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Ubiquitous Model for Persuasive Behavior Change Systems: A Case Study on Energy Efficiency

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Abstract:
In this paper, we develop a model for analyzing the motivation of individuals through persuasive ubiquitous technologies called the Ubiquitous Model for Persuasive Behavior Change Systems (UMPSBC). In the proposal of UMPSBC, we changed the Fogg Behavior Model (FBM) by inserting the Hierarchical Model of Intrinsic and Extrinsic Motivation (HMIEM) situational motivation level into FBM's motivation layer. UMPSBC was applied in a case study focused on energy efficiency in which we evaluated whether intervention in the motivation of individuals causes a change in behavior regarding sustainability and consequently if this change causes u-Learning processes, making the individual behavior more sustainable. The results suggest that there were indications of u-Learning processes, as individuals responded positively to most triggers(tips) and also by the fact that there was a reduction in electricity consumption.

Keywords: u-Learning, Persuasive Technology, Self-Determination Theory,Ubiquitous Model for Persuasive Behavior Change Systems, Fogg Behavior Model, Motivation, Domotic.

1. INTRODUCTION

The Brazilian Electric Energy Agency approved in 2017 an increase of, at least, 29% in its service taxation. In the South of Brazil, the State Electric Power Distribution Company, the price increase varied between 29% and 34%, representing the highest historical increase in the whole national territory (ANATEL, 2017). In parallel with this, Achão (2003) observed a growth in residential electric consumption in Brazil related to an increase of the income.These phenomena is complex to analyze, since it involves the observation of a series of factors inherent in consumer's behavior, such as: population income growth, average time of device use, among others. However, residential consumers cannot understand impact of each equipment on its monthly consumption, and therefore in the cost of its electricity bill. From this context, we believe that by stimulating the processes of learning and awareness about the individualized consumption of devices, we can achieve a more sustainable behavior usage among the population.

The growing use of smart devices allows us to collect and analyze the daily actions of individuals and mobile technologies. From this perspective arises the concept of ubiquitous computing, which is the integration of computing with human actions and behaviors at any time and anywhere (Weiser, 1991). Domotic is defined as an automation and control system capable of communicating interactively and following instructions previously established by the user in a ubiquitous manner (Muratori and Dal Bó, 2011). Although smart homes can communicate and interact with the user (usually focus on energy efficiency), individuals do not easily accept the interference of this technology (automatic on/off decision) in their daily lives, which is frustrating, affects energy efficiency and causes missusage or disconnection of equipment. From this scenario arises our research question, **how to develop ubiquitous devices that enhance home automation in energy efficiency, and convince its benefits to the users?**

Recently, studies have been conducted in the investigation of the use of technologies and the processes of knowledge acquisition from situations of individual's interest. This type of learning is called ubiquitous learning (u-Learning) (Santaella, 2014). In u-Learning, the individual acquires knowledge through his/her interaction with the environment. However, the learning process occurs only when knowledge becomes part of their behavioral repertoire. When we talk about behavioral change, we refer to the change mediated by Persuasive Technology (PT). PT consists of the intersection between technology and the concept of persuasion (Fogg, 2002). Persuasion is an attempt to shape, reinforce or change behaviors, feelings about a problem, or action to influence the thoughts or actions of others individuals (Hogan, 2010). The Fogg Behavior Model (FBM) considers that behavioral change in PT is related to the sending of triggers that are resources used to induce an individual to perform a particular behavior

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(Fogg, 2009). The choice of triggers (tips) to send will depend on the ability and motivation level of the individual facing the intended task (Fogg, 2009).

The FBM consists of a conceptual model that only describes the factors for behavior change in persuasive systems, serving as a high-level descriptor for the development of PT. However, if we want to use it as a model, we will not find in FBM an accurate representation of how to describe human motivation. In this context, Self-Determination Theory (SDT) is a model that can complement the FBM by allowing the analysis of individuals' motivation (Deci, 1987). SDT is the study of human motivation and is classified along a *continuum* into the following types (Deci, 1987): *(i)* Intrinsic motivation, pleasure inherent in performing an activity (joy, pleasure, or fun). *(ii)* Extrinsic motivation, a wide variety of actions in which the objectives extend beyond those inherent in the activity. *(iii)* Amotivation, lack of connection between individuals' actions and outcomes.

The Hierarchical Model of Intrinsic and Extrinsic Motivation (HMIEM) considers that there are several ways to represent the motivation of the individual (Vallerand, 1997). These representations are related to each other and determine the type of individuals' motivation towards an activity, context, or in general (Vallerand, 1997). According to Vallerand (1997), this theory concerns the individuals' satisfaction of the following innate psychological needs: *(i)* autonomy, freedom to choose the course of action. *(ii)* competence, interaction with the environment. *(iii)* relatedness, feeling of connection with other individuals. Deci (1987) considers that the types of motivation can be ordered along a *continuum* that ranges from lower levels (amotivation) to higher levels (intrinsic motivation) of motivation. Our contribution to the conception of u-Learning processes is to develop a model to analyze the motivation of individuals through ubiquitous technologies called the Ubiquitous Model for Persuasive Systems for Behavioral Change (UMPSBC).

In UMPSBC, we change the FBM by inserting the proposed situational motivation level in HMIEM into the FBM motivation layer. In this paper, we consider only the situational level because we believe that u-Learning is related to this level when it integrates individual's actions and behaviors with the devices that are connected at any time and everywhere, which enables the observation of individuals while they are involved in their daily activities. We develop a case study that aims to evaluate if the intervention in the individuals' motivation causes a behavioral change in relation to sustainability, and consequently if this behavioral change affects the u-Learning processes, making the individual behavior more sustainable. The results of this study allowed us to observe that there was evidence of the benefits of u-Learning, as individuals responded positively to most triggers (tips) and also by the fact that there was a reduction in electricity consumption.

The remainder of this article is organized as follows: Section 2 shows papers related to the topic of the article. Section 3 introduces the Ubiquitous Model for Persuasive Systems for Behavioral Change. Section 4 applies the model in a case study focused on energy efficiency. Section 5 shows the results and discussions. Finally, in Section 6, we present the conclusion and perspectives of future work.

2. RELATED WORKS

In this section, some papers related to Persuasive Technology and Self-Determination Theory will be presented. Studies related to SDT highlight the use of technologies as a means to influence individuals' motivation. Chame et al. (2018) developed a computational model to evaluate the types of individual's motivation called Dynamic Computational Model of Motivation (DCMM), which was built from the HMIEM. The hypothesis of DCMM models is continuity between the types of motivation through a Continuous Attractor Neural Network (CANN). Wati and Koo (2012) developed a model for investigating the motivational factors of behavior in the use of green information systems (*Green-IS*). Koo and Chung (2014) evaluated the type of motivation when using sustainable technology like sensors to measure electricity consumption through psychometric instruments. Firssova et al. (2014) evaluated the motivational aspects of individuals using mobile devices in classroom learning processes through questionnaires. Nikou and Economides (2017) developed a model that integrated elements of acceptance and motivation to assess the behavior of individuals while using mobile devices.

Regarding persuasive technology, Tolêdo (2016) developed a *framework*, called *SmartTrigger*, to aid in the process of developing persuasion strategies based on the FBM. This model associates the effectiveness of behavior with motivation and ability levels. Li (2013) investigated the influence of persuasive messages on the individual's social life. Besides, the authors also analyzed the impact of affective and cognitive response on people's behavior. Li et al. (2012) and Mouri et al. (2015) described a system to help users store their ubiquitous learning records so they could review and analyze them as needed. Also, this system, called SCROLL (*System for Capturing and Reminding of Ubiquitous Learning Log*), was able to send reminders and recommendations according to the individual's location. Considering that the reviewed studies do not describe environments that deal with behavior change during the u-Learning process, do not highlight how they verify these processes, nor do they assess the impact of these elements on the behavioral change of individuals, we propose the development of the UMPSBC in a u-Learning environment through the use of mobile devices.

However, we do not find in the literature works related to our initial research question " how to develop ubiquitous devices that enhance home automation in energy efficiency, acting in line with the motivation of the individual? ". Because of this, the research presented in this paper differs from the others by presenting details of the model related to the behavior change through the use of persuasive technologies in u-Learning environments. Furthermore, details about elements that can be used to assess the level of individuals' motivation are inserted in these media. We believe that our study can contribute to the challenge of developing learning environments by integrating persuasive motivational elements into individual's actions and behaviors through technology, which enables a constant analysis of their actions.

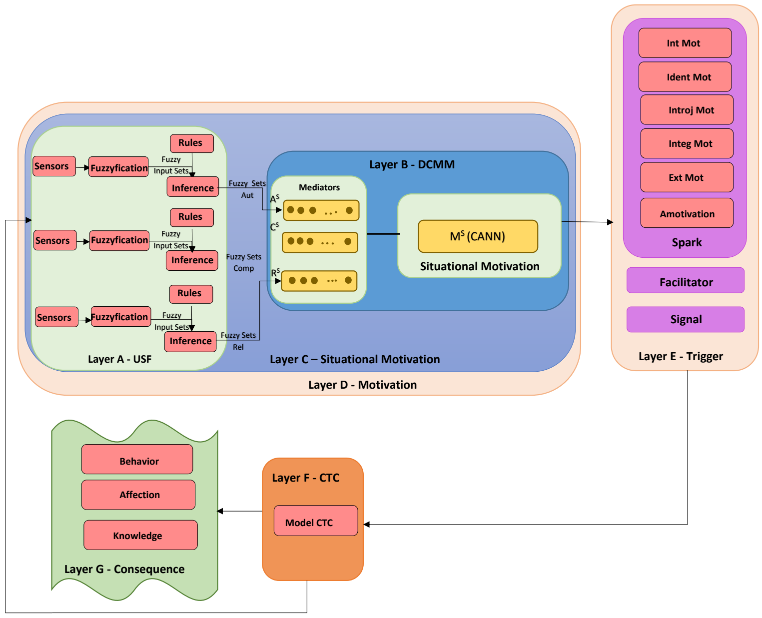

Fig. 1. Ubiquitous Model for Persuasive Systems for Behavioral Change.

3. UBIQUITOUS MODEL FOR BEHAVIORAL CHANGE

In this paper we propose the development of a model to analyze the individuals' motivation through ubiquitous technologies called Ubiquitous Model for Persuasive Behavioral Change Systems (UMPSBC) that is presented in the Figure 1.

UMPSBC, like HMIEM, divides motivation into three types: intrinsic, extrinsic motivation, and amotivation. These types of motivation can be ordered along a *continuum* that ranges from lower levels (Amotivation) to higher levels (Intrinsic Motivation) of self-determination.

Although the model described by Vallerand (1997) classifies motivation at the situational, contextual and, global levels. In this paper, we consider only the situational level that according to Vallerand (1997) is the central element of his model when focused on the analysis of individual's motivation while performing a certain activity. The research of Fogg (2002) complements this statement by revealing that PT are directly related to behavioral change that occurs consciously and voluntarily from situations in which the individual exercises a choice in the face of a set of options. Santaella (2014) adds that ubiquitous technologies can change individual behavior imperceptibly, which in turn enables ubiquitous learning processes.

To explain the process of UMPSBC development, we have organized the model in seven layers ($A/B/C/D/E/F/G$), as we can see in Figure 1. Layer A brings the Ubiquitous Situational Factors (USF) available in the social environment; the USF can be human or non-human factors. Layer B encapsulate the Dynamic Computational Model of Motivation (DCMM) to evaluate the consequences of motivation in different types and levels. In this model, mediators are the individual's self-perceptions of their basic needs (autonomy, competence, and relatedness) that need to be met; This data is obtained by translating the BPNS-Diary instrument (Basic Psychological Needs Satisfation and Frustation Scale - Diary version) (Chen et al., 2015) to sensors. Layer C consists of specifying the situational level of the DCMM model to detail the relationship between ubiquitous elements and the individual's basic needs. Layer D uses the SmartTrigger Framework, which in turn, encompasses the DCMM to assess situational motivation types and USF to measure basic needs. Layer E contains the triggers. Layer E process motivation and abilities triggers (tips) based in observations of the responses of individuals in Layer F through the Trigger-Consequence Communication model (CTC). The CTC is responsible for sending the triggers and observing the individual's actions in the environment. Layer G is associated with the observation of the individual's action after receiving a certain trigger.

In the 4 section, we will introduce the application of UMPSBC in an energy efficiency context. We choose this theme because it involves a challenge related to the behavioral change of individuals regarding sustainable consumption.

4. STUDY CASE

4.1 Scenario Description

The application of the persuasive system was developed from the UMPSBC in a case study associated with energy efficiency in the Sapiens project [1], which aimed to develop PT in the field of energy efficiency to enable the user to understand and manage their electricity consumption efficiently. In this project, a ubiquitous intelligent persuasive environment was developed for monitoring electricity consumption and acting on the behavior of individuals by sending triggers (tips) to promote sustainable behavior.

[1] http://www.nautec.furg.br/index.php/projetos-pt/SapiEns

The management resulting from our study collected data from the teachers' living rooms and the research laboratories of the Intelligent Robotics and Automation Group (NAUTEC), of the Federal University of Rio Grande (FURG). Sapiens through the system consists of *SmartCam*, *SmartPlugs* and a mobile application called SapiEns. *SmartPlugs* are a device responsible to mesure and send power consumption information of the connected equipment for app, and also enable remote device activation. *SmartCams* is an equipment that verify and report a human presence in the environment, both sensors are represented in Figure 2.

Fig. 2. *SmartPlug* and *SmartCam*

The SapiEns system developed by Mota et al. (2016) is a persuasive mobile app capable of ubiquitously managing, and receive data information of SmartCams and SmartPlug. Besides, the mobile app interface has the following functionalities: *login*; *user data control and goals*; *access control*; *help system*; *information feed*; *trigger (tips) and consumption management*; *screen customization*, and *integration with other systems* (e. g. Facebook, Twitter), as well as *triggering behavior tips* (Figure 4 and Figure 5) to persuade individuals to reduce their electricity consumption. Figures related to the app interface is in Portuguese because the case study was applied in Brazil.

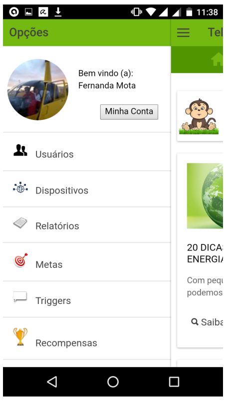

Fig. 3. App interface menu screen. In this screen we can see a welcome message in Portuguese, and the user items, devices, reports, goals, triggers and rewards in the home screen menu.

The app's interface home screen provides the individual with a news *feed* with content on sustainable habits primarily aimed at saving electricity. In Figure 3, we have the app menu screen consisting of a set of features and services such as: *system users*, *connected devices*, *consumption reports*, *goals*, *triggers (tips)*, *rewards*, and

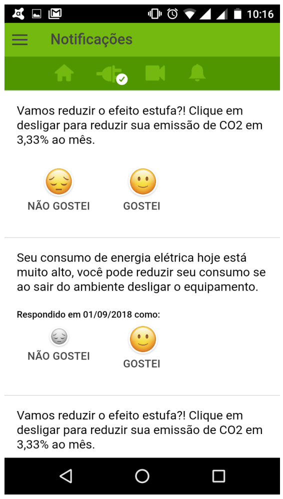

Fig. 4. Example of trigger (tips) that was sent to individuals with no motivation.

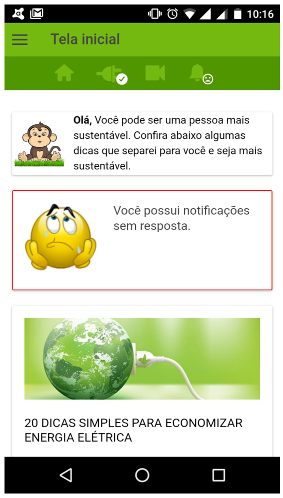

Fig. 5. Notification that a trigger has been received.

help. In Figure 4, we can see a Portuguese example of a trigger (tips) that was sent to individuals with no motivation. In this image there are two triggers (tips) in Portuguese: (i) "Let's reduce the greenhouse effect ?! Click to turn off and reduce your CO2 emission by 3.33%." (ii) "Your electricity consumption today is very high, you can reduce your consumption if when leaving the environment turn off the equipment." Besides, there are the options I liked and didn't like for each trigger. In Figure 5, the notification that a trigger (tip) was received is represented. We can see the following messages in Portuguese: (i) welcome, "hello, you are now a more sustainable person. Check out some tips that I separated to make you more sustainable." (ii) notification, "you have unanswered notifications." (iii) news, "20 simple tips for saving electricity."

4.2 Experiment Description

The case study was applied in the following sequence: $NT(t) \rightarrow M(t) \rightarrow T(t) \rightarrow M(t)$, where NT represents the step in which individual proceeded with his/her activities without receiving any triggers (tips) to understand the user behavior; T represents the stage in which interventions were performed by sending triggers (tips), based NT identification of the user while performing the activity; M represents the measurement of the data consumption devices connected to the system; t indicates the number of days that the system has been evaluated for each step.

In $NT(t)$, we analyze the psychological needs of individuals and their spending habits through two instruments: *(i)* BPNS - Diary to evaluate the level of individuals' need; and *(ii)* an instrument developed by the authors of this article called the Electric Power Consumption Habit Scale (EPCHS), to assess individuals' electricity consumption habits. EPCHS was developed in Portuguese [2] and in Spanish [3]. The study was applied in a group of four students and one teacher, with a total of 5 individuals, aged between 25 and 40 years, at the Federal University of Rio Grande, in the city of Rio Grande, Brazil.

In $NT(t)$ stage, we measured the consumption of electricity in four teachers rooms and two laboratories at the Federal University of Rio Grande (Furg) from May 1, 2018 to July 31, 2018. We investigated the variation in electricity consumption through multivariate analysis.

5. RESULTS AND DISCUSSION

The results were obtained from a case study focused on the efficient electricity consumption. In the $NT(t)$ stage, we analyze the psychological needs of individuals and their consumption habits through two instruments: BPNS - Diary and EPCHS. The BPNS questionnaire data were utilized to measure the individuals initial psychological necessities.

Regarding the autonomy of individuals, the results of BPNS showed that 40 % of individuals have very low autonomy, competence, and relatedness. The results of EPCHS showed that as for the use of the computer, 40 % of respondents said they turn off the equipment when leaving the environment. About the monitor, 40 % of individuals always turn off, 20 % do just 80% of the time, and 20 % never turn off.

In the $NT(t)$ step, we measured the electricity consumption in four teacher room. We apply the Kolmogorov-Smirnov normality tests $z - value$ (Hair et al., 2009). The results showed that the distribution of consumption data is not normal for any room and at any time of day with high values of *Skewness* and *Kurtosis* (Hair et al., 2009).

Our analysis allowed us to observe that the individuals in the laboratories have higher consumption than the ones in the teacher rooms that usually stay in this place between 8 am and 6 pm. Since in B05, the students forget the lights on 10 am from 16 pm. While on B06 individuals leave the room and do not turn off the lights at 10 am from 3 pm. Regarding the teachers rooms, we observed that individuals usually occupy the rooms for a maximum of two people.

Because power consumption data is not normalized we use the Wilcoxon rank-sum test to compare consumption data from the NT phase to the T phase. The H_0 hypothesis is that the differences, or individual observations in the case of the single sample, have a zero centered distribution Wilcoxon et al. (1970). In this paper, we are interested in the hypothesis (H_0), which indicates that there is difference in average hourly consumption between the NT and T phases. The hypothesis H_0 was rejected because the value of Z is equal to $-14,905$ and $p < 0.001$ which indicates that there was no difference in average consumption between the two phases. The results of the Wilcoxon test showed that there were 1,561 cases in which the consumption in the T phase was lower than in the NT, 938 in which it was higher and 431 which were equal. We can say that there was a reduction in consumption in the T phase by observing that the consumption in this phase is 215.18 with a standard deviation of 18.52 which is lower than in the NT phase which obtained an average consumption of 213.79 and standard deviation of 14.95.

In the T phase, 44 triggers (tips) were sent by a mobile app to each individual within two weeks. At this stage, we observed that the subjects had very low autonomy, competence, relatedness and amotivation to reduce their electricity consumption in B06, but as we can see in Table 2 they accepted most of the triggers (tips). The data presented in Table 1 [4] indicate that 66% of individuals had very low autonomy, competence, and low relatedness and amotivation to reduce electricity consumption and 33% high autonomy, competence, and relatedness, and all individuals accepted most of the triggers that were sent. Considering the motivation levels and user needs, the systems automatically identifies the appropriated trigger (tip) to send to the user.

Table 1. Motivation and response type of triggers in room B05

B05			
User	**Trigger**		**Motivation**
	Accepted	**Rejected**	
UserA	77%	23%	Introjected Regulation
UserB	62%	38%	Amotivation
UserC	54%	46%	Amotivation

Table 2. Motivation and response type of triggers in room B06.

B06			
Usuário	**Triggers**		**Motivation**
	Accepted	**Rejected**	
User A	81%	19%	Amotivation
User B	65%	35%	Amotivation
User C	77%	23%	Amotivation

In this case study, we can observe that although individuals state that they turn off the equipment most of the time, they often forget about the equipment turned on when they leave the environment. Besides, we can see that there were signs of u-Learning processes, as individuals responded positively to most triggers, and also by the fact that there was a reduction in electricity consumption. Returning to Santaella's considerations, u-Learning can only be verified in real-life situations.

6. CONCLUSION

Our research contributes to the integration of conceptual frameworks of behavioral models, Persuasive Technologies

[2] https://forms.gle/Px2ESc4UDLYawQZX6
[3] https://forms.gle/dzQhJJzcRwuv43va8
[4] We used the same data in both tables.

and u-Learning. The main contribution of this paper is the development of a model to analyze the motivation of individuals through persuasive ubiquitous technologies, called the Ubiquitous Model for Persuasive Change Systems (UMPSBC). In the proposal of the UMPSBC, we changed the FBM by inserting the HMIEM level of situational motivation in its motivation layer. Regarding our initial research question **" how to develop ubiquitous devices that enhance home automation in energy efficiency, and convince its benefits to the users? "**, we do not find in the literary works that help us answer our question. Because of this, we developed a model related to the treatment of behavior change through the use of persuasive technologies in u-Learning environments and also by detailing the elements that can be used to assess the motivation level of individuals who are inserted in these environments.

In order to apply the model, we developed a case study in which we evaluated whether intervention in the motivation of individuals causes a change in behavior regarding sustainability and consequently if this change causes u-Learning processes, making it more sustainable. The results suggest that while individuals state that they turn off equipment most of the time, they often forget about the device turned on when they leave the room. Besides, we could see that there were signs of u-Learning processes, as individuals responded positively to most triggers and also by the fact that there was a reduction in electricity consumption. Returning to Santaella (2014) considerations, u-Learning can only be verified in real-life situations. As future work, we propose to *(i)* apply the model in other domains; *(ii)* conducting a study with a larger number of participants; *(iii)* use other instruments (sensors or questionnaires) to validate the model.

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