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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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Abstract:

Behavior change is a highly relevant and studied topic in the psychology discipline. Through integrating technologies into everyday life, behavior change support systems (BCSS) have gained attention in information systems discipline. Oinas-Kukkonen and Harjumaa (2009) have offered a persuasive systems design (PSD) model, a leading framework to provide a generic technical design process including 28 design principles. However, the model lacks a clear picture about which among these 28 design principles one should select for specific implementations. Consequently, researchers and developers who implement BCSS lack structured and evidence-based guidance. They need to invest time and cognitive resources to analyze different design principles. Because the influence of persuasive systems links strongly to processual state of behavior change, we combine the PSD model with Prochaska and DiClemente's (1983) transtheoretical model (TTM) and posit a model that recommends appropriate design principles for the five transitions along the behavior-change stages. We refined the model using a systematic literature review. The results specify the PSD model and guidelines to select effective design principles for developing BCSS.

Keywords: Behavior Change Support System, Persuasive Systems Design, Transtheoretical Model, Design Principle.

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1 Introduction

People stay in their established behaviors even though they know that different behaviors would benefit them. 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 continue to rise. Despite this discrepancy between desired and actual behavior, individuals cannot change their established behaviors sustainably. The psychology discipline contains much research on behavior and how one can influence it. Established behavioral models include the transtheoretical model (TTM) (Prochaska & DiClemente, 1983), the theory of planned behavior (Ajzen, 1991), or the health belief model (Siddiqui et al., 2016).

Fogg (2003) envisioned the potential for persuasive technologies to support people in changing their attitudes and behaviors. Based on Fogg's (2003) research, Oinas-Kukkonen and Harjumaa (2009) defined the behavior change support system (BCSS) concept and introduced BCSS as "a key construct for research in persuasive technology" (Oinas-Kukkonen, 2010). BCSS include mobile apps, social media, or interactive websites that focus on changing attitudes or behaviors. BCSS have already proven successful in the health (e.g., Langrial et al., 2013) and environmental contexts (e.g., Shevchuk & Oinas-Kukkonen, 2016). Additionally, researchers see further potential to employ BCSS in a working environment to support digital transformation's behavioral aspects (Merz, 2020; Nkwo, 2019).

The persuasive systems design (PSD) model (Oinas-Kukkonen & Harjumaa, 2009) represents by far most referenced technical framework in research for developing BCSS (Otyepka, 2018). The PSD model recommends a generic design process that starts with analyzing the persuasion context and presents multiple design principles. The PSD model proposes that one select context-specific design principles but does not offer a clear picture about how one should do so (Wiafe et al., 2014). In designing persuasive systems, one needs to select effective design principles because one cannot practically include a high number of design principles (e.g., studies apply on average only 15 design principles among the 28 that the PSD model proposes) (Merz & Ackermann, 2021)). Moreover, studies highlight the need to choose the right design principles rather than implementing as many as possible (Prochaska & Norcross, 2001; Wildeboer et al., 2016). Therefore, BCSS researchers and developers need to invest time and energy to conduct a laborious context-related analysis of users' needs and fit design principles before implementing their projects rather than focusing their cognitive resources on specifically designing BCSS.

In this study, we fill this gap between technical framework and context-related behavioral model. Because the influence of technology-enhanced behavioral interventions strongly relates to the state in the behavior-change process (Oinas-Kukkonen & Harjumaa, 2009; Prochaska & Norcross, 2001; Vandelanotte & de Bourdeaudhuij, 2003), we combine the widely used and frequently validated states of change in the TTM (Prochaska & DiClemente, 1983; Prochaska & Norcross, 2001) with the PSD model (Oinas-Kukkonen & 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 that the PSD model defines. We conducted a systematic literature review to refine our conceptual model in detail and to ensure that the model accords with existing research studies about BCSS.

With this work, we make a descriptive contribution to the literature by showing BCSS researchers and developers the role that the PSD model's design principles play in the behavior-change process and by offering implementation examples. We also make a pragmatic contribution by developing implications and guidance for developing BCSS and theoretically specify the PSD model in order to facilitate the BCC design process.

2 Theoretical Background

Persuasive technology accompanies and supports the behavior-change process. It refers to "any interactive computing system designed to change people's attitudes or behaviors" (Fogg, 2003). While persuasive technology constitutes its own research domain, BCSS constitute research objects in that domain (Oinas-Kukkonen, 2010). According to Oinas-Kukkonen (2013), a BCSS refers to "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" (p. 1225). One typically develops BCSS based on design principles (Oinas-Kukkonen, 2010).

2.1 Design Principles

Design principles incorporate design knowledge about artifacts' design and allow one to transfer knowledge about how to achieve desired effects to different applications (Möller et al., 2020). In particular, Fu et al. (2016) note 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" (p. 1). However, research has often used design principles ambiguously and formulated them inconsistently (Gregor et al., 2020), which impairs one's ability to present design knowledge in an accessible form. To account for that issue, Gregor et al. (2020) suggested a design principles schema for decomposing and classifying design principles into three categories based on the user activity: 1) design principles "about user activity" (i.e., the principles state what users can do with the artifact), 2) design principles "about the artifact" (i.e., the principles concern an artifact's feature without directly addressing user activity), or 3) "about both" user activity and artifact (i.e., the principles combine design knowledge about user activity and an artifact's feature) (Gregor et al., 2020).

Based on the ability of design principles to provide design knowledge about user activities and system features, design principles constitute the foundation for developing information systems (Fu et al., 2016; Möller et al., 2020). As such, frameworks such as the PSD model (Oinas-Kukkonen & Harjumaa, 2009) incorporate them.

2.2 PSD Model

When developing BCSS, most researchers refer to the PSD model (Otyepka, 2018). The PSD model acts as a meta-level model and serves as a wide framework that includes generic steps and design principles for designing BCSS (Räisänen et al., 2010). In order to draw on the most referenced and established technical framework in research for BCSS development, we build our study on the 28 principles in 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 1 shows the design principles as Oinas-Kukkonen and Harjumaa (2009) described them. To further specify their nature as a strong foundation for our study, we classified them into three categories based on Gregor et al. (2020): artifact, user activity, or both. We coded the classification independently with an inter-rater reliability of 0.96 (Cohen's kappa).

Table 1. PSD Model Design Principles (Oinas-Kukkonen & Harjumaa, 2009) and their User Activity Classification based on Gregor et al. (2020)

Category	Design principle	Example requirement (Oinas-Kukkonen & 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

Table 1. PSD Model Design Principles (Oinas-Kukkonen & Harjumaa, 2009) and their User Activity Classification based on Gregor et al. (2020)

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 truthful, fair, and unbiased information.	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 perform their target behaviors and to see the outcomes of their behavior.	User activity
	Social comparison	System should provide a means for comparing performance with other users' performance.	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 in the primary task support category "support the carrying out of the user's primary task" (Oinas-Kukkonen & Harjumaa, 2009, p. 492). Applying Gregor et al.'s (2020) classification, we identified that the category 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 & Harjumaa, 2009). The design principle personalization covers two aspects: content that the system determines for the individual user and content that individual users themselves determine based on their preferences.

The dialogue support category comprises design principles that provide feedback to users (e.g., by praise, rewards, and suggestion) "potentially via verbal information or other kinds of summaries" (Oinas-Kukkonen & Harjumaa, 2009). 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 system credibility support category contains design principles that can emphasize the credibility and expertise that underlies the system (e.g., using verifiability and authority) (Oinas-Kukkonen & Harjumaa, 2009). The design principles on credibility support describe system features without user activities (according to Gregor et al. (2020)).

The category social support category contains design principles that motivate users through social influence and promote users to exchange information between them (e.g., using social comparison and cooperation) (Oinas-Kukkonen & Harjumaa, 2009). In this category, the design principles provide a means to enable user activities except for the design principle recognition, which describes support through system features (according to Gregor et al. (2020)).

Oinas-Kukkonen and Harjumaa (2009) integrated the 28 design principles into the PSD model (Figure 1) as follows. First, one analyzes the persuasion context and, based on the findings, selects persuasive design principles. Second, 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 one should select these design principles according to the behavior-change context (Wiafe et al., 2014). However, Oinas-Kukkonen and Harjumaa (2009) designed the model such that one can extend it by integrating suitable theories to specify certain aspects (Räisänen et al., 2010).

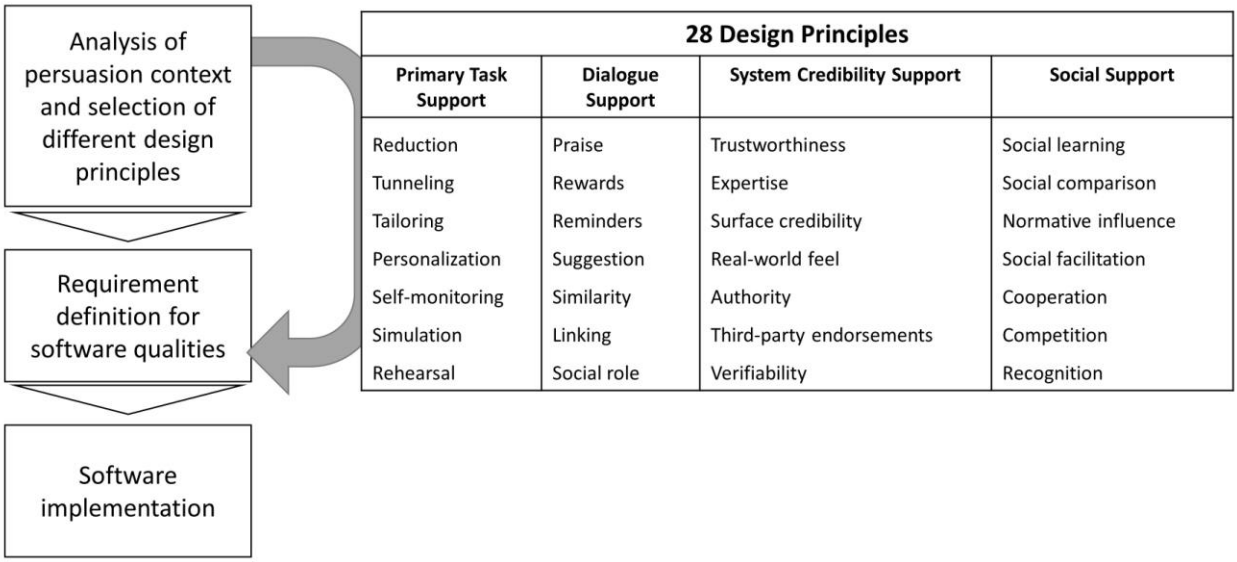

Figure 1. Generic PSD Steps with Design Principles (Oinas-Kukkonen & Harjumaa, 2009)

2.3 Transtheoretical Model

The TTM (Prochaska & DiClemente, 1983) constitutes one model that specifies the behavior-change context in a structured and procedural form. Researchers in the psychology domain widely use the TTM, which describes the process for changing behavior in six consecutive stages (e.g., Boff et al., 2020; Friman et al., 2017; Hashemzadeh et al., 2019): precontemplation, contemplation, preparation, action, maintenance, and termination (Prochaska & Norcross, 2001). Depending on the stage, persuasive technology should support users to change their behavior in different ways (Oinas-Kukkonen & Harjumaa, 2009; Prochaska & Norcross, 2001; Vandelanotte & de Bourdeaudhuij, 2003). Therefore, these stages provide guidance and feasible context to select fitting design principles.

2.3.1 Stages of Change

Prochaska and Norcross (2001) describe the change stages as follows: in the precontemplation stage, people might wish to change but do not intend or seriously consider changing their behavior patterns. They might lack awareness of their behavioral problems, though their families, friends, or employees often do know about them. In the second stage, contemplation, people recognize their problems and think about working on their behavior. During that second stage, people "seriously consider changing the problem behavior" (Prochaska & Norcross, 2001) but do not intend to change their behavior yet. Next, in the

preparation stage, people prepare to take action and 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 action stage. Next, in the maintenance stage, people continue their behavioral change and try to prevent relapsing to their problem behavior. In this stage, people strive to reach the last stage, termination, in which they complete their behavior change and do not risk relapsing into their former behavior (Prochaska & Norcross, 2001).

2.3.2 Transitions

Focusing on the behavior-change process, we address the five transitions between the stages, which we depict in Figure 2.

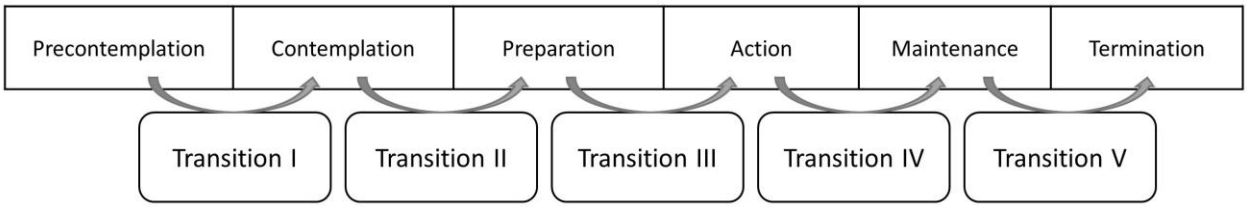

Figure 2. Transitions along the Stages of Change

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

In the first transition from precontemplation to contemplation, BCSS need to reveal the problem behavior to users to raise awareness of their problems. In the second transition from contemplation to preparation, BCSS should further highlight the problem behavior and show the benefits of a changed behavior to form the intent to change. Therefore, BCSS should focus on increasing consciousness and awareness of the problematic behavior. Users in the transition from preparation to action (transition III) need BCSS that support them in performing their target behavior. BCSS should facilitate users' initial approach to adopt their intended behavior. To support users during the fourth transition from action to maintenance, BCSS should reinforce users' new behavior and strengthen their will to maintain it. For the last transition from maintenance to termination, BCSS should help users to form habits and make the changed behavior their regular behavior to prevent relapses.

2.3.3 Related Work

Other researchers have also recognized the potential in combining persuasive technology and behavioral models. Wiafe et al. (2012) analyzed the PSD model's persuasion context with the three-dimensional relationship model between attitude and behavior (3D-RAB model), which categorizes users' state of cognitive dissonance. While they discussed 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 we still lack a link between the persuasion context and the way in which one should select design principles.

Klein et al. (2011) used the TTM to build 16 different constructs that included some design principles but also external factors that do not directly translate to design features (e.g., emotions and self-efficacy). In contrast to Klein et al. (2011), we concentrate on the 28 design principles in the established PSD model that one can directly implement into BCSS.

Oinas-Kukkonen (2010, 2013) introduce the "outcome/change design matrix", which presents three behavior outcomes (forming, altering, reinforcing) and three behavior-change types (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 constitutes a pre-condition for them to sustainably change behavior. Additionally, both approaches share the same goal to consider targeted forms of behavior change: the matrix shows possible forms of behavior change using the two dimensions behavior outcomes and behavior-change types, whereas we use a process-based perspective based on the behavior-change stages. Building on the behavior-change stages, we can examine the specific users' needs and present guidance for referring design principles. In contrast, the matrix takes a descriptive view. Therefore, one should not see the two approaches should as competing but as mutually extending each other due to their different characters (descriptive vs. rather normative).

3 Method

We create a model that recommends appropriate design principles for the five transitions along the behavior-change stages in two steps. First, we developed a model that linked the 28 design principles to the TTM stages. Second, we refined our resulting model via systematically reviewing the literature on implementing BCSS.

3.1 Development of Model Based on Theoretical Background

In the first step, we carefully studied the original papers that introduced the PSD model and the TTM to ensure that our model reflects the underlying models as closely as possible. We independently mapped the 28 design principles to the transitions weighted by their ability to address users' needs (see Section 2.3.2) in each transition. To ensure an unbiased opinion in this initial mapping, we independently coded the 28 design principles into three categories: 1) slight recommendation, 2) recommendation, and 3) strong recommendation. During the mapping, we both identified a fourth category "no recommendation/not applicable". Table 2 shows the number of assigned categories and where we agreed and diverged. To measure the inter-rater agreement between two independent coders with more than one exclusive category, one can use the Cohen's Kappa coefficient (Cohen, 1960; Fleiss et al., 2003). In our case, the Cohen's kappa coefficient κ equaled 0.445 (with $p_0 = 0.729$, $p_e = 0.361$), which indicates a moderate agreement rate (Landis & Koch, 1977).

Table 2. Results of the Independent Coding

		Researcher 1				∑
		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
∑		38	12	67	23	140

Weight	Category
0	Not applicable / not recommended
1	Slight recommendation
2	Recommendation
3	Strong recommendation

We discussed the mapping with a third, independent researcher and resolved identified inconsistencies. In sum, we concluded four recommendation levels as follows:

1) Strong recommendation indicates that the design principles serve users' core needs (see Section 2.3.2) to transition from their current stage in the behavior-change process to the next. Thus, one should consider these design principles as high priority when designing BCSS that support this transition.
2) Recommendation indicates the corresponding design principle does not directly address users' core needs in a specific transition but supports the transition to a high extent.
3) Slight recommendation indicates that the design principle might have positive effects on users' transition but does not include an effect that the transition directly needs.
4) Besides these classifications, some design principles are not applicable or not recommended in specific transitions because nothing indicates they will have a positive effect.

For example, the design principle suggestion refers to a system that "should suggest that users carry out behaviors during the system use process" and that "fitting suggestions will have greater persuasive powers" (Oinas-Kukkonen & Harjumaa, 2009, p. 493). Regarding the five transitions, suggestions cannot reveal problem behavior to users, which they require for the first transition. Therefore, suggestion is not applicable / not recommended for designing a BCSS that targets the first transition. On the contrary, users in the second and third behavior-change stages need to see the benefits associated with a changed

behavior and an approach to take the first steps toward it. Specific suggestions for behavior and actions address those core needs to transition into the preparation and action stages (Prochaska & Norcross, 2001). Thus, we categorized suggestion as strongly recommended for designing BCSS that target the second and third transitions. For the fourth transition, when users in the action stage strive to reach maintenance, they need to strengthen their will to maintain their changed behavior that they already started performing (Prochaska & Norcross, 2001). In this transition, the design principle suggestion does not address the users' core needs in contrast to design principles such as reminders, self-monitoring, and competition (Oinas-Kukkonen & Harjumaa, 2009). Therefore, we categorized the design principle suggestion as slightly recommended for designing BCSS that target the fourth transition. Regarding the fifth transition where users form a habit and make the changed behavior a regular behavior, suggestion's relevance rises compared to the fourth transition to prevent a relapse. Consecutively, we categorized the design principle suggestion as recommended for the fifth transition.

In addition, we categorized some design principles, such as personalization, trustworthiness, and expertise, as recommended for all BCSS transitions since they address users' basic needs. We incorporate this finding by assigning these design principles to "basic requirements". The way in which we understand basic requirement concurs with Herzberg et al.'s (2008) hygiene factors concept.

3.2 Refinement of Model Based on Systematic Literature Review

In the second step, we studied the role that design principles play in the transition phases in a systematic literature review to ensure that the model concurs with existing research studies about BCSS and to refine the conceptual mapping (see Figure 3). A systematic literature review mitigates the risk that we disregarded studies that could contradict our model and the risk that we used studies that caused a biased model (Boell & Cecez-Kecmanovic, 2015). Outlining the approach transparently, we defined a search protocol as Boell and Cecez-Kecmanovic (2015) and vom Brocke et al. (2015) have suggested.

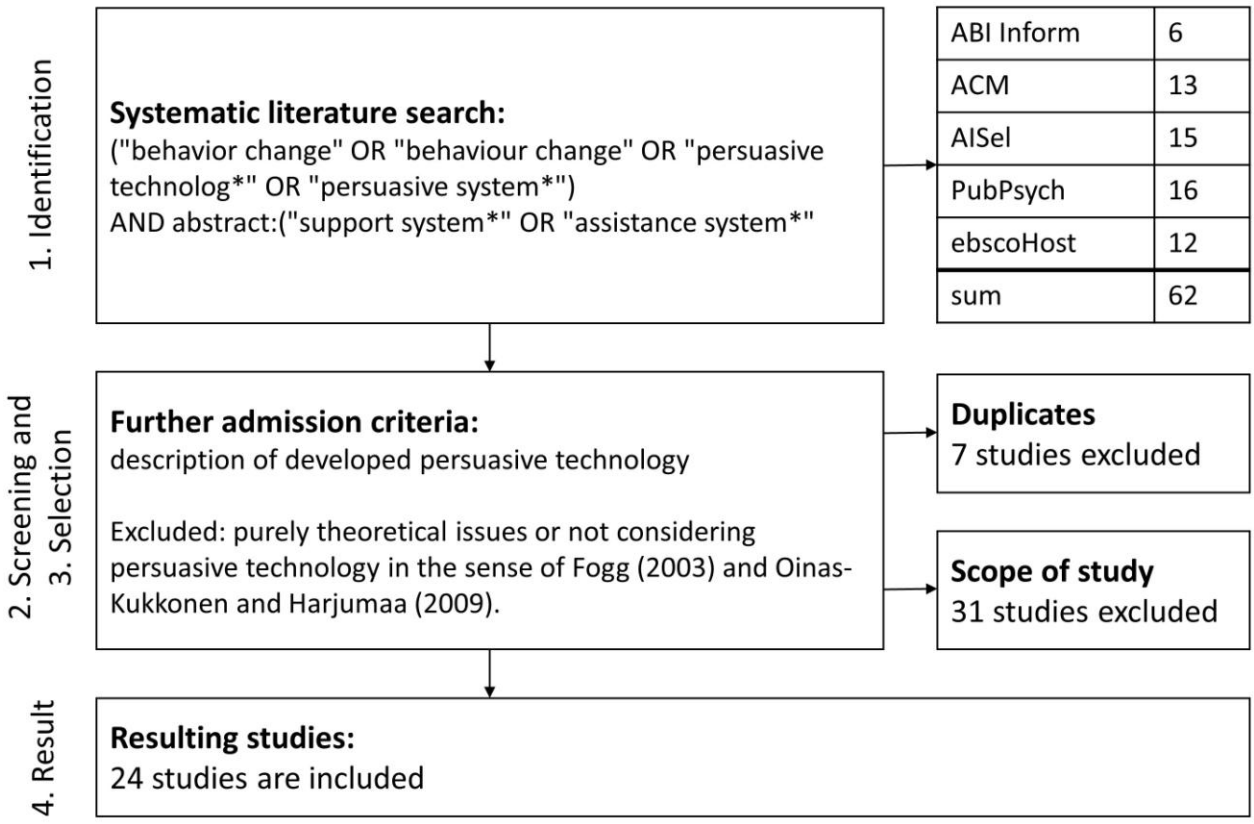

Figure 3. Literature Review Flow Chart

To systematically identify relevant studies that introduced 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*"),* which led 62 studies. We further checked whether studies described a developed persuasive technology so that we could clearly analyze the design elements. We excluded seven duplicates and 31 papers that dealt with purely theoretical issues or did not consider persuasive technology in the same sense as Fogg (2003) and Oinas-Kukkonen and Harjumaa (2009). We did not define specific inclusion criteria and, thus, included all remaining studies (i.e., 24) in our literature review to refine the model.

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

Based on the theoretical analysis and insights from the literature review in step two, we supplemented our example from step one as follows: the design principle suggestion is not applicable / not recommended for designing BCSS that target the first transition. In fact, from our literature review, we found that users tend to be averse to advice when they do not experience any problems yet (Phillips & Landon, 2016). As for the second and third transitions, Nguyen et al. (2018) and Song et al. (2017) implemented suggestions to reveal the benefits associated with a changed behavior and an approach to take the first steps toward it. Thus, we found confirmation for categorizing the design principle suggestion as a strong recommendation for the second and third transitions. As for the fourth transition, we found that suggestion can act as a form of feedback and positively affect whether people change their behavior (Wilson & Djamasbi, 2017), which concurs with a slight recommendation. Furthermore, because suggestions can help users recall target goals and present new perspectives (Nguyen et al., 2018), suggestion has the ability to prevent a relapse, which indicates a recommendation for the fifth transition.

4 Analysis

Table 3 presents the resulting way in which we mapped the different design principles to the five behavior-change transitions and presents the studies that we used for the refinement and our discussion. The table links the 28 design principles in the PSD model (see Figure 1) to the transitions along the behavior-change stages in the TTM (see Figure 2). We weighted the design principles using a color scale from white (not applicable / no recommendation) to black (strong recommendation). A black dot indicates a basic requirement; that is, that a principle pertains to the entire behavior-change process. The listed studies indicate and substantiate the weighting we applied to the referring design principles.

Of the 28 design principles in the PSD model, we identified 11 as basic requirements. We categorized the remaining 17 into the four recommendation levels. Linking the 17 design principles and the five transitions resulted in 85 combinations: 31 (36%) show not applicable or not recommended in the referring transition, 17 (20%) show a slight recommendation, 11 (13%) show recommendation, and 26 (31%) show a strong recommendation in the referring transition. The mapping reveals that the seven design principles in the category system credibility support act as basic requirements (Lehto & Oinas-Kukkonen, 2013; Oinas-Kukkonen, 2013). Most design principles relate to the fourth and fifth transitions (i.e., from action to maintenance and from maintenance to termination, respectively).

In Sections 4.1 to 4.6, we discuss the role that the design principles in the PSD model play in the behavior-change process along with example implementations. We start with the basic requirements that pertain to the whole transition process before discussing the five transitions.

Table 3. Resulting Mapping of the Design Principles to Behavior-change Transitions and Referring Studies

Category	Principle	I	II	III	IV	V	Studies (see Section 3.2)
Primary task support	Reduction			■	▒		Lehto & Oinas-Kukkonen (2013)
	Tunneling	▒	■	▒			Sunio et al. (2018)
	Tailoring	▒	■	▒	▒	▒	Liang et al. (2006), Schäfer & Willemsen (2019), Sunio et al. (2018)
	Personalization			•			Kelders (2015), Klein et al. (2014), Lehto & Oinas-Kukkonen (2013), Lehto & Oinas-Kukkonen (2015), Nguyen et al. (2018), Oinas-Kukkonen & Harjumaa (2009), Schäfer & Willemsen (2019), Wilson & Djamasbi (2017)
	Self-monitoring				■	■	Harjumaa & Muuraiskangas (2013), Klaassen et al. (2015), Klein et al. (2014), Kulyk et al. (2014), Lehto & Oinas-Kukkonen (2013), Sunio et al. (2018)
	Simulation	▒	■	▒		▒	Lehto & Oinas-Kukkonen (2015), Sunio et al. (2018)
	Rehearsal		▒	■			Harjumaa & Muuraiskangas (2014), Langrial,et al. (2014), Lehto & Oinas-Kukkonen (2015)
Dialogue support	Praise		▒	▒	■	■	Harjumaa & Muuraiskangas (2014), Lehto & Oinas-Kukkonen (2015), Toscos et al. (2006)
	Rewards				■	■	Nguyen et al. (2018), Wilson & Djamasbi (2017)
	Reminders				■	■	Harjumaa & Muuraiskangas (2014), Klaassen et al. (2015), Kulyk et al. (2014), Langrial et al. (2013), Langrial et al. (2014), Lehto & Oinas-Kukkonen (2013), Lehto & Oinas-Kukkonen (2015)
	Suggestion		■	■	▒	▒	Lehto & Oinas-Kukkonen (2015), Nguyen et al. (2018), Phillips & Landon (2016), Song et al. (2017)
	Similarity			•			Kulyk et al. (2014)
	Liking			•			
	Social role			•			
System credibility support	Trustworthiness			•			Lehto & Oinas-Kukkonen (2014), Lehto & Oinas-Kukkonen (2015)
	Expertise			•			
	Surface credibility			•			
	Real-world feel			•			
	Authority			•			
	Third-party endorsements			•			
	Verifiability			•			
Social support	Social learning	▒	■	▒		▒	Davis (2012), Nkwo (2019)
	Social comparison		▒	▒	■	■	Davis (2012), Lehto & Oinas-Kukkonen (2015), Nkwo (2019), Sunio et al. (2018)
	Normative influence	▒	■	▒	▒	▒	Kamphorst et al. (2014), Sunio et al. (2018)
	Social facilitation		▒	▒	■	▒	Nkwo (2019)
	Cooperation				■	■	Divjak & Rupel (2018), Minichiello et al. (2019)
	Competition			▒	■	■	Davis (2012), Nkwo (2019)
	Recognition				■	■	Davis (2012), Nkwo (2019)

White: not applicable / no recommendation
Light grey: slight recommendation
Dark grey: recommendation
Black: strong recommendation
Black dot: basic requirement

4.1 Basic Requirements

According to the analysis, 11 design principles act as basic requirements along the five transitions, which means one should consider them regardless of the specific behavior-change stage: personalization, similarity, liking, social role, and the design principles in the system credibility support category (trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability).

Researchers have addressed personalization as a relevant design principle throughout the entire behavior-change process as personalized elements have a strong ability to motivate users (Harjumaa & Muuraiskangas, 2014) and lead to users feeling more engaged and invested (Wilson & Djamasbi, 2017). Therefore, personalization has the potential to support people in starting their behavior change and in preventing relapses into old and undesired behavior patterns (Harjumaa & Muuraiskangas, 2014; Schäfer & Willemsen, 2019). BCSS developers have integrated personalization by allowing users to create their own profile with a name and picture (Kelders, 2015; Oinas-Kukkonen & Harjumaa, 2009) or to select design features (Lehto & Oinas-Kukkonen, 2015). Additional examples include personalized feedback or advice (Klein et al., 2014; Lehto & Oinas-Kukkonen, 2013; Nguyen et al., 2018) and personalization based on tailoring by leading users to individually set their goals (Schäfer & Willemsen, 2019).

Kulyk et al. (2014) emphasized that BCSS users appreciate similarity, liking, and social role. Oinas-Kukkonen and Harjumaa (2009) addressed the relevance of the design principle similarity in stating that systems that remind users about themselves will likely persuade them more than systems that do not. The design principle liking adds an attractive and appealing look and feel (Oinas-Kukkonen & Harjumaa, 2009). Oinas-Kukkonen and Harjumaa (2009) further specified that BCSS that include the design principle category act more persuasively.

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. While considering these design principles when designing BCSS does not enable user activities, their absence would result in dissatisfaction. Trustworthiness, expertise, and authority affect a BCSS's persuasiveness as they let the system seem truthful, fair, and unbiased and demonstrate knowledge, experience, and competence (Oinas-Kukkonen & Harjumaa, 2009). Surface credibility, real-world feel, third-party endorsements affect the extent to which users perceive a system as credible because these they provide a competent look and feel, information about the people behind the BCSS, endorsements from respected sources, and links to outside sources (Oinas-Kukkonen & Harjumaa, 2009). Lehto and Oinas-Kukkonen (2014, 2015) highlighted this category's importance as perceived credibility strengthens the intention to continue.

4.2 Transition I: Precontemplation to Contemplation

Users in the precontemplation stage do not know that the addressed problem exists (Prochaska & Norcross, 2001). Due to this unawareness, one can find it difficult to reach potential users because they do not actively look for a behavior change and a transition to the next contemplation stage. Therefore, only a few design principles pertain to BCSS for the first transition. To reach users in the precontemplation stage, other efforts outside BCSS may prove beneficial (e.g., family, friend, or coworker interventions or supplementary measures such as marketing). The most fitting design principles for the first transition include simulation and social learning (recommendation) and tunneling and normative influence (slight recommendation). These design principles can reveal the problem behavior to users.

Simulation enables users to observe the link between cause and effect (Oinas-Kukkonen & Harjumaa, 2009). For example, Sunio et al. (2018) used simulation in a slideshow to present before-and-after pictures. One can also reveal the effect that certain behaviors have with social learning when users observe others performing the behaviors (Oinas-Kukkonen & Harjumaa, 2009). One can address social learning by, for example, including experience reports (Davis, 2012) or by enabling users to exchange best practices (Nkwo, 2019).

Tunneling guides users along the attitude-change process by providing relevant information (Oinas-Kukkonen & Harjumaa, 2009). Additionally, one could add normative influence, tailoring, and expertise as

design principles in the first transition to increase the likelihood that a person will adopt a target behavior (Lehto & Oinas-Kukkonen, 2015; Oinas-Kukkonen & Harjumaa, 2009; Sunio et al., 2018).

In the first transition, the design principles reduction, self-monitoring, rehearsal, praise, rewards, reminders, suggestion, social comparison, social facilitation, cooperation, competition, and recognition cannot address users' needs. The model does not recommend the design principle suggestion for the first transition because it can lead users to reject the precontemplation stage when they do not have problem awareness yet (Phillips & Landon, 2016). Design principles such as rehearsal, praise, and reminders require a certain awareness of the problem that people in this stage lack. Other design principles such as rewards, recognition, and cooperation lack applicability because they require users to execute the target behavior (Oinas-Kukkonen & Harjumaa, 2009).

4.3 Transition II: Contemplation to Preparation

In the contemplation stage, users know they have an existing problem but do not actively intend to change (Prochaska & Norcross, 2001). Transitioning to the preparation stage mostly relies on the categories primary task support and social support. In detail, the model strongly recommends the design principles tunneling, tailoring, simulation, social learning, and normative influence for the second transition. These design principles can raise awareness about the problem behavior, show benefits that a changed behavior can have, and, therefore, help users form the intent to change. In this second transition, tunneling guides users and provides means for action (Liang et al., 2006). Tailoring refers to ensuring that information aligns to the context and the targeted user group's needs (Oinas-Kukkonen & Harjumaa, 2009). As an example for tunneling and tailoring, Oinas-Kukkonen and Harjumaa (2009) suggested providing relevant information about the problem behavior and possible treatments and stories from peers that refer to different user groups. Sunio et al. (2018) applied tunneling and tailoring by reporting personalized diagnostics that included a goal and directed users to relevant new elements. *Simulation* highlights the problem behavior by showing the results of behavior change, which agrees with its function in transition (I) (Lehto & Oinas-Kukkonen, 2015). Social learning and normative influence provide a means for users to change their behavior and motivate them by allowing them to observe other people performing the target behavior and gathering people with the same goal (Oinas-Kukkonen & Harjumaa, 2009). Social learning can connect people by, for example, using a shared fitness journal (Consolvo et al., 2006). Normative influence impacts behavior by, for example, adding peer pressure (Oinas-Kukkonen & Harjumaa, 2009) or taking users' culture and environment into account (Kamphorst et al., 2014).

Besides these strong recommendations, the model recommends rehearsal. Rehearsal can raise awareness by emphasizing a changed behavior's benefits (Harjumaa & Muuraiskangas, 2014) and helps people prepare for real situations (Langrial et al., 2014; Oinas-Kukkonen & Harjumaa, 2009). One can implement rehearsal in various forms, such as a roleplay (Harjumaa & Muuraiskangas, 2014) or a video-based exercise builder (Lehto & Oinas-Kukkonen, 2015). Additionally, the model slightly recommends praise, social comparison, and social facilitation to raise motivation and strengthen the intent to change (Lehto & Oinas-Kukkonen, 2015; Sunio et al., 2018).

Design principles that do not pertain to BCSS that address the third transition include reduction, self-monitoring, rewards, reminders, cooperation, competition, and recognition. As for the first transition, one cannot implement these design principles per their definition as since they require users to perform the target behavior (Oinas-Kukkonen & Harjumaa, 2009), which they do not yet do in the second transition (Prochaska & Norcross, 2001).

4.4 Transition III: Preparation to Action

Users in the third transition need BCSS that help them with an initial approach (a "game plan" (Prochaska & Norcross, 2001)) to take their first steps and form their intended behavior. The model recommends principles primarily in the primary task support and social support categories for this transition since they provide guidance and a means for the change in addition to social components that emphasize motivation to change.

The model strongly recommends the design principles reduction, suggestion, and rehearsal for the third transition. Reduction breaks down complex behavior into simple tasks or subtasks (Lehto & Oinas-Kukkonen, 2013; Oinas-Kukkonen & Harjumaa, 2009) and, therefore, also lowers the barriers to take the first step towards the target behavior and increases users' willingness to engage with the BCSS. Suggestion offers specific applications of the target behavior, such as an exercise plan based on

preferences and goals (Lehto & Oinas-Kukkonen, 2015). Advice proves especially effective when users experience some form of loss or the situation involves low risk (Phillips & Landon, 2016). Rehearsal explicitly helps people prepare for real situations (Oinas-Kukkonen & Harjumaa, 2009) as a training technique (Langrial et al., 2014).

Besides these strong recommendations, the model recommends the design principles tailoring, praise, social learning, and normative influence. Tailoring supports users to make better choices (Schäfer & Willemsen, 2019). Praise has the ability to strengthen individuals' motivation to reach their goals (Harjumaa & Muuraiskangas, 2014; Toscos et al., 2006). Social learning can supplement tailoring by showing users their peers' behaviors and helps them to build individual goals for the intended behavior (Consolvo et al., 2006). Normative influence can induce active behavior via defaults. Such defaults can appear, for example, as default goals and contribute to tailoring by facilitating users' decision process (Loock et al., 2013). The PSD model does not explicitly introduce goal setting as a design principle. However, researchers have widely studied goal setting and found that it influences behavior (Locke & Latham, 1991, 2002) and that one should consider it in the behavior-change process. As for the design principles in the PSD model, goal setting may combine suggestion, reduction, tailoring, and normative influence. Therefore, setting an individual goal has a strong potential to support the third transition from preparation to action.

In the third transition, the design principles self-monitoring, rewards, reminders, cooperation, and recognition lack applicability because they do not focus on supporting an initial approach to the target behavior. As we describe for the first and second transitions, the design principles per definition only apply when users already perform the target behavior (Oinas-Kukkonen & Harjumaa, 2009), which they do not yet do in the third transition (Prochaska & Norcross, 2001).

4.5 Transition IV: Action to Maintenance

During the fourth transition, BCSS should reinforce users' new behavior and strengthen their will to maintain their changed behavior. Therefore, design principles that analyze users' behavior come into focus. Two categories in particular address these needs: dialogue support and social support.

The model strongly recommends the design principles 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, helps them to achieve their goals (Oinas-Kukkonen & Harjumaa, 2009). Regarding the intended continual interaction with BCSS, self-monitoring has the potential to help users better recognize their behavior patterns. Because deviations become recognizable, the appearing links to negative consequences encourage users to make progress (Sunio, et al., 2018) and serve as guidance (Kulyk et al., 2014). Furthermore, self-monitoring functions as a reminder, warning, advice, or assessment (Klaassen et al., 2015). Example implementations include calculators for one's own eating habits or medication (Klein et al., 2014; Lehto & Oinas-Kukkonen, 2013). Displaying users' behavioral values besides the values for their peers combines self-monitoring and social comparison. Praise provides information-based feedback via, for example, words, images, or sounds (Oinas-Kukkonen & Harjumaa, 2009), which has positive effects on individuals' motivation (Harjumaa & Muuraiskangas, 2014; Toscos et al., 2006). The design principle rewards gives credit for performing the target behavior and can provide great persuasive powers (Oinas-Kukkonen & Harjumaa, 2009). Therefore, one should integrate rewards into BCSS as soon as users enter the action phase and perform the desired behavior. Rewards can function as positive feedback (Harjumaa & Muuraiskangas, 2014), which leads users to recall their target goals (Nguyen et al., 2018). In this way, rewards can contribute to altering and reinforcing behavior (Wilson & Djamasbi, 2017). The design principle reminders can call the target behavior to the users' mind (Oinas-Kukkonen & Harjumaa, 2009), make them remember to use the system during the intervention (Langrial et al., 2013, 2014; Lehto & Oinas-Kukkonen, 2013), and keep them motivated (Lehto & Oinas-Kukkonen, 2015). One can implement reminders as regular text messages (Klaassen et al., 2015; Lehto & Oinas-Kukkonen, 2013) or impulses at opportune moments (Harjumaa & Muuraiskangas, 2014), such as when users perform at a level lower than a target score (Kulyk et al., 2014).

Additionally, integrating competition can be beneficial and raise social motivation (Davis, 2012); however, such competitiveness must remain at a healthy level (Nkwo, 2019). Davis (2012) and Nkwo (2019), for example, implemented competition through social comparison. Social comparison and social facilitation can raise users' motivation and strengthen their intent to change (Sunio, et al. 2018; Lehto & Oinas-Kukkonen, 2015) and pertain highly to keeping users in action. Both go hand in hand as one can achieve

social facilitation with 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 & Harjumaa, 2009). BCSS developers have typically addressed cooperation through tasks that require teamwork (Divjak & Rupel, 2018; Minichiello et al., 2019). By offering recognition to an individual or a group, BCSS can increase the likelihood that users will adopt a target behavior (Oinas-Kukkonen & Harjumaa, 2009). For example, a BCSS that sends users appreciative and grateful messages to reward good performance addresses recognition (Davis, 2012; Nkwo, 2019).

Besides the strongly recommended design principles, the model recommends reduction in the fourth transition since one needs to keep users performing the new behavior. Slight recommendations in this transition include tailoring, suggestion, and normative influence. Tailoring supports users to make better choices (Schäfer & Willemsen, 2019), and suggestion provides specific applications of the target behavior (Lehto & Oinas-Kukkonen, 2015). The model indicates both design principles as only slightly recommended in this transition since users already know how to adopt their new behavior. For the same reason, the model also indicates normative influence as slightly recommended.

Design principles that cannot address users' needs in this transition include tunneling, simulation, rehearsal, and social learning. While the preparatory transitions require simulation, rehearsal, and social learning, they do not explicitly support users when performing the target behavior. In a similar vein, tunneling guides users in the attitude-change process (Oinas-Kukkonen & Harjumaa, 2009), which means that the need for it dissipates after the preparation stage.

4.6 Transition V: Maintenance to Termination

For the last transition, BCSS should help users to form habits and make the changed behavior their regular behavior. Therefore, BCSS developers need to integrate design elements of the fourth transition. In addition, they should apply elements of precontemplation that can address the importance of keeping up with the new behavior. Comparison to users' past status can help them to extend and reawake their motivation. Looking at the different categories, dialogue support and social support stand out.

Just as with the fourth transition, the model strongly recommends self-monitoring, praise, rewards, reminders, social comparison, cooperation, competition, and recognition for the fifth transition. Self-monitoring tracks users' behavior and makes progress or new behavioral patterns visual, which can help users maintain motivation (Harjumaa & Muuraiskangas, 2013) and visible deviations from the desired behavior remind people about negative consequences to stay on track (Sunio et al., 2018). Because the design principles praise, rewards, social comparison, cooperation, competition, and recognition can raise or strengthen motivation, one can implement them the same way as in the fourth transition but with a different focus. While a BCSS that targets the fourth transition focuses on motivating users to change their behavior, a BCSS that targets the fifth transition focuses on ensuring that users maintain their motivation for long-term behavior change. Additionally, one can use reminders to bind users to the BCSS in the long term.

In the fifth transition, the model recommends the design principles tailoring, suggestion, and social facilitation. Tailoring and suggestion rise in relevance compared to the fourth transition. Both design principles support users in giving advice regarding suitable exercises or impulses to simplify complex tasks of changing behavior (Song et al., 2017). While users in the maintenance stage have already prepared and rehearsed their actions, keeping up with their changed behavior represents a new task. Therefore, users need more support through tailoring and suggestion to facilitate the maintenance stage. Additionally, social facilitation can raise motivation, strengthen users' will to maintain behavior, and, consequently, prevent relapses. Additionally, the model slightly recommends normative influence, simulation, and social learning.

Design principles that cannot address users' needs in the fifth transition include reduction, tunneling, and rehearsal. While they facilitate initial steps in earlier transitions, they do not contribute to sustainable behavior change that users need to achieve the termination stage. In particular, Oinas-Kukkonen and Harjumaa (2009) define tunneling in a way that highlights its supporting effect in prepartory stages; that is, as bringing users "closer to the target behavior" (Oinas-Kukkonen & Harjumaa, 2009, p. 492). As soon as users perform the target behavior, this effect no longer supports their needs (Prochaska & Norcross, 2001).

5 Conclusion

Our model (see Figure 4) presents process-based guidance for developing BCSS based on the PSD model (Oinas-Kukkonen & Harjumaa, 2009) and the behavior-change stages in the TTM (Prochaska & DiClemente, 1983; Prochaska & Norcross, 2001). We introduce a tangible model for implementing fitting and effective design principles according to the targeted behavior-change stages to BCSS researchers and developers. Figure 4 summarizes the recommendation model in a condensed form. It fills the gap between analyzing the persuasion context and selecting different design principles for BCSS software implementations. The model provides guidance on which design principles one should implement in BCSS depending on users' current stage in the behavior-change process while not restricting individual decisions. The recommendation levels indicate the priority for implementation from strong recommendation, recommendation, and slight recommendation; the design principles at the bottom present the basic requirements along all transitions.

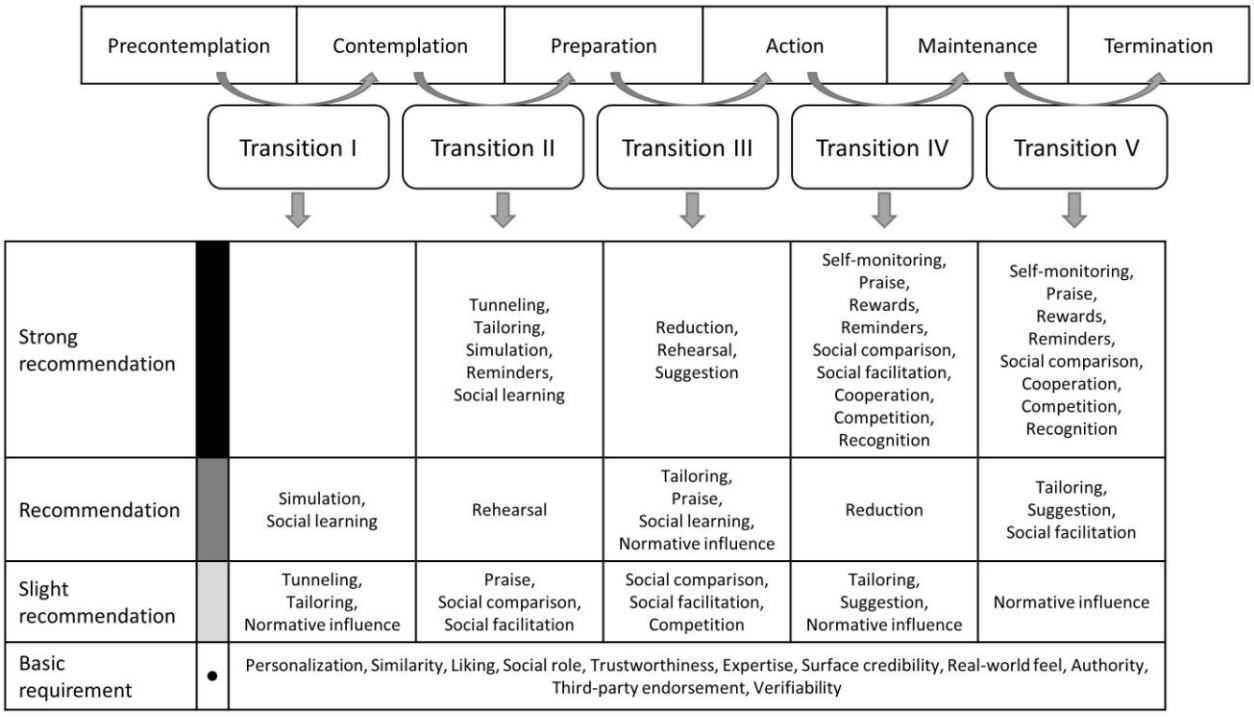

Figure 4. Condensed Model

The model presents the appropriate design principles for each transition along the behavior-change stages. Providing specific recommendations, the model depicts that BCSS developers need to choose the fitting design principles according to users' behavior-change stage.

Most existing BCSS focus on users in the action and maintenance stages (i.e., users in the fourth and fifth transitions) and who already have problem awareness and have begun preparing to change. This finding concurs with the results of our analysis that most design principles in the PSD model can address the fourth and fifth transitions (see Figure 4). Further, we identified that it is a major challenge for BCSS to reach users without intent to change behavior (i.e., support transition I). Our model further indicates that BCSS by themselves may not be sufficient enough to persuade users in the precontemplation stage. Other research areas as marketing have the potential to reach users and, therefore, to supplement BCSS that focus on the first transition.

Addressing all transitions allows BCSS developers to involve a broader target audience in using the BCSS independent of a user's behavior-change stage and to address problem awareness to prevent relapses. When a BCSS supports multiple transitions, we propose that one should design it with different sections and corresponding features for each transition. Merz (2020) proposed an implementation example in which the user passes different levels that each address a transition in the behavior-change process. Dividing a BCSS into specific sections related to the transitions allows BCSS developers to focus on most pertinent design principles for specific behavior-change stages. In addition to providing guidance on

choosing relevant design principles depending on the users' current behavior–change stage, the model emphasizes integrative approaches to design in persuasive systems.

Our paper has several potential limitations. First, our resulting model remains rather general despite our motivation to develop the model due to the PSD model's own generic nature. However, we decided consciously not to narrow the focus to maintain its applicability to different research disciplines (health, environment, work, etc.). Therefore, this approach provides a starting point for future research in developing more context-specific models. Second, we decided to draw on the behavior-change stages in the TTM to fill the gap between technical and behavioral model. Prochaska and DiClemente (1983) and Prochaska and Norcross (2001) originally developed the TTM to help treat people with addictive behavior, but researchers have since applied it in various other situations such as stress management (Velicer et al., 1998), academic procrastination (Grant & Franklin, 2007), and consumer debt behavior (Xiao et al., 2004). Furthermore, other behavioral models also address behavior-change stages, such as the 3D-RAB (Wiafe et al., 2011). The 3D-RAB states 12 transitions (Wiafe et al., 2012). In order to enhance the model's applicability, we decided on the less complex TTM with five transitions. Thus, further research could 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 we developed it partially based on subjective coding. However, following our methodological procedure in which we searched the literature using four interdisciplinary databases with a wide search string, we believe that we incorporated adequate studies into our analysis for confirmation and minimized potential bias.

While we tried to minimize our subjective bias when conducting our qualitative analysis, further research should validate our model and test its applicability when developing BCSS. Additionally, while we build on the PSD model as the most referenced and established technical framework for developing BCSS, we found indications that researchers have used design principles inconsistently in literature (Gregor et al., 2020; Möller et al., 2020). Therefore, further research should clarify the consistent understanding and formulation of design principles for BCSS. We found a particularly sparse theoretical base for the model regarding our identified basic requirements, especially for the system credibility support category since existing research has mostly neglected it (Matthews et al., 2016). Therefore, future research should investigate possible ways to implement these design principles and their potential. Also, research should examine and develop other design principles. First, many studies and BCSS developments have begun to add forms of feedback. For example, Wilson and Djamasbi (2017) defined the design principles praise, rewards, reminder, and suggestion as feedback. The PSD model states that the whole dialogue support category provides system feedback. To ensure consistent use and understanding, researchers should elaborate on the feedback concept further in the BCSS context. Second, in recent studies since the PSD model's development, the gamification concept has notably become increasingly popular. So far, the PSD model indirectly incorporates gamification via competition or cooperation. However, we require more research to elaborate on and integrate gamification more explicitly into the mode. Third, we propose integrating goal setting into the model as an additional design principle that can strongly contribute to the behavior-change process.

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