GreenLife: A Persuasive Social Robot to Enhance the Sustainable Behavior in shared Living Spaces

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ABSTRACT

This research aims to gain understanding of interactive technology, which could persuade building users to behave sustainably inside shared living spaces. By utilizing the research through design approach, we conducted a three-phase qualitative study to explore persuasive technologies for sustainability. First, we ran three focus groups (n=14) to explore what form of interactive technology could persuade building users to behave sustainably, and to investigate their related needs. Second, based on the focus group findings, we designed an application concept called GreenLife for the social robot Pepper. Third, we evaluated the GreenLife concept represented by video scenarios using an online survey (n=20). Most participants believed that social robots can persuade building users to behave sustainably by providing social feedback, valuable rewards, and reliable information on sustainability. A list of design implications was formulated to support the future design of social robots as motivators of sustainability in shared living spaces.

CCS CONCEPTS

• **Human-centered computing** → Human Computer Interaction (HCI); HCI Design and Evaluation Methods; User studies.

KEYWORDS

Social robots, Persuasive technology, Persuasive social robots, Interactive technology, Environmental sustainability, Social sustainability

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1 INTRODUCTION

Modern way of living has led to excessive use of renewable and non-renewable resources, generation of CO2 emission, water and air contamination, which all have drained our ecosystem [1]. It is estimated that by 2050 more than 6.5 billion people will reside in cities and surrounding areas, where they will spend the majority of their time indoors [2]. Compared to commercial buildings, residential buildings consume higher levels of energy, which is mostly from nonrenewable resources. Thus, it is essential to implement *sustainable solutions* which can lower the damaging impacts these buildings have on the environment. Sustainable development is defined as "*a development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" [3, pp.43]. Sustainable development in the form of green intelligent buildings can help to lower the consumption of nonrenewable resources, and at the same time improve the social life of people within these buildings by feeling part of the community, feeling of safety in the community, and having better quality of life [4].

In this paper our emphasis is on the concept of shared living spaces inside buildings to address both the *environmental* and *social sustainability* aspects of residential and semi-public building. Using shared spaces can influence environmental sustainability by lowering the usage of resources inside buildings. We also hypothesized that using shared spaces can also impact social sustainability by maximizing residents' sense of community and belonging, social interaction, wellbeing, health and overall quality of life [5].

Even small changes in the behavior of building occupants, such as turning off lights, covering or uncovering windows, and reducing heat can result in 20% energy savings [6]. Former research indicates that interactive technology can have an impact on *behavioral change* in the form of *persuasive technology*. Persuasive technology is defined as *the interactive information technology, which is designed to change the user's attitude and behavior* [7]. Thus, using interactive persuasive technology can assist people to change their attitudes and behavior by using several persuasion techniques such as advising, giving feedback, rewarding and social support [8]. When persuasive technologies are used to drive social influence strategies, such as social learning, social comparison, competition and reward, they become more effective at increasing people's ability to accomplish target behavior [9]. Similarly, persuasive systems can lead to positive behaviors and environmental sustainability, for instance in power consumption and water conservations [10]. One feasible persuasive interactive technology to use are embodied agents (social robots). According to Fogg [7], intelligent embodied agents can be used as persuasive social actors; they can encourage users to make certain goals more explicit and persuade the users to make more sustainable decisions based on the suggestions made by the system. Social robots have been researched for many social and motivational tasks in weight loss [11] and education [12] and they seem to be promising agents to adopt the role of a social motivator, and to boost behavior change for sustainability [13].

The overall aim of our research was to explore the potentials of interactive technologies to persuade people towards sustainable behavior in shared living spaces. More specially, the study evaluated a concept, which was designed as a social robot application. In this context, shared living spaces are common areas, where occupants of residential and semi-residential buildings utilize for instance saunas, laundry rooms, showers, communal spaces, workshops, shared electric cars, tools, recycling and waste disposal amenities. The aim is to motivate the building residents and visitors (referred to as users in this study) to show more sustainable behavior via social and playful applications designed for a social robot.

The research questions addressed in this study are:

1. What kind of human-centered intelligent technology solutions can persuade people to sustainable use of shared living spaces?

2. What are the design implications for social robots used as persuasive agents in shared living spaces?

The first phase of our *research through design* [35] process focused on exploring different forms of interactive technologies using focus groups. Next, we found certain needs to use social robots as potential technological solutions to motivate building residents to sustainable behavior inside shared living spaces in buildings. In phase two, we designed the concept of GreenLife application for the social robot Pepper. In the final phase, we evaluated the video scenarios we made to portray the interaction between the user and Pepper using an online survey. The approach is to apply persuasive technologies, more specifically social robots, as social influencing agents [14] to create more sustainable thinking and behavior for smart building residents. Moreover, we will consider the ethical matters of implementing social robots as motivators of sustainable behavior in shared living spaces.

2 RELATED WORK

2.1 Persuasive Technology for Sustainability

Sustainable development focuses on a long-term approach to establish a healthy community and prevent over utilization of natural resources by addressing economic, social and environmental aspects of sustainability [15]. Focusing on environmental and social aspects of sustainability, designing green buildings can be beneficial in managing these sustainable dimensions and improve the efficient use of natural resources. Currently, many green buildings have interactive solutions, such as smart metering systems, sensors and real time monitoring of data to inform the occupants about their energy consumptions; the aim of such interactive solutions is to change the behavior of the residents and assist them to consume less space, energy, and to be more aware of reducing material use and increase recycling. Thus, interactive technology can be utilized to support and persuade people towards sustainable behavior [16]. Persuasive technology can be in the form of an information system or computerized system designed specifically to persuade, form, or enhance the behavior of users [17, 18]. Oinas-kukkonen et al. [8] have suggested four persuasive principles categories for persuasive technologies. These include 1. Primary task (supporting users' primary task), 2. Dialogue support (providing system feedback to the users), 3. Credibility support (designing credible and persuasive systems), and 4. Social support (design a system that motivates users by leveraging social influence). In designing persuasive technologies, researchers or designers choose persuasive techniques based on the efficiency and suitability of the strategies in solving a problem.

2.2 Persuasive Social Robots

Social robots can interact and communicate with humans in a human-like manner, as well as with other robots, and even the environment [23]. These robots are being used in diverse domains such as a university lecturer or as a businessman working in an office managing deals [24]. They are also being used to facilitate communication with elderly people with dementia [25] and in studies with children with autism [26]. In short, these robots are created to influence humans to some extent [27]. As persuasive technology can influence human behavior or thinking, it can become influential when it is in the form of an embodied social agent. Hence, as humans show similar social responses when interacting with computers as when they interact with humans, social robots can be effective (technological) persuaders. Social robots can have a behavioral change effect in humans, such as helping humans to take medication or buying clothes; or they can have a cognitive effect such as changing the attitude of humans (helping humans to learn better), thus effective persuading is important for social robots' role in persuasion [27].

Persuasive robots are embodied agents that are designed to change the behavior, attitude or even cognitive process of humans [28, 29]. Persuasive social robots use various strategies such as social cues, social reinforcement, and social power in order to steer user's behavior [27]. An example of such robots is evident in the study done by Hashemian [30] - they explored social power in the form of reward and expertise as a type of persuasive strategies for social robots. In this study, researchers conducted user studies using two social robots to evaluate the effectiveness of such strategies in persuasion. The aim of the robots was to encourage users on a concrete choice by choosing their preferred coffee capsule based on the information given by the robots. As persuasive strategies, one of the robots interacted in a funny way by telling jokes and the other one was more serious and *provided the user with facts and information.* The participants then decided to choose their preferred coffee based on the argument of the robot. The results of the study showed both robots were equally persuasive with no significant difference between them.

Persuasive social robots can use verbal persuasion by providing feedback in order to change the behavior of a person. An example of such a robot is the persuasive and social, *iCat* robot [19], which was used to give feedback to the user to reduce the energy consumption during washing tasks with a stimulated washing machine. In this study, the users received *negative and positive feedback* based on their washing task through the robot's facial expressions (sad or happy face), illuminating lights (red or green) on robot's ears, and words (terrible or fantastic). For instance, the robot displayed disapproval when the participants set the temperature to 90 centigrade, and positive feedback when they set the temperature lower. The participants also received *factual feedback* based on the energy consumption shown by the energy-bar indicator. The study results showed that social robots providing negative and positive social feedback had strong persuasive effects on lowering energy usage. Another example of a persuasive social robot is the robot used as a driver assistant to give evaluative feedback to the driver. The robot provided feedback to the driver such as "excellent" based on the fuel consumption by giving the user the impression of being sustainable [31].

In another study, researchers have used *physical interaction* involved with the robot to persuade users to be conscious about environmental resources [32]. They used a robot called Floffy to educate 12 years old children the importance of the natural environment. Floffy was an environmental toy robot that was dependent on water and sun for existence and responded positively once located outdoors in the sun and fed with water. It showed a desire for water by jumping quickly and got happy when it was fed with water. When Floffy was placed indoors it showed a *negative response* as a sign to show desire for the outside environment and as the user got closer, it moved away, and its eyes turned orange. Once it was located outside in the sun it showed *positive behavior* by moving close to the user and its eyes turned green as a sign of happiness. The outcome of the study showed that the robot had potential in educating children the importance of water and sun energy resources, also it showed them to appreciate the environment in the same way as Floffy does, and to love the environment by offering a unique interaction mechanism [32].

Social robots can also be used to enhance social sustainability by creating social connection and interaction among people. In a previous study [14], Pepper was used in order to facilitate *connectedness* among strangers by being an interactive host to create positive ambience and user experience in events. A *playful* robotic application in the form of a game was implemented on Pepper in order to break the ice between visitors of a space. The game provided opportunities for players to get to know each by sharing fun and basic facts about themselves. The aim of the game was for players to find mutual interests with others so they could connect and socialize easier. The result of the study showed that people had pleasurable and positive encounters after interacting with the robot and the game, and they found the robot to be a useful icebreaker.

In a different study [33], researchers used a community-centered approach and conducted semi-structured interviews in order to gain knowledge about the community members' perception regarding using social robots in their retirement village. Before the interviews, the residents were familiarized with the concept of social robots in general and they were shown various pictures and videos of existing social robots in different roles in individual and group settings. The researchers explored members' collective viewpoints on novel meanings to sense of community and possible community roles for the shared robots. The results of the study revealed several ways in which the retirement village could benefit from using shared social robots. Most participants believed shared social robots could act as *social catalysts*, which worked inside the community by bringing individuals together. Additionally, the participants perceived introducing social robots in the community, could increase *sociality* and social interaction by creating opportunities for residents to talk and chat with each other. Moreover, most members believed social robots could be social enablers by helping them to become active community members and participate in different activities.

Based on our knowledge, currently there is no attention given in studying social robots in the context of green buildings. We believe these robots can be utilized as autonomous solutions where they can persuade building users towards sustainable behavior. The persuasive strategies used by social robots should be applied based on moral acceptability [27]. It is important to note that not everything which is acceptable in a human-human context is ethically acceptable in human-robot interaction (HRI). Compared to human-human interaction, "*the asymmetry between the persuader and the persuadee is bigger in case of persuasive social robots*" [27, pp. 68]. Also, some methods, which are unproblematic in human-human interaction may become problematic in HRI and they may raise ethical concerns. Persuasion on robots should be done only in an efficient form of communication to support appropriate goals for users [34].

3 OVERVIEW OF RESEARCH PROCESS

In this section we explain the research approaches we utilized in this study. Next, we will introduce three phases of our study separately in detail.

3.1 Research Approach and Phases

This study followed *research through design approach* [35] and *human-centered design* (HCD) approach [36]. By utilizing the HCD approach, we were able to understand users' needs and requirements and design concepts, which could address their desires better. Research through design approach was used to employ methods and processes to address users' under-constrained problems by creating prototypes, which could be preferred by them. Our research through design approach involved three phases including 1) *user needs study*, 2) *concept design*, and 3) *concept evaluation and synthesis*. The purpose of the user needs study phase was to explore potentials of persuasive interactive technology to support sustainable behavior in co-used buildings. The aim of the concept design phase was to design technological solutions to support sustainability in shared living spaces. Finally, the goal of the evaluation and synthesis phase was to evaluate the designed concept with users to synthesize principles and premises for intelligent technology design.

3.2 Study Phases

3.2.1 Phase 1: User Needs Study.

Study design. In this phase, focus group method [37] was employed (1) to find out about people's current perception on sustainability and the importance of it, (2) to identify the residents' current experiences and needs of sustainability in shared living spaces, and (3) to identify what form of interactive technologies can motivate people towards more sustainable behavior in co-used living areas. We used focus groups to generate information and collective views of the participants about the topic of our study. In order to have diverse data, we conducted three focus groups sessions in different locations in city of Tampere in Finland. The locations were all residential buildings, and one location had a semi-public building, where residents used it as a shared space in the community. The focus groups sessions were all held in Finnish language, so the participants could communicate easier in their native language. The sessions were two hours long and scheduled to run in the evening after working hours during November 2019 - January 2020. To generate detailed discussion, the maximum number of participants was decided to be five persons per group. As an incentive, each participant received one movie ticket for attending the focus group session. The advertisement for the focus groups was announced on Facebook's residential communication pages, and through buildings' housing committee meetings.

Participants. Overall, 14 Finnish participants attended the focus groups sessions. The participants were the residents and users of the buildings, where the focus groups took place. Many of the participants were above 50 years old (7); the rest were between the age of 36-40 years (2), 41-45 years (3), and <25 years (2). 6 participants were female, and most of the participants (7) did not have children. All participants (14) used smartphones as their most used form of technology.

Data collection and analysis. Before the focus group sessions started, the participants were asked to give their consent for the study. They were also given a short questionnaire in order to obtain information about their demographics, current most used form of interactive technology, the frequency they used that technology, and their current communication channels related to the usage of the building. We recorded the sessions by using a voice recorder. There were two researchers present in each session: the facilitator and observer/notetaker.

The focus groups' discussion consisted of three phases. In the first phase, the participants were first briefly introduced to the concept of environmental and social sustainability, as well as the purpose of the study and the focus groups. Next, the discussion began by asking the participants general questions regarding their community in the building, the types of shared spaces in their community, and the frequency of usage of shared living spaces by the community members. Moreover, we asked participants to share their general viewpoints about sustainability. In the second phase, the discussions continued by questions about the current needs and challenges of residents concerning sustainable use of the shared living spaces, and the current form of technology used to inform them about the sustainability of the community and buildings. In the third phase, the discussions were followed by showing the attendants pictures of different interactive technologies (smartphones, interactive public displays, social robots, informative public screens, augmented reality, virtual reality, and games) and asking them about their preferred technology and its potential features to contribute to residents' sustainable behavior in the shared spaces.

After the discussion was over, the participants received a questionnaire to share further information regarding the focus groups' topic. After completion of focus group sessions, the recorded discussions were transcribed and translated to English for the purpose of analysis.

We used the Content analysis method [38] to analyze the focus group data. The transcribed data was transferred to Excel sheets to find the main common themes among all three locations.

3.2.2 Phase 2: Concept Design of GreenLife Application.

The concept was designed based on the findings of the user needs study in phase 1. Based on the results (more detailed in section 4.1), it seemed that people were willing to use their existing technologies e.g. (smartphones) for sustainability persuasion; on the other hand, most participants also accepted the idea of a social robot as a sustainable motivator to be used inside shared living spaces. Thus, we designed a service called "*GreenLife*" that can be accessed both by interacting with the robot in the public space, as well as virtually through the user's personal device. In this study, our focus was on the physical interaction with the robot, thus the virtual interaction was not tested with users. Our selection of a social robot as the public space persuader can be justified with the previous research about their potential to initiate social interaction and persuasion [19, 39]; and their ability to adapt to various social roles such as in education [40], in health care [41], and in the context of environmental and social sustainability [14, 20–22, 33] to persuade users. Also, we wanted to evaluate a novel form of technology as a persuasion platform and gather users' feedback about it to further investigate the potentials of social robotics in this area.

The GreenLife application. Taking inspiration from the Lean UX process [42], we built a minimum viable product (MVP) to evaluate our solution with the target users. To ideate the concept, we utilized the robotic MVP canvas [51] as a design tool. After the ideation, our MVP was implemented as a video scenario, where the user could view the features of the GreenLife application, and the designed interaction between the user and the robot. In order to portray the actual interaction with a social robot, Pepper's voice was recorded and used in the video in parts where it needed to talk with the user. Also, we recorded one of the researcher's voice and used it in parts of the video where the user needed to talk to Pepper. The detailed information about the video scenarios will be provided in section 4.2.

GreenLife is a social robotic application concept in which a social robot acts as a guide to encourage the building residents to behave more sustainably inside shared buildings areas. The GreenLife application is designed to be used on "Pepper" humanoid social robot developed by SoftBank robotics [43]. Pepper is 1.2m tall, it is equipped with cameras, wheels, sensors, and microphones. Pepper has a tablet located on its chest so users can interact with it. Pepper was selected because of its features such as its human-likeness, appealing appearance, suitable size for interaction, its ability to make conversation with humans and the presence of the tablet that made it possible for users to interact with it through voice and touch modalities [44]. The main context of use for GreenLife is inside the shared spaces in buildings, for example in the common rooms, lobbies, laundry rooms, workshops, entrance of showers and saunas.

3.2.3 Phase 3: Concept Evaluation and Synthesis. We evaluated the GreenLife application through an online survey. As it was mentioned in the earlier section, in this study we designed GreenLife as a video scenario where the user could view the features of the application through the portrayed interaction between the user and the robot. In order to include the video in the survey, we divided the video into 4 sections. Each video lasted between 1.30-2:15 minutes and the total length of the entire video was 9.10 minutes. The videos were placed in the survey in separate sections and the questions related to each video appeared after the participants watched the video. The advertisement for the online survey was published on different communities' Facebook page for the duration of one week.

Participants. Overall, 20 participants answered the online survey questions. 5/20 participants were between the age of 31-35 years old, and 5/20 were 36-40 years old. 2/20 were 41-45 years, 3/20 were 25-30 years, 3/20 were above 50 years and 2/20 were 46-45 years. 14/20 of the participants were female; and 11/20 of the participants did not have children. 11/20 of the participants did not have any prior experience in interaction with social robots. Most of the participants (7/20) were from Finland, and (5/20) were from Iran, the rest of the participants were from various countries around the world. Most of the participants (11/20) were interested in social robots, while 7/20 were neutral about them, and 2/20 did not have interest in social robots.

Data collection and analysis. We used Google Forms to publish the online survey. The survey was 20-25 minutes long. Before the survey started, the participants were asked to give their consent in the study and their basic information. They were also given a questionnaire to specify their prior experience in interaction with social robots and their overall interest in social robots on a 7-point scale (1=totally uninterested, 7=totally interested). Next, the participants viewed each video individually and then they answered the questions related to each video. There were 12, 7-point Likert scale survey questions (1=totally disagree, 7=totally agree). The questions were mainly about the robot's role and guidance in shared spaces: robot's usefulness in providing the user with sustainable instruction, and energy consumption information. Also, we asked about users' viewpoints on the robot giving them rewards and feedback, it's trustworthiness, it's capabilities in motivating the user to sustainable behavior. Finally, we asked about the simplicity of GreenLife and usage of it for booking the shared living spaces in general. We put a text box after each video and the survey questions, to gather some qualitative data and for users to share additional thoughts about the videos.

Content analysis was again used to analyze the qualitative data gathered from the online survey. The process was similar to the user needs study in phase 1. Overall, we found 23 themes from the data we gathered in the online survey. The information about the themes are reported in the Findings section 4.3. Basic statistical analysis was used to analyze the quantitative data from the survey.

4 FINDINGS

In this section we will report the results of the user needs study, where we conducted three focus groups sessions. Next, we will report the details of a concept we designed based on the findings of the focus groups sessions, and finally, we will describe the results of the concept evaluation.

4.1 User Needs Study Findings

The findings of the three focus group sessions are reported in the following section. As we had three focus groups in three different locations, we refer to them as (L1), location 2 (L2) and location 3 (L3). L1, was a close community with less than hundred residents. L2 was the biggest community with less than four thousand residents with a multipurpose semi-public building used as one shared space for residents. L3 was a medium sized area with a population of less than one thousand. In this study, we refer to the users of the space (residents, visitors) as "users".

Sharing practices in the different locations. All three locations had similar shared spaces and facilities in the community buildings such as sauna, shower facilities, shared electric cars, common spaces, kitchen, workshops, laundry rooms, and freezer room. However, in L2, users also had access to a semi-public building where they shared sports halls, and bigger communal spaces for organizing meetings, and events. In L3, users shared a tennis court, a small beach area next to the lake, courtyard spaces for barbeque, kitchen, and communal spaces for arranging meetings and events. In all locations, most of the shared spaces were used daily or as much as needed depending on the availability and need of the users. To book the shared spaces, in L2, the users used the building websites' reservation system, in L1 they used pen and paper, and in L3 they used a mobile application. The communication channels for buildings' related matters in all three locations were Facebook groups, WhatsApp groups, email and in L3 they also used their own specific mobile application for using the shared spaces and obtaining sustainable instructions. In terms of the current technology used for sustainable information, in L1 users used energy consumption invoices; in L2 they used bulletin boards, and the community websites and in L3 they used smartphone applications for this purpose.

Current perception and role of sustainability. Some participants (6/14) stated that **sharing cars** with others can lead to a more sustainable lifestyle: "*I think sharing cars is very sustainable and we have two electric cars in our community to share whenever needed*" (F, 41-45 years, L2). Moreover, some participants (6/14) mentioned sharing **spaces and tools** with others led them to own or rent smaller houses and save money: "*Sharing spaces means we don't need to have a big house for a sauna, or a laundry room*" (M, 50+years, L1). "*We borrow and lend tools to each other, this way we don't have to buy some items or store them*" (F, 50+years, L3). Also, some participants mentioned shared spaces could sometimes create a **sense of community** for some people and bring them closer to each other. In some cases, people unite to organize events, or attend some events in the shared spaces and this can create a sense of community between people: "*People can feel they belong more to their community if they share spaces with other residents. Being part of the community can make people care more about their own environment*" (F, 36-40 years, L2). "*Sharing things and spaces with others make you part of the community*" (M, 50+years L1). his purpose.

Users' viewpoints on ways people can behave more sustainably in shared spaces. Some participants (8/14) mentioned **sustainable guidelines**, **clear** and **easy instructions** could be helpful ways for some people to learn about sustainability in a community. Moreover, they believed simple instructions and guidelines can be used by any age group, and this will encourage people to pay attention more to their sustainable behavior. Also, users believed accessible instructions can help people to carry out sustainable tasks easier and faster: "*Does everyone know how to recycle? We should have some instructions. It seems obvious, recycling, but it's certainly not obvious to everyone*" (F, 50+years, L3). "*Guidelines make it easier to know what rules apply and what we need to do in common places*" (M, 36-40 years, L1). Moreover, some participants (9/14) mentioned it was important for them to know how much energy they use individually and in shared spaces. Thus, they suggested **implementing systems that can inform them about their energy usage** can be helpful to conserve the energy better: "*We could introduce some sort of token system for the water in the showers, I thought it might work so that the token would let water run only for a certain number of minutes*" (M, 41-45 years, L1). "*A system that tells us for example how much heat we are using in our house and in the sauna can help us to save money and energy*" (M, 50+years, L3). Most participants (9) believed, an **easy to use system** that provides sustainable information can encourage people to use such a system more frequently: "*Convenient systems can motivate" (F, 50+years, L1). "easy systems can be motivating because we would not have to think about it*" (F, 41-45 years, L2).

Current challenges regarding sustainability in shared spaces. Some participants (8/14) stated they required a **basic system for reserving the shared spaces** as the current available solutions could improve or become less challenging. For instance, in L1 users used pen and paper to book the shared spaces: "*An electronic calendar for booking your turn in the sauna or laundry would be great*" (F, 50+years, L1), in L2 they used the community website to book these places which could be hard to locate easily on the community website for some older users: "*if I want to rent a space for an event, for example, then I would like to book that space easily without going to different pages*" (F, 36-40 years, L2); and in L3 users were unhappy about the current reservation system (community webpage) "*The thing about the sauna turns is that they can't be booked using the app [community mobile app] and the webpage is confusing to use for sauna turns*" (M, 50+years, L3). Another challenging factor for some participants (3/14) was that they **could not access the communities' sustainable information easily**. For instance, in L2, the sustainable information was mostly provided on the community website, and the users mentioned they cannot access the information easily: "*I know the community website has all the information but it is hidden in so many places and I can't find it easily*" (F, 41-45 years, L2). Additionally, some participants (2/14) mentioned they **do not understand the sustainable information** provided on the community website: "*Sometimes the information is too hard to understand, I prefer to read easy things about our community*" (F, 50+years, L2). Moreover, some participants (6/14) mentioned, they liked to have information about their **monthly energy consumptions** and keep track of their usage: "*I think it is good to know exactly how much energy we are using in our house and in other places monthly*" (F, 36-40 years, L1). Lastly, some participants raised concern over **lack of sustainable instructions** in the shared spaces.

Preferred interactive technologies in shared spaces. Finally, after showing the participants pictures of various interactive technological solutions to enhance sustainability inside shared living spaces, some of them (8/14) preferred to utilize **easy to use smartphone applications**: "*I prefer to use my phone, because I know how it works*" (M, 50+years, L2). "*Smartphone applications are the easiest option because we know how they work. I can't start learning new things now*" (F, <25 years, L3). 6/14 participants preferred to use easy to interact social robots: "*A robot could have clear instructions; we could get information from that robot. Maybe it could even move and speak, telling us to go this or that way.*" (F, 50+years, L2). "*They [social robots] could be used in recycling, for example. Which plastic container goes where?*" (F, <25 years, L3). Moreover, in L1, most of the participants mentioned they preferred not to use any form of technology and they liked to use the traditional ways instead: "*We've now reached a point where I would definitely not like to see any technology anywhere here. Not even digital information boards*" (F, 50+ years, L1). "*We use enough technology during the day*" (M, 41-45 years, L1).

4.2 GreenLife Application Design

Here we explain the design rationale and the detailed design of GreenLife, which was formed based on the findings of user needs study in phase 1, as well as on the insights from the related work. GreenLife was designed to function on Pepper robot, since it is a widely available robot platform with a variety of capabilities, its appealing appearance and its human-like features.

4.2.1 Design Rationale. In order to evaluate a novel form of interactive technology as a perceived motivator of sustainability in shared living spaces, we designed the GreenLife application concept. As a basic design criteria, the robot application had to be *easy to use* and *simple* for users to interact with. In order to make the robot's role more dynamic and motivational, we assigned few persuasive elements to it. For instance, previous research [19] confirmed that social robots can be more motivating when they provide users with feedback. Therefore, in GreenLife, Pepper was designed to offer *feedback* to the user based on the user's performance in various stages of the interaction with the application. Throughout GreenLife, Pepper was the guide and helped users by explaining every option into detail as they proceeded in the application.

Prior research [45] verified that use of *rewards* (*social* and *material*) is also a persuasive element for social robots. Additionally, rewards can have a vital role in persuading users to change their behavior persuasive design model (PSD) [8]. Therefore, in the GreenLife design Pepper could reward the users in different ways. One way was for Pepper to announce the users' reward by playing a short music and a clapping sound effect (social reward). Also, Pepper rewarded the user by giving them a voucher for a vegetarian restaurant when they reached hundred points in sharing their green stories (material reward).

Since the *sense of community* and *community engagement* were welcomed by the participants in the focus groups, in GreenLife we created opportunities for users to collaborate in creating sustainable contents by sharing their mutual mission in sustainability.

Based on prior research, a sense of place and belonging can promote collaboration between users; it can also promote more community participation and development [46]. As a result, in GreenLife, users could take part in sharing sustainable stories and photos together and promote communities which are more engaged in creating sustainable content. The next persuasive elements used in GreenLife were *comparison* and *competition* from the PSD model [8] to encourage users to behave more sustainably. For instance, users could compare their energy consumption with other community members anonymously and those who had the lowest energy consumption could earn points and received rewards from Pepper. We believed comparing energy consumptions and receiving points could create some levels of competition between users to lower their energy and consequently this will encourage some people to behave more sustainably inside shared living spaces.

4.2.2 Detailed GreenLife interaction procedure. The detailed interaction in GreenLife can be seen in the submitted compiled video[1] id="fn1"> https://youtu.be/PXM0oUIZ_pU </fn>.The compiled video is divided into 4 sections, and each section is introduced briefly before the video starts.

Book shared spaces. As the participants in the focus groups were interested in having an easy to use system to book the shared spaces, we designed the option of "*Book shared spaces*". As it is shown in video section 1, Pepper is located inside the shared living spaces in buildings. It first invites the user to interact with GreenLife. Next, Pepper asks the user if he or she wants to be introduced to GreenLife and its purpose. Next, it guides the user through the home page of GreenLife. The first option is the Book shared spaces where users can book various shared spaces. In this study we only designed booking for the laundry room option. Pepper asks the user to first put their username and password in order to be able to choose the date and time for doing their laundry.

Share your green stories. As stated previously, in order to encourage users to engage more in the community and collaborate in a mutual interest, we designed the option of "Share your green stories". As it can be seen in video section 2, in the Share your green stories option, Pepper explains to the user that he or she can share their sustainable green stories with the community in two ways: photos and stories. In stories, the user can write stories, read other members' stories, give comments, like and reply to others' posts. Pepper provides positive feedback once the user shares her story for the first time by saying "Excellent", and "Great job". Pepper encourages the users to share their stories and become part of the community and earn points for each story they share. As the user shares her first story, Pepper rewards the user with clapping sound effects, and a short music. It also notifies the user that once she collects hundred points, she will be rewarded with a gift voucher for a vegetarian restaurant. Pepper asks the users to put their email so the housing community can keep track of their points and give them their rewards once they reach hundred points in total.

Next, Pepper asks the user to check the "*Share your green photos*" option. Here, the community members share their sustainable photos with each other. Also, when the user shares her first photo as a reward, Pepper plays a clapping sound effect and praises the user by saying "*Excellent, you will receive five points now*". In the end of this section, Pepper plays a song and tells the user that she is now part of their sustainable community.

Enhance your green behavior. By choosing the "*Enhance your green behavior*" option, the user is guided by Pepper and told that she or he will have two options in this section. The first option is to choose "*Obtain sustainable instructions*", and the second option is "*Receive sustainable information*".

Obtain sustainable instructions. As the participants in the focus groups required easy and clear sustainable instructions, we designed the option of "Obtained sustainable instructions". In this study we only designed the recycling option. As it can be seen in video section 3, when the person chooses Obtain sustainable instructions, she or he will receive instructions for recycling in the form of videos, images, and tips. The user can watch short videos in order to get recycling information of the community, they can also watch instruction images, and finally they can read some tips on the tablet of Pepper. In order to make it fun for the user, Pepper asks the user to take part in a short quiz. The quiz is about the content which the user retrieved earlier in recycling instructions. By answering correctly, Pepper rewards the user by playing music and a clapping sound effect, and says, "*Great Job*".

Receive sustainable information. In order to address the focus groups participants' desire to receive sustainable energy consumption information we implemented "Receive sustainable information". As it can be seen in video section 4, users can get information about their individual energy consumption and common spaces energy consumption. In the individual consumption section, Pepper tells users to put their username and password given to them by the housing committee. Next, users can see their individual energy usage and compare it with past months as well.

Next, by selecting the common spaces' energy consumption, the user can see how much energy is used generally inside shared living spaces during the month. Also, the user can see how much she or he is using the energy resources in the shared building areas, and finally she can compare this energy usage with the average usage of other flats. Based on the energy used in the common spaces, Pepper provides feedback by saying: "*As you can see, the water usage was high during this month*" and it encourages the user by giving suggestions, for instance to lower the water usage in the showers. Pepper can also provide positive feedback to the user: "*As it can be seen you are using water and electricity lower than your neighbors, that's very good. Remember the house with the lowest energy consumption will receive points*". Pepper also reminds the users that they can receive gift vouchers if they have the lowest energy usage in the month.

Finally, in order to provide the users, the possibility of verifying the information provided in GreenLife, we applied the element of verifiability (credibility support) from the PSD model [8]. For this purpose, Pepper provides the housing committee's email address, so the user contacts them anytime required. Moreover, Pepper reminds the user that it is also possible to interact with Pepper virtually through the community web pages website during the time when physical interaction with Pepper is not possible.

[1]https://youtu.be/PXM0oUIZ_pU<fn

4.3 Evaluation of GreenLife

GreenLife application and booking spaces. Almost all the participants (19/20), believed GreenLife was **easy to understand** and **interact with**. "The app [GreenLife] was very clear and self-evident to me" (M, 25-30 years), "Interesting way of approaching sustainability subject" (F, 36-40 years). Also, 16/20 participants believed GreenLife was **useful** for booking the shared spaces, the rest of the participants (3/20) were neutral and (1/20) disagreed. While 12/20 participants thought social robot's guidance in booking the shared spaces was helpful, the rest were either neutral (5/20) or disagreed (3/20).

Share green stories and photos with other community members. Most of the participants (14/20) believed that sharing green stories and photos was a fun way **to get to know the community members**. Similarly, they stated taking part in performing something that was shared among the community members can enhance community interaction: "*I think anything that involves people to do something together can be motivating, and here seeing others doing something for the environment can motivate other people to do the same*" (F, 46-50 years). "*This [sharing green stories] can motivate people to care about their living environment and their neighbors*" (F, 41-45 years). On the other hand, there was a participant who did not find sharing sustainable stories useful "*Personally I wouldn't be interested in some neighbor's stories or photos. I only care about their sustainable behavior if it increases the building's energy consumption, of if they fail to recycle properly*" (F, 31-35 years). Some Participants perceived sharing stories could create **collaboration** between people and they could work together to create sustainable content: "*It would be fun to collaborate with your neighbors and comment on their posts*" (F, 25-30 years). Some participants mentioned sharing green stories could also be a learning experience for children as well because children can become interested in taking parts in tasks which are novel and creative: "*I think this green story is like a storytelling and this would motivate some kids to join and share pictures as well*" (F, 25-30 years). Almost all participants believed commenting on others' posts should be done anonymously.

In terms of ***rewards and the points*** given to the users in sharing green stories, 16/20 of the participants felt positive about having the rewards system in GreenLife. They believed rewards could be a **motivating** factor to encourage people to take part and share their stories with others. However, they mentioned rewards needed to be **meaningful** in order to be encouraging: "*Better rewards can be more motivating in changing behavior*" (M, 41-45 years). On the other hand, one person showed concerns over the validity of the stories being shared: "*Rewards at the same time, can motivate people to share fake stories, therefore there needs to be a way for the building manager or someone in charge to check the validity of the stories somehow*" (F, 25-30 years).

Providing sustainable instructions. While 10/20 of the participants believed the robot giving them sustainable instructions in the form of videos, images, tips could be motivating users to behave sustainably, 7/20 of the participants were neutral and the rest disagreed with this statement. Some participants mentioned they liked to have **concrete** and **specific** instructions about sustainable topics such as recycling: "I have a feeling people would need very on-point instructions, like "*I'm disposing of this burnt pan now, can I dump it into metal or is it mixed waste?"* (F, 31-35 years). "*Concrete instructions can help people more, for instance a page where you can see common household recyclables and where they belong or a search for if you have something you don't know where to recycle*" (F, 25-30 years). Moreover, some participants mentioned they preferred to have **personalized** and **customized** instructions as they can be more helpful and interesting to them because the information can be tailored to them directly: "*Some people might be interested to read documentaries and articles instead of watching video or images, so the robot can provide them with personalized information*" (F, 36-40 years). While 6/20 of the participants were neutral about the quiz given by Pepper to test their level of information on the sustainable instructions, 9/20 participants disagreed and only 5/20 of them enjoyed it.

Receiving sustainable energy consumption information. Most participants (18/20) believed a robot providing feedback and tips about energy consumption could be a **helpful** way to reduce energy consumption: "*Based on the energy consumption results, the robot's tips and feedback can help to know the problem areas and how to fix them*" (F, 25-30 years). Some participants valued the fact that Pepper could provide the user with realistic feedback: "*I liked how the robot was honest in reminding the user about how high the energy was used, I think this can affect you that even the robot is noticing your bad behavior*" (M 36-40 years).

Comparing energy consumption with others. Most participants mentioned comparing energy consumption with other flats could be an **encouraging** and **fun** way for energy conservation between community members. Additionally, as community members compare their energy consumption with each other, they can experience a feeling of **competition** which can make the process more encouraging for them: "*The comparison with other flats was fun and good, it can be a helpful way to reduce energy inside flats*" (F, 41-45 years). "*I would definitely like to know how much energy I used compared to other flats of the same size in the building, this can get competitive*" (F, 31-35 years old). However, there were two participants who did not find comparing energy with others useful "*I am not interested in knowing what others are doing, I only care about my own energy consumption*" (F, 25-30 years).

General findings about the robot's role. When asked about the motivational factor of the robot in sustainability, 16/20 participants agreed that the robot was motivating to them and 2/20 were neutral and the rest disagreed. Similarly, 11/20 of the participants found the robot **trustworthy** while 7/20 were neutral and the rest did not agree. 12/20 participants believed the social robot's guidance towards sustainable behavior was **useful**, 4/20 were neutral while the rest disagreed.

5 DISCUSSION

Prior research has explored the use of persuasive social robots to enhance environmental sustainability. In this study, we explored the potentials of social robots as interactive technologies, which can persuade people towards environmental and social sustainable use of shared living spaces.

5.1 Social Robots as Persuasive Agents in Shared Living Spaces

Shared living spaces can impact environmental sustainability **by lowering the usage of energy resources** inside buildings. Furthermore, shared living spaces can impact wellbeing of the building users by providing enablers for social connectedness and sharing. In line with previous research [19], our study suggests that social robots can be used to persuade people to behave more sustainably in shared living spaces. Employing social robots as motivators of sustainability inside shared living spaces in green buildings requires applying various persuasive techniques, which can make the process of persuasion and behavioral change smoother for users of shared living areas. Persuasive technology can be more encouraging when it comes in the form of social agents and therefore social robots are considered as powerful persuaders [19]. Our study shows the potential of assigning the social role of **sustainability motivator** for a social robot. Social role is considered as an element of the PSD model [8], which highlights that users find systems with social roles persuasive. Additionally, it must be noted that the human-like interaction and the physical embodiment of the robot play a major part in the role of the robot. The embodiment of the robot enhances the multimodal communication, perceived trust, pleasant experiences, and attractiveness of how helpful the robot is [50]. In our opinion, physical embodiment of the robot can enhance the chances of a robot to adopt a stronger social role as a motivator of sustainability.

Based on our study, and similar to earlier research [16], one prominent persuasive element for social robots is to exploit social reinforcement in the form of **feedback**. Since social robots can provide interactive forms of feedback, this might increase their chance of being persuasive. Previous research [16] shows that people are not sensitive towards social differences between computers and humans, and they react similarly when faced by different social agents. This leads to the idea that a robot's feedback about sustainable behavior could influence the user the same way as a human giving the feedback. It is possible that social robots as social actors can influence a person also in the area of sustainable behavior.

Similarly, as studied by Oinas-Kukkonen and Harjumaa [8], **tips** and **suggestions** offered by a system have great persuasive power. Based on our findings, social robots can potentially influence users' behavior by providing them with suggestions to perform certain behavior and tasks to conserve energy. For instance, in our study, Pepper's suggestion on lowering the usage of water in the showers was perceived as a useful and interesting way of approaching energy conservation. For our future development, we are aiming to include few nonverbal behaviors for Pepper. For instance, based on the sustainable suggestions it gives, it can show a sad or happy face on the tablet. This can evoke users' emotional responses, which can result in effective persuasion. Additionally, social robots, which provide **real** and **concrete** information about users' sustainable behavior such as energy consumption levels, can affect users' pro-environmental behavior. We assume, if the user can verify the sustainable data or know the sources of information, he or she will find the robot more trustworthy and useful. According to [7, 19], providing accurate content to users via outside sources enhances the credibility of the systems and increases power to persuade. Thus, it is advisable for the robot to provide users with real data that is retrieved from power companies or building committee websites.

In general, **rewards** can be used as positive incentives to acknowledge and increase persuasion and ultimately lead to possible behavioral change. Most participants in our study perceived rewards offered by Pepper as a motivating factor in persuasion, and they required the rewards to be more meaningful, however, they did not specify any information regarding social or nonmaterial forms of the rewards system. As discussed by [50] robot-like rewarding can be one of the most powerful ways for a robot to accomplish certain behavior or tasks. As discussed in [49], rewards should not appear too often in order to remain interesting to users. Similarly, rewards can result in promoting pro-environmental behavior [47], thus social robots giving rewards could persuade users to change their energy usage habits and become more aware of their actions while using the energy inside shared living spaces or inside their homes.

Consistent with previous research [48], we verify that **tailored information** can be helpful in changing users' behavior. Customized information, which users find more relevant to them can become more interesting to them and therefore, it can become more encouraging to them. According to [8], personalized information has greater capability in persuasion since it can be tailored towards users' needs, interests, and personality. Consequently, for a social robot to motivate users towards sustainable behavior it needs to offer tailored and personalized information content to address the user's pertinent interests and needs. An example of such a system is a robot that asks the user to customize the information and instructions they want to receive about recycling in the community.

We envision that social robots can be persuasive agents by applying social influence strategies. In our study, Pepper provided users with scenarios where they could **compare** their sustainable performance and behavior (energy consumption levels) with other community members and even with their own past performance (self-comparison). We believe when social robots provide users with personalized energy consumption information, they can be more novel and interesting to users which lead to their higher success in persuasion. Moreover, by comparing energy usage with other members, the robot can create **competition** among users which can lead them to lower their energy usage. Moreover, we believe comparing and competing sustainable behavior with other users can create a sense of community and belonging among them.

Our study revealed that social robots could enhance social sustainability by creating a sense of **community** and **belonging** among community members. In line with prior research [33], we assume using social robots to guide people towards shared goals can increase social interaction and inter-community relationship among users. Using social robots in shared living spaces can create opportunities for users to become more engaged in community tasks, which can promote community development for the members. In our opinion, a sense of community can be perceived in Share your green story, due to various reasons. One reason might be that some people perceived Pepper as an interesting and novel means of virtual communication and collaboration with others. Second, some people might think Pepper's ability to say phrases such as "excellent" and "good job" interesting, so they became motivated to share and comment on other's posts. Third, Pepper's ability to give rewards to users might be the most encouraging factor that persuades users to collaborate with other community members in Shared your green stories. Finally, users might perceive Pepper as the community's "*shared artifact*", which is there to help them to enhance their community relationship and engagement.

Although social robots can be used to persuade building users to behave more sustainably inside shared living spaces, it should be noted that introducing a new technology might require careful implementation for people to adopt it [33]. As it was seen in our focus group in L1, not everyone was keen on interacting with social robots or any other form of technology. Some people might overlook the idea of technology-mediated communication and prefer traditional ways of using the shared-living spaces. Similarly, it is vital for designers and robotic developers to note that the persuasion techniques, which are effective in human-human interaction might create some hardship in human-robot interaction and they may lead to ethical problems. For instance, the robot persuading a user to take medication is different from a robot using powerful psychological strategies to persuade a person to buy something [27]. It is essential to know that persuasion is only a form of communication and social robots should only be used to support goals, which are considered appropriate by users [34]. Thus, it is advisable to implement the robotic persuasive strategies with careful consideration and enough knowledge about the suitable target goal for users.

5.2 Design Implications

Based on our knowledge, currently there are no design implications that can help robotic designers and developers to implement concepts for using social robots to enhance the sustainable behavior of building users. Here, we have formed a list of seven design implications, which is based on our findings in both user needs study and online survey study. This list can contribute to the field of HRI and sustainable development in designing and developing persuasive robotic concepts, which can be used to increase sustainability in shared living spaces.

Persuasive features for social robots adopting the role of sustainability motivators inside shared living spaces:

1. The persuasive social robot needs to offer feedback about sustainability to users. Since social robots are a novel form of interactive technology, that is why feedback about sustainable behavior can be an interesting and memorable feature for the user. At the same time, people are more sensitive about the feedback provided by social robots, therefore it is sensible to provide feedback regarding the sustainable behavior of the users in order to have higher influence on users.

2. Persuasive social robots should provide reliable and verifiable sustainability information. Reliability and verifiability of sustainability information to users enhances the credibility of the robot and makes it possible for users to trust the robot. A trustworthy robot can have persuasive influence on users. Therefore, the robot should always provide the user with sources of information, or ways to verify the information.

3. Persuasive social robots should suggest personalized and customizable information to users. Providing personalized information to users can persuade them to behave more sustainably inside shared living spaces. Tailored information and instructions can address users' needs, and interests. Such robotic concepts will have higher capability for persuasion because users will become more interested in interacting with them and at the same time, they will obtain their preferred sustainable data.

4. Persuasive social robots need to offer significant rewards. Since rewards have persuasive powers, meaningful rewards can motivate users to change their behavior. A social robot providing rewards can be considered as a motivating phenomena that can increase the encouragement for behavioral change in users.

5. Persuasive social robots should provide opportunities for users to compare their sustainable behavior. Self-comparison and comparing performances and behavior with other people can have great motivational impact on users. By comparing energy consumption people can feel the sense of belonging to the community which encourages them to change their behavior and be more sustainable.

6. Persuasive social robotic strategies should consider ethical aspects of persuasion. Since in human-robot interaction the asymmetry between the persuader and persuadee is bigger, it is important to note it might not be ethical to use all persuasion strategies used in human-human interaction in designing and implementing persuasive social robots. Persuasion on social robots should be done to just form efficient target behavior in users.

7. Social robot's interference with the use of shared living spaces should be limited. Embedding social robots in buildings and shared living spaces, should be done in such a way that it does not interfere with users' natural use of spaces.

5.3 Limitations and Challenges

To explore the potential and feasibility of the social robots as motivators for sustainability in shared spaces, we conducted a qualitative user study (N=14) to begin our research through the design process [35]. However, we faced several challenges through this study. For instance, the focus groups were in Finnish language, and it made the process a bit challenging to find only Finnish speaking participants, therefore the number of participants is limited to 14. The reason we used scenario-based approach was due to the explorative nature of the study, however, in our future work we will implement the potential features and persuasive techniques on a robot to be evaluated on an authentic field study. Similarly, we conducted the second user study through an online survey with a limited sample size of only 20 participants, however, this can be normal in qualitative studies on this phase of the design process. Moreover, since we did not have a working prototype, we could not observe users' interaction with a physical robot. Such robotic concepts require more research with more users in order to generalize the findings about the persuasiveness of a social robot. Also, in order to measure the persuasiveness of the robot, and users' change of behavior, it is required to conduct longitudinal studies and iterate the concept to explore alternative concepts in addition to GreenLife. Finally, our focus in this study was to portray the interaction of the user with a physical robot, and we did not design the interaction of the user with the virtual robot on their personal mobile devices.

6 CONCLUSION

Sustainable thinking and behavior can be improved by using a persuasive system that is designed to promote positive behaviors and environmental sustainability; also, to promote wellbeing, quality of life and a more sustainable lifestyle for the users of green buildings. By conducting three focus groups in three different kinds of residential locations in a city of Tampere in Finland, we found certain needs to use social robots as the potential interactive technology to motivate people to sustainable behavior in shared living spaces. Based on the findings of the focus groups we designed an application called GreenLife for robot and next we evaluated it through an online survey. Due to their physical embodiment, human-like interaction, and their capabilities in performing various social roles, we believe social robots can motivate building users to be more pro-environmental. These robots can persuade people by providing them with rewards, feedback and tips on how to use the energy resources in shared living spaces. Moreover, these robots can provide the users with instructions and energy usage information to help them to conserve energy resources. Additionally, social robots may create a better-quality community by motivating the members to interact and collaborate with each other. Based on our research through the design process, we have formed a list of design implications that can be helpful in designing persuasive social robots for sustainable use of shared spaces in buildings. Also, our design implications can help green building developers to consider using social robots as a form of interactive technology embedded in the design of the smart developments to address both social and environmental sustainability. The design implications included for example providing easy to use robotic applications, providing social feedback in the form of positive feedback to the user, and offering rewards to users to encourage them to change their behavior. For our future work we plan to build a working prototype of our GreenLife application and evaluate it in an authentic context with real users.

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