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ORIGINAL ARTICLE

Categorizing users in behavior change support systems based on cognitive dissonance

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Abstract Most developers of behavior change support systems (BCSS) employ ad hoc procedures in their designs. This paper presents a novel discussion concerning how analyzing the relationship between attitude toward target behavior, current behavior, and attitude toward change or maintaining behavior can facilitate the design of BCSS. We describe the three-dimensional relationships between attitude and behavior (3D-RAB) model and demonstrate how it can be used to categorize users, based on variations in levels of cognitive dissonance. The proposed model seeks to provide a method for analyzing the user context on the persuasive systems design model, and it is evaluated using existing BCSS. We identified that although designers seem to address the various cognitive states, this is not done purposefully, or in a methodical fashion, which implies that many existing applications are targeting users not considered at the design phase. As a result of this work, it is suggested that designers apply the 3D-RAB model in order to design solutions for targeted users.

Keywords Behavior change support systems · Persuasive technology · Persuasive systems design · Cognitive dissonance · Behavior change

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1 Introduction

Behavior change support systems (BCSS) is the use of socio-technical information systems with properties that seek to form, alter or reinforce attitudes, behaviors or an act of compliance without the use of coercion or deception [1]. It is the use of technology to change user's attitude or behavior to a predetermined one [2, 3]. Accordingly, instead of achieving user target attitude or behavior as a side effect of using technology, systems are designed to intentionally change attitude, behavior or an act of compliance. The main distinguishing factor between BCSS and other interactive systems is that they are inherently transformative and deliberately attempt to infuse cognitive change in the mental state of a user [4]. In most cases, its definition and domain is limited to the features exhibited by the system. BCSS combine the positive attributes of interpersonal interaction and mass communication to achieve optimal persuasion [5], and they should be capable of demonstrating a change and/or reinforcement/shaping of either behavior or attitude [6, 7]. They are not the same as mass media persuasion [8], which often fails to accommodate individual difference, and instead provides generic solutions for target groups [9].

However, despite the increasing use of BCSS in behavior and attitude change interventions, appropriate methods to support their design are still insufficient [10, 11]. This can be attributed primarily to the fact that most of the existing methods for information systems design do not address the pertinent issues in BCSS; i.e., factors that need to be considered during design to support attitude and behavior change. Consequently, in most cases, BCSS designers adopt ad hoc design approaches, thereby limiting their potential effectiveness.

The introduction of the persuasive systems design (PSD) model [12] provides a promising step toward the

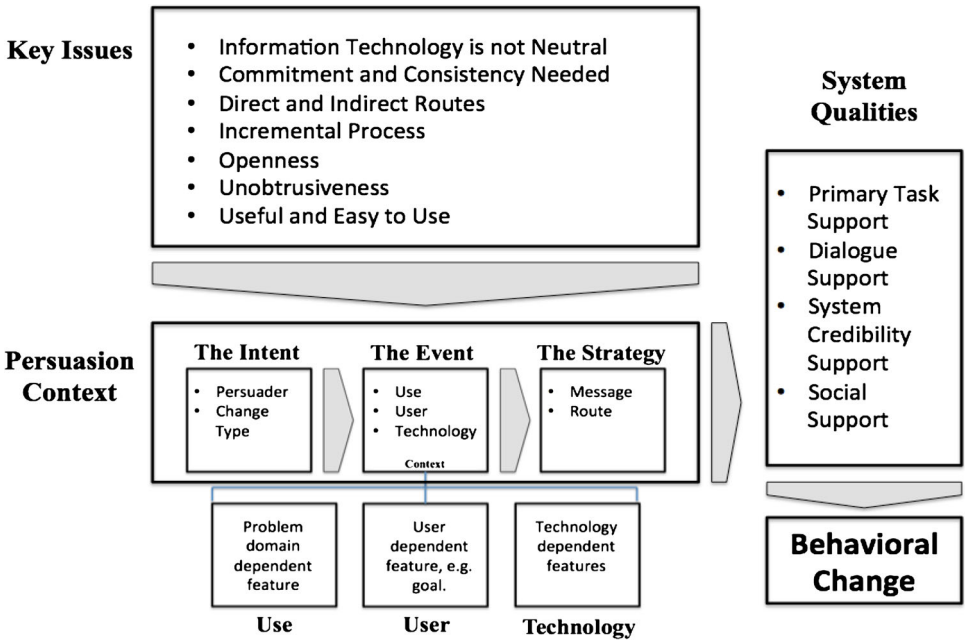

Fig. 1 Persuasive systems design model (cf. [12])

systematic development of systems that are capable of altering behavior or attitude. However, the model does not suggest specific guidelines concerning how to take those various steps that it proposes, and even more importantly, it does not explicitly address how BCSS can be designed to adapt to changes in users' cognition as they progress towards the target behavior. Generally, research in BCSS has neglected studies on how to change users incrementally from an act of compliance to attitude change through behavior change [1]. Rather they either aim to distinguishing behavior types [13] or suggest how designers can imitate other existing systems [14].

To address the need for a method that can effectively consider changes in a user cognitive state, and to address shifts in user demand and stability, this paper presents the three-dimensional relationships between attitude and behavior (3D-RAB) model. The model segments users into eight distinct states based on variations in their cognitive dissonance characteristics, concerning (1) their current behavior (CB), (2) user attitude toward the target behavior and (3) attitude toward change in behavior or maintenance of behavior. It applies the cognitive dissonance theory [15] specifically for designing systems that aim to change, alter or form behavior or attitude. It argues that dissonance between one's attitude and behavior serves as a motivating factor for persuasion [15] and continues that characterization of users better inform the design of BCSS. The model enables the designer to identify the cognitive needs of specific users and design systems to accommodate the changing needs of users accordingly. In effect, it provides information on how to study the changing cognitive dissonance patterns in users, and this facilitates the use of the PSD model for BCSS development. The proposed model uses a "user-investigation" approach, as compared to the "behavior-investigation" approach adopted by existing models.

The structure of this paper is as follows: The PSD model and the cognitive dissonance theory are summarized. This is followed by justification of the key attributes that need to be considered during BCSS design. The formation of the proposed model is followed by a description of how existing BCSS are mapped to the 3D-RAB model to identify how researchers have addressed the various target user segments as described by the model.

2 The PSD model

Although there are a number of descriptions for developing BCSS, the PSD model [4, 12] is arguably the first model to provide a comprehensive set of information required to analyze, design and evaluate BCSS. Thus, it has been successfully applied in developing and evaluating systems design to persuade [16]. It consists of three main phases, and it is based on the principle that before a successful BCSS is designed, there is the need to understand the key issues behind the development and the persuasion context (see Fig. 1). Oinas-Kukkonen and Harjumaa [12] suggested that based on their empirical work and conceptual analyses, seven postulates need to be addressed or considered during design. Two of these postulates relate to the designer's assessment of the user, two related to persuasion context, and the remaining three are related to system qualities.

The model analyses the persuasion context as an essential part of promoting attitude or behavior change [12]. The first step in analyzing the persuasion context is to consider the user intent, which is defined by specifying the persuader and change type. As proposed by Fogg [17], the persuader can be defined as being one of three main types: (1) the creator/producer of the interactive technology (endogenous), (2) those with governance of the interactive technology (exogenous), and (3) the user (autogenous). Type of change is defined as being either attitude change or behavior change.

The next step of analyzing the persuasion context is to understanding the event [12]. This is decomposed as the use context, the user context, and the technology context. Here, the designer needs to study and understand the domain specific issues at the use context level. Particular consideration is given to individual differences, in terms of the specific user information processing approaches and the target goals [18]. The third issue in event analysis is the consideration of the technology context. Technology context deals with the strengths and weaknesses of the technology when used to design the system.

The final step when analyzing the persuasion context is consideration of the strategy [12]. The PSD model argues that the designer needs to define the persuasive route (i.e., direct or indirect) in order to consider the message that will promote persuasion. The persuasive message can be communicated either through a direct or indirect approach, depending on the user characteristics, as proposed in the third postulate.

Although the model provides information concerning what should be done to study the potential user of the system, it fails to provide a specific set of guidelines concerning how to analyze the user, thus limiting some of its practical potential. For instance, the PSD model argues that the selection of appropriate routes, methods and strategy is necessary for designing an effective BCSS, yet it fails to provide practical information concerning how this can be done. As such the model would be more useful when used in conjunction with other methods to analyze the persuasion context [19].

By expanding on some of the postulates in the PSD model, suggestions can be made to address how some of the pertinent issues in the persuasion context analysis can be addressed. Specifically, the foundation of the second postulate provides relevant information that can be used to analyze the user context. Next, we discuss the cognitive dissonance theory [15].

3 The relationship between attitude and behavior: cognitive dissonance theory

One of the main assumptions behind the PSD model is that individuals prefer that their thoughts are in harmony with their behavior, as stated in the second postulate. This postulate finds its foundation in the cognitive dissonance theory [15]. The theory proposed that two cognitions are considered to be in dissonance if one opposes the other, thus creating an unpleasant psychological tension. In order to eliminate this dissonance, an actor can change his/her belief, action or perception concerning an action. People attempt to ensure that their behavior and attitude are in harmony [20]. Aronson [21], for example, explained that a cigarette smoker would normally experience dissonance when he/she first becomes aware that smoking can result in cancer. However, in order to eliminate this dissonance he/she might seek to find any contradictory evidence (however, weak), since it is physically difficult for him/her to stop smoking.

The theory places emphasize on three possible relationships that exist between attitude and behavior [21]. These are irrelevance, consonance and dissonance, and it argues that influence is mostly intrapersonal when incongruence exists between attitude and behavior.

By understanding the relationship between a user's attitude and behavior in terms of a target behavior, one can identify some pertinent information that guides BCSS design. The next section contains a discussion concerning the relationship between attitude and behavior and how it impacts the design of BCSS.

4 User attitude and behavior in persuasive design

Current behavior, attitude toward target behavior (ATTB), and attitude toward change or maintaining change are intrapersonal factors that need to be considered during BCSS design. Intrapersonal factors are factors that serve as internal motivators, or impediments for a user when changing his/her behavior or attitude. They contribute to a user's urge in performing behavior since they are capable of creating unpleasant and distressing feelings.

4.1 Current behavior (CB)

In BCSS design, CB is defined as the existing behavior of a potential user, which should be changed to the target behavior, or maintained if it is the same as the target behavior. Saidin [22] defined target behavior as the action that ideally should be adopted by the user and explained that target behavior is composed of acting, learning and thinking. In BCSS design, however, the assessment of behavior can only be achieved when it is overt, i.e., defining a significant reference point of change. This allows assessment of behavior change over a specific time. Consider, for example, the case of a BCSS designed to manage weight. It seems appropriate, in this specific

context, for a BCSS designer to consider target behavior in terms of "the amount of calories burned" or "reduction in body mass" in days, weeks, months or years rather than considering the action of weight loss as Boolean function. If the user is able to achieve the target behavior (even if this only represents a minor physical change), then CB is considered positive. If the user is unable to achieve the target behavior, then CB is considered negative. Hence, a person is considered to have a positive CB only if his/her behavior is the same as the target behavior.

4.2 Attitude toward target behavior (ATTB)

Attitude toward target behavior is the general evaluation that a user or a potential user of a BCSS holds in regard to the target behavior. The theory of planned behavior [23] argues that attitude toward behavior contributes to an individual's intention to perform a behavior. It is not always consistent with CB, and the direction of influence between attitude and behavior cannot be prescribed in all cases [15, 24, 25]. ATTB therefore may have an impact on behavior formation. In this paper, the consideration of the relationship between attitude toward behavior and behavior is not the same as explained in the theory of planned behavior [23].

Although we acknowledged that there is a relationship between ATTB and CB, we do not consider one to be a predictor or determinant of the other. Rather the goal is to characterize users in terms of the state of cognitive dissonance by considering inconsistency between attitude and behavior. Accordingly, ATTB is considered to be positive only if a user's attitude is in favor of the target behavior and negative otherwise.

4.3 Attitude toward changing/maintaining behavior (ATCMB)

Attitude toward change or maintaining behavior (ATCMB) is a person's tendency of agreement or disagreement in relation to a particular change or maintenance of behavior. This factor is considered to be positive when a user agrees to change to the target behavior, or maintain the CB in the case where his/her CB is the same as target behavior. It provides information on a person's readiness to change, or willingness to maintain existing behavior, respectively. In comparison with the abovementioned BCSS definition [1], attitude toward changing CB is similar to altering ones behavior, whereas the attitude toward maintaining CB is similar to reinforcing ones attitude. Mostly, the latter is ignored in studies regarding BCSS.

Self-efficacy plays a key role in this factor, as people who feel they have less ability or confidence to accomplish a task normally develop a negative attitude toward change or maintaining change [26]. Consider, for example, a woman who has experienced a close family member develop breast cancer as a possible result of hormone replacement therapy treatment. This individual, despite the low statistical risk, is less likely to personally consider a similar treatment due to the negative personal experience. On the other hand, although there are numerous warnings on motorways that illustrate the danger of speeding, some people still exceed the speed limit or drive too fast. These drivers are clearly being informed of the potential effects of speeding, yet they do not have a positive attitude toward change. This demonstrates that providing useful information about the potential effects of negative habits alone is not enough to trigger behavioral change.

5 The 3D-RAB model

The parametric permutation of the three factors discussed above leads to a model that categorizes users based on their current values of these factors. The value of each factor can be either positive (+) or negative (−). Users are categorized into these states by administering a questionnaire to assess their values or position of ATTB and ATCMB regarding a target behavior, whereas observation is used in measuring their CB values. The model comprises eight states that represent the 3D-RAB. These states and their corresponding relationships are shown in Table 1.

When expressed in terms of state transitions, the model expresses possible paths that can be used for positive persuasion (Fig. 2). In Fig. 2, states that are shaded represent those with negative CB.

Each state is on a path from the least desirable state (State 8, all values negative) to the most desirable, or "ideal" (State 1, all values positive). The solid arrows in Fig. 2 represent the positive persuasion paths (State 1 also has the re-enforcement path) which should be promoted, while the dotted arrows represent paths that may occur against the positive persuasion paths which should be prevented. As such, any BCSS should be supporting the positive persuasion paths, and such systems are expected to benefit from considering the different attribute values of states involved in the transition. A user of a BCSS application can therefore be considered to have made a "unit" change if he or she moves from one state to another. The strengths (levels) of dissonance can also be estimated from the combination of values among the three factors. The distinct levels of dissonance that can be identified from the model are strong cognitive dissonance, moderate cognitive dissonance, weak cognitive dissonance and no cognitive dissonance. Essentially when the values of CB and ATTB are the same there should be no dissonance. However, even

Table 1 Eight states in 3D-RAB

State	Current behavior (CB)	Attitude toward target behavior (ATTB)	Attitude toward maintain or changing target behavior (ATCMB)	Levels cognitive dissonance	Stability	Expected natural state transition tendency	Targeted state toward persuasion
1	+	+	+	None	Stable (+)	1	1
2	+	+	−	Weak	Unstable (+)	1	1
3	+	−	+	Moderate	Unstable (−)	7	1
4	+	−	−	Strong	Unstable (−)	8	2 or 3
5	−	+	+	Strong	Unstable (+)	1	1
6	−	+	−	Moderate	Unstable (−)	8	2 or 5
7	−	−	+	Weak	Unstable (−)	8	3 or 5
8	−	−	−	None	Stable (−)	8	4 or 6 or 7

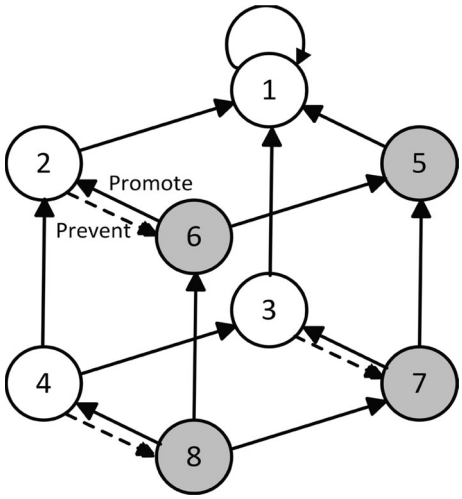

Fig. 2 State transitions in 3D-RAB

in such cases if the value of ATCMB is inconsistent with those of CB and ATTB, it creates some dissonance. Similarly, the level of cognitive dissonance is estimated for cases in which CB and ATTB have different values. These and other features of BCSS that should be involved for each of these categories of states are discussed in more detail below.

5.1 No cognitive dissonance

A user experiences no cognitive dissonance if his/her attitude toward behavior and ATCMB agrees with his or her behavior. This is because there is no psychological tension since there is consonance in attitude and behavior. There are two states characterized with no dissonance and these states are 1 and 8. However, State 1 favors the target behavior whereas State 8 opposes it. States in which there are no dissonance experiences stability thus making it difficult to change either their behavior or attitude. Ultimately, it is expected that most BCSS aim at changing users to State 1, which is considered to be the ideal state where the user is stable and the BCSS application aims to reinforce both attitude and behavior. Whereas those designed to target users in State 8 needs to consider changing all the three factors.

5.2 Weak cognitive dissonance

Even when there is an agreement between one's attitude and behavior, or when there is an inconsistency between these and the attitude toward change or maintaining the behavior, it creates dissonance, which can be considered as weak. For users in States 2 and 7, the weak level of dissonance is formed because, although users have the same CB and ATTB value, their ATCMB is opposite. In both states, it is expected that the level of dissonance will not result in a change in behavior without external inducement. As argued by Aronson [24] and Oinas-Kukkonen and Harjumaa [12], humans experience some amount of dissonance in their daily lives which they are comfortable with and which usually does not influence their decisions. Thus, BCSS applications designed for such users may emphasize a system feature that seeks to promote attitude reinforcement for users in State 2. These may include system credibility support features.

However, for users in State 7, BCSS designers can leverage the positive attitude toward change through the implementation of system qualities that seek to address behavior change first before changing ATTB. Since users are willing to change, system features such as reduction, suggestions, self-monitoring, tunneling may be used to support the performance of the behavior or action.

5.3 Moderate cognitive dissonance

When there is a disagreement between one's attitude and behavior, a dissonance is formed. However, such a dissonance can be moderate or strong. When the dissonance is moderate, the extent of unpleasant psychological tension experienced is relatively low, i.e., the urge to change the

attitude or behavior is not so strong although the user may feel a higher tension than that of the weak dissonance.

Target users in States 3 and 6 experience a form of moderate dissonance. In State 3, there is dissonance between the individual's CB and ATTB, yet the effect of the dissonance is reduced due to the agreement between the individual's CB and attitude toward maintaining the behavior. Therefore, BCSS applications that aim to target these users should focus on changing the current attitude of users to conform to their ATCMB and CB. In particular, it should demonstrate or promote attitude formation qualities or features through the provision of convincing and logical messages that will promote the positive change in ATTB to achieve the transition to State 1.

Similarly, in State 7, there is consonance between CB and ATCMB as they all have negative values whereas that of the ATTB is positive. However, in this state, system features of the BCSS application may seek to promote either a behavior change first or attitude toward the change first. In both cases, the features should be selected carefully to prevent the change in his or her ATTB: This will result in a transition to State 8 where all factors are negative.

5.4 Strong cognitive dissonance

A strong cognitive dissonance is formed when there is a resilient agreement between ATTB and attitude toward change or maintaining change but this disagrees with CB. This creates a strong and unpleasant psychological tension with a greater probability that the individual may change his/her current attitude or behavior so as to eliminate the dissonance. At such a state, the individual experiences an uncomfortable feeling and consequently recognizes the need for a change in attitude, behavior or behavioral beliefs. As explained by Festinger [15], and more recently by Harmon-Jones and Harmon-Jones [25], disparities in attitude and behavior create unpleasant tension that can lead to behavior or attitude change. There are two states in which target users experience strong cognitive dissonance and these are States 4 and 5.

In State 4, the individual's CB agrees with the target behavior. However, the individual's attitude toward maintaining the behavior and ATTB are negative. This form of dissonance creates a discomfort because of the emphasis on disagreement between the individual's CB and ATTB. This discomfort is further strengthened by the fact that the user has a negative value for ATCMB, i.e., the individual is not in the position of maintaining the CB. BCSS applications designed for such users must ensure that systems qualities are selected with tact, since users are more likely to change their behavior to eliminate the discomfort. It will also be helpful if designers investigate to identify what is causing the performance of the positive behavior.

It is recommended that BCSS should endeavor to endorse any existing activity that is promoting the positive behavior in addition to the inclusion of new features that will seek to change ATTB and ATCMB.

Users in State 5 also have a strong dissonance because although they have a positive attitude toward the behavior and are ready to change, they fail to perform the target behavior. Since users already have the positive attitude, it is imperative for designers to identify what is preventing the behavior and address it accordingly. As argued by Fogg [27], a number of issues can prevent a behavior even when an individual is having the right attitude. BCSS applications can use system features such as reminders, reductions, tunneling, among others to promote a behavior change while they reinforce the existing positive attitude.

5.5 Stability

As mentioned earlier, the variations in dissonance also create stable or unstable states that can be considered to be in favor or against the target behavior. In a stable state, an individual may feel comfortable and thus may not see the need or the urge to put in place measures that may change his/her behavior or attitude. This is because there is no dissonance in these states. States 1 and 8 are stable states. In State 1, the stability is positive since users perform the target behavior and all their associating factors are positive. However, since humans are engaged in constant cognitive processes and may change their behavior or attitudes over time BCSS applications must exhibit system qualities that will reinforce all the three factors. In State 8, user stability does not favor the target behavior hence BCSS applications for such targets need to promote a change in all three factors.

The remaining states are characterized with instability due to the various levels of dissonance they experience. Again, these instabilities may be positive or negative. States that favor target behavior are labeled with a positive sign (+), whereas those that are against target are labeled with a negative sign (−).

5.6 Expected natural state transition tendency

The expected natural state transition tendency states are such ones in which users may move to in order to eliminate or reduce dissonance. For instance in State 2, users have a weak cognitive dissonance and they may find it relatively easier to change their ATCMB as compared to changing any of the other two factors. BCSS designers can therefore focus their design to promote activities that will eliminate the dissonance in cases where the natural state transition favors the behavior.

5.7 Targeted state for persuasion

Targeted state transitions are states in which users can be migrated to during the course of persuasion. Although BCSS mostly aim at changing users in a gradual process, there is no existing method, framework or approach that specifically supports gradual persuasion design. The targeted transition state provides the designer with information on the next available transition that a user can be moved to. Each transition is made up of a unit change (i.e., a change in ATTB, CB or ATCMB). From the model, there are two main types of such transitions: behavior reinforcement and behavior changing states.

Behavior reinforcement is the process involved in emphasizing or promoting an existing behavior to ensure that a user does not change his or her CB [1]. In States 1, 2, 3 and 4, target users are already performing the targeted behavior, and hence, there is no need for designers to implement methods that aim at changing behavior. However, the model explains that although they may be performing the behavior, they may have varied levels of cognitive dissonance generated by different combinations of CB, ATTB and ATCMB. This is one of the most pertinent aspects the classification makes explicit. This classification supports claims made by Oinas-Kukkonen [1] that changes in BCSS can be classified into various types where each type is characterized by different levels of difficulty.

Although State 1 is classified as the ideal state [28], it is emphasized that it might not be necessary to move target users to this state in all cases since a persuader may only be interested in behavior change but not attitude change. Fogg and Hreha [13] argued that in some situations, a designer might want an individual to perform a behavior only once. Thus, in such cases the need to change attitude is less important.

State 3 appears to be practically impossible since one may argue that as long as a person performs the behavior, he or she may have a positive attitude. Nonetheless, some people perform behavior due to external forces which may include persuasion or coercion with a negative attitude toward the behavior. Consider for example the age restriction on alcohol intake. One can argue that some teenagers do not drink because of the restriction on them but not due to their positive attitude toward that behavior.

Stages 5, 6, 7 and 8 involve actual change in behavior. Behavior changing states are states in which there is the need for methods to be applied to ensure an overt change in CB. Nonetheless, there are variations in dissonance, and thus, users have attributes that can serve as an advantage or a disadvantage to persuasion as already discussed above.

5.8 Different paths for persuasion

As illustrated in Fig. 2, state transitions based on the three factors in 3D-RAB model generates a state space that encompasses the eight states. This provides the basis for paths for persuasion that indicate positive changes toward the target behavior. In total, there are fifteen different paths to State 1 (the ideal state), depending on the current state of the user. However, it is necessary for the BCSS designer to identify the most appropriate and effective path for persuasion. Consider, for example, a user in State 8. There are six possible paths that can be used for persuasion, assuming that the aim of the designer is to move the user to State 1. Hence, the designer may choose any of these paths, based on the user's profile, or the context of persuasion. More importantly, BCSS designers can change paths for persuasion whenever they identify that a current approach is not effective.

It is important to clarify that these paths are not related to the levels of cognitive dissonance or consideration of stability of each state. The understanding of these aspects in each state, however, can also inform the system qualities and features employed to enable the paths for persuasion.

6 Mapping of existing systems to the 3D-RAB

Although the various states identified by the model exist in theory, there is a need to establish whether they exist in practice. This is in part due to the logic that a designed artifact is only complete when it is demonstrated to have addressed an existing problem [29]. Accordingly, some existing BCSS that have been academically studied were mapped to the 3D-RAB model to establish whether they have addressed target users in any of the eight states proposed by the model. Ideally, it would have been appropriate to analyze all existing BCSS in the mapping process. However, due to the vast number of research publications in this domain, it is almost impossible to identify all of such systems consistently with any specific set of keywords. Thus, proceedings of International Conference on Persuasive Technology series were used. This conference series is (at the time of publication) the only comprehensive conference that seeks to address issues relating to attitude and behavior change systems; hence, it was used to ensure a consistent level in quality between studies.

As with any research of this nature, the main challenge is the ability to capture the intention of the designer. Thus, all papers that described any form of application or system that seeks to harness behavior or attitude change between 2006 and 2013 were identified. There were 72 papers of this nature, from which 61 were included in the analysis here, because they explicitly demonstrated or mentioned

the intention to alter behavior or attitude with the support of an interactive technology or system. This is to say that systems that did not demonstrate functionalities with an intention to change, reinforce or shape behavior or attitude [30–33] were discarded. In addition, some systems were identified to have appeared more than once. Examples of such systems include Percues [34, 35] and iCat [36–38] and these systems were considered only once for the study.

6.1 Method

The selected applications or systems were classified into the various states based on the definitions of ATTB, CB and ATCMB as discussed in the previous section. Although there was the potential bias and the possibility of our inability to capture the exact intent of the designers or authors, the classification was based on the target users as described by authors to ensure coherency. 19 out of the 72 applications reviewed provided an explicit description for the targeted users, representing 26.34 %. In cases where an author failed to provide an explicit description of the targeted users for a system or an application, we considered the potential of the system features employed in the application or system to change ATTB, ATCMB or CB to predict the intended targeted users.

A system was considered to have addressed ATTB if it aimed to change a user's behavior, but did not require the user to perform the behavior in the course of using the applications. For example in "Quit IT" [39], the player guides the avatar to stop smoking, thus pursuing positive actions. Hence, the application aims to change the user's attitude toward the target behavior by instilling ideas that can lead to real-world behavior change.

Systems were seen as targeting CB, if users were required to perform the target behavior while interacting with the system. An example of such a system is "Take a Break" [40]. In this application, cueing strategies and real-time reminders are used to interrupt the user to take a break while performing a task on the PC. The individual needs to perform the behavior in the "real world" in order to be considered as a user. Such systems address behavior change without necessarily promoting a change in attitude toward the behavior.

In cases, where the user encounters the persuasive application in the course of performing the negative behavior, without an option to avoid the persuasive message, the system was defined as aiming to change attitude toward behavior (ATCMB). For example, users of the personal health information system [41] had no choice but to use the application in their daily activities.

The main distinguishing factor for the classification between ATTB and ATCMB is that targets that have a negative ATCMB will not be interested in engaging themselves in any form of activity that aims to support behavior change. For example, although an individual may believe that performing daily exercises or physical activity is good, he or she may not purchase or download an application which aims at changing his or her behavior (even if it is free of charge), if he/she has a negative ATCMB.

The mapping of the applications to states in the 3D-RAB model was based on the overlapping features of applications that addressed ATTB, ATCMB or CB.

6.2 Findings and results

The study revealed that existing BCSS that have been academically studied focus mostly on changing attitudes or behavior in domains such as commerce, environment, education, health, safety, security and leisure. Out of the 61 applications reviewed, 31 (50.8 %) were related to health issues, 16 (26.2 %) were related to the environment, 4 (6.6 %) were designed to support commerce and 3 (4.9 %) each for education and leisure. In addition, 2 (3.3 %) were design to promote safety, one (1.6 %) for security related issues, whereas one (1.6 %) did not specify the domain the system was designed for.

It was observed that some of the applications aimed at changing users in multiple states. Specifically, 11 of the applications aimed at changing users in more than one state. However, majority of the systems studied focused on users in State 7. Twenty-nine out of the 61 aimed at changing users who have a negative ATTB, a negative CB, and a positive attitude toward change. This finding demonstrates that most of the existing BCSS applications assume that although their target users have negative CB and ATTB, they are willing to change their behavior. Such BCSS are mainly applications, which are freely downloadable. Thus, potential users who are willing to change may themselves decide to download and use them. Potential users who are not prepared or ready to change will normally not engage in activities without any form enticement to use the system.

State 5 was observed to be the next most targeted state with 19 systems. Intuitively, it was expected that this should be the most targeted state. This is because some researchers have demonstrated that in most cases users have the right attitude toward a behavior and are also willing to change, but fail to perform their desired behavior due to some external factors [42]. Since most of these applications aimed at changing only behavior, they employed systems features that ensure that users perform the right behavior. Particularly, they tend to focus on simplifying the behavior (reduction) and/or providing effective triggers to provoke a behavior.

State 1 recorded ten applications. Out of these ten, four were related to health, three for leisure and one each for commerce, education and environmental issues. These

systems focused on reinforcing behavior or attitude. Seven applications were identified targeting users in State 2, and State 8 also recorded a frequency of 7, whereas State 6 recorded 5.

It was also observed that none of the applications designed for health or safety aimed at target users in State 4. This might be due to designers not considering individuals, who have a positive behavior, but a negative ATTB and ATCMB. Thus, designers mostly assume that as long as one is performing a healthy behavior, they will not change their behavior in future. However, consideration should be given to health-related issues in which people may be performing positive behavior but may change in the near future.

No single application addressed or targeted all the eight states proposed. Thus, it can be inferred or deduced that none of the applications aimed at changing users through a stepwise approach or made provision for smaller changes through intermediate states to State 1 (the ideal state). Although no direct empirical evidence supports the claim that changing a target user through 3D-RAB model's stepwise transitions would be more effective than a one-off change, evidence does show that the probability of persuasion is increased when appropriate persuasive methods are used at the appropriate time [43]. Accordingly, it seems preferable that designers target attitude and behavior change one step/state at a time. Table 2 summarizes the distribution of cognitive states identified in the study.

7 Discussion

In this section, research and design implications of this research are discussed.

7.1 Research implications

As already mentioned, the key purpose of the 3D-RAB model is to categorize users into various states to enable an easier and a more specific yet effective approach for designing BCSS. To date, it is the only model that considers users' cognitive dissonance state during the design phase of a BCSS. However, it can also be used for segmentation of target population in behavioral and attitudinal change interventions in computer-mediated persuasion. This is because the introduction of ATCMB provides an additional measure that seeks to inquire an individual's readiness to change or motivation to maintain a current positive behavior. This will therefore enable human persuaders to be capable of understanding their target audiences better. Yet, ATCMB compounds a prominent issue in attitudinal research: the ability to measure attitude precisely. Researchers are still faced with issues regarding the ability to measure attitude accurately. Attitude is mostly obtained through self-reports or inferred from an observed behavior. However, since theory of cognitive dissonance argues that discrepancies may exist between one's attitude and behavior, the use of observation to measure attitude cannot be applied in this case. Hence, self-reporting can be considered to be the only appropriate method for measuring attitude in this context. This therefore implies that the 3D-RAB model will suffer all the limitations that are associated with the self-reporting approach to attitude measurement.

As for the mapping of target users of existing BCSS to the 3D-RAB model, our analysis here has some limitations. Firstly, it only covers papers from the Persuasive Technology Conference series. There could be an implicit bias that stems from the papers that tend to be accepted for these conferences in terms of areas and approaches. For instance, most of the conference themes for the Persuasive Technology conference series have focused on health-related issues. This at least to some extent explains the dominance of health applications in the study. However, as mentioned earlier, this series provide the most consistent basis in terms of quality and focus. Secondly, the classification of papers was carried out by one of the authors. This might have introduced a classification bias. However, the classification was attempted multiple times on the same set of papers to ensure accuracy, and it guaranteed consistency in terms of application of the classification criteria.

Table 2 Distribution of applications according to the eight states in 3D-RAB model

State	Commerce	Education	Environmental	Safety	Health	Security	Leisure	Unspecified	Total
1	1	1	1	0	4	0	3	0	10
2	0	1	0	1	3	0	2	0	7
3	0	1	0	0	0	0	0	0	1
4	0	1	1	0	0	0	0	0	2
5	0	0	5	1	10	1	1	1	19
6	0	0	0	0	3	0	0	1	4
7	1	1	8	0	17	0	1	1	29
8	1	1	2	0	2	0	0	1	7
	3	6	17	2	39	1	7	4	79

The 3D-RAB model itself benefits from further scrutiny. For example, the model enables us to infer the "levels" of cognitive dissonance of each state based on the values of CB, ATTB and ATCMB, as well as its stability. The assessment of stability logically follows the cognitive dissonance theory, i.e., stable when all three values are the same and unstable otherwise. However, the assessment of strength of dissonance (none, weak, moderate, strong) is inferred but not empirically tested. Further research is needed to evaluate whether the strength assessment is correct, e.g., by investigating the correlation between the inferred level of dissonance and the level of discomfort people experience in each state.

7.2 Design implications

Since research in BCSS for the most part have failed to address issues relating to changing individuals or users through a gradual process [1], the introduction of the 3D-RAB model will enable BCSS designers to apply the PSD model more effectively. Using the 3D-RAB model, designers will be able to explore the problem space in relation to the user context and apply precise methods or techniques to promote persuasion at each state. This will prevent information or system feature overload: the risk of providing users with irrelevant information or tasks during persuasion.

Although the model enhances the PSD model for BCSS design, it still fails to provide information on methods that can be used in selecting the appropriate system features or qualities during design. Essentially, the categorization of users is not sufficient for the selection of effective system features during BCSS design. Hence, the 3D-RAB model will provide a foundation for further research into methods for selecting appropriate system features when designing BCSS applications.

Another benefit of using the 3D-RAB is that it can be used to measure "smaller" changes in terms of dissonance, which is usually ignored during the design of behavior change interventions. By administering a before and after questionnaire, BCSS designers may be able to assess how users progress to other states from their current state. Currently, researchers mostly consider behavior change in terms of frequency (either reduction or increase in behavior). However, with the assistance of 3D-RAB, they may observe changes in other associating attributes such as ATTB and ATCMB. This will enable the identification of system features that are deemed appropriate for a particular type of transition or change.

One of the features of 3D-RAB that has not been explored so far is the use of estimation of the level of cognitive dissonance in design. It is useful in characterizing user types, but it may be exploited further in the selection of persuasion strategy and the design of interventions. For example, those in the state of strong dissonance can be considered to be more likely to change hence only a subtle nudge in the desirable direction may be sufficient, while those in the state of moderate or weak dissonance might require a more substantial intervention. Moreover, persuasion routes may be more or less difficult depending on the changes in levels of dissonance involved. For example, when the route involves a state change from weak to strong dissonance (e.g., from State 7 to State 5), it would require more effort than from strong to weak (e.g., from State 4 to State 2), as it is artificially introducing further dissonance in opposition to the tendency predicted by cognitive dissonance theory. As discussed above, the correctness of dissonance level estimation still requires empirical evaluation; however, the model provides a theoretical basis that can be considered in designing tools and interventions.

8 Conclusions

This paper has presented a model that can be used to analyze the relationship between attitude and behavior: the 3D-RAB model. The model postulates that in BCSS design, eight states of cognitive dissonance among the users should be considered, since each state is characterized with distinct user characteristics. Thus, designers need to apply specific methods to change users at each state.

The model was evaluated by mapping it to existing BCSS applications published in the international conference of persuasive technology between 2006 and 2013. It was identified that each of the state defined in the 3D-RAB model have been addressed by designers at some point, yet designers mostly do not explicitly describe their targeted state.

Although the 3D-RAB model presents a novel approach to the analysis of target users, with the benefit of adapting persuasion to suite specific user segments, there is a need for further studies to establish the best methods to support effective system features.

In conclusion, the 3D-RAB model does not seek to replace existing models for designing BCSS. Rather, it offers a method that can facilitate the analysis of the user context which is part of the PSD model [12], by providing a novel and unique approach to more accurately analyze target users and their specific persuasive requirements.

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