergaben dienen kann, soll der Prototyp zu einer Stärkung von Bewusstsein und Verhaltensweisen für Wissensdokumentation führen, um Wissensverlust zu verringern. Wir hoffen, dass das Artefakt Diskussionen und Weiterentwicklungen fördert, Persuasive Technology und die Berücksichtigung von Bewusstseinsbildung und Verhaltensänderung im Arbeitsalltag zu untersuchen und zu integrieren.

4.3 Essay 8: Goal-Setting for Knowledge Documentation using Persuasive Systems Design

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4.3.1 Abstract

Knowledge management and knowledge documentation are essential capabilities of organizations for innovation and competition. While documenting knowledge is often induced by extrinsic motivation, persuasive systems have the potential to change behavior by emphasizing intrinsic motivation. In this study, we explore goal-setting in persuasive systems in a design science project about knowledge documentation and derive 17 design principles from literature and theories. We apply the design principles by creating a process for guided goal-setting and implement the process in a persuasive system for knowledge documentation in form of a mobile application. We evaluated the artifacts in two iterations regarding the realization of the design principles as well as the acceptance and perceived impact of the persuasive system. The study's contribution is both the selection of the design principles, as well as the implementation in the form of a process and a mobile application.

4.3.2 Introduction

Knowledge management is a widespread discipline that evolved into an organizational necessity to realize the potential of organizations and employees (Girard and Girard 2015; Buck et al. 2021). While the technical possibilities of knowledge management systems are widely studied (Manesh et al. 2021), there are deficits in the practical application because users do not integrate knowledge management activities into their behavior (Curtis and Taylor 2018; Kautz and Mahnke 2003). Often users tend to focus on receiving information but are averse to participate by documenting existing or newly acquired knowledge (Kautz and Mahnke 2003). When goals for knowledge documentation are not apparent and clearly defined, we imply that documenting is neglected and not performed purposefully and sufficiently. This leads to loss of knowledge when experienced employees are not available anymore (e.g., retirement, job change, illness) (Jennex and Durcikova 2013) and increases the risk of outdated content in knowledge management systems, which then leads to repetition of errors, loss of competence and performance, as well as increased project costs (Ferenhof et al. 2016). Knowledge documentation is perceived with a high initial threshold especially when users do not have much experience in that context.

Persuasive systems are developed with the aim to impact users' attitudes or behaviors without using coercion or deception (Oinas-Kukkonen and Harjumaa 2009; Fogg 2003). They are instantiated as behavior change support systems (BCSS) (Oinas-Kukkonen 2013). Although knowledge documentation is often induced by external motivation (e.g., monetary rewards), persuasive systems have the potential to focus on an intrinsic point of view changing behavior towards a sustainable application of knowledge management without coercion or deception, reducing external efforts.

While the concept of goal-setting is often applied in persuasive systems (Consolvo et al. 2009; Graml et al. 2011; Fogg 2009), the descriptions of implementations lack details and miss out on supporting goal-setting in a guided form to provide a low threshold for initiating new behavior. Furthermore, we could not identify a BCSS that applies goal-setting in the context of knowledge documentation so far, nor have the design principles of persuasive systems been studied in the context of knowledge documentation. Deriving and presenting design principles transparently gained awareness in the light of emerging issues raised, among others, by Gregor et al. (2020).

Following Gregor and Hevner (2013), this leads to the research gap to investigate an exaptation of persuasive design of goal-setting to knowledge documentation. We therefore strive to answer the following research questions: 1) What is the impact of goal-setting using persuasive systems design in the context of knowledge documentation? 2) What are the design principles for designing such persuasive systems? 3) How can those design principles be applied into a goal-setting process and implemented as a prototype?

To address those questions, we follow the Design Science Research methodology presented by Peffers et al. (2007) to obtain design knowledge and tangible implementations (Klinker et al. 2021) by developing a feasible and applicable artifact with generalizable utility (Peffers et al. 2018): Section 4.3.3 explains how we derived design principles based on a systematic literature review, the Goal- setting theory (Locke and Latham

1991), and the Persuasive Systems Design (PSD) model (Oinas-Kukkonen and Harjumaa 2009), which is the most used framework for developing persuasive systems. We present in section 0 how we applied those design principles in a goal-setting process that guides users to set specific and challenging goals to document their knowledge. We used a mockup to evaluate if the design principles are successfully incorporated in the process as we had intended. Subsequently, described in section 4.3.5, we implemented the process in a mobile application as instantiation of a persuasive system. To investigate the acceptance and impact of the design, and to get detailed insights of the users' thoughts, we evaluated this artifact using observation and semi-structured interviews. We conclude with a discussion (section 4.3.6) and summary (section 4.3.7) of the findings, limitations, and ensuing further research.

Referring to the "Taxonomy of theory types in information systems research" of Gregor (2006), this study contributes as a theory of design and action (type five): It provides researchers and developers with 1) 17 specifically selected design principles for goal-setting in persuasive systems, 2) realization of those design principles in form of a process, as well as 3) implementation as a persuasive system in the context of knowledge documentation. The implementation serves as a proof of concept and initial validation (Fu et al. 2016). Furthermore, the study shows users a structured guide to initiate contribution in knowledge documentation using goal-setting.

4.3.3 Design Objectives and Principles

In this section, we outline the relevant theoretical background and highlight the research gap using a systematic literature review. The design knowledge embodied in the theoretical background and identified literature is used to derive the targeted design principles.

4.3.3.1 Theoretical Background

4.3.3.1.1 Introduction to Goal-setting

Goal-setting is a popular approach to increase motivation and task performance (Locke et al. 1981). There are many advices and how-to guidelines available in the scientific and non-academic literature. However, how to identify fitting goals highly depends on various aspects as individual personal and situational factors (e.g., abilities, endurance, task properties; additionally, this inherently influences what makes a goal "fitting")

(Hollenbeck and Klein 1987). To explore this complexity, researchers and practitioners widely investigated and describe what factors influence goal-setting (e.g., Hollenbeck and Klein 1987; Locke and Latham 1991; Erez and Zidon 1984) and which general properties goals should have (e.g., specific, measurable, achievable, relevant, time-bound Werle Lee 2010). The Goal-setting theory of Locke and Latham synthesizes the relationship between goal attributes and task performance (Locke and Latham 1991, 2002). The practical implications of the Goal-setting theory entail that goals should be 1) specific and 2) challenging; 3) users should set deadlines to increase persistence, and 4) the goal should be adapted to the abilities of the users: for example, in the case of a complex and challenging task, a learning goal (i.e., explore how to do the task) should be preferred over a performance goal (i.e., accomplish the task effectively) (Locke and Latham 2002).

4.3.3.1.2 Challenges in the Context of Knowledge Documentation.

Due to the complexity and various effects of the different aspects, advices on goal-setting might provide information that is too general to users to effectively provide actionable steps or even induce information overload. This is especially problematic when the context to which the goals are to be applied is complex or unfamiliar to the users. It is more difficult to make assessments when the topic is new, which corresponds to the ability to set goals (Earley et al. 1990). Therefore, when users newly approach knowledge documentation, they need closer guidance on what they should consider when setting goals as compared to users with experience in knowledge documentation. In this study, we focus on a guided process that provides a low threshold for initiation of behavior change towards knowledge documentation.

4.3.3.1.3 Design Principles of Persuasive Systems.

Applying goal-setting to persuasive systems has the potential to bring the process of setting goals in a form that is accessible and easily usable for users (Consolvo et al. 2009) without using coercion or deception (Oinas-Kukkonen and Harjumaa 2009; Oinas-Kukkonen 2013). BCSS are instantiated research objects that address users' behavior based on design principles (Oinas-Kukkonen 2013). The most referenced framework for developing BCSS is the persuasive systems design (PSD) model by Oinas-Kukkonen and Harjumaa (Oinas-Kukkonen and Harjumaa 2009) (Otyepka 2018), which considers 28 aspects in four categories: Primary Task Support (e.g., self-monitoring, reduction simple tasks), Dialogue Support (e.g., suggestions, praise), System Credibility Support (e.g., surface credibility, verifiability), and Social Support (e.g., normative influence, social learning) (Oinas-Kukkonen and Harjumaa 2009). The design principles proposed by the PSD model should be selected depending on the context of implementation (Wiafe et al. 2014; Oinas-Kukkonen 2013; Oinas-Kukkonen and Harjumaa 2009), however, the PSD model does not specify the selection of design principles in different application contexts (Wiafe et al. 2014).

In general, Fu et al. (Fu et al. 2016) define a design principle as a "fundamental rule or law, derived inductively from extensive experience and/or empirical evidence, which provides design process guidance to increase the chance of reaching a successful solution." (Fu et al. 2016). Gregor et al. (2020) emphasize the inconsistency of how design principles are formulated and used in research, and categorize design principles into three categories: 1) about user activity, 2) about artifact, 3) both (about user activity and artifact). Design principles in persuasive systems are no exception to general design principles. In this study, we select design principles from the PSD model and supplement this selection with design principles derived from meta-requirements identified in literature and theory on goal-setting (Möller et al. 2020b).

4.3.3.2 Analysis of Related Literature

To systematically review prior research on goal-setting in persuasive systems, we conducted a systematic literature review based on the following review protocol (Boell and Cecez-Kecmanovic 2015): We strive to identify studies that combine the aspects of goal-setting and persuasive systems to later on apply those findings to the context of knowledge documentation. To cover business and information systems research as well as more technical oriented content, we considered the databases ACM Digital Library, AIS eLibrary, IEEE Xplore, and ProQuest ABI/Inform Collection. We conducted a search without time restrictions looking for the terms "behavior change support system" OR "BCSS" OR "persuasive system*" OR "persuasive technolog*" in the Abstract AND "goal-setting" OR "goal setting" in the full text to also include studies that consider goal-setting, but do not describe them as a focus in their abstract. Our search revealed 51 results (6 ACM Digital Library, 23 AIS eLibrary, 16 IEEE Xplore, 10 ProQuest ABI/Inform Collection, minus four duplicates). We are aware that there exists a vast amount of studies on goal-setting outside of persuasive systems. However, considering the variety of results and recurrence of findings in the studies, we are confident that we could identify the most important aspects and explore goal-setting in the context of persuasive systems (Boell and Cecez-Kecmanovic 2014).

Regarding the context of the studies, none of the reviewed studies considers BCSS in the context of knowledge management. The considered contexts of research are mainly health (20 studies) and environmental/sustainability aspects (12 studies) which is in accordance with general findings about BCSS (Wiafe et al. 2014). The most referenced theory on goal-setting is the Goal-setting theory of Locke and Latham (Locke and Latham 1991, 2002); when designing BCSS, most studies refer to the PSD model of Oinas-Kukkonen and Harjumaa (Oinas-Kukkonen and Harjumaa 2009). While the reviewed studies highlight the importance of goals in persuasive systems, none describe specific steps or a process of how the users set their goals. Some studies imply that users set goals without specific guidance, for example, defining a number of steps (Rieder et al. 2019; Akker et al.; Katule et al. 2016) or sleep hours (Wilson et al. 2017) to be reached daily in the context of health. The mentioned design functions for a goal-setting process include tunneling (Shahri et al. 2016), tailoring (Yoganathan and Kajanan 2015), reduction of information (Sunio et al. 2018a), and suggesting a default goal (Oyebode et al. 2020). Those design principles directly refer to design principles listed in the PSD model. Additionally, multiple goals should be prioritized (Ren et al. 2014). Many studies highlight the importance for users to define their goals themselves (Shahri et al. 2016; Vassileva 2012; Wilson et al. 2017; Yoganathan and Kajanan 2013; Paraschivoiu et al. 2020). When users define their goals themselves, the resulting goals are more fitting to the specific needs of the users and the users are also more committed to those goals (Rieder et al. 2019; Vassileva 2012; Yoganathan and Kajanan 2013).

However, while the studies do not describe their specific implementation of the initial goal setting, they often describe following actions as monitoring of goals, reminding users, and giving feedback and rewarding (Harjumaa and Muuraiskangas 2014; Soror and Davis 2014; Ping et al. 2012; Kuonanoja et al. 2015; Langrial et al. 2012). Using self-monitoring and recommendations based on past behavior (Rieder et al. 2020; Rieder et al. 2019; Mohamed et al. 2017; Yoganathan and Kajanan 2013), users should be able to adapt their goals (Paraschivoiu et al. 2020; Sunio et al. 2018a; Oyebode et al. 2020). In this study, we focus on a low threshold for initial actions to set goals in the topic of knowledge documentation as a prerequisite to following actions as the monitoring of behavior.

4.3.3.3 Summarizing the Objectives and Design Principles

This study aims to present a tangible process to guide users to set fitting goals using persuasive system design. To provide users with a low threshold, we focus on supporting the initial goal-setting in a guided form. Considering this focus, we can derive twofold design objectives from literature and theories: 1) design objectives regarding the properties of the goal the BCSS guides the user to set, and 2) design principles for the BCSS itself.

Table 22: Design principles and their sources
(abbreviations: PSD model as PSDm, Goal-setting theory as GST)

	Principle	Short description / requirement	Derived from
about user	Commitment	Users should commit to their goals.	Rieder et al. 2019; Vassileva 2012; Yoganathan and Kajanan 2013
	Personalization	Goals should be set by the users themselves.	PSDm, GST, Shahri et al. 2016; Vassileva 2012; Wilson et al. 2017; Yoganathan and Kajanan 2013; Paraschivoiu et al. 2020
	Prioritizing	Multiple goals set should be prioritized.	Ren et al. 2014
about system	Authority	System should refer to people in the role of authority.	PSDm
	Expertise	System should provide knowledge and expertise.	PSDm
	Liking	System should be visually attractive to users.	PSDm
	Praise	System should offer praise as a form of feedback.	PSDm, Langrial et al. 2012
	Real-world feel	System should provide information of the organization (…) behind its content and services.	PSDm
	Reduction	Behavior should be presented in simple tasks.	PSDm, Sunio et al. 2018a
	Similarity	System should imitate its users in some specific way.	PSDm
	Suggestion	System should offer fitting suggestions/a default goal.	PSDm, Oyebode et al. 2020; Graml et al. 2011
	Surface credibility	Look of the system should convey competence.	PSDm
	Tailoring	Information should be tailored to the users' context.	PSDm, Yoganathan and Kajanan 2015
	Third-party endorsements	System should provide endorsements from respected sources.	PSDm
	Trustworthiness	Information should be truthful and unbiased.	PSDm
	Verifiability	Outside sources should be able to verify information.	PSDm
both	Tunneling	System should guide the user through the process by providing means for action.	PSDm, Shahri et al. 2016

First, to derive the objectives for the goals, we summarize the identified objectives from the Goal-setting theory and related literature. The resulting goals should be: specific, challenging, time-bound, measurable, achievable, relevant, and should favor learning goals over performance goals when the user is not experienced (Locke and Latham 2002; Locke et al. 1981; Werle Lee 2010).

Second, to derive the design principles for the BCSS, we selected applicable design principles from the PSD model (Oinas-Kukkonen and Harjumaa 2009). We excluded the design principles that are not applicable in the scope of goal-setting (e.g., simulation) and that require interaction with other users (e.g., competition) to focus on an individual process. We further supplemented the resulting list (see Table 22) with design principles derived from the Goal-setting theory and the identified literature (section 4.3.3.2). We categorized the design principles to the three categories proposed by Gregor et al. (2020) and summarize our derived design principles in Table 22. Six of the selected design principles of the PSD model correspond with findings from literature (e.g., suggestion, expertise); two design principles are added context-specific (commitment and prioritizing). In line with the PSD model, the short descriptions are formulated in an imperative form (Fu et al. 2016).

4.3.4 Design of Goal-setting Process

Based on the preceding identification of design objectives and principles, we developed a goal-setting process that applies the design principles and guides users to set specific and challenging goals to document their knowledge.

4.3.4.1 Development of Goal-setting Process

Considering the design objectives and principles, we first deduced eight process steps and then sequenced them in a feasible order. Figure 20 shows the resulting goal-setting process and addressed design principles.

To provide the user with background information about underlying theories and examples for each process step, we designed an information button on each screen that accompanies the process. This provides expertise, trustworthiness, authority, third-party endorsements, and verifiability, as well as non-intrusive suggestions and tailored information (i.e., tailoring).

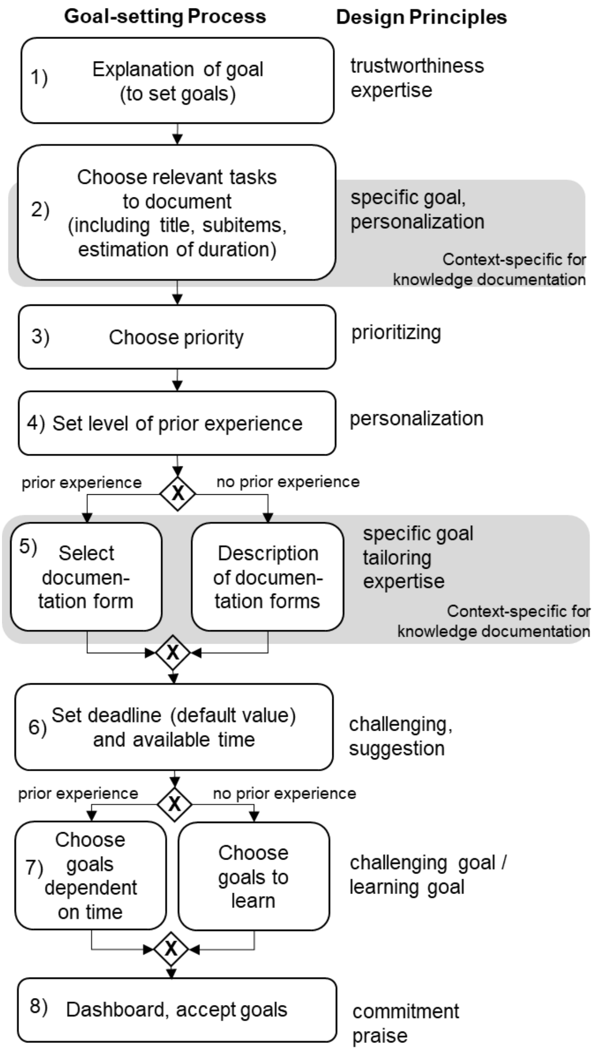

Figure 20: Goal-setting Process and Addressed Design Principles

1) The artifact starts with an introduction to build trust and explain further actions. 2) Next, the user is asked to specify tasks or documents to consider in their documentation. To specify the goal, the artifact requires additional information on subitems and an estimation of duration. 3) After this loose collection, the user can prioritize their list. 4) As knowledge documentation is depending on the form of documentation (structured, semi-structured, or unstructured documentation), the artifact distinguishes between users with experience with those documentation forms and users without. 5) The process follows with a selection if the forms are known, and more information if the forms are unknown. This process step is context-specific to knowledge documentation and should be replaced with necessary content regarding the application domain (e.g., forms of execution, tools). 6) To specify a time-bound goal, the user defines a deadline and assesses, how much time they can invest for knowledge documentation until that deadline. A

deadline of one week is suggested as a default value by the system. 7) Depending on the prior experience, the artifact guides the user to a performance goal or a learning goal. A learning goal provides the user with the possibility to explore their strategy to conduct the task effectively. The performance goal compares the estimated time to complete the documentation with the available time of the user and suggests selecting or deselecting goals accordingly. 8) The goal-setting concludes with a dashboard of the specified goals. The user can accept and is congratulated on setting their goals.

The other design principles (e.g., surface credibility, tunneling, liking) are implemented overarchingly without direct reference to a specific process step.

4.3.4.2 Evaluation of Goal-Setting Process

4.3.4.2.1 Design of Evaluation.

Following, we choose an early evaluation using a mockup to assess if the developed process follows a sequence that is perceived as reasonable and fitting to users and if we fulfilled the implementation of the identified objectives for the goals and design principles (section 4.3.3.3). This evaluation ensures that the designed the goal-setting process is in accordance with the selected design principles and builds a base for an in-depth evaluation of the impact of the design principles in section 4.3.5.2.

We build an interactive mockup in PowerPoint that allows users to trace the process and assess the early design of the artifact. Each step of the goal-setting process was implemented as one screen. We gave the mockup to five users with different levels of experience of knowledge documentation to assess the feedback of users with different levels of familiarity with knowledge documentation (section 4.3.3.1.2): One user stated to have experience, two with some experience, and two without experience. Using a questionnaire for feedback, the users did have no time constraints or surveillance when familiarizing themselves with the mockup.

The questionnaire asked for feedback regarding the order of the process steps, as well as if the objectives and design principles (Table 22) are perceived as fulfilled (three-point Likert scale: fulfilled, partly fulfilled, or not fulfilled). Free text fields allowed for comments and suggestions for improvement regarding each aspect.

4.3.4.2.2 *Results of Evaluation.*

All responses affirmed that the process was perceived as reasonable. 70% of responses rated the objectives and design principles as "fulfilled", 30% "partly fulfilled", and only one design principle was rated "not fulfilled" by one user (<1%, in the aspect of reduction). Tunneling, surface-credibility, and real-world feel were rated especially well and as fulfilled by all users. The results on praise and suggestion are more ambiguous (1x fulfilled, 3x partly fulfilled). The users requested more recommendations on which options should be used in which situation. The aspect of reduction was the design principle rated lowest (2x fulfilled, 2x partly, 1x not fulfilled) as a result of the close guidance. Regarding the objectives for the goals, two users requested more aid and examples regarding the formulation and deadline for a time-bound goal.

The results did not reveal different perceptions of users with experience, with some, and users without experience of knowledge documentation. One user with no prior experience stood out with their detailed feedback and agreed to a follow-up interview further discussing the results and further development.

Following the evaluation, we subsequently added more examples and details, where possible as hints directly on the screens, or using the information button as non-intrusive support. In the mockup, the selection of the deadline was set to one week. In the next iteration, we made sure that the deadline can be personalized while still offering the default suggestion as guidance.

While we only surveyed a small number of users, we obtained detailed feedback for the subsequent development iteration based on users with different levels of experience in the application context. The results confirm that the proposed mockup incorporates the targeted design principles as base for subsequent implementation and assessment.

4.3.5 Design of Persuasive System

In this section, we describe the implementation of the design principles and goal-setting process into a persuasive system in form of a mobile application. We evaluated the system in semi-structured interviews of 20 users with different levels of experience in knowledge documentation to assess the acceptance and impact of the system.

4.3.5.1 Development of Persuasive System

Oinas-Kukkonen and Harjumaa (2009) describe the development of persuasive systems in the PSD model with the three steps: 1) analysis of persuasion context, 2) selection of persuasive design principles and requirement definition for software qualities, and 3) software implementation.

Ad 1) The persuasion context is defined by intent (persuader change type), event (use, user, technology), and persuasion strategy (message, route) (Oinas-Kukkonen and Harjumaa 2009): Our persuasive system intends to initiate contribution in knowledge documentation using goal-setting. To overcome the initial threshold, the system addresses to form a change of complying to a new behavior which helps to achieve a behavior change (Oinas-Kukkonen 2013). We consider users with different experiences in knowledge documentation and aim to provide guidance while considering the complexity and variety in applying goal-setting. Accordingly, we chose a flexible and independent mobile application. The system's strategy aims to persuade by creating goals that enable and stimulate action and contribution (Locke and Latham 2002).

Ad 2) The selection of design principles and following implementation is according to sections 4.3.3 and 0 (objectives for goals, design principles, and process definition).

Ad 3) Based on the goal-setting process and the results of the evaluation of the mockup, we developed a functional application for Android, IOS, and web using the cross-platform development kit Flutter. Analogously to the mockup, each step of the goal-setting process is implemented as one screen. While our artifact was originally in German language, we translated the texts into English for the demonstrating screenshots of the Android version in Figure 21.

4.3.5.2 Evaluation of Persuasive System

4.3.5.2.1 Design of Evaluation.

Since we are addressing a lack of adopting knowledge management systems in the first place, it is essential to also evaluate the acceptance of the persuasive system. Further, we evaluate the impact of the selected and implemented design principles to gain design knowledge and potential for further development.

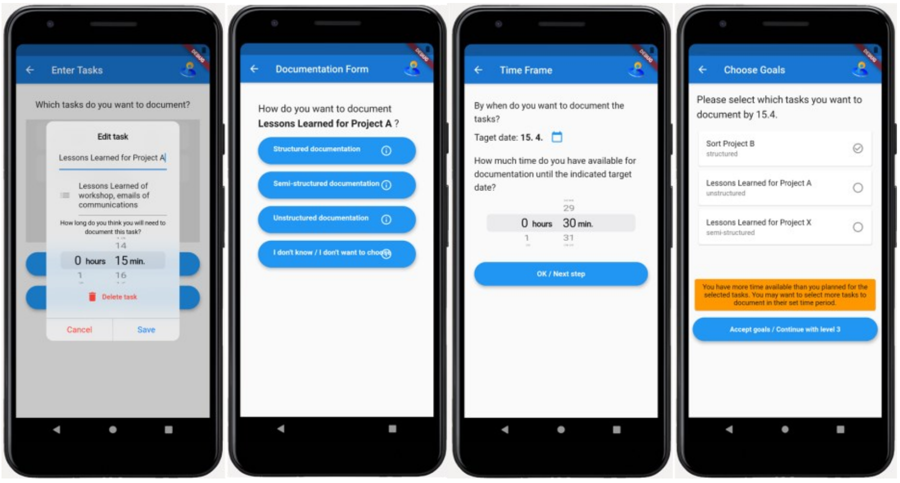

Figure 21: Screenshots from application: process steps 2), 5), 6), and 7)

To obtain detailed insights into the users' utilization and thoughts, we observed the users during familiarization and application of the prototype to their current work and daily tasks. Further, we conducted semi-structured interviews, which allow to investigate specific aspects but also to include more feedback using open questions (McIntosh and Morse 2015). We based the interview questions that assess the acceptance of the persuasive system on the constructs of the Technology Acceptance Model of Davis (1989) (i.e., perceived ease of use, perceived usefulness, intention to use), we further asked about positively and negatively perceived aspects to obtain unbiased feedback on the design. This allows us to assess which design aspects have the most negative and positive impact to the users.

We interviewed 20 users with different levels of experience (twelve male, eight female): two users stated that they had experience in knowledge documentation, seven that they had some experience, and eleven with no experience. The observations and interviews were conducted virtually using the web application, recorded, and the responses were transcribed for the analysis.

4.3.5.2.2 *Results of Evaluation.*

The recordings took 24 minutes on average (min. 12 minutes, max. 40 minutes). Users with no prior experience took more time to familiarize and describe the system (recordings on average 27 minutes) than users with some experience (recordings on average 19 minutes). During familiarization, the users set on average 2.1 goals (min. 1 goal, max. 4 goals).

We analyzed the transcripts and feedback and clustered the responses to measure system acceptance (perceived ease of use, perceived usability, and intention to use, Davis 1989) and which design aspects and objectives of the goal were addressed by the users. We coded the responses regarding the system acceptance to three levels as presented in Table 23.

Table 23: Results Regarding System Acceptance

Aspects	yes	partly	no
Ease of use	19	0	1
Usefulness	17	2	1
Intention to use	11	4	5

Regarding the ease of use, users highlighted the clear structure, understandable explanations, and simple design of the app. Following the linear process, the concept is easily comprehensible. The information button to provide background information about underlying theories and examples was mentioned positively but should be displayed more conspicuously. Inhibitors to ease of use are that users had difficulties prioritizing and estimating the duration of the tasks. Regarding the perceived usefulness, users stated that the app would help them to set goals and especially highlighted their awareness for knowledge documentation and the explanatory texts. As inhibitors of usefulness, the users mentioned the long process and stated that they would need more specific guidance.

The majority stated that they would intend to use the system: Factors are the high relevance of knowledge management and fostered self-management capabilities. However, of the 20 users, four users expressed that they were not sure about using the system or would possibly use the system (assigned in Table 23 to “partly”), five users stated that they do not think they would use the system (assigned to “no”). As inhibitors, six of these users specified a missing integration into a more comprehensive system with more functions than just goal-setting and three users would require direct integration into their team or job, for example, as work instructions.

Regarding the properties of the resulting goal, the users overall perceived that the resulting goals would be specific and challenging (see Table 24, we do not have responses by all users about that aspects).

Table 24: Results about Objectives for Goals

Aspects	yes	partly	no
Specific goal	11	5	1
Challenging goal	13	3	0

While the users mostly stated that the system guides them to define specific and challenging goals, users suggested a more detailed structuring of the goals, for example, in form of categories and subgoals that cover parts of the overall goal as well as intermediate goals. While setting deadlines leads to specific and challenging goals, estimating the duration of tasks was perceived as difficult.

Regarding the assessment of responses from users with different levels of experience in knowledge documentation, all three users that did not perceive the system as useful are of the group of users without prior experience in knowledge documentation. Beyond that, however, we did not identify notable differences in the responses of users with and without prior experience.

4.3.6 Discussion

Investigating how a persuasive system should be designed to guide users to set specific and challenging goals, we followed design science methodology and firstly derived objectives and design principles based on theories and a systematic literature review. We identified 17 design principles that, referring to the categorization of Gregor et al. (2020), mostly (13) describe system features, three of the design principles are about users and one (tunneling) is about both (system and user). During the development of the goal-setting process, we found that we could not assign all design principles to a specific process step, but that some design principles address basic requirements (e.g., surface credibility, expertise, tunneling). We therefore want to bring such general design principles and their implementation to the attention of researchers and developers. The responses to the goal-setting process indicate that we were able to apply the targeted design principles. Although we expected that users without experience might evaluate the artifact differently, the evaluation did not reveal different perceptions. To provide users with a low threshold and clear guidance, examples of goal formulation and wording in the chosen application context are essential. We therefore want to highlight the importance of the design principles suggestion and tailoring of information.

Subsequently, we implemented the goal-setting process into a functional persuasive system. The results of the evaluation indicate users' acceptance of the system regarding perceived usefulness and perceived ease of use. Regarding the intention to use, the results are mixed because of missing integration into other systems and their organizational structures. This indicates that the concept of the artifact is accepted but does not reach its potential as a singular and standalone implementation. Overall, the evaluation confirms the selected design principles and goal-setting process. Further, we observed that design principles are not mentioned directly in the interviews, which emphasizes that design principles are inherent to artifacts. We suggest a distinction between design principles that address basic user requirements (e.g., surface credibility) and those that address user interaction that users are actively conscious of.

Regarding our implementation in the context of knowledge documentation, the results affirm that the developed process and persuasive system guide users to create specific and challenging goals. Besides the identification of positive aspects and issues that should be addressed further, we noted that the depth of detail requires further discussion: While a detailed guidance does not inherently lead to a reduction of steps and time, it can reduce cognitive effort and is especially suitable for initial actions of users with low knowledge in the referring context. The users even stated to require more guidance. In future improvement, different pathways with, for example, shortcuts could provide personalization with different process steps regarding the necessary level of guidance.

Further, estimating the duration of tasks was found to be particularly difficult. To provide additional guidance, the system could provide more tangible suggestions for duration (e.g., how much time one should take to write down lessons learned or document processes) based on learning from inputs.

4.3.7 Summary

This study investigates goal-setting in persuasive systems by selecting persuasive design principles, developing a goal-setting process and implementing it in a mobile application as a persuasive system. Persuasive systems focus on supporting behavior change without using coercion or deception (Oinas-Kukkonen and Harjumaa 2009; Fogg 2003). Deriving specific persuasive design principles for goal-setting therefore provides an intrinsic point of view to goal-setting. We applied the persuasion context to knowledge documentation because knowledge documentation is a complex environment that is perceived with a high threshold and research has not applied goal-setting prominently in the context of knowledge documentation so far.

The findings from designing and evaluating the artifacts emphasize that guidance in this context is an aspect that is perceived as useful and valuable. We present the selection of design principles and apply them in a process as well as a persuasive system. The evaluations did not indicate that users with experience in knowledge documentation perceive the artifacts much differently than users with less experience.

While we conducted the evaluations with only a limited number of participants, we are confident that the detailed answers provide tenable responses and contribute to a greater understanding of designing goal-setting in persuasive systems, especially in the context of knowledge documentation. For the evaluation, we deliberately decided to observe and interview users instead of providing a questionnaire. While this may influence behavior, it provides a high level of detail and insight into the thoughts of the users to assess the acceptance and impact of the system. For further evaluations the artifact should be improved and applied in more practical use cases. In this study, we investigated goal setting as an independent activity to allow for a generalization beyond knowledge documentation. Further development of an artifact should consider functions regarding cooperation and interaction with other users and stakeholders, and integration into other information systems (e.g., calendar, task management systems) and workflows.

Combining persuasive systems and knowledge documentation addresses the behavioral aspects of knowledge documentation and focuses on attitudes and behavior instead of technical aspects. We hope that our findings help researchers and developers to create meaningful persuasive systems and further engage discussions on the implementation of goal-setting.

4.4 Essay 9: Persuasive Systems in the Context of Knowledge Documentation: A Human-centered Approach to Derive Design Principles

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4.4.1 Abstract

Knowledge management and documentation are essential for innovation as well as for preventing loss of knowledge and performance. To mitigate the lack of applying knowledge management activities, extrinsic measures and functional technologies should be supplemented by taking into account users' preferences and perceptions of the situation. Building on the impact of persuasive systems on behavior and attitudes, this study investigates the design of persuasive systems in the context of knowledge documentation. The analysis of responses to reflective questions and topic modeling of user feedback reveal insights into the perception of knowledge documentation. The insights are utilized to extract and formulate design principles and aspects that are identified as important and have a development focus. The study provides researchers and managers with understanding that allows human-centered implementations of the synthesis of personal knowledge sharing and knowledge documentation.

4.4.2 Introduction

Knowledge management, as a core capability of many organizations and a capability that fosters digital innovation itself (Buck et al. 2021), has been subject to major innovations in the last decades, from manual storage of documents to automated gathering of information using artificial intelligence (Di Vaio et al. 2021; Kauschinger et al. 2021; Manesh et al. 2021). However, despite the innovations in knowledge management, there is a lack of utilizing and applying knowledge documentation in organizations (Davenport 1994; Aboelmaged 2018; Pereira et al. 2021). Costs of unsuccessful knowledge documentation are concurrent with loss of knowledge and competence, increased project costs and risks (Jennex and Bartczak 2013), and the repetition of errors (Ferenhof et al. 2016).

Due to its relevance, knowledge management activities are often imposed by extrinsic measures, such as monetary rewards, or social influence. However, employees' actions that do not reflect inner attitudes and perceptions can lead to uncertainty, stress, and decreased performance (Ryan and Deci 2000). While there are plentiful reasons why knowledge management is impeded in organizations, a major part of them is related to human behavior and attitudes (Phung et al. 2016; Cleveland and Ellis 2015; Disterer 2001). This entails that sustaining intrinsic behavior of knowledge management actions builds on human-centered approaches towards benefits and problems (Chen et al. 2018; Ranasinghe and Dharmadasa 2013). Hence, to advance knowledge documentation applied at an individual level, existing measures should be leveraged using human-centeredness, and functional technologies should be supplemented by engaging peoples' awareness of behaviors and attitudes.

Information technology that is designed to change users' behavior and attitudes is considered persuasive technology (Fogg 2003) and implemented in behavior change support systems (BCSS) (Oinas-Kukkonen 2010a). There are promising studies that persuasive systems can be applied in organizational settings and for organizational transformation (e.g., Seidman and McCauley 2009; Nkwo 2019; Li et al. 2017), however, there is a lack of investigating the design of persuasive systems in the context of knowledge documentation, which benefits from a systematic human-centered approach. Therefore, we take a human-centered approach that builds on users' feedback and preferences towards designing persuasive systems in the context of knowledge documentation. We specify the research question: *How should persuasive systems be designed with a human-centered approach in the context of knowledge documentation?*

Answering this question implies a contribution of theory and action using prescriptive statements in the means of Gregor (2006) and Gregor et al. (2020). As design principles serve as prescriptive statements that codify design knowledge indicating "how to do something to achieve a goal" (Gregor et al. 2020, p. 1622), we aim to extract and codify design knowledge in the form of design principles. In order to develop transparently and systematically derived design principles, we follow the method of design principle development of Möller et al. (2020b): Based on an artifact that represents a BCSS for knowledge documentation, we extract design requirements from user feedback and users' input constituting a human-centered approach that reflects users' attitudes and preferences. In this analysis, we identify 1) relevant aspects that should be included in such a BCSS and 2) design aspects for the implementation. Based on the obtained design knowledge, we formulate design principles according to the design principles schema of Gregor et al. (2020).

This study extends the current body of knowledge by exaptation of known solutions to a new domain (Gregor and Hevner 2013), as we contribute by 1) obtaining new insights into the perceptions and preferences regarding knowledge documentation, 2) exploring a state-of-the-art topic modeling technique to reveal design knowledge from user feedback, and 3) derive design principles for knowledge documentation based on user feedback and users' input about their preferences and perceptions of their situation. Our analysis is based on the needs to improve knowledge management but implies insights that are transferable to other organizational contexts of meaningful human-centered systems.

4.4.3 Theoretical Background

This study is grounded on 1) persuasive systems for knowledge management and knowledge documentation, and 2) the development and design principles of persuasive systems. This section summarizes underlying theories and related literature in these research areas.

4.4.3.1 Persuasive Systems for Knowledge Management and Documentation

Knowledge management comprises various activities such as identifying and creating new knowledge, developing new knowledge, storing and retaining, and sharing and utilizing knowledge (Probst and Romhardt 1997; Pawlowski 2013; Manesh et al. 2021). The **knowledge management activities**, as described by Probst and Romhardt (1997), comprise knowledge…

1) goals: giving direction to knowledge activities; either normative, strategic, or operational goals
2) identification: making existing knowledge transparent; supporting knowledge retrieval and search
3) acquisition: acquiring and buying knowledge and skills externally
4) development: creating and approaching new ideas
5) distribution: transferring knowledge and exploiting synergies
6) use: application of existing knowledge and know-how in day-to-day business
7) preservation: protecting the organization from knowledge loss
8) measurement: measuring and controlling the success of knowledge activities

Those activities consider explicit as well as tacit knowledge, with Nonaka and Takeuchi (1995) ascribing the relation between explicit and tacit knowledge creation as socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit), and internalization (explicit to tacit). **Knowledge documentation** refers to externalization and combination when knowledge is articulated and synthesized (Nonaka and Toyama 2017). While knowledge management activities are mostly supported and performed by knowledge management systems, their application grounds on human situational actions (Wiig 2003) and, therefore, their behaviors and attitudes.

Interactive technology that affects users' attitudes and behavior is considered **persuasive** (Oinas-Kukkonen and Harjumaa 2009; Fogg 2003), thus we focus on systems that are persuasive in character. **BCSS** are considered a "key construct for research in persuasive technology" (Oinas-Kukkonen 2010a, pp. 4–5) that aim to "form, alter or reinforce attitudes, behaviors or an act of complying without using deception, coercion or inducements" (Oinas-Kukkonen 2010a, p. 6). Thus, BCSS are not about imposing change but focus to induce internal compliance by providing, for example, trust, tailored information, and feedback (Oinas-Kukkonen and Harjumaa 2009).

As for the **related literature**, persuasive systems are already applied and studied in diverse contexts such as health and disease prevention (e.g., Orji et al. 2019; Asbjørnsen et al. 2019; McKay et al. 2019), education (e.g., Steinherr 2021; Widyasari et al. 2019; Müller et al. 2015), environment (e.g., Böckle and Yeboah-Antwi 2019; Graml et al. 2011; Andersson et al. 2018), and work-life (e.g., Seidman and McCauley 2009; Qudaih et al. 2014). Studies to improve work-life comprise, for example, the aim to increase water consumption at the working place (Profita et al. 2014; Chiu et al. 2014), reduce energy consumption, and foster organizational learning (Kljun et al. 2019) such as security training (Qudaih et al. 2014). Among the variety of application contexts, they show that persuasive systems are applicable to impact behavior in a working environment. However, design principles of persuasive systems for improving knowledge management have not been investigated so far (Merz 2020). Further studies that investigate design principles for knowledge management outside the domain of persuasive systems focus mainly on functional aspects (e.g., Pitt et al. 2017; Schacht and Mädche 2013; Stenmark and Lindgren 2004; Richardson et al. 2006).

4.4.3.2 Development and Design Principles of Persuasive Systems

The persuasive systems design (PSD) model of Oinas-Kukkonen and Harjumaa (2009) is the most commonly referenced framework about how to design BCSS (Merz and Ackermann 2021). The PSD model describes the development process in three steps: analysis of persuasion context, selection of persuasive design principles, and software implementation (Figure 22). The PSD model list 28 design principles in four categories describing system qualities for persuasive systems: 1) primary task support, 2) dialogue support, 3) credibility support, and 4) social support (Oinas-Kukkonen and Harjumaa 2009).

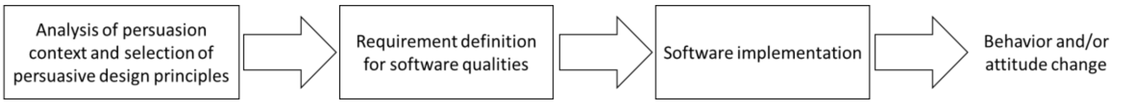

Figure 22: Steps in Persuasive System Development (Oinas-Kukkonen and Harjumaa 2009)

In order to make design knowledge usable and transferable to other systems, design principles serve to specify design knowledge in prescriptive statements (Oinas-Kukkonen and Harjumaa 2009; Gregor et al. 2020; Fu et al. 2016). However, Gregor et al. (2020) elaborated that design principles of information systems are often ambiguously defined and not formulated in a way so that they can contain applicable and transferable knowledge. In particular, while the PSD model suggests 28 design principles for BCSS, those are considered as "not fulfilling the recent research requirements regarding coverage and the specification that design principles should be developed and formulated in a systematic and clear form" (Merz and Ackermann 2021, p. 7) which is in line with the findings of Wiafe et al. (2014) and Gregor et al. (2020).

Furthermore, there is a lack of studies that investigate applicable design principles for the first two stages of change and focus on raising awareness (Merz and Steinherr 2022). Merz and Steinherr (2022) assign the design principles of the PSD model to the stages of behavior change of Prochaska and Norcross (2001) based on theoretical argumentation. Besides some basic requirements of credibility support that are overarching over all stages such as personalization and trustworthiness, they strongly recommend the design principles tunneling, tailoring, simulation, and reminders to gain awareness and intent to change behavior. However, those design principles only consider the design principles that are proposed in the PSD model. Therefore, Merz and Steinherr (2022) provide a foundation for combining the concepts of the stages of behavior change with the PSD model based on theoretical argumentation. In contrast, our study aims to extend the current body of knowledge by developing design principles that reflect the users' preferences using empirical results.

4.4.4 Research Design

Answering our research question, *how should persuasive systems be designed with a human-centered approach in the context of knowledge documentation?* (Section 1), we aim to identify design principles for persuasive systems in the context of knowledge documentation based on users' preferences. In order to systematically develop meaningful design principles, Möller et al. (2020b) suggest two approaches: 1) a supportive approach that is based on literature and existing design principles, and 2) a reflective approach that extracts design principles from the design and evaluation of artifacts. To our knowledge and the literature review of Merz (2020), design principles for persuasive systems in the context of knowledge documentation have not been investigated in literature so far. Therefore, we follow the example of Möller et al. (2020a) and utilize the reflective approach based on an artifact that represents a BCSS for knowledge documentation.

In the reflective approach, the step "extract design principles" is subsequent to the step "design artifact". However, the step "extract design principles" is not further specified by Möller et al. (2020b). While other researchers such as Altendeitering and Guggenberger (2021) and Zschech et al. (2021) employ focus group discussions, we explore an asynchronous approach to extract design principles using users' input and feedback. This asynchronous approach allows to factor in a higher number of responses than using focus groups and therefore to obtain a wide overview of perceptions and feedback.

While the acceptance of a BCSS in the context of knowledge documentation has already been assessed (Merz 2022), the specific design requirements remain a novel research subject. Therefore, for extracting design knowledge from the artifact, we first aim to investigate what should be designed and implemented, and second, how it could be designed and implemented. This comprises that design principles indicate "what [the artifact] should allow the user to do" (Gregor et al. 2020, p. 1629) and "the characteristics it should possess" (Gregor et al. 2020, p. 1629). Subsequently, we utilize the gained knowledge of both analyses to formulate design principles according to the design principles schema of Gregor et al. (2020). As such, we specify the process step "extract design principles" of Möller et al. (2020b), which follows the steps to design the artifact, into the three sub-steps depicted in Figure 23. We further detail the sub-steps in the following.

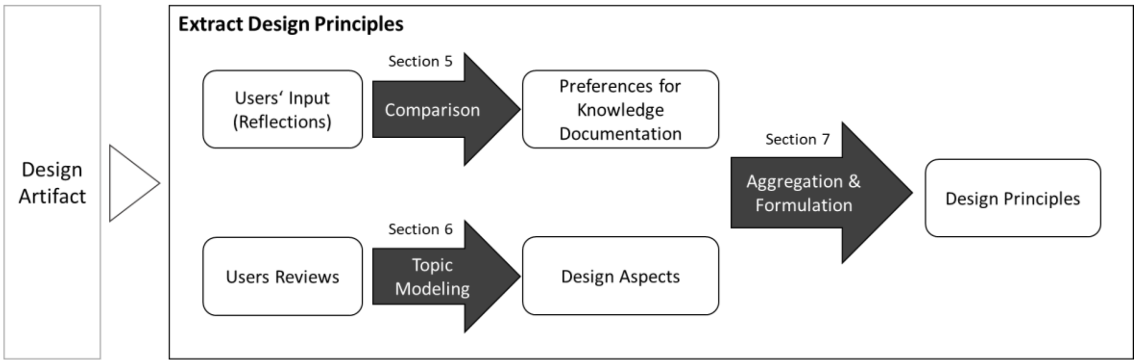

Figure 23: Process of extracting design principles from design and evaluation of an artifact

We first ensure to include relevant practical aspects for deriving the design principles. To achieve this, we examine and analyze data about users' reflection on knowledge documentation which we derive from input to the BCSS. This provides us with insights into users' thoughts and descriptive knowledge about their preferences for knowledge documentation. We describe this analysis in Section 5 (*Extracting Preferences for Knowledge Documentation from Users' Reflections*).

Second, we extract design aspects from user feedback about an artifact, which represents a BCSS for knowledge documentation, using topic modeling combined with sentiment analysis. Topic modeling denotes a type of natural language processing that discovers coherent clusters that can be interpreted as topics in texts such as user reviews and feedback (Pietsch and Lessmann 2018; Jelodar et al. 2019; Cheng et al. 2014). Topic modeling diminishes research bias and ensures consistent results; we further validate and extend the insights by manual screening. A sentiment analysis classifies the polarity of a text towards a positive or negative opinion of the writer (Feldman 2013; Nielsen 2011). The analyzed topics reveal aspects that are most frequently discussed in the user feedback. We imply that those are especially important design aspects to users. We describe this analysis in Section 6 (*Extracting Design Aspects from User Feedback*).

Third, we aggregate the obtained knowledge to derive design principles based on users' preferences and identified design aspects. We formulate the design principles applying the design principles schema of Gregor et al. (2020) that specifies the components of a design principle (aim, implementer, user, context, mechanism, enactors, and rationale). We present the formulation and resulting design principles in Section 7 (*Design Principles for Knowledge Documentation*).

4.4.5 Design of Artifact

The design of the artifact is based on a design science research project that is described by Merz (2020) and Merz (2022). Hence, the design is only briefly summarized here; the structure is depicted in Figure 24. As a BCSS, the artifact is developed based on the PSD model. The structure adopts the stages of behavior change (precontemplation, contemplation, preparation, action, maintenance) of Prochaska and DiClemente (1983) and Prochaska and Norcross (2001) in form of levels that specifically support users to transition to the next stage of behavior change.

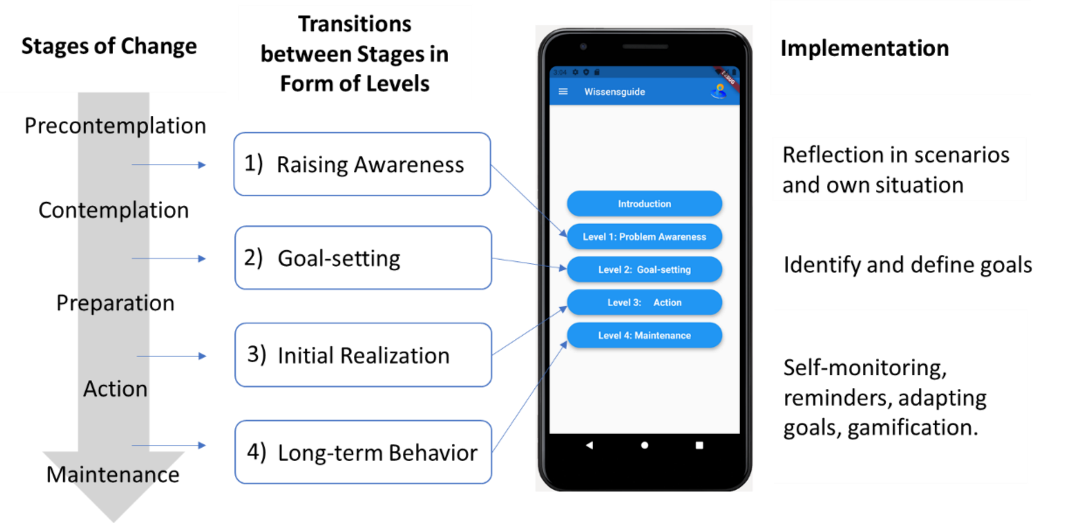

Figure 24: Structure of the artifact adapted from Merz (2022)

The first level uses the reflective cycle of Gibbs (1988) to induce impulses about the description of the situation, feelings, analysis, and conclusion in scenarios that are based on the knowledge management activities of Probst and Romhardt (1997). The second level guides the user to set specific and challenging goals using a goal-setting process of persuasive systems for knowledge documentation (Merz and Hurm 2022). These self-defined goals are forwarded to the subsequent levels: The third and fourth levels support the initial realization of actions and long-term behavior using self-monitoring, reminders, adaption of goals, and gamification elements (Merz and Hurm 2022).

An evaluation of the artifact indicates acceptance and perceived relevance of the artifact; the assessment shows that the strength of the prototype lies in forming awareness for knowledge documentation (Merz 2022). Considering this, we can build on this artifact to identify design knowledge that is inherent to reflection about knowledge documentation and extract design principles that focus on users' perspective and their requirements. That means we focus on users' reflections in the first level and further qualitative feedback on design aspects.

4.4.6 Extracting Preferences for Knowledge Documentation from Users' Reflections

The artifact utilizes reflection to induce contemplation and awareness for knowledge documentation. The input of the users (i.e., choice in scenarios and answers to reflection questions, Figure 25) provides insights into the perceptions of knowledge documentation of users. Therefore, we describe users' recent views on knowledge documentation to investigate important aspects of knowledge documentation.

4.4.6.1 Obtaining Users' Reflections

The artifact guides users with scenarios and reflection questions to contemplate knowledge documentation. To cover a wide range of aspects, the scenarios are based on the knowledge management activities of Probst and Romhardt (1997). These activities comprise knowledge goals, identification, development, distribution, use, preservation, and measurement[6]. In each scenario, users have three to four options to choose their desired preference. When interpreting the results, it is important to note that the users have to decide for the option they are most drawn to, which means that it is not possible to select two options. An overview of the scenarios and reflection questions is depicted in Figure 25; Figure 26 shows the scenarios and reflection questions on the example of the knowledge management activities distribution and use (i.e., scenarios 4 and 5).

The scenarios are presented using a question that sets a context of the knowledge activity where the user selects their preferred option. After the selection of their general preference (i.e., the option that they would desire), the following reflection questions connect the scenario to the current situation of the user in their organization. They guide the users to contemplate questions of the reflective cycle of Gibbs (1988) that comprise 1) description of the current situation, 2) their feelings, 3) the reasons for their feelings, and 4) conclusion about willingness to change. Table 25 specifies the reflection questions.

[6] With a user-centric focus, the activity of knowledge acquisition is excluded because this does not regard to user behavior but refers to recruiting and acquisition.

Scenarios / Knowledge management activities	Choice of desired option
1 Goals	1) Company wide culture 2) Identify future successful knowledge 3) Implementation and specification of knowledge management
2 Identification	1) Ask predecessor 2) Ask colleagues 3) Read process documentation 4) Read entries in company wiki
3 Development	1) Address in a team meeting 2) Remember yourself 3) Make a physical note 4) Store in database / file system
4 Distribution	1) Via team meetings 2) Company wide file system / data base 3) Team internal file system / data base 4) As little as possible / during breaks
5 Use	1) Demonstration by colleague 2) Process documentation 3) Company wiki / external resources 4) Videos and podcasts
6 Preservation	1) Colleagues / successors are trained personally 2) (Process) documentation in detail 3) Roughly / briefly documented 4) Hardly documented
7 Measurement	1) Survey of new and departing employees 2) Quality of knowledge documentation 3) Quantity of knowledge documentation

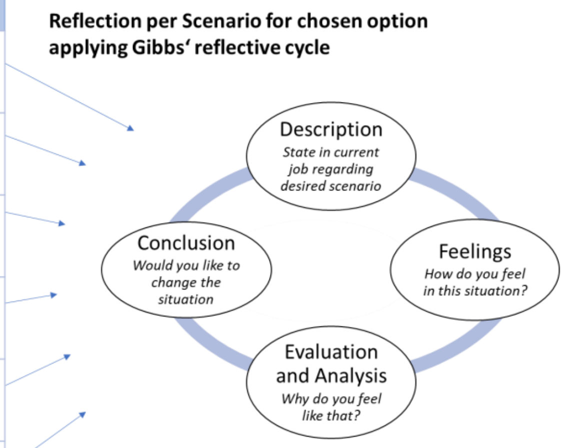

Figure 25: Implementation of scenarios and reflection questions of Level 1

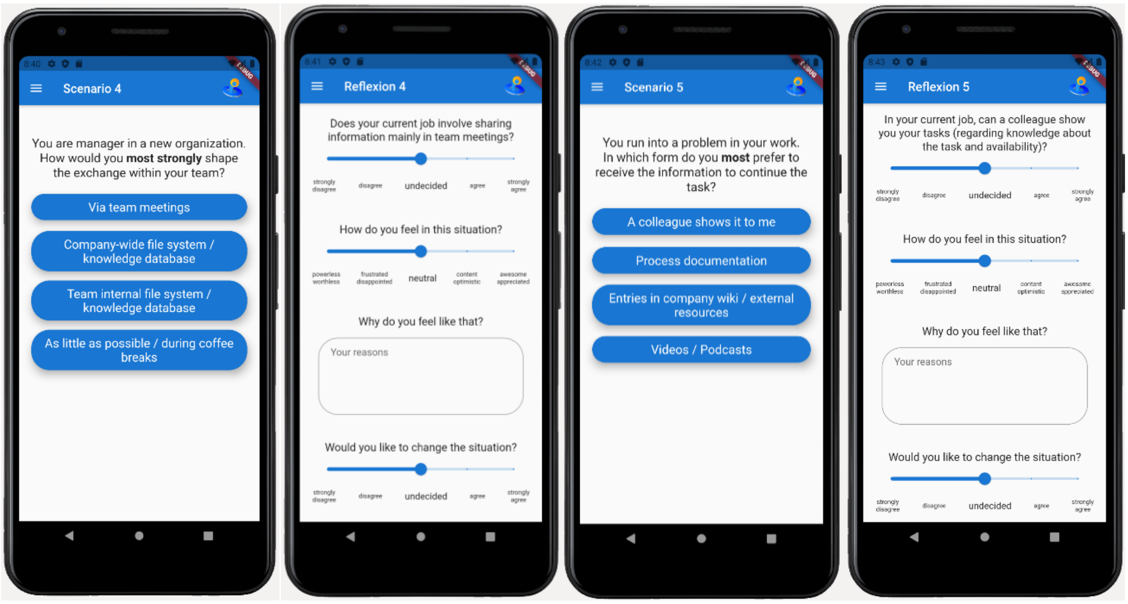

Figure 26: Example of the scenarios 4 and 5 and referring reflections

Table 25: Reflection questions and input parameters

Aspect of reflective cycle	**Question**	**Input / Measure**
Description	The formulation is specific to the selected option, conveys the question: What is the situation in your current job regarding the desired scenario? e.g., scenario 4, selected option 'sharing information via team meetings': Does your current job involve sharing information mainly in team meetings? (Figure 26)	Scale from 0 to 5: Strongly disagree (0), disagree, undecided (2.5), agree, strongly agree (5)
Feelings	How do you feel in this situation?	Scale from 0 to 5: Powerless/worthless (0), frustrated/disappointed, neutral (2.5), content/optimistic, awesome/appreciated (5)
Analysis and Evaluation	Why do you feel like that?	Free text field
Conclusion	Would you like to change the situation?	Scale from 0 to 5: Strongly disagree (0), disagree, undecided (2.5), agree, strongly agree (5)

We approached students of the faculty of Business and Economics. Since business graduates usually work as knowledge workers, they represent the current and future target group of the BCSS to convey awareness and behavior for knowledge documentation; as such, they handle knowledge-intensive tasks and exhibit knowledge as relevant innovation capability (Buck et al. 2021). Further, we consider, on the one hand, that the responses and input of the masters' students indicate at least an initial work experience; on the other hand, they provide insights into a young user group of entry-level employees and their needs to their future employers. To study users' perceptions, we analyze the input data of 101 users to the design described in Figure 25 and shown in Figure 26. The students were asked to apply the BCSS to their current job or studies. About 60% of the users denoted their thoughts about the reasons for their feelings in the free text field. Any input data is anonymous; the data was retrieved in July 2021.

4.4.6.2 Results of Users' Reflections

Table 26 presents the quantitative results of the users' reflections. The results show which options are preferred by the users and how they rate their current situation in their job (description), how they feel about that situation (feelings), and their willingness to change the situation (conclusion). We present the mean and standard deviation (sd) of the users' input. With a scale of 0 to 5 (Table 25), 2.5 is the center of the scale. The qualitative input to the reasoning (input into the free text field) is described in Sections 4.4.6.2.1 to 4.4.6.2.7.

Table 26: Results of users' reflections

Users in %	Choice	mean (sd)		
		Description	Feelings	Conclusion
1) Knowledge Goals		**2.60 (1.23)**	**2.54 (1.09)**	**3.38 (1.23)**
45.54	develop a company-wide knowledge culture	2.72 (1.05)	2.45 (1.10)	3.56 (1.16)
35.64	implementation and specification of knowledge management	2.26 (1.28)	2.43 (1.02)	3.13 (1.16)
18.81	identify future successful knowledge	2.96 (1.36)	2.96 (1.09)	3.42 (1.40)
2) Knowledge Identification		**2.56 (1.34)**	**2.76 (1.24)**	**2.86 (1.35)**
35.64	ask colleagues	2.81 (1.26)	2.85 (1.37)	2.64 (1.55)
26.73	ask a predecessor	2.59 (1.44)	2.96 (1.08)	2.69 (1.21)
19.80	read process documentation	2.31 (1.33)	2.38 (1.18)	3.19 (1.08)
17.82	read entries in a company wiki	2.29 (1.27)	2.71 (1.12)	3.19 (1.27)
3) Knowledge Development		**3.75 (1.10)**	**3.27 (0.98)**	**2.86 (1.35)**
41.58	store in some kind of electronic file system/knowledge database	3.69 (1.09)	3.07 (0.99)	2.68 (1.14)
34.65	make a physical note	4.18 (0.79)	3.46 (0.85)	2.07 (1.30)
20.79	address in a team meeting	3.21 (1.19)	3.33 (1.11)	1.96 (1.06)
2.97	remember yourself	3.33 (1.56)	3.33 (0.59)	3.33 (1.56)
4) Knowledge Distribution		**3.08 (1.25)**	**2.95 (1.06)**	**2.43 (1.20)**
38.61	via team meetings	3.43 (1.05)	3.37 (0.90)	2.15 (1.23)
35.64	team internal file system/knowledge database	3.13 (1.33)	2.81 (1.04)	2.40 (1.26)
23.76	company-wide file system / knowledge database	2.45 (1.22)	2.45 (1.11)	2.92 (0.86)
21.98	as little as possible/during coffee breaks	3.13 (0.63)	3.13 (0.63)	2.50 (1.25)

Users in %	Choice	mean (sd)		
		Description	**Feelings**	**Conclusion**
5) Knowledge Use		**3.02 (1.39)**	**3.00 (1.17)**	**2.50 (1.34)**
47.52	a colleague shows it to me	3.52 (1.13)	3.28 (1.01)	2.11 (1.20)
31.68	process documentation	2.46 (1.38)	2.77 (1.20)	2.85 (1.30)
10.89	videos or podcasts	2.73 (1.58)	2.84 (1.32)	2.61 (1.64)
9.90	entries in company wiki/external resources	2.75 (1.46)	2.50 (1.25)	3.13 (1.15)
6) Knowledge Preservation		**2.69 (1.37)**	**2.72 (1.08)**	**2.74 (1.24)**
59.41	process documentation/documented in detail	2.54 (1.42)	2.68 (1.12)	2.94 (1.19)
28.71	colleagues/successors are trained personally	2.93 (1.33)	2.93 (1.10)	2.33 (1.30)
6.93	roughly/briefly documented	2.68 (1.04)	2.86 (0.56)	2.50 (0.94)
4.95	preferably not/hardly documented at all	3.00 (0.61)	2.25 (0.50)	2.75 (1.22)
7) Knowledge Measurement		**2.02 (1.17)**	**2.30 (0.93)**	**3.23 (1.06)**
49.50	survey of new and/or departing employees	1.75 (1.30)	2.15 (1.00)	3.38 (1.04)
44.55	quality of the entries in the company wiki/documentation	2.28 (0.96)	2.47 (0.81)	3.03 (1.07)
5.94	quantity of the entries in the company wiki/documentation	2.29 (0.86)	2.29 (0.86)	3.54 (0.86)
49.50	survey of new and/or departing employees	1.75 (1.30)	2.15 (1.00)	3.38 (1.04)

Based on the results, we examine the user inputs in the scenarios that represent users' preferences and reflections on knowledge documentation. The following Sections 0 to 4.4.6.2.7 detail the input to the seven scenarios (i.e., the knowledge management activities) and specify the qualitative input about the users' evaluation and analysis of their feelings (i.e., their input into the free text field).

4.4.6.2.1 *Knowledge Goals*

In the scenario about knowledge goals, users can decide how they would redesign the focus of their organization regarding knowledge management. Users value a knowledge culture (46%) but also the implementation and specification of knowledge management measures (36%). Identifying future successful knowledge was chosen less often as the preferred option (19%).

Besides capturing the quantitative data, the BCSS asks the users about the reasons for their feelings, which addresses the steps of analysis and evaluation of the reflective cycle. Of the 101 users, 68 entered a reason for their feelings into the free text field. The reasons for the feelings of the users are similar for all three options: Users who rated their feelings as low specified that they are feeling replaceable and not included in the organization. They called for more exchange to improve their situation. Users with a positive feeling emphasize that knowledge culture and application of measures depends on the responsibility and motivation of their colleagues. Overall, users indicated a high willingness to change in all three options (over 3.0).

4.4.6.2.2 Knowledge Identification

In the scenario about knowledge identification, users can decide how they would like to look for information when they are trained in a new job. Over 60% prefer obtaining knowledge from other persons such as colleagues (37%) and predecessors (27%). In the case of those options, users are content about their current situations (scores of feelings are 2.85 and 2.96). The reasons of users with a positive feeling highlighted the effectiveness and assertive social impact of personal knowledge transfer. Users with a low perception and feeling emphasized the reasons that they felt uncomfortable and frustrated to depend on other people (such as colleagues and their predecessor) and that they are bound to their availability.

About one third of the users indicated process documentation (20%) or wikis (18%) as their favored option. However, the users that desired this mostly want to change the current situation in their organization in that aspect (scores of conclusions to change are both 3.19). They specify that knowledge documentation would have saved them time and that they appreciate having access to information at all times.

4.4.6.2.3 Knowledge Development

In the scenario about knowledge development, users can decide how they would proceed when they obtain new information that is relevant to their tasks. While in other scenarios where users had the choice between personal contact and impersonal knowledge documentation, the users favored personal contact, only about 21% of the users selected to address new knowledge in a team meeting. Most preferred to use an electronic file system (42%) or even make a physical note (35%). This might indicate that users prefer to write down knowledge when they have to document knowledge but favor receiving knowledge from other persons.

Overall, the descriptions and feelings in this activity of knowledge development are perceived as quite positive (scores over 3.0). It is also notable that addressing knowledge in team meetings has the lowest score to change that situation in all scenarios (1.96). Of the 101 users, 61 entered a reason as analysis and evaluation of their feelings into the free text field. Users that preferred physical notes specifically refer to some kind of ‘sticky notes’ to organize their tasks and to-dos.

4.4.6.2.4 Knowledge Distribution

In the scenario about knowledge distribution, users can decide how they would shape the knowledge exchange in their team. Most users prefer to share knowledge via team meetings and also rate this option quite high in terms of the current implementation (3.43) and their positive feelings towards that (3.37). It is notable that more users prefer a team internal knowledge database (36%) over a company-wide database (24%). Considering their reflections on the reasons for their feelings, users consider that it is difficult to grasp a complex structure in a wide file system. Team internal systems have rather less complexity, facilitate protecting sensitive data, and provide most of the data relevant to the users.

4.4.6.2.5 Knowledge Use

In the scenario about knowledge use, users can decide how they would prefer to receive help when they run into a problem at work. In line with the results of the other scenarios, most users prefer personal contact to receive knowledge when they run into a problem (48%). The scores of the descriptions and feelings of users that prefer to work with colleagues are especially high (3.52 and 3.28). However, about one third of the users (32%) would prefer written documentation. Further, it is notable that users almost equally favor videos or podcasts (10.9%) or entries in a company wiki (9.9%). This preference might be due to the target group of students / young workers but also points to further potential to enrich classical wikis with demonstration videos or tutorials.

Differences in the reasons specified in the reflection of their feelings mostly regard the difference between having colleagues available for help or being able to work independently without needing to interrupt colleagues.

4.4.6.2.6 Knowledge Preservation

In the scenario about knowledge preservation, users can decide how they would leave their knowledge to their organization when they are changing jobs. Almost 59% of the users would leave their knowledge in a detailed process documentation; 29% would favor training others personally. This is in contrast to the scenario of knowledge identification (second scenario) where the users were asked how they would like to look for information when they are trained in a new job. There, 62% indicated to prefer to receive knowledge face-to-face (36% by colleagues, 27% by their predecessor, rounded values). This reinforces our inference that users prefer to externalize their knowledge in form of documentation but prefer to receive knowledge directly from others, such as colleagues.

The reflections of the reasons for their feelings indicate that sharing knowledge personally induces positive emotions because people feel valued and appreciate to experience reciprocity. Besides, personal knowledge sharing can provide more detailed information and personal insights. On the other hand, users have low motivation to share knowledge with a successor because there is no direct benefit to them. However, just about 12% indicated that they would only roughly or hardly document their knowledge. It is notable that none of those few that selected not to document their knowledge indicated a positive feeling about that but overall had an ‘ok’ feeling or lower.

4.4.6.2.7 Knowledge Measurement

In the scenario about knowledge measurement, users can decide how they would check the success of the knowledge management activities of their organization. Regarding the measurement and assessment of knowledge management activities, users preferred to survey new or departing employees (50%). Their reasons indicate that this would be appreciated by new employees because it shows that they are valued and that it raises awareness for knowledge documentation from the beginning. Users further clearly value the quality of documentation (45%) over quantity (6%).

It is notable that of the 50 users that would prefer to use surveys of new and/or departing employees, 25 indicated that they (strongly) disagree that employees are interviewed about that in their current organization. In all three choices, users indicated that they would like to change their current situation (score over 3.0).

4.4.7 Extracting Design Aspects from User Feedback

In order to focus on users' perspective and their requirements for knowledge documentation, we consider reviews that reflect users' feedback to the first level of the artifact[7]. To diminish research bias in analyzing the reviews, we apply topic modeling to identify aspects that are important to the users. In the following, we describe 1) the design of the questionnaire, 2) details of the topic modeling approach, and 3) the results of the analysis.

4.4.7.1 Description of Questionnaire

We aim to obtain qualitative user feedback such that we can identify qualitative design aspects from the feedback. In order to guide users to provide meaningful feedback, we based the questions on the constructs of the technology acceptance model of Davis (1989) because, in comparison to later acceptance models such as of Venkatesh and Davis (2000), this model considers the core measures to identify the intention to use a system and it is reasonably detailed to serve as the base for the qualitative questionnaire. The main independent constructs of the technology acceptance model are perceived ease of use and perceived usefulness. Additionally, we added questions to prompt general feedback for positive as well as negative aspects.

In line with the obtained user preferences, we addressed students on master's-level of the Business and Economics faculty that represent the current and future target group of the BCSS to convey awareness and behavior for knowledge documentation. The first level of the artifact, which addresses raising awareness, and the questions were provided in the context of a master's level lecture with the introduction to "take a critical, differentiated, and comprehensible position on the following questions". The participants had one month to respond to the assignment. We presented the users with six questions, shown in Table 27, with the mentioned BCSS referring to the described artifact.

[7] The obtained reviews are different data as the evaluation data used by Merz 2022.

Table 27: Questions to obtain the user feedback

a)	To what extent is the design - structure and appearance - of the BCSS comprehensible or incomprehensible to you?
b)	To what extent is the content - wording of the texts - of the BCSS comprehensible or incomprehensible to you?
c)	To what extent do you feel that the BCSS is or is not fulfilling its purpose of raising awareness of knowledge documentation?
d)	To what extent do you consider the BCSS to be useful or not useful?
e)	Which aspects of the BCSS do you consider most valuable or positive?
f)	Which aspects do you consider irritating or negative about the BCSS? How could the BCSS be developed further to improve these aspects?

4.4.7.2 Procedure

There are multiple machine learning techniques for topic modeling. The method of Latent Dirichlet Allocation (LDA) is the most popular approach (Jelodar et al. 2019; Pietsch and Lessmann 2018). Biterm Topic Modeling (BTM) is specially developed for the analysis of short texts (Cheng et al. 2014). However, exploring the results of LDA (using the Python library Gensim) and BTM based on Cheng et al. (2014) revealed high volatility of the results due to the size of our data set. Therefore, it emerged necessary and expedient to utilize a model that refers to a pre-trained model in order to obtain meaningful results. Following recent developments and insights (Sánchez-Franco and Rey-Moreno 2022; Ebeling et al. 2021; Abuzayed and Al-Khalifa 2021), we apply the topic modeling technique BERTopic that enables topic modeling with Google's transformer language model BERT (Grootendorst 2020; Devlin and Chang 2018). Using topic modeling diminishes research bias when analyzing the reviews. Furthermore, we manually screened the results for plausibility and to obtain a deeper understanding of the responses and identified topics.

We implemented the topic modeling in Python. In line with necessary and common steps to prepare texts for topic modeling, we preprocessed the user reviews applying lemmatizing, tokenization, lowercase, part-of-speech tagging, as well as removing non-alphabetical characters and stop words of Python's Natural Language Toolkit. BERTopic supports multiple sentence embedding models; as we are not bound by performance requirements, we apply *all-mpnet-base-v2* that is trained for general purposes and shows the highest quality (Grootendorst 2020).

Based on exploration, we identified that the responses often discuss more than one aspect using a number of sentences. Therefore, we consider each sentence individually in the analysis. Based on the sentences, we use BERTopic to identify topics of the user reviews for the targeted concepts. This results in dense clusters that serve us as topics on sentence-level.

Furthermore, we apply a dictionary-based sentiment analysis to determine whether the responses tend to be positive, negative, or neutral. The applied word list is developed by Nielsen (2011) and consists of 2,477 English words that are coded with a range of minus five (negative sentiment) to plus five (positive sentiment). This sentiment analysis provides further information about the judgment of the users.

4.4.7.3 Results of Analysis

The analysis aims to identify aspects that are most discussed by the users and, therefore, indicates aspects that should be considered for implementing related systems. We examine the topics of the responses to each question grouped into their targeted constructs because this provides detailed insights into users' perceptions and requirements. The topics are specified by their four most important words that we present in Table 28 (regarding ease of use), Table 29 (regarding usability), and Table 30 (regarding positive and negative aspects). We further disclose how often each topic was identified and show the calculated sentiment score (mean and sd) of each topic. As the most important words might not be informative on their own, we further investigated the underlying responses, to assure and deepen our understanding of the identified topics for the description and analysis.

We obtained 57 usable and complete responses from the participants. With the responses of 57 users to the six questions, we obtained in sum 342 user statements that provide feedback to the artifact and comprise design knowledge. The responses to each question a) to f) have on average 94 words, with a standard deviation (sd) of 13.97. Considering each sentence individually for identifying the topics, the feedback contains in sum 1,697 sentences (question a: 371 b: 295, c: 243, d: 251, e: 215, f: 322).[8]

[8] According to Grootendorst 2020, BERTopic calculates one topic per analysis that contains outliers that should be ignored in the results. Therefore, the counts in the Tables 4 - 6 do not sum up to the numbers listed here.

4.4.7.3.1 Design Aspects for Ease of Use

Questions a) and b) target the perceived ease of use of the artifact. Question a) is about the design of the structure and appearance of the app; question b) focuses on the content such as the wording of the texts (Table 28).

a) To what extent is the design - structure and appearance - of the BCSS comprehensible or incomprehensible to you?

b) To what extent is the content - wording of the texts - of the BCSS comprehensible or incomprehensible to you?

Table 28: Topics and sentiment scores of responses to questions a) and b) regarding ease of use

Count		Topics, identified with their four most important words	Sentiment mean (sd)
a)	188	Level, scenario, introduction, design	0.60 (1.54)
	54	Colour, structure, design, color	0.28 (1.41)
	12	Slider, reflection, set, slide	1.67 (2.06)
b)	120	Scenario, answer, situation, reflexion	0.48 (1.54)
	56	Knowledge, introduction, company, overview	1.04 (1.81)
	41	Comprehensible, word, text, content	0.44 (1.53)

The overall sentiment mean for question a) is 0.64 (sd = 1.57); the sentiment mean for question b) is 0.66 (sd = 1.81). Regarding the ease of use, the responses emphasize the general structure that follows levels and scenarios, the choice of color, text size, and control elements such as the implemented slider. Users further responded to whether the content of the scenario descriptions, introduction, and general wording was perceived as comprehensible. They especially discussed text-heavy content and emphasized a balanced mix of images or illustrations and text.

4.4.7.3.2 Design Aspects for Usability

Questions c) and d) target the usability of the artifact. Question c) is about the perception of the purpose of raising awareness; question d) addresses if the artifact is perceived as useful (Table 29).

c) To what extent do you feel that the BCSS is or is not fulfilling its purpose of raising awareness of knowledge documentation?

d) To what extent do you consider the BCSS to be useful or not useful?

Table 29: Topics and sentiment scores of responses to questions c) and d) regarding usability

Count		Topics, identified with their four most important words	Sentiment mean (sd)
c)	207	Knowledge, documentation, scenario, awareness	0.86 (1.73)
	35	BCSS, awareness, knowledge, documentation	1.11 (1.66)
d)	87	Knowledge, documentation, management, app	1.52 (1.90)
	39	Level, change, motivation, implementation	2.31 (2.30)
	23	BCSS, knowledge, useful, management	2.83 (1.15)
	17	BCSS, consider, change, use	1.82 (2.24)

The overall sentiment mean for question c) is 0.89 (sd = 1.72); the sentiment mean for question d) is 1.82 (sd = 2.08). It is notable that the sentiment scores of those categories are especially high which is in accordance with the quantitative evaluation of the app (Merz 2022). Users emphasize the potential of the reflection to increase awareness for knowledge documentation and how the BCSS guided through the thought process using the scenarios. Overall, it was considered useful to foster interest in knowledge documentation, motivate users via levels to track progress, as well as that the BCSS helps to increase awareness and contemplation of change using self-reflection.

4.4.7.3.3 *Focus on Positive and Negative Aspects*

Questions e) and f) provide means to address general feedback, specifically requesting positive aspects and aspects for further development (Table 30).

e) Which aspects of the BCSS do you consider most valuable or positive?

f) Which aspects do you consider irritating or negative about the BCSS? How could the BCSS be developed further to improve these aspects?

Table 30: Topics and sentiment scores of responses to questions e) and f) of positive and negative aspects

Count		Topics, identified with their four most important words	Sentiment mean (sd)
e)	50	Scenario, think, situation, answer	1.20 (1.75)
	45	App, use, gamification, design	1.58 (1.94)
	37	BCSS, knowledge, documentation, management	1.89 (1.85)
f)	102	App, summary, overview, screen	0.54 (2.36)
	83	Knowledge, documentation, company, information	0.82 (1.50)

The overall sentiment mean for question e) is 1.41 (sd = 1.84); the sentiment mean for question f) is 0.48 (sd = 2.06). The identified topics of the positive aspects regard how the scenarios guide reflection and contemplation, the implemented gamification design to engage users, as well as the aim of the BCSS to emphasize and enhance knowledge documentation. One might expect the sentiment score of the negative aspects (responses to question f) to be negative. While the responses address aspects for improvements, they are formulated using an overall neutral wording and therefore are not identified as negative by the sentiment analysis. The identified topics of the negative aspects concern the design of the summary of the reflection and missing integration into a company context.

4.4.8 Design Principles for Knowledge Documentation

In order to answer the research question, *how should persuasive systems be designed with a human-centered approach in the context of knowledge documentation?* (4.4.2), we aim to codify the obtained design knowledge in form of design principles (Gregor et al. 2020; Fu et al. 2016; Möller et al. 2020b). The obtained design knowledge comprises insights into the perceptions of knowledge documentation (Section 4.4.6) and the topics that users discussed in their feedback to ease of use and usability (Section 4.4.7). These insights provide us with aspects that indicate important preferences and aspects for development. To systematically derive and formulate design principles, we apply the design principles schema of Gregor et al. (2020).

4.4.8.1 Instantiated Design Principles Schema

Gregor et al. (2020) specify that design principles should aim to provide design knowledge via prescriptive statements that are understandable and useful in a real-world design context. Thus, they should explicitly describe the components 1) implementer, 2) user, 3) enactor, 4) context, 5) aim, 6) mechanism, and 7) rationale (Gregor et al. 2020). In Table 31, we specify each of the components to persuasive systems in the context of knowledge documentation. Implementer, user, and enactors are overarching for all of our derived design principles; the other components (context, aim, mechanism, and rationale) are instantiated individually for every design principle.

We consider mechanisms as *important* when the option is preferred by over one fourth of the users; we chose this benchmark based on the number of options and because the results confirmed this as a separating benchmark (greater margin to options below 25% than options above 25%). Further, we consider them having *development focus* when they have a score of the conclusion to change greater than 3.0 (and over 10% choice to ensure a minimum of relevance). The benchmark of 3.0 of the conclusion score denotes the 60% mark on the scale of 0 to 5 and filters the number of options to 40%. Therefore, we selected this as the benchmark to indicate aspects with development focus.

Table 31: Instantiated components of the design principle schema of Gregor et al. (2020)

Design Principle Components		**Specification / Instantiation**
overarching	1) Implementer	Implementers are defined to "instantiate abstract specifications in a concrete design context" (Gregor et al. 2020, p. 1633). Therefore, we determine the implementer as the researchers and developers of persuasive systems in the context of knowledge management and documentation.
	2) User	"Users are those whose aims are to be achieved" (Gregor et al. 2020). This transfers to the users of persuasive systems, such as employees.
	3) Enactor	Enactors "perform actions as part of the mechanisms that are used to accomplish the aim" (Gregor et al. 2020, p. 1633); enactors can be "both human and nonhuman" (Gregor et al. 2020, p. 1633). In accordance, we employ managers and BCSS as enactors of the design principles.
	4) Context	Following our research context and question, we derive design principles for persuasive systems in the context of knowledge documentation; to impact the behavior of users, we adopt a human-centered focus based on users' preferences.
individual for design principle	5) Aim	The knowledge management activities of Probst and Romhardt (1997) describe the aim targeted by the design principles.
	6) Mechanism	The analysis of the preferences of the users provides us with design knowledge about 1. *important preferences*: options that are preferred by over one fourth of the users (over 25%) 2. *aspects with development focus*: options that show a score of the conclusion to change over 3.0 (and over 10% choice to ensure a minimum of relevance)
	7) Rationale	Rationales are "justification for believing that the mechanisms will lead to achieving the aim" (Gregor et al. 2020). Those are provided in the qualitative reflection and enriched in the user feedback.

4.4.8.2 Formulating Design Principles

Applying the instantiated schema as described in Section 4.4.8.1, we derive and formulate three categories of design principles as illustrated in Figure 27.

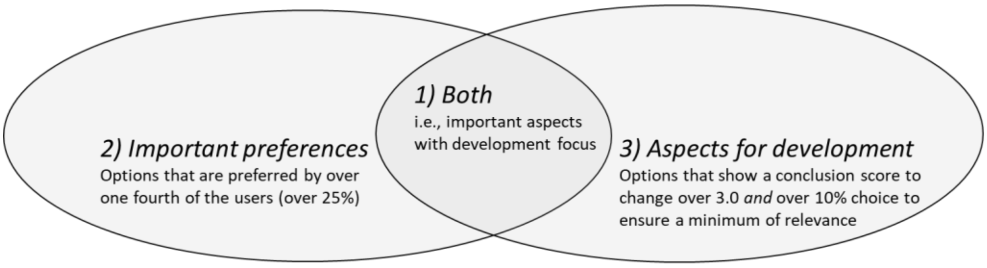

Figure 27: Categories of derived design principles

4.4.8.2.1 *Important Aspects with Development Focus*

The following design principles denote the aspects that are chosen by at least over 25% of the users, indicating an important aspect, as well as have a score of over 3.0 (i.e., 60% on the scale from 0 to 5) in the conclusion to change, indicating an aspect for further development. We present the identified aspects in form of design principles in Table 32. To provide a concise overview, we aggregated the mechanisms and aims where possible.

Table 32: Important aspects with development focus

Component	**Specification**
Aim	*For specifying knowledge goals*
Mechanism	engage on a company-wide knowledge culture as well as specify the implementation of knowledge management
Rationale	because this provides reciprocity, measures, and a feeling of involvement.
Aim	*For assessing the success of knowledge management activities*
Mechanism	survey new and/or departing employees
Rationale	because this achieves direct feedback, shows appreciation, and raises awareness.
Mechanism	consider the quality of the entries in the company wiki/documentation
Rationale	because people value quality over quantity.

4.4.8.2.2 *Important Aspects*

The following design principles denote the aspects that are chosen by at least 25% of the users, which indicates an important aspect, but have a conclusion score to change below 3.0 (therefore, they are not included in Section 4.4.8.1). The identified aspects are specified as design principles in Table 33.

Table 33: Identified important aspects

Component	**Specification**
Aim	*For supporting the search and retrieval for knowledge*
Mechanism	provide means to ask colleagues and predecessors
Rationale	because personal learning empowers effectiveness and social impact.
Aim	*For fostering the approach of new knowledge and ideas*
Mechanism	facilitate to enter information in electronic file system/knowledge database
Rationale	because this ensures long-term storage.
Mechanism	allow physical notes for short-time information and reminders of tasks
Rationale	because this provides a direct and personal overview.
Aim	*For shaping knowledge distribution*
Mechanism	Employ knowledge sharing in team meetings
Rationale	because personal knowledge transfer allows for direct contact and social effects.
Mechanism	employ an internal file system / knowledge database as a supplement to an organization-wide communication
Rationale	because this allows for less complexity while ensuring adequate access rights.
Aim	*For fostering knowledge use*
Mechanism	provide means to teamwork and support among colleagues
Rationale	because this provides direct feedback and personal knowledge transfer.
Mechanism	make process documentation available
Rationale	because this provides information independent of the availability of others.
Aim	*For knowledge preservation / protecting the organization from knowledge loss when employees are leaving the organization*
Mechanism	facilitate the documentation of knowledge and processes
Rationale	because reciprocity in sharing provides positive emotions and a feeling of appreciation.
Mechanism	facilitate the personal training of colleagues and successors
Rationale	because this allows for the transfer of detailed information and personal insights.

4.4.8.2.3 Aspects for Development

The following design principles are aspects that have a score over 3.0 for the conclusions to change and are chosen by at least 10% of the users to ensure a minimum of relevance (however, less than 25% of the users to avoid an overlap with the principles presented in Table 32, Section 4.4.8.1). This denotes design principles that emphasize focus for development and change, in addition to the aspects presented in Table 32. The identified aspects are specified as design principles in Table 34.

Table 34: Identified development aspects

Component	Specification
Aim	*For specifying knowledge goals*
Mechanism	emphasize to transparently identify future successful knowledge
Rationale	because this fosters including people towards the success of the organization.
Aim	*For supporting the search and retrieval of knowledge*
Mechanism	provide process documentation and structured wikis
Rationale	because this provides explicit information independent of the availability of others.

4.4.9 Discussion and Implications

The design principles present the design knowledge obtained in the analyses of the user preferences and feedback (Sections 4.4.6 and 4.4.7). Their formulation specifies the components of the design principles schema of Gregor et al. (2020). Thus, applying a human-centered approach, we obtained insights about design aspects and users' preferences for knowledge documentation. We structured them along the targeted knowledge management activities.

For identifying the design aspects, we applied topic modeling to the user feedback. The aspects are represented by the topics extracted with the machine learning algorithm. On the one hand, this reduces researcher bias and allows fast independent results on a large database. On the other hand, feedback is often dependent on nuances that might not be captured in the topic analysis. Therefore, we additionally screened the underlying comments manually to validate the topics and gain further insights. The approach provides an overview of the most discussed aspects that is easily scalable to additional data. Our overview of the topics distinguishes the concepts perceived ease of use, usability, and positive as well as aspects for improvement. The sentiment scores highlight which aspects are perceived particularly positively.

Further, we derive the design principles from the preferences of the users and their reflections regarding their current situation. The reflection captures users' scoring about the description of the state in their current organization, their feeling about that, and their conclusion whether they would like to change the situation. They can reflect the reasons for their feelings using free text. This provides insights into the users' thoughts regarding knowledge documentation. In order to reduce the number of steps and choices, the options are restricted such that users have to decide for the one preference they are drawn to most. Therefore, the results reflect their first priority and do not consider a kind of ranking. The preferences and reflections point to aspects to implement in a persuasive system for knowledge documentation. The findings allow distinguishing the findings whether they

- can be assigned as important aspects that are preferred by many users (over 25%)
- imply aspects for development that users indicate a high conclusion to change (over 3.0)
- or both, with high relevance and conclusion to change.

To convert the insights into design principles, we applied the design principles schema of Gregor et al. (2020) to ensure communicating and specifying the relevant components of the codified design knowledge. Gregor et al. (2020) present their design principles schema to render design principles that are "understandable and useful in real-world design contexts" (Gregor et al. 2020). Contemplating this schema, we promote the structured composition with the specified components. The schema especially allows for varying levels of abstraction which is represented in the context and aim of the design principles. Our derived design principles evince a high level that allows for further specification regarding the needs of the implementer and users. This is particularly important considering that we focused on a human-centered view which is necessary but not sufficient to ensure the success of information systems (Schermann and Merz 2018).

The details of the design principles indicate that the balance of personal knowledge sharing and independent documentation should be carefully contemplated. The appropriate mix depends on the referring tasks (routines to unexpected situations, Wiig 2003) as well as characteristics of personality and relationships (Anand and Walsh 2016). The findings provide insights from users' point-of-view in deciding on a strategy that combines the benefits of personal knowledge transfer and the independence of structured knowledge documentation from the availability of others. In accordance with this, the responses emphasize that knowledge sharing activities depend on the motivation and sense of responsibility of their colleagues and managers. While there are wide collections of the barriers of knowledge management activities (such as Phung et al. 2016;

AlShamsi and Ajmal 2018), this underlines the relevance of social influence and impact of appreciation and self-efficacy on knowledge sharing.

4.4.10 Conclusion

While knowledge management and documentation are a complex and widely investigated research and management field (Alavi and Leidner 2001; BenMoussa 2009; Akbari and Ghaffari 2017), emerging innovations yield digital transformation that reforms functionalities of knowledge management and entails adaption of human behavior (Manesh et al. 2021). To responsibly advance existing measures, systems and innovative functional technologies should be supplemented leveraging human-centeredness and users' perceptions and preferences. Therefore, this study investigates the design of persuasive systems in the context of knowledge documentation using a systematic human-centered approach to gain understanding of perceptions and reactions to existing technology, as well as derive implications to encourage behavior towards knowledge documentation. To achieve this, our approach is bilateral: First, we obtained information on the preferences of 101 users including their quantitative assessment of the description of their current situation, their feeling about this situation, and their conclusions to change this situation. This is supplemented with qualitative reasons for their feelings. Second, we analyze qualitative feedback of 57 users to five questions regarding ease of use, usefulness, positive and negative aspects of the design of BCSS using a state-of-the-art topic modeling approach. The results extend and enrich existing findings with 1) new insights into the perceptions and preferences regarding knowledge documentation, 2) exploring a current topic modeling technique to extract design knowledge, and 3) deriving design principles based on user feedback and users' input about their preferences and perceptions of their situation.

This discerns aspects that are indicated as important, as well as aspects for development that are indicated with a need for change, or both (i.e., important aspects with development focus). This provides practical implications to managers about users' preferences and perceptions of current knowledge documentation. Among others, the results emphasize the combination of knowledge management that is based on personal transfer with documented knowledge that provides information independently of others. Further, the results indicate that users tend to favor receiving information from personal sharing but prefer to provide knowledge via documentation. Addressing users' feelings strengthens the perception of appreciation, self-efficacy, and value.

Finally, the analysis presents the identified and described aspects in the form of design principles. This provides researchers and developers of persuasive systems with insights and understanding about the implementation, especially regarding the ease of use and usefulness of persuasive systems. While this is based on the feedback and requirements in the context of knowledge documentation, we presume that the results also pertain similar to persuasive systems in other contexts. Therefore, transferring relevant insights might serve as a base of user feedback for other designs with the aim to enhance awareness, behavior, and attitudes.

Despite our best efforts, our study is inherently subject to limitations. First, the design aspects and user input are based on the design of the selected artifact. To counteract this issue, we build on the approved artifact design of Merz (2022) that is bound to a high rigor. Further, we are confident that the presentation enables assessing and transferring the obtained design aspects to other contexts appropriately. Second, we derive the data from users that are still students and do not yet have a long-term professional career. Thus, they might lack experience relevant to the study. However, this group represents the target group of entry-level employees and their needs and perceptions to their future employers. Further, it became clear from the responses of the students on master's-level to the questions that they have at least initial work experience, which yields relevant background for this study. Given the early shaping of behavior and attitudes, as well as emerging developments, we even promote the value of presenting insights into this target group. Last, we selected the benchmarks for indicating important aspects and aspects with development focus based on the number of options and the capability of the benchmarks to partition the data. Selecting different benchmarks and/or considering a more detailed ranking could reveal further details. However, in order to derive actionable implications, we argue for the value of distinguishing between the three concluding groups of important aspects with development focus, important preferences, and aspects for development.

With this in mind, we underscore the need for further research about users' perceptions and preferences of knowledge documentation concerning technological innovation. Investigating further persuasive systems could supplement the insights into relevant design aspects; comparison with a target group that has a long professional career could reveal differences and conformities based on work experience; assessing systems that incorporate artificial intelligence simulating humans (e.g., in form of chatbots) could yield further insights on users' preference on personal sharing knowledge. Further, we apply the reflective approach of Möller et al. (2020b) with a human-centered approach based on user feedback and perceptions. Therefore, we derive the design principles rather inductively. Hence, we suggest extending and evaluating our findings with a deductive approach.

Rapid innovation creates numerous opportunities and risks and requires synergizing technology with human behavior and attitudes. Therein, managing and documenting knowledge is and will constitute a capability for digital innovation that is essential for the advancement of current solutions (Buck et al. 2021). To contribute to the development of meaningful systems, we provide design knowledge on persuasive systems for knowledge documentation derived with a human-centered approach that emphasizes users' preferences, perceptions, and behavior.

5 Conclusion

The essays of this dissertation comprise contributions on designing BCSS in the context of knowledge documentation. This constitutes the title of “Designing Behavior Change Support Systems in the Context of Knowledge Documentation: Development of Theory and Practical Implementation” and answers the superordinate research question “*How should a BCSS be designed to persuade users to change their behavior towards knowledge documentation?*” (Section 1). To answer the research question, the essays present various research methods and approaches (Table 35).

Table 35: Methods and approaches of this dissertation in numbers

systematic literature reviews comprising 417 studies	independent coding of 2,876 variables	two structural equation models with 10 variables
topic modeling of 342 statements	design of BCSS in the context of knowledge documentation	20 semi-structured interviews
feedback from 141 users	245 investigated design principles	4 real-world examples

In sum, the essays of this dissertation present:

- **417 studies in systematic literature reviews**
  - Essay 2: 226 studies of 42,330 projects (Section 2.2.4.1)
  - Essay 3: 42 studies that apply design principles (Section 3.1.4)
  - Essay 4: 24 studies for the recommendation model (Section 3.2.4.2)
  - Essay 5: 18 studies as knowledge base (Section 3.3.5.4)
  - Essay 6: 56 results on behavior change, 130 results on knowledge management systems (Sections 4.1.2 and 4.1.3)
  - Essay 8: 51 studies about goal-setting in BCSS (Section 4.3.3.2)
- independent mapping and **coding of 2,876 concepts**
  - Essay 2: coding of 2,058 variables (Section 2.2.4.2)
  - Essay 3: coding 705 applications of design principles to the categories of the PSD model (Section 3.1.5)
  - Essay 4: mapping 85 links between design principles and the stages of change (Section 3.2.4.1)

- **two structural equation models**
  Essay 2: meta-analytic structural equation investigating 13 hypotheses about the relations between seven concepts of user participation in information systems (Section 2.2)
  Essay 7: investigating the relationship between the three constructs of the TAM (Section 4.2.5)
- **topic modeling** of 342 statements with BERTopic
  Essay 9: 342 statements of 57 users (Section 4.4.7)
- implementation of the **artifact / prototyping**
  Essay 6: underlying idea and conceptual design of the artifact (Section 4.1)
  Essay 7: presentation of the artifact in form of a prototype called *wissensguide* (Section 4.2)
  Essay 8: focus on the design of goal-setting in the artifac (Section 4.3)
  Essay 9: description of extracting design knowledge using the artifact (Section 4.4)
- **20 semi-structured interviews**
  Essay 8: semi-structured interviews with 20 users, on average 24 minutes (Section 4.3.5.2)

The analyses include:

- feedback from **141 users**
  Essay 7: 15 users for quantitative evaluation of the BCSS (Section 4.2.5)
  Essay 8: quantitative assessment of 5 users and semi-structured interviews of 20 users (Sections 4.3.4.2 and 4.3.5.2)
  Essay 9: quantitative feedback of 101 users (Sections 4.4.6 and 4.4.7)
- **245 investigated design principles**
  28 design principles of the PSD model (considered in Essays 3 - 8), in addition to those:
  Essay 3: 62 concepts as design principles of 15 studies (Section 3.1.5)
  Essay 5: 125 design principles of 18 studies, formulation of 14 new, aggregated design principles (Sections 3.3.5.5 and 3.3.5.6)
  Essay 8: 2 design principles identified specifically for goal-setting (Section 4.3.3.3)
  Essay 9: 14 new design principles (Section 4.4.8.2)
- the application of the created models in **four real-world examples**
  Essay 1: applied and validated the decision model based on real-world data from a German bank (Section 2.1.5)
  Essay 5: three real-world examples as proof-of-concept of the set of design principles (Section 3.3.5.7)

The dissertation further creates different models, such as

- a *quantitative* decision model on choosing an omni-channel strategy (Essay 1, Section 2.1.4),
- a *qualitative* recommendation model on selecting design principles (Essay 4, Section 3.2.6),

and applies different approaches of design principle development, such as

- a *supportive* approach to aggregate 125 concepts to 14 design principles (Essay 5, Section 3.3.5.6),
- a *reflective* approach to extract 14 design principles from users' input and feedback (Essay 9, Section 4.4.8.2).

Therefore, this dissertation contributes to both the development of theory as well as the practical implementation of BCSS. The following is a summary of the contributions to "development of theory" and "practical implementation", as denoted in the title "Designing Behavior Change Support Systems in the Context of Knowledge Documentation: Development of Theory and Practical Implementation".

5.1 Contributions to the Theoretical Knowledge Base

The dissertation extends the theoretical knowledge base of designing BCSS. Thus, we investigate design principles of persuasive systems design and examine how and when they should be applied. The research is grounded on an extensive **overview of the application of design principles** (Essay 3). The literature analysis indicates that the PSD model of Oinas-Kukkonen and Harjumaa (2009) is the most cited model for designing persuasive systems but that its design principles should be specified and standardized. Based on that descriptive overview, we determine **a recommendation model** when the design principles should be applied to meet the users' needs and **aggregate design knowledge to 14 explicitly formulated design principles**. Those design principles follow recent insights into design principles development (Möller et al. 2020b) and formulation (Gregor et al. 2020). As such, they specify the design principles suggested in the PSD model of Oinas-Kukkonen and Harjumaa (2009) and also detail additional design knowledge, such as explicitly presenting goal-setting as a persuasive design principle. As a consequence, we **offer a new guideline for designing BCSS**: Researchers and developers of persuasive systems aiming at behavior change can identify the transition of behavior change they are addressing and prioritize the design principles according to the recommendation model presented in Essay 4 (e.g., self-monitoring for a transition from the stage action to maintenance). Essay 5 specifies an aggregation of persuasive design principles including a decomposition to their components aim, actors, context, mechanism, and rationale as demanded by Gregor et al. (2020). Researchers and developers can apply those design principles **when creating, implementing, and evaluating persuasive systems**. Referring to those synthesized concepts reduces ambiguity in the application of design principles and the communication of design knowledge. Overall, we point out to users that they should be aware of persuasive elements in information systems, as they may be capable to influence behavior unconsciously for the better (e.g., towards a healthy lifestyle) or worse (e.g., addictive behavior, technostress).

5.2 Contributions of the Practical Implementation

Aside from theoretical contributions, the practical implementation presents the design of a BCSS in the context of knowledge documentation. To the best of our knowledge and a systematic state-of-the-art analysis (Essay 6), the artifact developed in the course of this dissertation is **the first BCSS in the context of knowledge documentation**. Thus, constituting a novel contribution, it presents a specific implementation as an example and research object to identify design knowledge, create meaningful systems, and support behavior change. Overall, the insights substantiate the capability to supplement information systems for knowledge documentation with persuasive elements. The findings emphasize focusing on perceived usefulness when designing BCSS to achieve system acceptance (Essay 7).

Further, the persuasive elements are applied in four levels according to the four transitions between the stages of behavior change (precontemplation, contemplation, preparation, action, and maintenance; Prochaska and Norcross 2001). In particular, the essays **specify an approach to raise problem awareness**, which is usually presumed in other BCSS and information systems, using a combination of scenarios and reflection questions. Supporting goal-setting with persuasive elements is an approach that provides a low threshold guiding users to set specific and challenging goals. In particular, the essays present **17 specifically selected design principles for persuasive goal-setting** and their application to a goal-setting process as well as the presentation of an implementation example (Essay 8). Tunneling the users in that process using examples and tailored information was identified as especially important to guide the users, and thus should be considered with high priority when developing BCSS.

When communicating the design of systems, design principles are powerful concepts to provide prescriptive statements that codify design knowledge and specify design elements, such as tunneling and tailoring. As the selection of fitting design principles is critical for system performance, we extract design principles for knowledge documentation from users' reflections and feedback to the BCSS (Essay 9). Considering the **preferences of 101 users**, the human-centered approach obtains **design principles that**

combine knowledge management activities with the users' point of view. In line with prior literature, the feedback emphasizes dependence on other people as a barrier to personal knowledge sharing but with strong social effects and detailed exchange. A successful knowledge strategy should include a balanced combination of knowledge sharing that considers the users' preferences regarding knowledge management activities. Our findings further indicate that users tend to favor receiving information from personal sharing but prefer to provide knowledge via documentation. In order to determine a fitting knowledge management strategy, we present **14 preferred mechanisms and rationales for the knowledge management activities** in Essay 9 (e.g., survey of new and departing employees for assessing the success of knowledge management).

5.3 Limitations

The studies are limited by the restricted scope of the projects. For example, screenings and mappings of prior research **might miss literature** on this topic (Boell and Cecez-Kecmanovic 2015). To mitigate this limitation, the essays ground on extensive literature analyses including multiple explorative and systematic literature reviews. By including a variety of databases, explicit and general search strings, however, we are confident that we did capture a representative picture of the current state of research. Additionally, our results are overall in line with existing findings and literature reviews but contribute novel insights by detailing and improving aspects in the context of the specific essays. This indicates that we did not miss substantial research in those contexts.

Further, our analyses might be subject to **researcher bias**. We mitigated research bias using scientific measures such as considering interrater reliability and evidence-based decisions. As such, we stressed fostering transparency and objectivity to achieve replicable results. Considering the practical implementation, most feedback is derived involving students that have limited work experience. Therefore, the **results are limited to this user group** as well as their attitudes and expectations. However, this group represents the target group of entry-level employees and reflects their perceptions of the research subjects. With the digitization and transformation processes where systems and company cultures are shifting towards new mindsets (Hildebrandt and Beimborn 2021; Solberg et al. 2020), this even provides valuable insights into the attitudes of possible future employees.

The BCSS is so far investigated as a **supplementary artifact without integration into a functional knowledge management system** or organizational workflows. With regard to the scope of the dissertation, this evaluation assesses the systems acceptance and potential of the approach but does not allow to draw conclusions about further effects on integration and measure change of behaviors. This would require longitudinal studies subsequent to the initial development of the artifact, which is the essence of this dissertation. To mitigate this limitation, we evaluate using the TAM of Davis et al. (1989) that predicts system use. Moreover, the essays provide an evaluation in form of proof-of-concept as demanded for dissertations by Davis (2005) and by Gregor and Hevner (2013) for novel artifacts.

5.4 Outlook towards Further Research

While this limits the findings regarding the performance in work environments, it points to future and emerging research and developments. Based on the results, future research should integrate persuasive systems with functional knowledge management systems and assess their design and success factors in working environments and in relation to workflows. For example, **existing knowledge management systems could be extended** using the approach to include the reflection regarding the inherent goals of knowledge documentation as well as setting specific and challenging goals. Further, monitoring the goals' progress would benefit from the functions of the knowledge management system to measure and assess the behavior.

While the essays overall consider persuasive systems design as a whole, future research should further explore and **detail specific design elements**. For example, gamification of systems could serve as a powerful instrument that comprises persuasive elements. Considering that gamification is often implemented in forms of competition, this could also have a negative impact on motivation (Bartlett et al. 2017). Therefore, determining the role of gamification in persuasive systems and tailoring gamified elements to the specific users and application context could be subject for further research.

Based on the stages of change of Prochaska and DiClemente (1983), this dissertation fosters awareness for behavior in the context of knowledge management and promotes addressing awareness in other contexts. While awareness for behavior is often presumed for system use, building problem awareness is generally the starting point for actions and behavior change (Prochaska and DiClemente 1983). This dissertation provides specific design principles and practical examples on **building problem awareness** in the context of knowledge documentation. Thus, it fosters and paves the way to include awareness and behavior change into further functional systems to improve behavior and actions (e.g., task management, knowledge sharing, learning).

Further regarding the design knowledge, this dissertation focuses on design principles of BCSS in the domain of knowledge management. Using exaptation as specified by Gregor and Hevner (2013), the findings could be **adopted and extended to advance other research areas**. As such, the presented recommendations for design principles and practical implementation as demonstration examples could advance innovations that promote intrinsically motivated behavior also in other contexts (e.g., sustainability, wellbeing, education).

5.5 Summary

In summary, this dissertation extends prior design knowledge about designing BCSS in the context of knowledge documentation by developing theory and showing practical implementation. Combining technical and psychological models within information systems frameworks based on the principles of abstraction, originality, justification, and benefit (Österle et al. 2011), this dissertation draws on design science to propose prescriptive knowledge in the form of design principles and a specific artifact.

The essays **contribute in a descriptive way** by characterizing users' perceptions and attitudes towards knowledge documentation as well as detailing the application and use of design principles in persuasive systems. This entails designing a BCSS in the context of knowledge documentation as a research artifact, which constitutes a **pragmatic contribution**. This practical contribution comprises the design to incorporate the stages of change in a persuasive system as well as specifying approaches for building problem awareness, goal-setting, and design principles for the transitions between the stages. As a **theoretical contribution**, it explains the role of user participation to the performance of information systems projects, identifies fitting design principles depending on the target of the BCSS, as well as validates the relevance of BCSS in the context of knowledge documentation.

Providing descriptive, pragmatic, and theoretical contributions, this enriches the domain of persuasive technology as well as the domain of knowledge management and provides researchers and developers **means to design, evaluate, and advance BCSS**. While BCSS solely cannot achieve immaculate behavior regarding knowledge management, which depends on various aspects including culture and technological means (Phung et al. 2016; Singh and Kant 2008), they **foster that knowledge documentation is applied** and integrated into behavior. Therefore, the dissertation contributes to **improving knowledge management activities** on an individual level that extends and enhances technical and organizational means (Al Saifi 2015). As growth and development build on how existing knowledge is preserved and acted upon, supporting behavior change points to sustainable behavior and innovations in organizations as well as in information systems research.

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