

Towards the design of a mobile application with persuasive elements to increase energy flexibility

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ABSTRACT

Global demand for electricity is set to increase in the coming years, particularly with the growing use of electric vehicles. To avoid consumption peaks, users will need to be more energy-flexible. This article therefore presents an application that aims to help users become more flexible in their energy consumption. To design this application, an initial survey enabled us to identify user profiles. Alongside this, nudges and persuasive techniques were listed that could be used in the application to encourage users to change their behaviour. Several user paths were then designed to adapt the persuasive elements of the application to each user, notably according to their personality traits (Big Five model). Finally, the application, its limitations and prospects are presented.

CCS CONCEPTS

• **Human-centered computing** → **Interaction design process and methods.**

KEYWORDS

Application, Persuasion, Energy Flexibility, Personality, Design, Nudge

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1 INTRODUCTION

Global demand for electricity from individuals and industries is increasing. In developed countries, the transport domain contributes the most to this increase due to the introduction of electric vehicles (EV): their market share is set to increase from 8% in 2021 to 50% in

2030 [2]. The production of electrical energy is also subject to strict environmental constraints, as the European Union has set itself the objective of producing 80% of its electricity from renewable sources by 2050 [9]. Thus, from 2030, the aim is for 60% of electricity to come from wind or solar power [1]. This represents many challenges, including managing intermittency: renewable energies do not produce electricity all the time and the power they supply can vary considerably over short periods. In this context, energy flexibility is considered a necessary adaptation from the point of view of both electricity producers and consumers. It is therefore essential that consumers are willing to be flexible and are ready to change their habits in the way they use electricity. This work proposes to present a part of the design process for an application aiming at increasing users' energy flexibility. More precisely, it focuses on adapting persuasion methods for different user profiles so that consumers can better learn with an increased energy literacy, how adapt their electricity consumption.

2 THEORETICAL FRAMEWORK

To attempt to change behaviours through technology, several authors [13, 16, 23] have mentioned persuasion methods or techniques that are used through technology, and even in the context of energy consumption [6]. Persuasive technologies are non-coercive, with a real intention to change a person through technology (thus differentiating planned changes from simple side effects), and lastly, having to seek to change attitudes or behaviours, or both [14]. Nudges are also used to guide users towards specific behaviors [22]: these are more accurate than persuasion techniques as their objective is generally to guide the user towards a specific behaviour. However, in this case, the user remains free to make his/her own choices and there is no attempt to change them. While there is no official taxonomy of nudges, multiple authors [12, 22, 31] identified lists of them. They can also prove useful to incite environmentally friendly behaviours or more economic electricity consumption [5, 26]. To enable an application to persuade users, engagement and retention were also studied. They show the attraction and effectiveness of an application and enable users to be encouraged to continue using it. Engagement refers to the voluntary investment in the cognitive, emotional and behavioural resources of a client or user in interactions with the brand (or a technology) [8]. Retention is an engagement metric since it considers the extended use rather than just the initial adoption [27]. Users' engagement with an application is important, as it keeps them from abandoning its use. As a psychological state, engagement comprises a dynamic and interactive relationship with an agent or an object (for example,

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Table 1: Effectiveness of nudges and persuasion techniques according to personality traits

Personality trait	Nudge or persuasion technique	Author(s)
Openness to experience (high)	Sensitive to Reinforcement, Less sensitive to Cooperation, Comparison, Competition and Rewards	[10, 17]
Openness to experience (low)	Sensitive to Authority, Consensus, Sympathy, Social influence	[18]
Conscientiousness (high)	Sensitive to Commitment, Reciprocity, Conformity to Authority, Simulation, Objective-fixing and Suggestion, Less sensitive to Sympathy, Cooperation, Competition	[3, 10, 17]
Conscientiousness (low)	Sensitive to Social Influence	[18]
Extraversion (high)	Sensitive to Loss aversion, Personalization, Self-monitoring and feedback, Comparison, Punishment, Objective-fixing, Suggestion, Competition, Rewards	[17]
Extraversion (low)	Sensitive to Social Influence	[18]
Agreeableness (high)	Sensitive to Authority, Commitment, Sympathy, Conformity, Reinforcement, Cooperation, Simulation, Punishments, Personalization, Competition and Rewards	[3, 10, 17, 18]
Agreeableness (low)	-	-
Neuroticism (high)	Sensitive to Consensus, Social Influence	[17]
Neuroticism (low)	-	-

a brand, a product or a medium), which meets the instrumental (e.g. utility) and experiential (e.g. emotional satisfaction) values of a user [24]. User retention, a concept close to engagement, is widely used to measure the success of applications as it corresponds to a higher level of adoption and engagement [25]. A high level of retention and high retention rate is necessary in an application order to lead users to progressively change their behaviours and attitudes concerning energy flexibility. Energy literacy is an element that allows users to be more adaptable and flexible from the point of view of their energy consumption. Users also tend to adopt environmentally friendly attitudes, for example, if they are conscious of their overuse of energy (higher costs, higher CO₂ emissions, network instability, etc) [19][29]. Finally, in a few studies, links between personality traits (according to the Big Five Factor model [21]) and the effectiveness of nudges or persuasion techniques have been identified in the literature [3, 10, 17, 18]. These are resumed in Table 1. Thus, persuasion techniques can be adapted to suit the personality of users.

3 METHODOLOGY

3.1 Context of the study

This study is part of a collaborative study carried out in the Grand Duchy of Luxembourg involving its main electricity supplier and two research institutes. This project, called FlexBeAn (“Flexibility potentials and user Behaviour Analysis” - <https://www.flexbean.lu/>), aims to better understand the energy flexibility capacity of residents in Luxembourg in order to act on them. One of the means of action favoured and developed was the design of a mobile application integrating persuasion elements that are adapted to electricity consumers.

3.2 Identifying user profiles

In order to identify different personality profiles and match them with the most appropriate nudges and persuasion techniques, a questionnaire was proposed to 459 electricity consumers in Luxembourg. The questionnaire was composed of five main sections: sociodemographic data (gender, age, level of studies, profession, level of income, members of the household, type of accommodation (house/apartment...) or the main heating system within the accommodation), values related to behaviours and beliefs in terms of the environment (measured with the Environmental Portrait Value Questionnaire (E-PVQ) questionnaire [4]), personality (measured with the short Big Five Inventory (BFI-10, [7, 21]), technology affinity (measured with the Affinity for Technology Interaction questionnaire (ATI, [28]) and energy literacy (measured with a questionnaire based on 13 multiple choice questions).

3.3 Design of the mobile application

The mobile application, aiming to change consumer attitudes and behaviours around flexible energy, was designed according to a human-centred approach, in line with the ISO 9241-210 norm [11]. For this, the project team (2 User Experience (UX) researchers, 1 information science researcher and 2 IT specialists) defined the different user experiences, from the downloading of the application to the different contents that users could consult to enhance his learning of energy literacy (see Results section for the different types of content offered).

4 RESULTS

4.1 Identification of user profiles

There were 459 responses to the survey carried out to find out the profile of electricity consumers in Luxembourg. The general sociodemographic profile is mainly composed of men (n= 361, 79%),

with age groups fairly distributed (17% of 26-35 years old, 25% of 36-45 years old, 25% of 46-55 years old and 23% of 56-65 years old), mainly homeowners ($n=428$, 93%) of detached houses ($n=215$, 47%, and 28% for semi-detached houses). Concerning the personality traits of the Big 5, the general profile of the respondents is as follows: As a reminder, possible scores range from 1 to 5. The higher the score, the stronger the personality trait in this dimension: 2.78 for Extroversion, 3.48 for Agreeableness, 3.27 for Conscientiousness, 2.66 for Neuroticism, and 2.92 for Openness to experience. Each personality trait was cross-referenced with different variables to check whether it influenced them. It can therefore be observed, for example, that gender is correlated agreeableness ($F(1.454) = 5.099$, $p = 0.024^*$ (Female = 3.668; Male = 3.427) and neuroticism ($F(1.454) = 6.931$, $p = 0.009$ (Female = 2.900; Male = 2.593), with scores significantly higher for women than for men. Tenants also have significantly higher levels of neuroticism than homeowners ($F(1.454) = 8.291$, $p = 0.004$ (Homeowner = 2.620; Tenant = 3.161)). Considering connections with the “Environmental Portrait Value Questionnaire” (E-PVQ) [4], it seems, in particular, that the more consumers are interested in protecting nature and the environment (biospheric dimension), the more extroverted ($r = 0.098$, $p = 0.037$) and conscientious they are ($r = 0.133$, $p = 0.004$), but the less agreeable they are ($r = -0.100$, $p = 0.032$). Finally, the more consumers declared themselves at ease with the technologies (ATI questionnaire), the less extroverted they were ($r = -0.092$, $p = 0.050$).

4.2 Adaptation of persuasion techniques

As the literature showed that persuasive elements in technology and a higher energy literacy could incite users to change their behaviors (and therefore eventually make them more flexible with energy consumption) nudges and persuasion techniques are added to the application through different types of contents proposed daily to users to enhance their learning of energy flexibility, as follows:

- The “Did you know” type of content asks if the user knows about an information (related to energy or the environment). This type of content enables a user’s energy literacy to be measured and increased. After answering, “Yes, I knew about it” or “No, I didn’t know”, users see the percentage of other users that chose each response.

- The “Do you agree?” type of content asks if the user agrees with a statement. This type of content enables the user’s energy literacy to be measured and his/her engagement to be maintained via an action that positions him/her (techniques of solicitation and commitment [16]). Here also, users will be able to see the percentage of users that chose each response.

- The “Quizz” type of content, which asks the user to choose the correct answer to a question related to energy literacy or flexibility. The aim of this type of content is to keep the user committed by challenging his/her knowledge as well as evaluating it, enabling designers to assess the effectiveness of the application.

- The “Challenge”, proposes to the user to commit to perform an action to be more flexible or economical with energy consumption. A second part of the content reappears a day or a week later to request confirmation that the user effectively carried out the action. Here, the aim is to get the user to commit (which related to the aims and planning [15] persuasion technique; the intention to act

[22], commitment [23], [16], commitment and consistency [23]; pre-commitment strategies [22]). If the user carries out an action successfully, an encouraging messages is displayed (conditioning technique [13], rewards and threats [15]).

- The “Tip”, suggests an advice and some tips for improving energy flexibility and possibly reducing consumption (shaping knowledge) [15]. The user is thus freer than with a challenge, and there is no social comparison with the results or answers as the user can simply answer “Ok! Thanks!” to the tip content. In this way, users’ energy literacy and flexibility can also increase.

In the “Did you know”, “Do you agree”, “Quizz” and “Challenge” types of content, it is possible for the user (after responding) to see the percentage of other users who responded to each question. This way, the nudges and persuasion techniques related to social comparison are implemented (social norms nudge [20]; social reference [30]; social comparison [26], social proof principle [23], behaviour comparison [15]). After visualizing or responding to content, the user can also rate it (with a thumbs up or thumbs down). This is then found in the content history. Proposing daily content is also a way to keep users engaged without overwhelming them. If not consulted, content can accumulate over time, allowing the user to be more active at a more opportune time for him or her.

5 DISCUSSION AND CONCLUSION

This study presents the development of a mobile application to encourage citizens to be flexible in terms of energy faced with a demand for electricity that will increase in the coming decades. Firstly, the literature review enabled the main nudges and persuasion techniques to be identified in order for them to be implemented into the application while remaining in keeping with the personality of potential users. Secondly, a study enabled different user profiles to be identified in Luxembourg depending on personality, affinity with technology, energy literacy, and behaviours and beliefs concerning the environment. Although certain research works have been concerned with matching personality traits from the Big 5 model with nudge types, few of them tried to add these results into an interactive system while proposing personalized and adaptive interactions. This study attempts at taking up this challenge with the first steps of its design process being presented in this article. Furthermore, we sought to raise the profile of the targeted users by examining personality profiles in Luxembourg during the survey, which enabled us to establish new links between individual characteristics. Thanks to these preliminary steps, a prototype of a mobile application was developed with the objective of offering personalized content adapted to the user profile. Nevertheless, the survey results are probably not representative of the whole Luxembourgish population. Indeed, we observed an unequal distribution between men and women. However, we can indicate that the persons contacted were invited to respond in the name of their household, and men frequently manage administrative aspects within the home. In addition, 93% of the persons questioned declared that they were homeowners, whereas, in reality, homeowners represented 84.5% of citizens in Luxembourg in 2023. For future research, focused user testing of mobile applications is planned to verify or improve persuasive strategies. This step should ensure us that the application

offers a satisfying user experience and check if the suggested content corresponds to what consumers expect from it. This could also confirm the effectiveness of particular persuasion techniques on some personality traits. Secondly, the implementation of additional gamification functionalities is also considered with points and rankings, or even based on a social dimension, by adding friends, leading to more comparisons between users. These functionalities could add more engagement and persuasion dynamics.

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