

FOX: A Flexible and Heterogeneous Mixed User Model to Address Sustainable Behaviour in Smart Environments [†]

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Abstract: Addressing how human behaviour can be taken into account when designing for sustainability is an emerging topic in the development of pro-environmental person-centred smart systems. Indeed, user diversity and categorisation in the context of sustainable behaviour was already studied by some scholars in recent literature. However, the complexity of the individual present some open challenges that still have to be further investigated. In this work, behavioural theories and user characterisation are analysed together to better understand the human factors when trying to influence sustainable lifestyles and actions. Then, theoretical frameworks are combined and mapped in a novel user meta-model, coined FOX, that classifies the individual dynamically taking into account its heterogeneity and diversity. The dimensions involved in the FOX proposal are explained by describing the categorisation of each dimension. Besides, an example of the potential application of the model is exposed to better contextualise the work presented. Finally, controversial aspects and emerging ideas of the proposal are equally discussed throughout the paper as well as we discuss the use of FOX model to inform the design of behaviour change interventions related to sustainability.

Keywords: sustainable behaviour change; human computer interaction; user modelling; behavioural theories; smart environments

1. Introduction

When developing technologies, in particular in the field of Smart Environments, the environmental impact should be taken into account. Sustainability has an uprising relevance that should be faced broadly. Sustainable Human-Computer Interaction (SHCI) aims at enhancing the environmental impact of technologies. Following the approach of Mankoff et al. [1] sustainability can be described through two main orientations: (1) sustainability in design, related to the optimisation of the materials and processes of the hardware and software; and (2) sustainability through design, related to influencing sustainable lifestyles and decisions. This way, SHCI addresses the relations and interactions of the individual with digital/tangible systems or technologies in order to improve sustainability [2]. Users' interactions and behaviours are therefore analysed to (1) better understand

how to address the human factor; and (2) enhance the management of technological devices, systems and processes in order to minimise its impact in the environment. Besides, this is a paramount factor in human-centred intelligent environments [3], where actions are usually recognised to adapt interventions and to offer feedback related to people's characteristics and needs. For that, it is necessary to assume the complexity of the individual and to understand the different factors that may have an influence on persons' behaviours and actions [4]. Thus, the study of the diversity of the individuals emerges as a relevant issue. In this context, the fact that people are different from each other it must be taken into account. Moreover, individuals also differ themselves depending on the moment, due to many different factors (e.g., an individual with the habit of taking always the stairs instead of the lift can change this due to a temporal injury). Therefore, heterogeneity needs to be understood as a flexible and dynamic.

Following the ideas of Hekler et al. [5], to influence sustainable lifestyle and actions, behavioural theories must be taken into account. Therefore, the paper is structured as follows: in Section 2 the state-of-the-art is analysed, exposing the theoretical frameworks to understand the behavioural processes and other approaches that address the user diversity for sustainable behaviour. Next, the FOX meta-model is described, detailing the dimensions and analysing the key factors that involve the proposal. Section 4 offers a discussion of the most controversial issues, explaining the limitations of the work. Then, the application of the model is exposed to contextualise the presented model. Finally, in Section 5 the conclusions extracted from the research work are summarised and the future research lines defined.

To avoid misunderstandings on terms used in this work, it should be clarified that the different elements involved in the behavioural theories and frameworks are called Constructs. The elements that compound the user meta-model are called Dimensions, being these based on the behavioural constructs in most of the cases. Besides, these dimensions are understood in the context of the Behavioural Technologies (BT) addressed to enhance the awareness towards sustainable behaviour.

2. Behavioural Theories and User Models to Improve the Sustainable Behaviour

In this section, the state-of-the-art is described to analyse the most relevant works related to the research presented in this paper. In order, to frame the theoretical context, first, we expose behaviour change models applied to sustainability. Then, other complementary user models and characterisations are described, and finally, conclusions of the revision of related work are resumed to contextualise the contribution presented in this work.

2.1. Theoretical Frameworks of Sustainable Behaviour Change

In the literature, we can find different approaches to cope with the decision making process. In this work, we highlight three relevant behavioural models that offer different approaches to frame the actions of individuals.

2.1.1. Transtheoretical Model

The Transtheoretical Model (TTM) [6] is a longitudinal model that analyses the process of change to understand how it happens. It divides the stages of behaviour change in six: pre-contemplation, contemplation, preparation, action, maintenance and termination. There are other complementary constructs as Process of change, Decisional Balance and Self-Efficacy. The Processes of change involve ideas that are used to progress through stages. Decisional Balance is related to the advantages and disadvantages of changing, and Self-Efficacy to the confidence in developing the desired behaviour and the temptation to avoid it. This behaviour model was applied to boost sustainable actions and lifestyle by some scholars: He et al. [7] developed specific strategies to boost the pro-environmental behaviour in the different stages of change. Besides, Wising, Chirez and Adams [8] proposed a work using TTM to enhance industrial energy efficiency targeting the change of the energy culture. Figure 1 shows the different stages of the TTM.

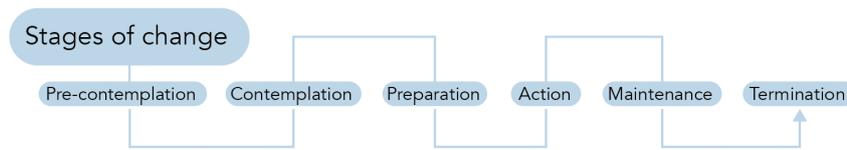


Figure 1. The Transtheoretical model of behaviour change.

2.1.2. Values-Beliefs-Norms

The Theory of Values-Beliefs-Norms (VBN) is a theoretical framework for sustainable behaviour based on values and norm-activation processes (see Figure 2). The main idea of VBN is that individuals who accept a movement’s basic values, believe that valued objects are threatened. Due to this, they trust that their actions can help restore those values and experience an obligation (personal norm) for pro-movement action that creates a predisposition to contribute giving support in different levels [9]. This predisposition is linked to different types of implication levels, and in consequence, behaviour types. The different constructs proposed by this framework are chained. Thus, the values will affect the developed pro-environmental beliefs, creating a personal and subjective norm that will inform the sustainable behaviour change. The Subjective Norm is triggered when individuals perceive that certain behaviours they perform have negative impacts on questions on which they are confident. The values are intrinsic from the individual, but they may be aligned with the environmentalism and develop increasing beliefs that end up in the development of Pro-environmental Personal Norm. Beliefs appear with the New Ecological Paradigm, which is related to the acceptance of the fact that human actions harm the environment. The next step is to be aware of the consequences, and then the ascription of responsibility. Next, the norm will be created and the individual will adopt the behaviours and action according to this norm. This approach was refined later by Stern et al. [10]. Besides, Petkov et al. developed a study addressing interventions through feedback to different user types depending on the different values outlined by Stern’s theory [11].

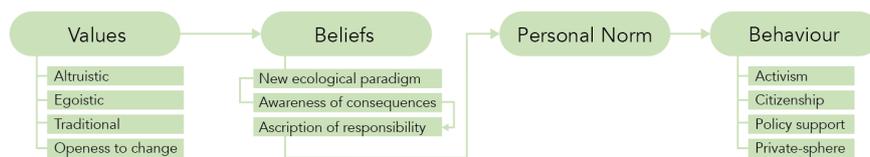


Figure 2. The Value-Belief-Norm theory of behaviour change.

2.1.3. Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) [12], is a conceptual theory that addresses the intentions as the immediate antecedent of behaviour (see Figure 3). These intentions are influenced by Beliefs, Attitudes and Behavioural Control (the perceived Self-Efficacy over a specific action). This framework helps to understand how people’s behaviour can be changed or directed with a series of predictable aspects that can influence the intended conduct. This theory is determined by the link of the decision-making process and the execution of the activity, being the intentional behaviour conditioned by three constructs: the subjective norm, the perceived ability or efficacy to perform the desired behaviour and the attitudes towards the behaviour. This framework was applied to the pro-environmental context by Coskun and Erburg to face the user diversity for sustainable behaviour [4]. Besides, Greaves, Zibarras and Stride analysed intentions in relation to sustainability using TPB theory in the context of the workplace [13].

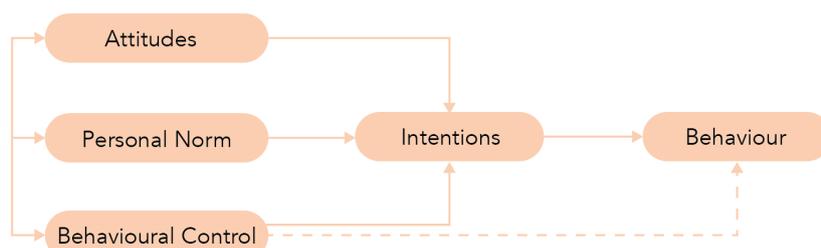


Figure 3. The Theory of Planned Behaviour.

2.2. User Models and Characterisations Addressed to Sustainability

In addition to behaviour change models, some works explore user diversity to understand how the individual behave. In this way, Lockton et al. developed user-profiles for sustainable behaviour taking into account the differences in behavioural traits, defining the Pinball, Shortcut and Thoughtful user types, based on the different models of the human system [14]. Coskun and Erburg proposed another categorisation, based on the TPB [15] and identified four personas in the context of the sustainability [4]. Petkov et al., applied the VBN to develop a user categorisation to implement personalised eco-feedback [11] and He et al. [7] used the TTM to the same purpose. Cor and Zwolinski identified two types of individuals using questionnaires to measure the key-factors [16]. Lilley Bailey and Charnley developed personas focusing on the self-repair behaviour among other factors [17], Halko and Kientz addressed the differences on individuals’ personality concerning behaviour change techniques [18], and Kaptein, Lacroix and Saini developed profiles based on the persuasion level [19].

2.3. Insights Extracted from the Literature Analysis

After the review of related work, some conclusions can be highlighted to guide research on how to better understand the human factor to influence sustainable lifestyles and actions. Following the statement of Coskun and Erburg [15], there is no standard method to explore user heterogeneity and it is complicated to extract validated knowledge. Besides, each author applies a different approach with specific criteria in a specific context. Thus, it can be difficult to extrapolate knowledge and to further analyse the impact of these proposals. Moreover, most of the proposals are based on a single dimension of the user. Therefore, the application of existing taxonomies may lead to several shortcomings derived from the narrow view when not understanding the different factors that influence the individual [5]. Finally, the lack of dynamic categorisation of the users among all the paper revised presents major a gap that should be tackled to improve the better understanding of the individual in every context.

3. Addressing the Heterogeneity Dynamically: The Meta-Model

Aiming at coping with the shortcomings revealed when analysing the state-of-the-art, this work proposes a meta-model of user characterisation addressing the heterogeneity and diversity of the individuals. This work combines behavioural approaches for sustainability in order to (1) face the shortcomings derived from the use of a single behavioural approach; (2) offer a unified theoretical background to address the design of specific and personalised behavioural interventions and (3) advise the limitations derived from the different contexts and environments that may influence specific behavioural dimensions. The framework presented in this work contemplates specific user dimensions that will help at boosting the awareness about sustainable actions. Hereafter we describe the specific behavioural dimensions and its implications. Figure 4 shows the elements and relations proposed in the envisaged model.

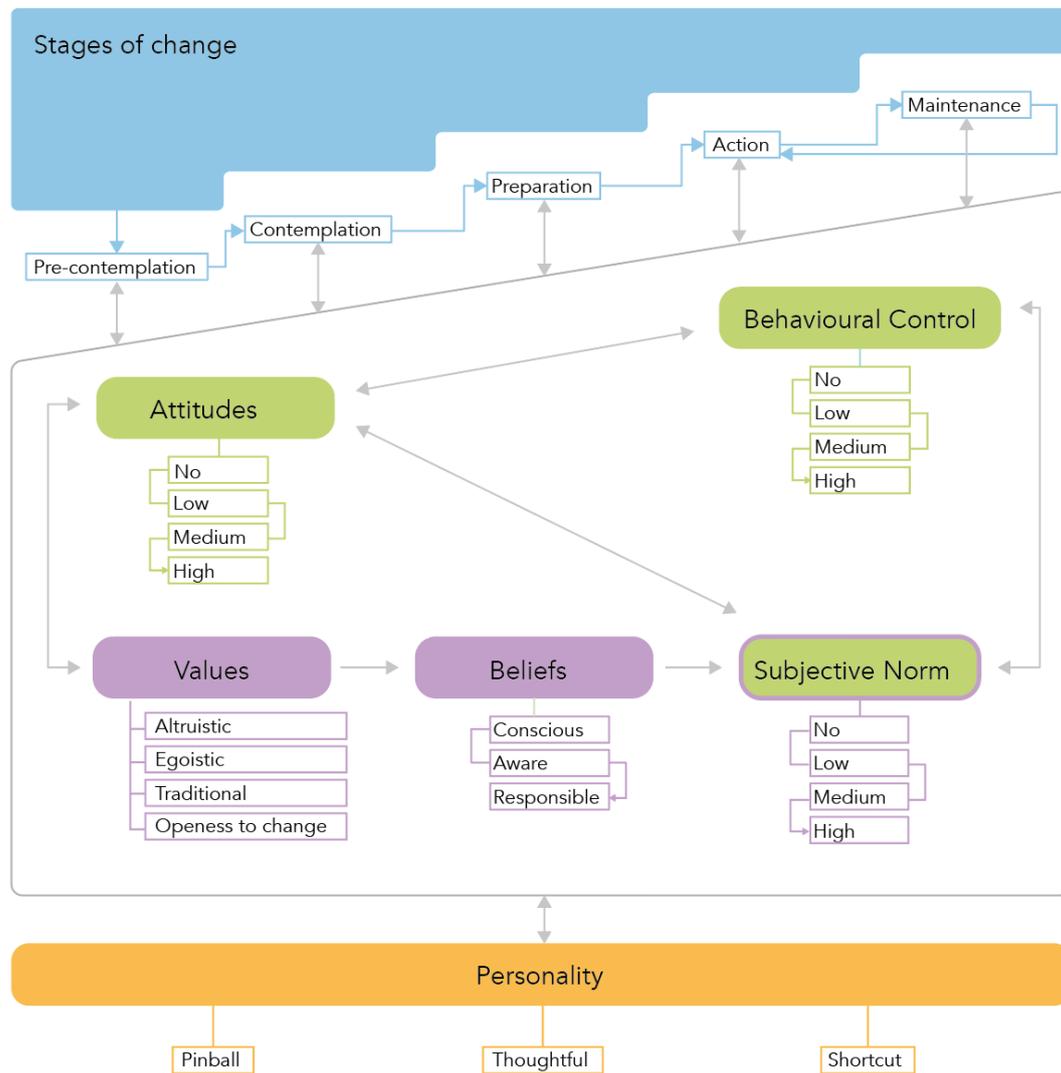


Figure 4. The FOX model with the specific dimensions and relations.

3.1. Stages of Change

As previously exposed, the TTM approaches the behavioural process taking into account the stages of change in the time [6]. Although this model involves complementary constructs, Stages of Change set the basis of the framework, offering a key dimension to locate the user in a longitudinal position of the behaviour change process. The *Stages of Change* are included in the model as a whole dimension of the user, and phases are understood as the elements of this dimension. In the FOX model, the complementary constructs that involve the TTM (Process of Change, Decisional Balance and Self-Efficacy) are supplied through complementary dimensions (Attitudes, Subjective Norm, Behavioural Control, Personality Traits, Values and Beliefs) which act as reinforcement in the different phases. Following the pro-environmental approach proposed by He et al. [7], the stages of change are classified as:

- Pre-contemplation: The user has no intention to take action in the next six months.
- Contemplation: The individual intends to take action in the next six months.

- Preparation: The individual intends to take action within the next month and has taken behavioural steps to face it.
- Action: Significant changes in behaviour within the past six months.
- Maintenance and Relapse: Besides significant changes in the behaviour for more than six months, the person tries to sustain the acquired actions and to prevent the relapse.

3.2. Personality

When developing behavioural technologies, the diversity between individuals with similar context, values and habits (e.g., siblings, friends...) implies a differential factor. The diverse personalities can be determinant on the acceptance and adoption of the inputs. Therefore, this appears as a dimension that should be included when addressing user diversity for sustainable behaviour change. In this context, the characterisation proposed by Lockton et al. [14,20] fits well due to the understanding of behaviour by approaching personality concerning pro-environmental behaviour. This author identified three user types: Shortcut (self-regulating models of the human system), Pinball (linear models of the human system), and Thoughtful (learning models of the human system).

- Shortcut: Self-regulating human models systems are understood as narrowly rational users, and makes choices to minimise energy or cognitive expenditure. This means wanting the fastest or easiest way to do things.
- Pinball: Linear human systems implies a user who only reacts simply to inputs, doing the same thing each time the same stimulus is applied and does not think about any decisions.
- Thoughtful: The learning human systems can be understood as people who think about what they are doing and why, analytically, being able to set and modify their own goals. In this classification, individuals learn from their mistakes and change their behaviour accordingly.

This classification is included in the FOX model as a Personality dimension to face different typologies regarding sustainable behaviour change. The elements of the dimensions are selective in each case due to the relation with the behavioural action, i.e., the individual may react differently to a particular input but must react in a single and specific way. For example: when receiving a mobile notification, the user may act ignoring it (self-regulating models), closing it (linear models) or opening it and reading the whole information (learning models). Thus, a single individual may act differently to an input, but the action will be only one in each moment.

3.3. Attitudes

Following the ideas of the TPB, behavioural beliefs produce a favourable or unfavourable attitude toward behaviour. Thus, sustainable attitudes can be related to the intrinsic and/or extrinsic motivations of individuals due to their different values. The attitudes can change dynamically depending on the situation and the behavioural values [21]. Encouraging the users and improving the attitudes towards sustainability, targets the motivational side, thus enhancing the awareness of the individual. For all of these reasons, this dimension is included in this work. Attitudes are categorised incrementally as follows:

- No Environmental Attitude: In this case, the user does not think about pro-environmental behaviour and therefore beliefs towards sustainable behaviour do not exist. The individual does not see its benefits or its immediate positive impact including other barriers that difficult positive beliefs toward sustainable behaviour.
- Low Environmental Attitude: The users' beliefs towards sustainable behaviour are not positive. The individual thinks that pro-environmental attitude may be positive, but does not see its benefits or its immediate positive impact. Besides, it may perceive several barriers that difficult positive beliefs toward the behaviour change.

- **Medium Environmental Attitude:** The users' beliefs towards sustainable behaviour are at the medium level. The individual thinks pro-environmental attitude is positive but perceives several barriers that difficult the fully positive beliefs toward the behaviour change.
- **High Environmental Attitude:** The users' beliefs towards sustainable behaviour are at the maximum level, thinking that pro-environmental attitude is very positive.

3.4. Behavioural Control

Behavioural control is another construct proposed by the TPB that is linked with control beliefs of the user towards the specific target behaviour [21]. The Behavioural Control is related to the perceived Self-Efficacy and is directly linked with the target action or behaviour change. It emerges as a dimension that influences directly the pro-environmental behaviour of the individuals. Therefore, *Behavioural Control* is included in the meta-model, being a key issue to analyse when addressing the user diversity for behaviour change. The classification proposed is:

- **No Behavioural Control:** The user perceives that has no control over a specific behaviour.
- **Low Behavioural Control:** The user thinks that the desired behaviour is difficult and that there are many barriers to face the desired action or behaviour.
- **Medium Behavioural Control:** The user thinks that is not difficult nor easy the target behaviour, and that some barriers difficult the change.
- **High Behavioural Control:** The user perceives that the target behaviour is easy and affordable.

3.5. Subjective Norm

The subjective norm is based on how sustainable behaviour is perceived by the individual and its context. Following Ajzen's idea, normative beliefs result in perceived social pressure or Subjective Norm [21]. Therefore, if the importance of sustainability is a familiar concern to the individual and his/her environment, the subjective norm may be high due to its relevance in the near context. This idea was addressed also by Stern, et al., defining subjective norm as the sense of obligation derived from the pro-environmental beliefs [9]. In this context, Ajzen's subjective norm is related to external motivations and Stern's approach to more internal ones. In this work, the norm involves both intrinsic and extrinsic motivations of the individual when developing a subjective norm: the pressure that the environment may put in the person and the sense of obligation that the individual feels due to his/her own beliefs. Taking into account that Subjective Norm is related to the internal rules of the individual and it is included in the model to cover the personal norms of the individuals. In this way, the *Subjective Norm* dimension is categorised as:

- **No Subjective Norm:** The individual does not have subjective rules about pro-environmental behaviour and has neither internal or external pressure to adopt it.
- **Low Subjective Norm:** The individual feels that pro-environmental behaviour is not a bad idea but does not feel important in his/her own life due to the absence of personal or social norm.
- **Medium Subjective Norm:** The individual feels that pro-environmental behaviour is a positive idea but is not fully convinced and feels relaxed about the need to adopt the behaviour.
- **High Subjective Norm:** The individual feels that pro-environmental behaviour is an obligation due to social and personal rules.

3.6. Values

Values is a dimension extracted from the VBN theory and involve the user personal concerns related to sustainability. In this context, these are the starting point to acquire responsibility for pro-environmental behaviour. Nevertheless, according to Petkov et al. values alone are not enough to boost behaviour change [11]. Taking into account that individuals have different kinds of personal values, motivation may be increased by improving these. Stern's paradigm proposes four types of

values related to the pro-environmental behaviour: Altruistic, egoistic, traditional and openness to change [10]:

- *Altruistic*: These values are focused on avoiding threats for other people. Thus, altruistic individuals are those care about others and for equality.
- *Egoistic*: These values are related to the needs and wants of the individual e.g., the gains and loses.
- *Traditional*: Values related to security and to maintain the current status to preserve the habits and traditions.
- *Openness to change*: Values related to the curiosity, involving individuals interested in different problematic as sustainability. These values involve the stimulation derived from achievement and improvement.

3.7. Beliefs

Beliefs are the last dimension extracted from the VBN and involve the concerns related to the effects of human activity on the environment [10]. These are derived from values, following the idea that things relevant to those values are under threat. This behavioural construct is included as a dimension to better understand individual's beliefs concerning pro-environmental values. These are related to the risk perceived on environmental problems, and they can be classified as:

- *Conscious*: This category involves the beliefs of the individual's that are accepting a new ecological paradigm.
- *Aware*: This category are classifies individuals who are aware of the adverse consequence for valued objects due to the environmental problem.
- *Responsible*: This category involves individuals that perceive the ability to reduce the threat and, therefore, are more willing to take action and to adopt sustainable behaviour.

3.8. Mapping the Dimensions: The Meta-Model

The analysed dimensions are mapped in a novel user-model that combines behavioural approaches found in the literature. Mixing and linking the most common theoretical models and user-classifications may help avoiding a narrow perspective of each individual model by offering a more complex way to understand the behaviour of individuals.

The classification proposed in this work includes different categories depending on the dimension. There are quantitative categorisations e.g., *Attitudes*: indifference can be 0 value and the a positive attitude 10. On the other hand, qualitative dimensions such as *Personality* or *Values* are divided by qualities and specifications but cannot be understood in an incremental measurement context. This way, categories such as *Beliefs* dimension may involve both approaches: consciousness, awareness, and responsibilities are qualitative but also quantitative if they are understood as chained, being the consciousness the first state and the responsibility the last.

The dimension *Stages of Change* has a longitudinal approach and it should be contextualised through phases, where the individual is placed in any specific stage. Due to this, the FOX model include all other dimensions along with the different phases, covering user diversity through all the stages of the change process. This approach can be observed in Figure 4. *Personality* is another dimension that is placed according to its specific nature. Taking into account that the "models of the human system" proposed by Lockton et al. [14] involve a broad contextualisation of the individual in regard to sustainable behaviour, this dimension is placed in the bottom of the model and linked with the other elements of the model.

The other dimensions of the meta-model are linked following the relations proposed by each behavioural model: (1) the dimensions extracted from constructs of the VBN are chained, being the *Values* the starting point, the *Beliefs* based on the values the next item and *Subjective Norm* that user develops based on two previous factors the last dimension. (2) *Attitudes*, *Behavioural Control* and

Subjective Norm are part of the TPB and therefore, these are linked to map the influence that each dimension have in others. Hence, the dimensions preserve their placement and context proposed in their own behavioural framework and should be understood with their links and relations to do not miss the influences that each dimension can imply in others. *Subjective Norm* is included in the VBN and TPB, and therefore, is placed as a single dimension related to both models and maintaining the links (see Figure 4).

As we exposed previously, different behavioural models complement each other addressing the complexity of the individuals. To better connect the different items, Figure 4 illustrate the links through arrows. Following with this idea, each dimension acts complimenting others and reinforcing the different approaches proposed by the theoretical frameworks.

4. Application of the Meta Model

One of the applications of this model is to be used to inform the design of behaviour change interventions. This way, why and how these interventions improve awareness of sustainable behaviour could be studied and analysed. To better understand the model and how it can be applied in design and implementation of user heterogeneity when influencing sustainable actions, hereafter we expose a simple textual example of a possible application using a *persona*, [22]. This is in line with the approach followed by He et al. [7] when describing the application of TTM to pro-environmental behaviour change.

4.1. The Example of Jon

Jon lives with Peter and their dog Zero in Berlin. He is 34 years old and recently started a new job in a very prestigious architecture studio. He is hard-working and values productivity. He is very familiar with computers and wears a health tracker among other smart devices.

4.1.1. The Specific Context of Jon

At Jon's new job, they are very concerned about the environmental impact of their buildings. They try to reduce the energy demand of the buildings they design, and besides, they try to face the sustainability of their workplace. Due to this, they have installed sensors across the building to capture data and optimise the usage of processes and devices. Besides, they created a smartphone app named Foxi to offer feedback and data about environmental concerns to motivate and influence workers.

4.1.2. Categorising Jon

In his second day at work, at lunchtime, Jon decides to download and use the app that his company developed to boost the awareness about the importance of sustainable behaviour. To create his profile, he answers some questions in the app. Next, he goes to his desktop and works normally. In the following days, the Smart Environment of the workplace catches relevant data about Jon, and by comparing it with the data of the app, a preliminary categorisation is implemented:

- *Stage of change*: Jon is categorised as *contemplator* because he recognises some problematic behaviours and he is thinking of improving them.
- *Values*: His values are categorised as *altruistic*.
- *Beliefs*: Jon was included in the *aware* category taking into account his environmental beliefs.
- *Subjective Norm*: The Subjective Norm of Jon is *medium*: in his work environment the norm is very high but in other environments (at his home, for example) there are no a pro-environmental norm.
- *Attitudes*: The attitudes of Jon regarding sustainable behaviour are categorised as *medium*.
- *Behavioural control*: The behavioural control of Jon in the context of his workplace is *low*.
- *Personality*: The personality of Jon is categorised as *Shortcut*.

4.1.3. Implementing Interventions

Once Jon is located in the dimensions of the FOX model, specific interventions are implemented to improve the awareness of pro-environmental lifestyle. Taking into account the existing categorisation of Jon, the following strategies are implemented:

- *Stage of change*: To motivate Jon to change to the next stage, preparation, the application gives information of benefits of being sustainable.
- *Values*: The Foxi app offers a data visualisation of the impact of the climate change in other people in different parts of the world to enhance the importance of being sustainable addressing values. Besides, Jon can access to other relevant data taking into account other factors (e.g., economic data, about the impact on animals and plants and so on).
- *Beliefs*: Taking into account the data gathered by sensors in Jon's workplace, they decide to implement an awareness campaign showing data of the average energy waste of a single individual at work and tips to avoid it, aiming at motivating workers at being responsible with their own actions.
- *Subjective Norm*: To boost the Subjective Norm in relation to the sustainability, Foxi app shows the profile and data of prominent pro-environmental people (in this case famous architects). Besides, it offers a social network to boost relationships with other people with similar interests.
- *Attitudes*: To enhance pro-environmental attitudes, Jon's company showcased a documentary film about the impact of climate change.
- *Behavioural control*: The Foxi app offers reminders that can be personalised by Jon. This way, he does not forget turning off the devices when leaving the office.
- *Personality*: As a Shortcut user, he makes the effortless choice. Therefore, the Foxi app has every single process set by default (favouring the most pro-environmental options).

4.1.4. Measuring and Updating the Model

Once the interventions are implemented, the next step is to compare whether there have been improvements in motivation about sustainable behaviour. Through a short survey (by using the Foxi app) and the data gathered by the Smart Environment, the new status is recognised and the model updated.

- *Stage of change*: After the interventions, Jon started to plan new pro-environmental actions. Therefore, the model updated this dimension and now Jon is in *preparation* stage.
- *Values*: The values of Jon were aligned with pro-environmental issues and now the altruism of Jon involved sustainability concerns. Besides, he consulted data related to expenses and money savings. Therefore, Foxi app improved the visibility of this data and the categorisation of Jon changes from *altruistic* to *egoistic* dimension depending on the most viewed data.
- *Beliefs*: Jon has taken responsibility for the environmental problem. Therefore, its categorisation changes to *responsible*.
- *Subjective Norm*: After the interventions, the Subjective Norm of Jon raised, and now is categorised as *high*.
- *Attitudes*: In the update of the model, the attitude of Jon about sustainability raised and now Jon has a high pro-environmental attitude.
- *Behavioural control*: After the interventions, the behavioural control of Jon is categorised as *medium*.
- *Personality*: Jon maintains most of the time the Shortcut behaviour, but the system detected that, mostly at the weekends, he checked other data (as his historic energy expense). Therefore, in those days the app will give feedback to boost his knowledge and to help him to learn about his behaviour.

5. Discussion

This early proposal combines behavioural models and categorisations to face the awareness of sustainable actions and lifestyles. The main objective of this framework is to offer a theoretical background that can be applied in several ways: to understand diversity (e.g., developing user archetypes), to apply interventions to boost the sustainable behaviour and to analyse the relations and causes of the different dimensions among others. Nevertheless, this proposal should be understood as an incipient approach that needs to be further studied and analysed to address each specific context and target users. Besides, other factors as demographics should be taken into account when applying the model to understand the behaviour change process of individuals.

This proposal was addressed based on theoretical frameworks applied to improve the awareness and motivation about sustainable behaviour. Therefore, this model should be understood as context-specific and should be contextualised to frame the pro-environmental behaviour. Nevertheless, after the context-related literature review, the dimensions of this model may have the potential to be adapted to other contexts.

The use of the model, in a broad sense, is a key point that should be discussed: on the one hand, the analysis of specific dimensions can bring valuable knowledge that is needed to extract findings on how to measure and categorise the users. Nevertheless, addressing a single specific dimension without understanding the context offered by other dimensions and its relations may bring a narrow view and involving several shortcomings [5]. Therefore, although addressing one specific dimension, the context of the framework and the other elements and relations should be carefully understood and analysed.

Considering this meta-model presents a novel categorisation, there are some limitations that should be taken into account: (1) this model has not been tested yet, nor applied in experimental conditions. Thus, it cannot be understood as a validated proposal; (2) the included dimensions target attributes related to the behavioural process of the users, being necessary to complement these dimensions with others that may influence each strategy (e.g., the use-context of a specific system) and (3) the difficulty on validating the measurement and categorisation of the dimensions makes necessary to apply specific rules and measures to each context and/or strategy.

6. Conclusions and Future Work

This piece of research proposes a holistic meta-model of the user based on behavioural dimensions applied to foster the motivation about sustainable lifestyle. It aims at facing the heterogeneity of the individuals through a dynamic categorisation to offer a flexible framework to be applied in the ideation and development of Smart Environments.

Although further research is needed to extract validated findings of the model and its performance, this work sets a starting point to develop a person-centred approach and to target users' needs addressing diversity and complexity of people when facing pro-environmental awareness.

This proposal sets research lines that are included as a future work that should be developed to extract more knowledge and solid findings on this early work. 1) an in-depth analysis and study of the meta-model in order to validate it and to better define and measure the categories of each dimension; 2) testing of the model with different groups and individuals (i.e., specific target users, researchers, practitioners...) to include valuable insights from different points of view and to validate the proposed framework; 3) Complement the model with other specific and context-related dimensions that may influence users' behaviour; and 4) explore the application of the model with different methods in different phases to better understand its possibilities.

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