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Design Principles of Persuasive Systems – Review and Discussion of the Persuasive Systems Design Model

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Completed Research

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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.

Keywords

Persuasive Systems Design, Behavior Change Support Systems, Design Principles.

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 2010). 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. 2020) 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.

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*. (Harjumaa and Muuraiskangas 2014; 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.

Table 1. Description of the Design Principle *Suggestion* in the PSD Model of Oinas-Kukkonen and Harjumaa (2009)

As presented in Table 1 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 (Gregor et al. 2020; Möller 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. (2020) 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. (2020) 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.

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 (Oinas-Kukkonen and Harjumaa 2009; Wiafe et al. 2014), 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.

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 2). The results regarding the theoretical studies are presented in Figure 1, the results of the practical studies as well as overall sums are presented in Figure 2.

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 et al. (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').

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

Figure 1. Design Principles in Theoretical Studies

Categories of design principles	Design Principles	Practical studies (22): 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	Overall sum (42): 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 2. Design Principles in Practical Studies and Sums over All Included Studies

	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**	

Table 2. Identified Additionally Used or Proposed Design Principles

Figure 1, Figure 2, and Table 2 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 (Berg et al. 2018; Lehto et al. 2013; Meedya et al. 2019). This indicates that those design principles should be thoughtfully considered in the design process.

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.

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; Meske and Amojo 2020; Schneider et al. 2016). 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 et al. 2019; Orji and Mandryk 2013). 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 (Orji et al. 2019; Valk et al. 2017) 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 (Bartlett et al. 2017; Oinas-Kukkonen and Harjumaa 2009), 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) and considered it as "too harsh" (Karppinen et al. 2016). 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. 2020). 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. (2020) 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.

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 1 and Figure 2.

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.

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