An Explorative Study on Motion as Feedback: Using Semi-Autonomous Robots in Domestic Settings

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***Abstract*—This paper presents motion as *feedback*. The study is based on empirical data from an explorative study of semi-autonomous robots used in domestic settings. We explore feedback received from stationary technology, e.g., a smartphone, and technology that is self-propelled, e.g., a semi-autonomous robot. The paper has its theoretical foundation in the *familiarity* concept used as a contextual and analytical tool for unpacking *feedback*. The data analysis is done through thematic analysis. The findings are structured in: *feedback* received from a smartphone app technology, *feedback* received from the robot-mediated via an app; and *motion as feedback* received from the robot. *Motion as feedback* is discussed in terms of: (a) what type of emotions feedback triggers in the users, and (b) making sense of the motion as *positive, negative, homeostatic, archival* and *transition feedback*. We argue that having *familiarity* in mind when designing new technologies, can make it easier for the user to *know-how* to *engage with* the technology. Our conclusion is that: a semi-autonomous robot technology can become more familiar to the user if it triggers positive feelings, if its motion is coherent, if its navigation is appropriate to the situation, and if its motion is not disturbing or interrupting the user; and lastly, *familiarity* needs to be considered when designing for a robot for the elderly.**

Keywords – feedback; motion as feedback; semi-autonomous robot; familiarity; emotions.

I. INTRODUCTION

This paper builds further on our reported work on how *feedback* from digital technologies may trigger the feeling of fear for technology when using those [1]. We have in our previous work used fear as an umbrella term for emotions, such as *angst, anxiety, concern, doubt, dread, unease, uneasiness, worry, aversion, fright, phobia,* and *presentiment* [2]. In this paper, we extend this work by looking at the *motion* of robots as a type of *feedback*. We do this by running a study where researchers test out a robot, and by introducing a robot in the homes of the elderly.

The questions that we address are: 1) What kind of emotions are triggered in the user by improper or lack of feedback when *engaging* with digital technology: a smartphone app or a semi-autonomous robot? 2) How is a motion made sense of by the users when *engaging* with a semi-autonomous robot, in their homes? Moreover, if motion is illustrated as a type of feedback – what do we learn from their experiences?

The rest of this paper is organized as follows. We continue by introducing some terminology used in this paper and a short background for the study. Section II gives an overview of the current state of the art on different types of robots used in home and outside the home. Section III elaborates on feedback as understood within Human-Computer Interaction (HCI). We introduce feedback as *visual* and *textual* feedback. Based on the literature, we describe *polarity-, homeostatic,* and *archival feedback*, which we later use in our mapping of *motion as feedback.* We continue then by introducing the reader briefly to *motion as feedback* and the robot's navigation. Section IV continues with positing this paper on a theoretical level, elaborating on the *familiarity* concept grounded in literature. Section V gives a detailed account of the methodology and methods for this study. Section VI presents in details the findings based on empirical data. Section VII discusses the findings through the lens of *familiarity* while elaborating on the *motion as feedback*. Finally, Section VIII concludes the paper and gives directions for further work.

A. Terminology

A domestic setting provides the opportunity for those who live there, or are around, to use technologies that are still, such as a smartphone, or technologies that move, such as a semi-autonomous robot.

A smartphone *is still technology.* We define still technology as *a technology that does not move by itself; it is not self-propelled, i.e., it does not change its location without the continuous intervention of a human or another object*. Examples of analog and digital *still* technologies are a table, a sofa, a notebook, a speaker, a lamp, a mobile phone, or a smartphone. One could argue that a smartphone is indeed a mobile technology. We agree with this if we talk about the way it is used. However, when it comes to its form of motion or locomotion, a smartphone or mobile phone does not move around by itself and change its location, unless they are moved by *someone* or *something* that can move. However, a smartphone or a mobile phone can vibrate, and one could argue that vibration is a type of movement. However, this type of movement is not an intended movement of changing its location, or of navigating an environment.

We define a *semi-autonomous robot as an in-motion technology that can move by itself; it can be self-propelled, that follows a locomotion process, i.e., it can change its location without a necessary and continuous intervention of a human or another object*. Examples of in-motion analog and digital technologies are mechanical robots and semi-autonomous robots, which can navigate a place by themselves, such as semi-autonomous vacuum cleaner robots, or lawn mowers.

In this paper, we use this terminology interchangeably: smartphone app technology, in order to refer to still technology; and semi-autonomous robot technology for referring to in-motion technologies, here a semi-autonomous vacuum cleaner robot.

B. Background

According to the literature, robots are defined as: "physically embodied systems capable of enacting physical change in the world." [3]. Following [4], industrial robots refer to robots that move around or transport things, and usually operate on conveyor belts, in packaging, and assembling [4]. Industrial robots usually perform repetitive routine tasks, often having a predefined navigation path. Professional service robots are similar to industrial robots, but they are used outside the industrial setting: they can transport things, by navigating around the environment [4]. To these, robots used in healthcare also add up [3]. They refer to the micro-robotics that are used *inside* the body, protheses robotics that are used *on* the body, and robotics that are used *outside* the body. Other robots are used to support mental or behavioral therapy, such as those used for people with diagnoses on the autism spectrum disorder, those with cognitive impairments, or as companions [3]. However, they usually perform tasks to assists people: cleaning nuclear waste [4], supporting surgeries in hospital settings, or carrying around medicines or instruments, see for example the work from [5] or [6]. The robots that are outside the body and can move semi-autonomously usually have pre-defined paths and navigate in uncluttered environments.

Further, the third wave in HCI discusses digital technology in our homes [7]. However, we still seem to have less knowledge on the use of moving objects in the home than about the use of stationary technology – although several existent projects are studying the use of robots in the home. These are usually included under the category of personal service robots, following [4]. Amongst personal service robots are: robotic vacuum cleaners, lawn mowers, and assistive robots for the elderly or the un-abled [4].

This study is part of the Multimodal Elderly Care Systems (MECS) [8]. The project focuses on the design of a robot for the independently living elderly. We define elderly as old adults ($\geq$ 65 years), according to definitions used in gerontology [9][10]. However, within the frame of the MECS project, this study consists of a qualitative interpretative phenomenological evaluation of the interactive systems as experienced by participants in their daily lives, and the phenomena surrounding them. We followed the HCI definition - a "discipline concerned with the *design*, *evaluation,* and implementation of interactive computing systems *for human use* and with the *study of major phenomena surrounding them*." [11, 15, emphasis added]. The setting for this study was the homes of our participants.

II. STATE OF THE ART

According to state of the art in robotics, published in 2016 U.S. Robotics Roadmap, the focus area of the field is currently on: aging well and quality of life, robotics used in the medical field in surgeries and interventions, and the robots used as "clinical workforce support" [3, 73]. The study also says that a *one-size fits all* approach is hard to be achieved in robotics [3].

A thorough overview of the robots used in studies for supporting independent living is given in [12]. There are several projects studying the use of robots in the home. A project concerning the care of the elderly is Acceptable robotiCs COMPanions for AgeiNG Years (ACCOMPANY) [13][14]. ACCOMPANY developed Care-O-Bot robot. Care-O-Bot is amongst one of the robot assistants used for housekeeping and home care [13][14][15][16]. Care-O-Bot is a state-of-the-art robot designed to be used in the home [17]. A couple of other projects studying these type of robots are named in the work of [17], such as Handy 1, Movaid, and Nursebot built for the elderly or the disabled; GuideCane, Hitomi, PAM-AID, PAMM, Smart-Cane PAMM, and Smart-Walker PAMM. These robotic prototypes were built to be walking aid for the blind, elderly, or the disabled [17].

At EU-level, several projects studied the use of robots in the home. Amongst the European Union projects are: Robot-Era Project [3], MARIO Project on Managing active and healthy aging with use of caring service robots, EURON RoboEthics Roadman, EP6, ETHICBOTS, BREATHE, and ICT & Ageing Project [18]. Another project was the Multi-Role Shadow Robotic System for Independent Living (SRS) [19]. The project focused on studying the frail elderly people: the elderly whose Activities of Daily Living (ADL) are limited by their health problems [19]. Many of the frail elderlies use walking chairs, sticks, or wheelchairs [19]. The study shows that teleoperated robots may be accepted in some situations, whereas direct physical interaction with a service robot can be, at times, difficult [19]. It seems that "housing-related needs" are central for learning and adopting the technology *if* these technologies function well [19, 303]. For instance, the study also indicates that men have more difficulties than women with housekeeping tasks, while women have difficulties in reaching things [19]. A similar study to ours talks about introducing personal service robots, a Roomba Discovery vacuum cleaner, in homes [20]. The home is viewed as an ecology of products, people, activities, a social and cultural context of use, and a place – a bounded environment [20]. It seems that the expectations one has of technology are highly related to shaping the initial expectations of technology. The use of the robot also influenced the practice of housekeeping: in some households, the male participants set-up the robot; in others, only the women use it [20].

Companion robots are also used in studies with the elderly. An example of a companion robot is PARO, the seal robot [21][22][23]. The seal robot PARO was used in facilities for the elderly in the Nursing-care Robot Promotion Project, in Japan [22]. An initial study showed that the elderly participants suffering from various mental or behavioral issues, but who interacted with PARO over time improved their communication, reduced their aggression and wandering, as well as improved the sociability of the participants, over time [22]. PARO also seems to be widely accepted across cultures [24]. Other examples of companion robots are Pepper and NAO used in exploratory studies, as shown in [25]. AIBO, Furby, and NeCoRo are a few other robots representing animals that were used in therapy with children, or in nursing homes with the elderly [21][22].

Another project from the EU project within the Ambient Assisted Living (AAL) is Enabling Social Interaction Through Ambient (EXCITE) [26]. The project introduced the Giraff robot in several homes with the purpose of studying "social interaction through robotic telepresence" [26, 827], an idea that stemmed from the RoboCare project [27].

Finally, it seems that "20% of the world's population experience difficulties with physical, cognitive, or sensory functioning, mental health or behavioral health" [3]. In numbers, there are around 190 million people experiencing difficulties with ADL, including physical tasks and cognitive tasks [3]. Further, it seems that the aging of the workforce has consequences within the healthcare field [28][29]. A study from [30] shows that, for instance, in Sweden, the cost for the home care for the elderly would increase between 20 and 35% between 2013 to 2020, whereas this could instead be reduced by 50% as of 2020, with the digitalization of the home care services [30]. In Norway, the elderly population will increase by 21% by 2050 [31]. Furthermore, the active working force will not be able to tackle the healthcare needs imposed by this increase [31] and yet among the action plans taken at the European Union's level, regarding this societal challenge, is the digitalization of health through the use of Information Communication Technologies (ICT's) [32]. Moreover, several studies address directly or indirectly the issue of the digital divide between users with ICT literacy and those, with reduced ICT literacy. Elderly are often included in the group of users with reduced ICT literacy as shown in [33][34][35][36]. Yet, all the above yield at how important it is to make sense of the design of today's technologies, including those that *move*: semi-autonomous robots for the use in the homes of the elderly. Nevertheless, one of the designing principles for designing good smartphone technologies and semi-autonomous robots is to give informative feedback when an error occurs [37][38]. Understanding feedback is, therefore, highly relevant in this context. Next section gives an introduction to the main topic discussed in this paper: feedback.

III. FEEDBACK

In this section, we describe how feedback is currently discussed in the HCI literature.

Feedback is an abstract concept that was used in a number of disciplines. Diverse elaborations and explorations of feedback definitions are encountered from control theory and cybernetics to the definitions used in HCI [1][39]. Before going further, we wish to turn to the definition of feedback, within HCI, as explained by Norman (2013): informing the user, in some way, that the system is working, as a response to the user's action [40].

Feedback in the interaction with a desktop computer interface was well established a long time ago and often already understood by the user [41]. Here are a few examples based on Apple's User Interface Guidelines dating back to 1992: feedback to the user when typing in passwords by displaying a bullet character for each typed character by the user; feedback of a cursor showing a delay after user has moved a big document to the trash bin; a dialogue box feedback informing the user about his or her actions' result; when the user deletes everything from the trash bin, an *empty trash* text should be displayed; when selecting an option in a radio button, the user should see a bullet in the selected option; when an option from a menu is chosen by the user, the option is hoovered or the background color is changed; when an item is selected from a palette of patterns or colors, that option is highlighted or outlined; moving around windows on the desktop is illustrated immediately to the user through the windows new position; an active window is highlighted or outlined; when a user shall be informed about potential dangers, such as an unsafe document to be opened, or a non-reversible action, the user should be informed through a caution alert box, where the user has the possibility to cancel the action or to proceed further; or a button that is clicked or hoovered over shall be highlighted [41].

According to [42], feedback is an important concept that is studied, especially within education. However, within the HCI field, it seems still to remain ambiguous and primitive, and "is oversimplified" [42, 253]. While some of the literature identifies feedback as a response to the user's action [9], others talk about feedback as a way "to communicate the state of the system independently of the user's action" [43, 316]. Feedback can be visual, auditory, haptic, and some talk about it as bio-feedback in HCI studies that measure or self-track the human [1]. Others talk about eco-feedback in sustainability and environmental HCI studies, or affective feedback [1].

Further, language seems to play a central role in HCI, in auditory and textual feedback. However, we have also seen that language *per se* used in the interaction with computers or machines does not always work: see for instance the example of the natural language processing ELIZA used in early days of Artificial Intelligence (AI), mentioned in [44]; or the example of textual feedback using technical language of "it cannot connect to the *cloud services*" [1, 176]. [44] talked about how the HCI field evolved based mainly on conversational and linguistic development, a common language [44]. This was mainly a question of mutual intelligibility through language.

But the HCI field has evolved, and while *visual, auditory and textual feedback* still remain essential, it also seems to become more common to *interact with things that move*. As [45] has earlier put it: the conditions for the possibility that the world as an adjacent to everyday interaction becomes an interface for computation, we could, in his words, through this type of interaction "capitalize our familiarity, skill and experience in dealing with the everyday world around us" [44, 1]. In addition to the development of a *common language*, we also need to develop *a shared understanding*, *mutual intelligibility of the motion* of the robot: "A robot in the real world, however, must consider the execution of the plan as a major part of every task. Unexpected occurrences are not unusual, so that the use of sensory feedback and corrective action are crucial" (Raphael, cited in McCorduck, 1979, p. 224), in [44, 23]. How can then the movement itself of things be applied in order to facilitate human interaction with things? What experience of the robot's movements should be designed for? And what do these movements communicate to the user? How are these movements interpreted by the user as feedback? How do we describe patterns of movements, styles of movement, or ways of moving? How can these movement styles be mapped as feedback to the user?

Before going further, we would like to explain polarity feedback, homeostatic feedback, and archival feedback – types of feedback that we found in the existent literature. This is later our departure point for discussing *motion as feedback*.

A. Polarity Feedback: Positive and Negative

Polarity feedback can be regarded as *positive* or *negative* [42], *depending on how the feedback is interpreted by the user, compared to the user's expectations.* According to [42], feedback as information retrieval, in the broader sense of it, is formed by a message, a cognitive interpretation, and its context. For instance, a user sets the temperature on a thermostat in a room to be 25°C degrees. In this situation, the visual feedback can be translated as positive, if it shows the temperature set by the user, or at least close to what the user has set (23°C degrees, or perhaps 26°C degrees) could still be accepted. However, if the temperature of the room does not seem to be close to what the user has set, say 15°C degrees or 35°C degrees, the feedback is translated as negative feedback. In other words, positive feedback is when the system responds accordingly or at least close enough to the input of the user, meeting the user's expectations. On the other hand, negative feedback is when the system does not respond exactly or close enough to the user's input, resulting in a high difference between the system response and the user's expectations. Negative feedback does not necessarily need to have a negative value, (+)15 °C can still be considered a negative value.

B. Homeostatic Feedback

Feedback has a polarity, positive, and negative, but it can also be homeostatic [46]. *Homeostatic feedback* is a *type of feedback that is constant, regardless if the feedback is positive or negative; the state of the feedback is the same over a longer time period*. Polarity feedback and homeostatic feedback are not *mutually exclusive*: positive or negative feedback can also be at the same time homeostatic [42]. Taking the same example of receiving feedback from a thermostat on a room's temperature homeostatic feedback is when the thermostat shows over a longer period of time exactly 25°C degrees, according to the user's input. But homeostatic feedback can also be negative feedback of 15°C, or 30°C degrees, over a longer period of time. If the thermostat does not start, although the user has pressed a start button, it can also be translated into a homeostatic negative feedback.

C. Archival Feedback

The literature discusses archival feedback [46]. This type of feedback is distinguished from immediate feedback [46]. *Such a type of feedback logs and remembers the system's previous actions, in such a way that it can return to a previous state*. A concrete example is when the user uses the UNDO button: if the actions of the user were logged over time, then the UNDO button performs a positive action, e.g., the system goes back to a previous state. This type of feedback that logs and remembers previous states of the system is called archival feedback. If the UNDO button cannot perform this operation, pressing the UNDO button gives a negative feedback, e.g., nothing changes – the system stays the same. However, the system should inform the user anyway, that nothing was changed. This is then not an archival feedback, but rather the user receives a negative feedback on its input regarding the archival feedback.

D. On Motion - As Feedback

Following Mitcham's (1978) in [47] it seems that a tool is activated by the human agency, while a machine can, to a certain degree, operate independently [47]. Following this definition, we could say that a semi-autonomous robot used at home is in a way a machine – something that acts independently, but also a tool, since it is controlled at some degree by the user: through a button, or by using an app as a remote controller, or through a remote controller.

In general, humans know where they are, or how to navigate their way where they want to get [47]. One can navigate his or her way based on own knowledge or familiarity with the place, or by using a map. This is done through their own body's locomotion [47]. Wayfinding is different from navigation, by moving from a location to another region (compared to navigation, which is moving from one location to another location) [47, 219-242]. A semi-autonomous robot is moving within a home through both types of motion: first, through wayfinding, by creating a map of the place; and second, through navigation, moving around on the already mapped space. These types of movement can be classified as locomotion, or a global movement, according to [48]. Besides these movements, a robot also has its own motions, such as moving the head of a robot, moving an arm, without changing the robot's location. The authors classify this type of movement as a local movement, or to use the term from robotics, configuration movement [48]. In this paper, the local movement is considered as *still* type of motion. The paper is mainly concerned with the locomotion type of movement. Rather than going into the depths of motion and animation techniques here, we would like instead to focus on exploring further domestic robot's *motion as feedback*: What kind of feedback does the user receive and in, which situations? What are the implications of the motion for the feedback? How is the robot motion perceived by the users in terms of feedback?

We have earlier conceptualized feedback [39] based on Hall et al. (1968) proxemics [49]. We have identified that a semi-autonomous robot includes the same types of feedback as a smartphone app technology, but in addition, it has the motion element [39]. We observed that the motion of the robot could be considered as a type of feedback that it is manifested through *distributed feedback*, via extended proxemics, when the feedback from a robot is given via an app [39]. We noticed that this type of feedback was *distributed* when using an app. To simplify the discussions later, we illustrate (a) getting feedback from a smartphone app technology vs. (b) getting feedback from a robot (Fig. 1). We also noticed that while feedback from a smartphone is direct, feedback from a robot can be both direct, from the robot, or *distributed*, via an appWe build in this paper further on the earlier reported work, the *motion as a form of feedback*, by investigating the *motion* of the robot, and by looking at how it is made sense by the users. We do this by bringing up examples from our empirical data (Section VI). We make sense of *motion as feedback* based on our empirical data, by distinguishing between feedback from a smartphone and a semi-autonomous technology, reshaping and molding the notion, understanding and making sense of the motion as feedback. In this way, can these various types of *motions* be perceived as *feedback* by the participants? How can we classify then these *motions as feedback*? Introducing a common vocabulary may help us to talk about motions of semi-autonomous things in homes in a better way, similarly to perspectives from other fields, such as mathematics, physics, medicine, or biology: anthropomorphizing – moving like a human; zoomorphic – animal movement, robot morphing – moving like a machine. We continue in the next section by laying our theoretical foundation: the *familiarity* concept. The concept will later in the paper help us to unpack and understand the *feedback* notion.

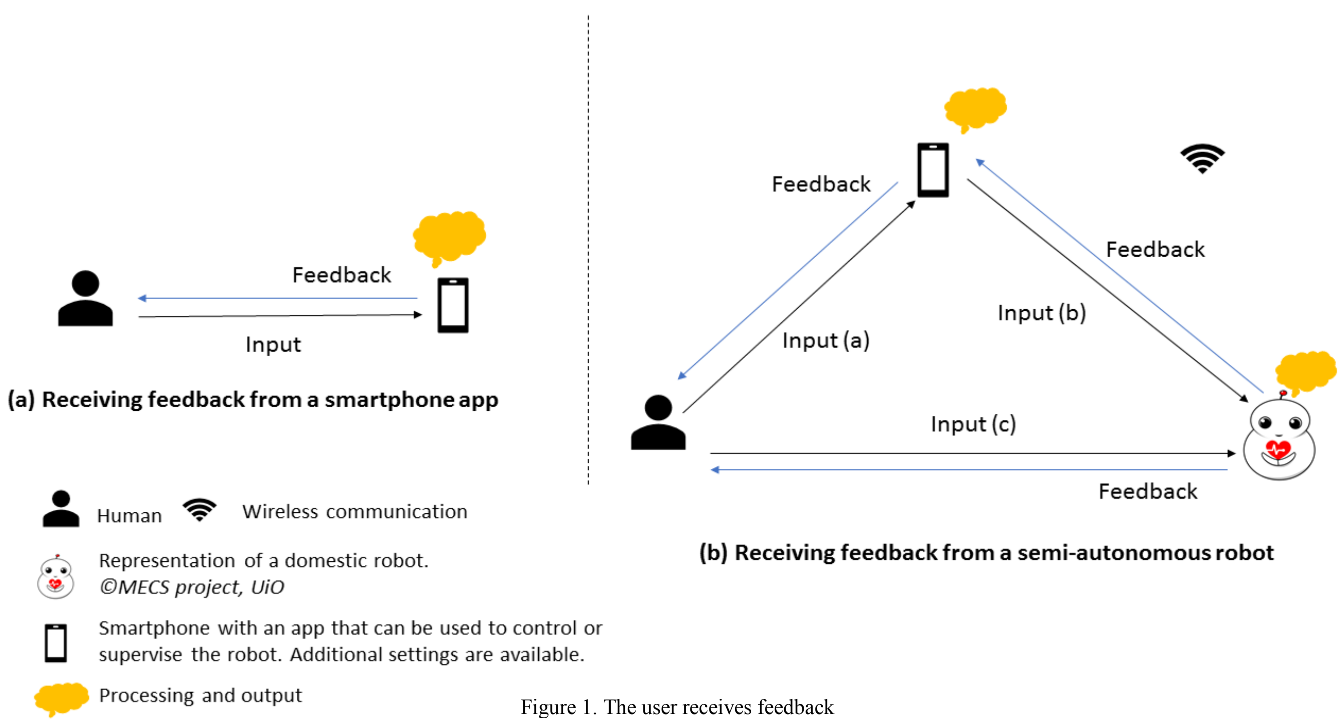

Figure 1. The user receives feedback

IV. Theoretical Foundations: On Familiarity

According to [50], theory helps us "to structure knowledge, to evaluate and assess it, to construct it and share it" [50, 126]. Amongst their six models of using theory, there are also: theory as a contextual tool, where the researchers start with a research question and take a position, often referring to theory as concepts, ideas, or perspectives; and theory as an analytical tool, where the researchers use the theory to analyze and interpret the findings in the light of the theory [50]. In this paper, we have used both these types of using theory: for both the former and the latter one, we posit the paper within the frame of the familiarity concept used in HCI.

The concept of *familiarity* is illustrated in Heidegger's Being and Time as "[knowing] its way about" [51]. *Familiarity* can be described as an intimate, close, and friendly state, or interaction [52]. In Dreyfus' view, *familiarity* gives one the tools to respond correspondingly to different situations [53]. In HCI, *familiarity* has been used as a base for the design. For instance, this concept can be used in the skeuomorphic design. Skeuomorphic design refers to when the digital interface adopts some of the physical artifact's properties in order to accommodate better the user by making the digital artifact looking more familiar [54]. Such an example is, for instance, when a digital interface imitates the paper look of an old book. Others have used it within the design of tangible systems [55]. However, it seems the concept is still underexplored within HCI, while it seems to be important in the sense-making of using technology. For instance, [56] found that *familiarity* plays a central role in individuals' relationships with technology [56]. Later, [57] pointed out that *familiarity* concept did not get too much attention in the field of HCI, besides his previous work together with Van de Walle [57].

Inspired by the work of Heidegger, Mereleu-Ponty, and Dreyfus, [58] tried to make sense of everyday's examples of interacting with technology, the readiness of coping with it in everyday life situations. Further, *familiarity* is based on several key points [55]. Among these are: *familiarity* with digital technology depicts a "*know-how*" relationship [58] based on a tacit knowledge; *familiarity* is based on everyday use, on reading about it, and being taught how to use it; *familiarity* with digital technology means knowing how to use it, or using Turner's words, "*to be ready to cope with it*" [55, 25, emphasis added]. *Familiarity* is also a form of *engagement*, of what Heidegger calls involvement [59]. However, *familiarity* with technology is more difficult because involvement with technology can become complex [59]. Involvement represents a form of care, enfoldment, entanglement, according to [55]. *Familiarity* also has *an affective part* that builds upon feelings of closeness, of being at home, feelings of comfort, ownership, and warmness [55]. Inspired perhaps by Heidegger's "being-in-the-world," he calls this relationship of *co-existence* with technology as *being-with* [55]. According to the author, an appropriate way of *becoming familiar* with technology is to integrate it within the participants' everyday life [59]. He sees this type of relationship as a *co-existence relationship* with technology [59]. Turner (2008) also says that *familiarity* can be illustrated as one's perception change rather than knowledge creation [57] .

Finally, [60] also argued for *familiarity* as a basis for universal design. They mean that HCI is based on the distinction between man and machine [60]. Furthermore, [61] described it as an intimate or close relationship, where humans *engage with*- and *try to understand the technology* [61]. The authors propose *a salutogenic approach*, as a way of focusing on the factors that contribute to *well-being* and *health*, rather than treating or fixing a disability, incapability or weakness [61]. In this paper, we try to understand the participants' *engagement with the technology*, by making sense of the *feedback* received from the technology, being it a smartphone app or a semi-autonomous robot.

In the next section, we continue by introducing our methodology and methods used in this study.

V. Methodology and Methods

According to [62], interpretive research is afforded through "language, consciousness, and shared meanings" [62, 2]. Boland (1985) in [62, 2], says that "the philosophical base of interpretive research is hermeneutics and phenomenology." Further, we followed one of Ricoeur's thesis that hermeneutics builds upon phenomenology [63].

In addition to the earlier reported work [1], we have now included both researchers and several elderly people in the study. We describe next our study context, study design, the robots used in this study, selection of robots, participants, data collection, and data analysis, as well as ethical considerations.

A. Study Context

The study was performed in the old district area of Oslo, Norway. The area has approximately 3000 senior citizens, over 67 years old. Some of these elderlies choose to live in accommodation facilities for the elderly. The elderly usually live there independently, or together with their partners. However, the accommodation is provisioned with a 24/7 reception staffed with at least two personnel, available for the elderly, a gym, a restaurant for taking breakfast or lunch, which is also open to the public, a library where meetings or various courses are held, and an open area for coffee breaks and other events. Several studies have been performed in such facilities [64][65][66][67][68], but none of these report data on the use of robots or semi-autonomous robots in the homes of the independent living elderly.

B. Study Design

This study was divided into three stages. The first stage was a pilot phase, with the purpose of learning, and getting a pre-understanding of the context (stage 1). Next, several of the researchers involved in the project tried out the semi-autonomous robots in their homes (stage 2). After some of the researchers have tried out the semi-autonomous robots, we started introducing the first available robot in the homes of the elderly (stage 3). In some cases, the robots were run in parallel in both homes of the elderly, and homes of the researchers.

C. *Robots in this Study*

In this study, we have used semi-autonomous vacuum-cleaner robots in the homes of our participants. Selecting such a robot was a bi-informed choice. On the one hand, our elderly participants reported earlier *familiarity* with semi-autonomous robots, such as vacuum-cleaners and lawn-mowers that they have seen on TV and were keen to test out. These types of robots are sometimes referred to as *domestic robots* or *domotics*. On the other hand, the study is part of the MECS project, that aims to develop a robot for independent living elderly. This study was made at an incipient phase of the project. The project did not have yet any fully developed robot for the independent living elderly, such as a safety alarm robot, in place at the time. Therefore, we chose to build on our senior participants' familiarity with the robots, e.g., by selecting semi-autonomous vacuum cleaners to be used in their homes.

We have initially investigated several potential robots to acquire for our study. We finally selected three of them for the purpose of our study: iRobot Roomba 980 [69], Neato BotVac, and Samsung PowerBot VR20H. Table I below gives a summary of the technical specifications of the robots.

TABLE I. SUMMARY: TECHNICAL SPECIFICATIONS OF THE SELECTED ROBOTS

Robot / Specifications	iRobot Roomba 980	Neato BotVac	Samsung POWERbot
Dimensions (Depth x Width x Height)	35 x 14 x 9.2 (cm)	33.5 x 32.1 x 10 (cm)	37.8 x 13.5 x 36.2 (cm)
Weight	4 kg	Ca 4.1kg	Cca 4.8 kg
App as a remote controller	YES. iRobot Home App	Yes. Neato Robotics	Yes. Powerbot, smart home app.
Charging	Battery and electricity	Battery and electricity	Battery and electricity

D. *Selection of the Robots to be Used in the Elderly's Homes*

When the robots were introduced in the homes of the researchers in the first stage of the project, we noticed soon that iRobot Roomba 980 and Neato were the most appropriate for the elderly, due to their reduced sizes, compared to BotVac robot. This led us to make the choice of only using iRobot Roomba 980 and Neato in the elderly's homes.

E. *Participants*

13 participants took part in this study: seven (7) of the participants were researchers that tested the robots as part of the pilot study, including the authors (SD, HJ), during the period of times ranging from about one week to about one month. At this stage, 2 females and 5 males participated. Six (6) elderly persons used the semi-autonomous vacuum cleaner for about one month: 5 females, and 1 male. Three of the elderly participants were included in the previously reported work [1]. The participants had different backgrounds and presented different levels of interest in modern technologies.

The researchers are represented in this study by both junior and senior researchers. The elderly participants (≥65 years), part of the MECS project, were recruited through MECS' partner organization. Due to the high commitment that the study required, including weekly visits, the use of the robot, photos, participant diary notes as domestic probes, observations, and interviews, only six elderly participants were willing to participate within the timeframe of study data collection. The participants were self-selected and took part in the study based on their free will. Some of the participants took part in the study through the snowball effect by finding out about the study from others.

F. *Data Collection*

The data was collected from researchers and the elderly. The data collected from researchers was retrieved through diary notes and photos (Table II). The data collected from the elderly participants were retrieved through interviews, elderly's diary notes used as domestic probes, photos, researcher's notes, and headnotes (Table III on the next page). Headnotes are "experiences, impressions, encounters, and evaluations that are continuously present in [the] memory," according to [70] following [71]. Each senior participant received a notebook to be used for their diary notes. We kindly asked the elderly participants to note down in their diaries the situations they encounter. These notes, or posts, as we named them, were written by the elderly, especially when something unusual or unfamiliar occurred.

TABLE II. OVERVIEW OF THE DATA COLLECTED FROM RESEARCHERS

#	Data collection methods - Researchers		
	Timeframe	***Documentation***	***Robot used***
1	One week	Yes. Diary notes, seven posts (one per day), ca 4 and a half A4 pages, analog format, 28 photos	Neato
2	Ca two week	Yes. 3 pages of A4 notes, digital format, 4 photos enclosed	Neato
3	Ca one week	Yes. Short notes on strengths and weaknesses of using such a robot, digital format	iRobot
4	One week	Yes. 1 page of notes, digital format	Samsung PowerBot
5	Ca one week	Yes. Half page was written notes on strengths and weaknesses, digital format	Neato
6	Ca one month	Yes. Four pages of written notes, 22 posts, digital format	Neato
7	Ca one month	Yes. Ca 19 A4 pages of written notes, analog format	Neato

G. Data Analysis

The process of analysis started already while being in the field, as a form of doing some preliminary work [72]. This has been followed by a multiple stage analysis process, where the data went through some analytical filters. Specifically, we have followed thematic analysis from V. Braun & V. Clarke to analyze the data collected in stage 2) and 3) [73]. This was done in 5 steps. We have first started by trying to familiarize ourselves with the data (step 1). We did this by creating a map of data and resources, which later resulted in Table II, respectively Table III. At this stage, we had put aside the initial research question, to be open for novelty, for what may come up and we did not think of, trying to focus on what the participants found interesting. Thereafter, our analysis was done in a bottom up fashion starting from coding each of the resources (step 2). We have then grouped the resources in three categories based on the data sources: researcher's diary, researcher's observation notes during elderly's observation and elderly's own diary notes, and interviews. At this point, the raw data became textual data, in the form of transcribed interviews, notes, or interview summaries. All the interviews with the elderly were transcribed verbatim by author SD. The transcribed interviews alone resulted in around 26000 words exclusive the pilot interview (circa 33500 words together with the pilot interview). At the same time, the author (SD) went through the photos taken (n=147). The coding was done by reading the material "line-by-line to identify and formulate all ideas, themes, or issues they suggest, no matter how varied and disparate" [74, 143]. This resulted in a variety of scattered codes.

Next step was collating the codes further into sub-categories for each of the data sources (step 3). This was done through color coded post-it notes by the author (SD). We cannot claim a full inter-reliability of the study, as the coding was done by one author (SD) [75]. However, following [75], validity, in this case, is not of "a particular concern", as the study focuses on exploring the potential challenges one may encounter when a robot is introduced in the home [75, 212]. Moreover, the findings were discussed at different points during data collection amongst the researchers in the project. In addition, the collated codes were discussed by the authors (SD, HJ) during the data analysis.

As a result, the data collected through researcher's diary, researcher's observation notes and elderly's diary notes, and interviews resulted in [n=51], [n=47], respectively [n=124] collated codes: a total of [n=222] codes. At this stage, we were searching for themes. We observed that some of the collated codes were present across several of the resources: written utterances during our drop-in visits (usually once per week, or on request), and utterances from the interviews. We

TABLE III. OVERVIEW OF THE DATA COLLECTED FROM THE ELDERLY

#	Data collection methods - elderly					
	Gender (Female F, Male M)	***Interview***	***Elderly's Diary notes***	***Researcher's notes***	***Photoswe re taken by the researche rs***	***Eventual details about the robot used, if any assistive technologies were used, and level of information technology literacy***
1	F	Circa 1 hour, audio-recorded pilot interview, transcribed verbatim (SD) AND Circa 1 hour and 45 minutes of untranscribed audio-recording from the installation of the robot	Yes. Circa 5 A4 pages, analogue format.	Yes. Circa 2 A4 pages.	Yes. 36 photos	iRoomba, 87 years old, walking chair, did not use the app
2	F	Circa 40 minutes, audio-recorded, transcribed verbatim (SD)	Yes. Circa 3 A4 pages notes, analogue format	Yes. Circa 2 A4 pages.	Yes. 4 photos.	iRoomba, walking chair, necklace alarm that she does not wear it, high interest in technology, used the app, has a smartphone,
3	M	Circa 25 minutes, audio-recorded, transcribed verbatim (SD)	Yes. One letter-size page, analog format, short notes.	Yes. Circa 4 letter-sized pages.	Yes. 10 photos.	Neato, wheelchair, not interested in technology, did not used the app, easy to use, has a wearable safety alarm
4	F	Circa 33 minutes audio-recorded, transcribed verbatim (SD)	Yes. One A4 page, analog format	Yes. Circa 2 A4 pages.	Yes. 36 photos	iRomba, wheelchair, interested in technology, did not use the app, easy to use, does not have a smartphone, wearable safety alarm
5	F	Circa 45 minutes audio-recorded, transcribed verbatim (SD)	Yes. One letter size page, analog format.	Not available	Yes. 13 photos	Walker, did not use the app, not interested in technology, does not have a smartphone, wearable safety alarm
6	F	Circa 43 minutes, audio-recorded, (transcribed verbatim) (SD)	Yes. 4 letter-size pages, analog format.	Yes. Circa 1 letter-sized page.	Yes. 16 photos	Interested in technology, no walker, wanted to use the app, but gave up, does not have any wearable alarm

looked for performative utterances [76]. This was carefully paid attention to due to two main reasons: in order to observe whether or not the researchers and elderly encounter the same type of challenges with the robot, and how information technology literacy influenced the attitudes towards the robot.

Finally, the collated codes and findings were discussed between the authors (SD, HJ) at multiple times. At this stage, we reviewed the themes resulted (step 4). The final analysis resulted in three main themes: robot, home space, and human emotions and perspectives on perceived autonomy (step 5).

H. *Ethical Considerations*

The project is in line with the ethical guidelines from the Norwegian Center for Research Data (NSD) (ref. nr: 50689). The data collected during this study were stored on the Services for Sensitive Data (TSD) facilities, owned by the University of Oslo, Norway, operated and developed by the TSD service group at the University of Oslo, IT-Department (USIT). All the data was anonymized. Prior to starting the study, the participants were given detailed information about the study. The participants could withdraw at any time without giving any explanation and without any consequences for them. The participants willing to participate signed informed consent before taking part in the study.

During the study, we had constant contact with our participants, through regular visits, often each Wednesday, on pre-agreed times, but also on demand, if they needed any support or had questions. Sometimes, we called them on the phone just to check if there was anything they wondered regarding the robot. They also received our contact details and could contact us at any time.

VI. FINDINGS

This section presents the findings from this study. The findings are structured in three categories: the user receives feedback from a smartphone technology (Sub-section A), the user receives distributed feedback via an app (Sub-section B), and robot motion as feedback and its implication for the user (Sub-section C). The findings are supported by empirical examples. A detailed account is given below for each of these.

A. *Findings: The User Receives Feedback From A Smartphone Technology*

In this section, we present a situation where the user receives feedback from a smartphone app technology. This is illustrated through textual feedback that is either improper or lacking. Fig. 2 illustrates the situation presented here.

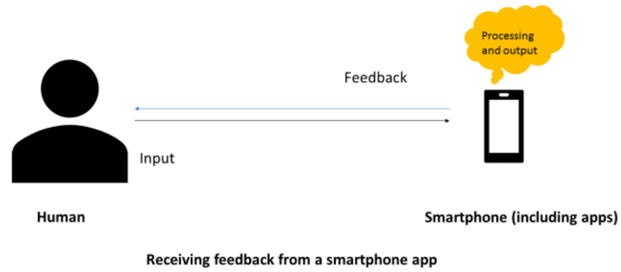

Figure 2. Feedback between smartphone technology and a (human) as user

1) *Providing Improper Feedback*

The user is provided with improper textual feedback [1]:

a) "SMS shows full. Do I need to buy a new phone?": One of the participants told us about her experience with the mobile phone and the feedback of SMS - full blinking icon. Her concern was that she could not store any longer the photos she received from her family. The participant was concerned that she had to buy a new phone, and that this would lead to losing the existent photos.

b) "Where is the 'No' option when updating software?": Another situation described by one of the participants was related to getting constant updates, where she gets either the option 'Now' or 'Later,' but not a 'No' option. She contacted the company providing the operating system via a handwritten letter and asked about this option. To her surprise, she got called up by the customer service, and got offered help on how to deal with the two options available, 'Now' and 'Later,' but the company had no plan to introduce a No-option. The participant explained that she knew how to deal with the updates, but what she wanted was that the feedback should embed a 'No'-option alternative. Regarding this design issue, this has to do with the continuous update of software and the point of view of the elderly on these always encountering updates. This example illustrates a situation where feedback messages do not provide enough options.

2) *Lack of feedback*

"You were terribly afraid of doing something wrong": In one of our interview sessions, one participant describes that when she learns using new technologies, she is so afraid of doing something wrong. A concrete example is that the technology, being it smartphone or tablet, does not provide any feedback on how *to get back to basics*: "so you were very afraid that... I did not feel I could come back to the base. But I was afraid to do something wrong."

By this, the participant means that the applications are built in such a way, that one is expected to have that intuitive knowledge, but for new users, it can be difficult to understand how to navigate within an app, and one can easily get stuck.

B. *Findings: The User Receives Distributed Feedback From A Robot via an App*

This sub-section illustrates the situation when a user receives feedback from a semi-autonomous robot technology via a smartphone, through an app. We illustrate first some of the implications that the use of such an app has for the user at the installation time. Thereafter, we illustrate some situations where the users received either improper feedback, or the feedback was lacking. An illustration of the situation is presented in Fig. 3 below.

Some of the participants have chosen to install the app in order to control the robot remotely. Several steps had to be followed in order to install the app. As the diary notes show, for Neato robotics app, for instance, one should create an online account. This, required an email address. This required a Wi-fi connection to the network. One of the issues that occurred during this step at the installation of the robot in one of the participants' homes was that the robot required a 5 GHz Wi-fi, while the participant's router had only 2.4 GHz.

The next step was to choose the right robot amongst several robots listed in the app. The final step was to connect to the robot. Once the app was installed, a map of the local space was created within the app after the robot has moved around. The map provided the approximate area, including obstacles, edges of space, and door limits (Fig. 4).

One of the participants gives a rich description of his experience on installing the app: "Today, it's time to get this thing going. First, I need to connect to the vacuum. This involves enabling Wi-fi on the vacuum, then connect your phone to the vacuum's Wi-fi access point (yes, the vacuum has its own Wi-fi access point). Then you can use

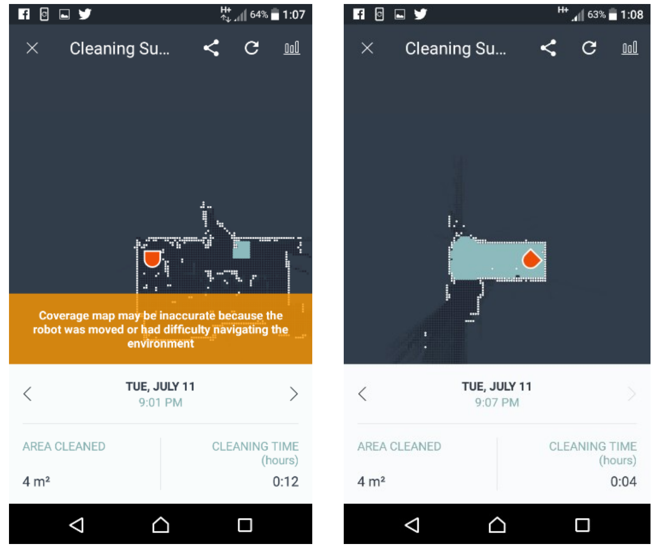

Figure 4. Example on the map is shown in a robot app that was generated by the robot

the Neato app to choose the actual Wi-fi point to connect to. On the one hand, this makes it easier to configure the robot since you connect only to it and you get the richness of a mobile app to input information (including passwords to access point), but it's not without some flaws. First, I assumed it would show the access points right away; it didn't. So, I typed in the access point and the password. I should also point out that I connected it to the "guest" Wi-fi, not our main Wi-fi. It's suddenly at this point that I realize how little I trust this thing belonging to the main network, and I start to think about other ways to partition the network. […] Regardless, the phone tells me that the process may take up to 3 minutes and that I should watch

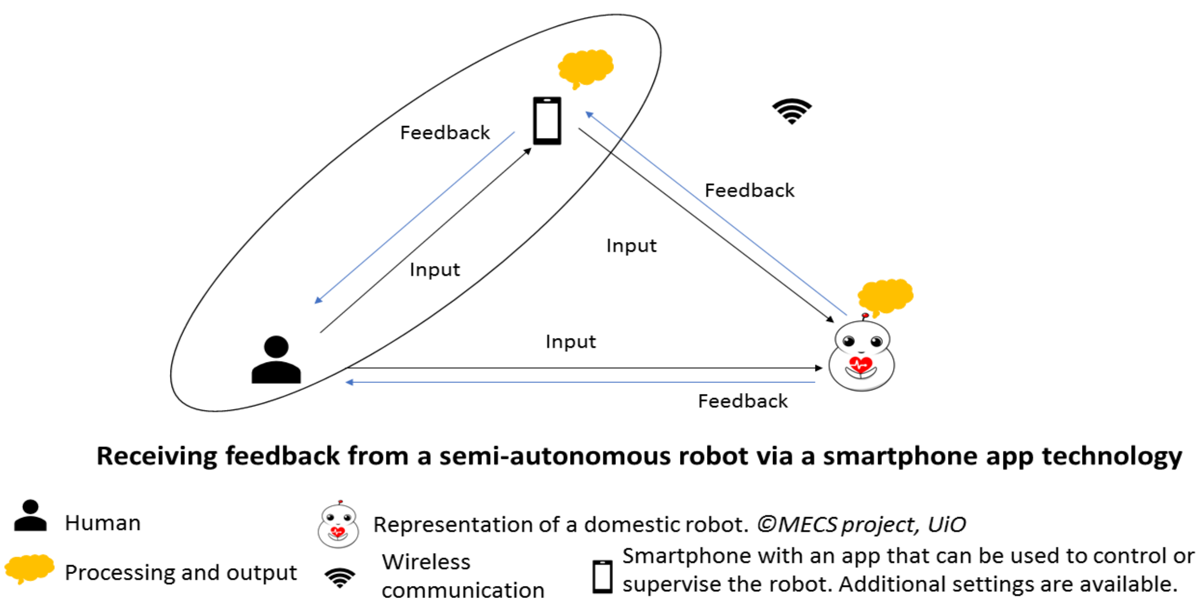

Figure 3. Feedback from a semi-autonomous robot technology to a (human) user mediated via an app

the robot's display screen during this time. I do, but it only shows the current setting of Wi-fi on. When I try to move back, I accidentally turn off Wi-fi, and I put the system in an uncertain state. I try to re-enable the wi-fi, but now the phone and the robot are confused. The phone, after 3 minutes, reports that the wi-fi information was "incorrect" and urges me to try again. But the robot refuses to rebroadcast its Neato access point. […] I switch the vacuum off using its hardware switch and then turn it back on. I go through the process again (with a lighter touch on my fingers). […] Then, I can choose the network and enter the password. This time it connects shortly thereafter. At this point, the robot asks for a name, I just give it Neato, and I set it out for its first vacuum tour" (Diary notes, Researcher).

Further, we found out that many of the in-app instructions and paper instructions that came along with the robot were available only in *English*. Many of the elderly participants pointed out that they do not feel comfortable about using technologies in English, and it would have been better to have it in their mother tongue, Norwegian. Here is an example of what one of the participants say: (Participant): "Yes. So it was another time when it got stuck in the charger, and it blinked. It was something about the light, but I did not understand what it was. I have missed a Norwegian instruction manual. It would have been very nice to have one." (Interviewer): "You are not the first person saying this. […]" (Participant): "Because even if I understand pretty well English, these technical things are a lot worse, because you do not understand them so well: technical language is more difficult!" (Interview, Elder person).

1) Providing Improper Feedback:

Another issue that seems relevant to the use of the app was when a power outage occurred, and the app stopped working, as it required an Internet connection. During a power outage, the app controlling the domestic robot stopped working, according to one of the elderly participants. The participant got a message that the app "cannot connect to the cloud services". The use of technical terms, such as "cloud service" when giving feedback to the user, seems to be inappropriate. She said: "It was just standing still there, or when I pressed on it where it says something about cloud-service. It didn't do anything, but I thought you would come tomorrow" [1]. The technical term "cloud service" confused the elderly user. The user, in this case, relied on the researchers help to come along the next days.

Another participant wrote in his diary notes that the robot urged for attention through a feedback message: *"Please clear my path (2000) and a red cross"* (Diary notes, Researcher), without understanding the meaning of the error 2000. Another participant referred to the message he received from the app as a "cryptic message." One of the participants explained that the app does not give proper feedback regarding the area of the room: *"The area cleaned shown on the map is 4 mp2. But the hall and room 3 are more than 4 mp2."* (Diary notes, Researcher).

2) Lack of Feedback:

It seems that one of the participants has used the app to schedule the robot. However, the participant did not get any notification (e.g., lack of feedback) when the robot once started to run: "Went out to meet some friends, when I got home, I found the robot running. Apparently, I had turned on a schedule when I had last used the app. I'm not sure *how* I did this, but I did it. The Wife was home, so she picked up the rug in the entryway." (Diary notes, Researcher) Another similar situation is illustrated in one of the participant's diary notes: "We went out for a walk, and when we came home the robot was vacuuming, it had sort of cleaned the rug in the entryway, but not really. […] A bit annoyed, I looked at its schedule. It seems it will be going at 9:30 tomorrow evening. We'll be ready for it this time. I enjoy that it has created a staggering vacuuming schedule, but a bit annoyed that it just launches itself out there." (Researcher, Diary notes).

C. Findings: Robot Motion as Feedback and its Implications for the User

In this section, we present situations where the users interact or engage with semi-autonomous robot technology. We make sense of the movements illustrated as *feedback*, as they happened. The situations illustrated that: *the incoherence semi-autonomous robot's motion triggered various feelings*, including stress, anger or other feelings related to robot personification; *the users received indirect feedback to do facilitation work*, such as moving things around in home, lift the robot and move it manually to another place; and *that the robot's motion creates noise*. An illustration of the situations described here is given in Fig. 5.

1) Movement Triggers Feelings

a) Feelings of Incoherence in Robot's Motion: Some participants pointed out incoherence in the robot's movement. The feeling of incoherence was triggered by the non-regular pattern of the movement, the user not being able to predict it. Indirectly, the robot motion gave a feeling of incoherence. Here are some examples: "I think it starts in one room, and then it goes to another, and then it goes again to the first room. I think it is a bit strange that it does not finish in the first room, and it goes perhaps to the kitchen, and then it comes back, and it continues likes this, and then goes out again. I think it was very strange (break), really, very strange." (Interview, Elder participant); "[…] And suddenly it started going by itself one morning. I thought it was very strange." (Interview, Elder participant); "One time when I pressed on HOME, it started going around by itself, so I had to carry it back" [the participant means here that she pressed on the HOME button, but she had to carry manually the robot back to its charging station].

b) Feelings of Anger, Stress, or Annoyance: Some of the participants found it stressful to follow the robots' movement: "There? [it reads out loud from own diary notes]: Puhhh… It was a bit stressful to keep an eye on it. […] Yes, I think it was a bit stressful because it went so many times over the same place. And I think it is a waste, such a waste. It went back and forward, and I wanted then to... I just put my foot in his way, so it couldn't go another way. You decide very little over it." (Interview, Elder participant); In another elderly's participant diary notes was written: "[…] Is this helping, or it will be Stressful [note that the participant writes the word Stressful starting with capital S]" (Diary notes, Elder participant). Another participant points out feelings of anger triggered by the robot motion: "So it was a bit stressful there! I was angry at it." (Interview, Elder participant). Another participant said: "At the beginning, it was a little odd to have a device moving on its own while we are sitting in the living room or having dinner. Since this was our first experience with this kind of technology, it makes sense to be annoyed or even scared by this robot at the beginning. However, having a remote control to terminate the robot manually or to change the current function overcomes the fear!" (Diary notes, Researcher).

c) Feelings of Personification – Robot as a Companion: However, besides feelings of incoherence in movement, stress, and anger, the robot also awaked feelings of personification – they viewed the robot like a pet, or someone in the home, that they talked to (Interview, Elder participant). Some of the participants personified the robots by giving them names such as King Robot, Frida, or Snilla.

2) *Robot Enacts the User to do Facilitation Work*

a) The Robot gets Stuck in Obstacles: There were several situations when the robot got stuck, in curtains, under the bed or sofa, in cables, or things around the home. Here are some exemplifications from both elderlies and researchers: "I got my brother fixing the cables under the bed, so they are not in its way. […] If it had gotten stuck there, I wouldn't have been able to come down there. I was very afraid of this. So no cables were supposed to be there! I felt so much better then!" (Interview, Elder participant); (Interviewer): "Okay… But you also wrote in your diary notes that you had to clean a bit before you could run the robot."; (Participant): "[…] I have lots of chairs here. I have put those two on top of each other because otherwise, it stops all the time. So I have removed them. And the cables […] Yes, I have cleaned a bit."; (Interviewer):" Did they get stuck in the cables on the floor?" (Participant): "I have tried to remove those. Yes, because it stopped a bit... or it brought those with it. So I had to clean." (Interview, Elder participant). Some situations are illustrated below (Fig. 6).

Figure 6. Situations where the robot got stuck and needed facilitation work

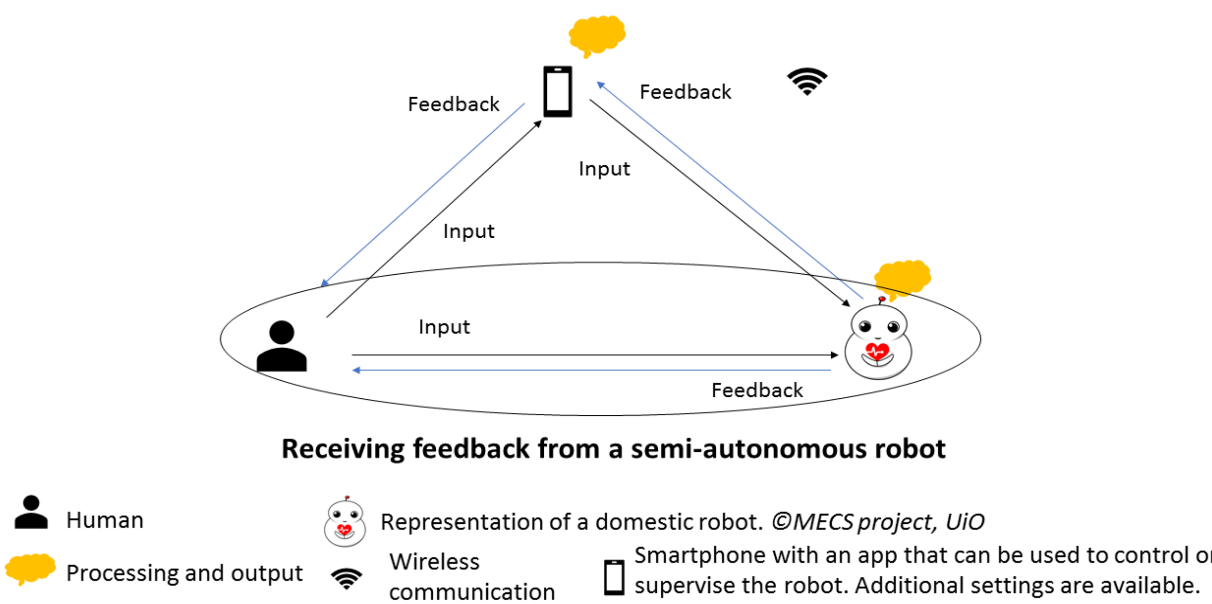

Figure 5. Feedback from a semi-autonomous robot technology directly to the (human) user

A few other examples are: "[…] A chair had to be taken outside of the room, two pillows and a basket were set on a table, two cables had to be taken up. Two doors had to be closed. […]" (Diary notes, Elder participant); "The robot got stuck in the carpet's tassels and stayed still. It took some time to free R from the tassels, so I took away the carpet. […]" (Diary notes, Elder participant); "R got stuck under a little table, I have freed R and lifted the machine to the charging station." (Diary notes, Elder participant); (Interviewer): "Do you see this as a problem?" (Participant): "Well… As I am quite strong, it works. But not everyone can lift and carry it." (Interview, Elder participant); "On a shelf, it was a lamp, but its cable was down on the floor. The robot got stuck, and it dragged the lamp down. As a result, the lamp got disassembled in 2 pieces. Luckily it was a plastic lamp & it didn't break. I could put it together." (Diary notes, Researcher). One of the commented on how a robot generates other types of work – additional and facilitation work is needed to be done. "[…] The *goal* I had was to make the *floor clean*; but to get to this – I needed to install something on the floor… A paradox." (Diary notes, Researcher).

Several participants suggested that one needs to do some facilitation work regarding the surface where the robot should navigate: "It started working, but it got stuck on the TV stand. I got a message about 10 minutes out. I then came back and freed it. It went for a while but got lost under the table. I pulled out the chair, and it seemed to go OK. Afterward, it did OK, though it tried to climb the entrance to the laundry room." (Diary notes, researcher); "I pressed "HOME" button, it started. After a while, it got stuck. I remembered the previous installation at home when the app gave notifications about this – when I was out-of-the-house. This information was disturbing at that time since I did not want to do anything with it. It interrupted a nice train journey I remember now and started off a train of thoughts of where it was stuck, and why (since I had done my best to make a "clean floor" there as well." (Diary notes, Researcher). Another participant pointed out: "Managed to move small, light things like a tiny rug, map tube" (Diary notes, researcher). A few others said: "After getting tired of the robot getting stuck, I put the stripe on the area it always got stuck, and it worked fine. Yay!" (Diary notes, researcher); "I had to move the chairs that were under the table because it was too small. I've noticed that it didn't reach." (Interview, Elder participant); "Yes, it pulled the cables a few times. Especially those behind the sofa, it is a long cable, and it pulled it out. Now I have fastened it, so it doesn't go on it any longer." (Interview, Elder participant); "Isn't it supposed that robots do their job on their own, without needing one's assistance?" (Diary notes, Elder participant); "A few times I had to move because it got stuck a lot. So next time I had to move those things out [talks about furniture] But I think it is a bit confused because it seems to have memory. When I moved the furniture, I think it was a bit confused, I think. But yes, I had to move the furniture." (Paraphrasing from an interview with an elder participant).

b) The Robot Escapes and Indirectly Asks for Facilitation Work: Two of the elderly participants encountered situations when the robot would escape from their apartment. Here are some examples from our data: (Participant): "[reads out loud from his diary notes] Her name is Frida. It behaved well. It got away one of these days. I forgot to lock the entrance door, and it disappeared in the hall."; (Interviewer 1): "[surprised] Okay. So it disappeared??"; (Participant): "Yes, yes. That one is wild. It went fast over the doorstep."; (Interviewer 1): "So you had to go and bring it back."; (Participant): "Yes, yes, yes. Yes, but maybe after it finished, it would have come back by itself. I don't know."; "I also had that door open, and it was out in the hall. But after, I closed the door, and it had to stop there.". Some examples when the robot tries to go over the doorsteps are exemplified in the images below (Fig. 7).

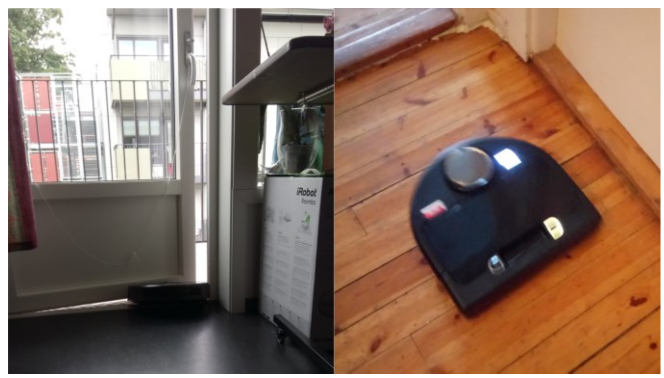

Figure 7. Robot escapes

c) Motion Creates Noise

Several participants, both researchers and elderly, reported that the motion of the robot created noise. Noise, in this case, can be accounted as a form of feedback for the motion, with the meaning of: "the robot is ON, and navigating around." Here are a few excerpts from our data exemplifying this: "R has started just now. The Radio attenuates the sound from R." (Diary notes, Elder participant); "[…] I have pressed on clean, but it was just standing there and making noise. I had to lift it to the charging station, press clean and R continued its tour." (Diary notes, older participant); "Back to the engine sound. I guess this is to be worked with; to make it quieter. Perhaps it could be possible to make user settings; how much power should be used, and this will again regulate the sound/noise. It is hard to think of the sound as nothing but noise… The sound from the movement is very low in comparison to the sound from the vacuum engine. It is also more pleasant to the ear." (Diary notes, researcher participant); "Checked the schedule, and thought nothing was on. So, I went out, but it turned out that it was actually going at 9:30. I wasn't there, but the wife was trying to sleep and complained about all the noise it made. But it got stuck somewhere, constantly asking for attention. When I finally got home, it was waiting at the front door, stuck in the carpet. It complained that it wanted the roller cleaned. I just put it away for tomorrow." (Diary notes, researcher participant); "Noise, can't use together with TV watching" (Diary notes, researcher participant); "Any way to pause cleaning once it starts, e.g., to take a phone call? Via app?" (Diary notes, researcher participant).

Finally, in this section, we have illustrated situations on the motion as feedback and its implications for the user, based on empirical data. In the next Section, we continue with discussing and unpacking further motion as feedback through the lens of familiarity based on the situations presented here, and also coming back to our initial stated research questions.

VII. Discussion

"The designer of any artifact that is a tool *must communicate* the artifact's intended use and, in some cases, the rationale for its behavior, to the user. There is a strong sense, therefore in, which the problem with such a premise, however (as archaeologists well know), is that while the attribution of some design intent is a requirement for an artifact's intelligibility, the artifact's design per se does not unequivocally convey either its actual, or its intended use. While this problem in the interpretation of artifacts can be alleviated, it can never fully be resolved, and it defines the essential problem that the novice user of the artifact confronts. Insofar as the goal of design is that *the artifact should be self-evident*; therefore, *the problem of deciphering an artifact defines the problem of the designer as well*." [44, 14-15, emphasis added].

What kind of *emotions* are triggered by *improper or lack of feedback when engaging* with a smartphone app or semi-autonomous robot technology? How is a *motion* made sense of and understood by the users when *engaging* with a semi-autonomous robot, in their homes? If the *motion* is illustrated as a type of *feedback* – what do we learn from their experiences?

It seems that *emotion* and *motion* are, at least etymologically, interconnected. Etymologically, *emotion* dates back to the 12th century from the old Franch *emovoir,* which means to *stir up,* and from the Latin *emovere,* which means to *move out, remove, agitate* [77]. In the late 17th and 18th century, the term illustrated "a sense of strong feeling," and later was extended to any feeling, according to the Online Etymological Dictionary [77]. The term *motion* dates back to 13th -14th centuries and it means *"the process of moving," movement, change*, coming from the Old French *mocion*, and from the Latin *motionem*, with the meaning of *"a moving, a motion, an emotion"* [78]. The term *locomotion* dates back to the 17th century and is formed from the Latin *locus,* which stands for a *place,* and the term *motion* [79]. Further, findings from our data present issues related to the robot, to the home space, and to human's emotions and perspectives on perceived autonomy. We choose to limit our discussions related to the issues encountered that are related to the robot's movement. The research questions are analyzed and reflected upon, based on the findings presented in Section VI, the Sub-sections A-C. We do this through the lens of the *familiarity* concept by reflecting on the *motion as feedback*.

A. *The Role of Familiarity for the Emotions Triggered by the Engagement with Technology*

The first question that we address is: *What kind of emotions are triggered in the user by improper or lack of feedback when interacting or engaging with a smartphone app or a semi-autonomous robot technology?*

An intuitive interface is an interface that the user naturally knows how to use it, whereas *a familiar interface* is an interface that the user has been exposed to over time and learned how to use it [80]. Raskin (1994) suggested that we should use the word *familiar* instead of *intuitive* [57][80]. We have earlier noticed that elderly participants *feared* interaction with *unfamiliar* digital technology because they did not master it, they did not feel able to learn it, and it was not in their zone of proximal development. At the same time, we also noticed that *the language* used for giving feedback to the users, in a breakdown situation, was often inappropriate: either by providing improper feedback or through lack of feedback. We talked about improper feedback as textual feedback using technical terms for transmitting a message. This triggered in the elderly feelings of *fear,* including its derivatives: *angst, anxiety, concern, doubt, dread, unease, uneasiness, worry, aversion, fright, phobia,* and *presentiment* [81].

Many of the studies on feedback within HCI are inspired by human-to-human conversational interactions [43][46]. However, specifically, [44] noticed earlier that human-machine communication was using English as the "natural language" for communicating between humans and machines [44, p. 28]. This choice was anchored in Austin's (1962) "*How to do things with words*," that language through its utterances can be a form of action, but this requires an appropriate interpretation of its interlocutor [76]. We noticed in our study that the interlocutor could not always interpret the use of technical terms. This is an issue of *mutual intelligibility*, as [44] would call it. Therefore, designers should consider avoiding the use of those in textual feedback. Similar findings to ours were presented in the study of eco-feedback from [82], that pointed out that householders participants did not understand the language used in the textual feedback. In addition, the Macintosh User Interface Guidelines, dating back to 1992, pointed out that feedback should be proper, and inform the user as much as possible, instead of providing the user with a technical language such as: "The computer unexpectedly crashed. ID = 13" [41, 9]. We encountered a similar situation in our findings when one of the participants received the error message: "*Please clear my path (2000) and a red cross*". This type of error message is improper because it did not make sense for the participant. Feedback should be *appropriate* and *timely* [41]. In addition, another study showed that seniors that are not *familiar* with particular technical terminology do not use these words [60]. In our findings, a similar situation occurred when one of the participants pointed out the use of *technical language* in the feedback they received via an app: "it cannot connect to the *cloud services.*" [1, 176]. These are, however, examples from the everyday' participants' interaction with the robot but are nevertheless important to be accounted to make sense of them. [58] explained that making sense of everyday examples of interacting with technology, of coping with it in everyday life situations is an indication of our *familiarity* with the technology. This relies upon the *know-how*, following Dreyfus in [59].

Feedback, however, has cognitive attributes that can be interpreted by the users. For instance, [42] talks about the *mind* and the *text*, and how the information transmitted can change the state of someone's mind and/or affect, depending on the conceptualization and interpretation of the information. We have seen concrete examples in this study of how someone's interpretation of robot motion changed his/her state of mind to stress, anger, or feelings of personification. However, apart from the *emotions* triggered by smartphone app technologies, moving further to the emotions triggered by the semi-autonomous robot, we noticed the following: the incoherence in motion triggered various feelings, including stress, anger or other feelings related to robot personification. When a technology triggers *emotions* within a user, being positive or negative, it means that the user *engages* with it, rather than *interacts* with it [83]. Interaction is a form of "'dialogue' with the technology" [83, 62]. *Engaging* with the technology also has an *affective* part, in comparison to interaction [83]. We have also observed that amongst different mechanisms *to engage with technology*, to be able to *maintain a dialogue* with it, *to cope, to co-exist with it*, one is *feedback*. If, for instance, *motion feedback* supports this *engagement* with the technology in itself, rather than just the interaction with it, we become more *familiar* with it. The repertoire of *emotions* awaken by the participants' experience of the robot is the result of their interaction, *engagement*, or even *familiarity* with it. The *emotions* triggered in both elderly and researcher participants were often of stress, anger, annoyance. However, we observed that, in general, elderly often felt as non-experts when using the robot and did not have the same deep tacit knowledge as the researchers in this study, that seemed to be more *familiar* with using the same technologies, or similar ones. We also observed that both the independent living elderly and the researchers in this study were challenged in many ways by interacting with a semi-autonomous robot technology: perhaps more than with a smartphone app technology. Many of these challenges arose due to additional interaction elements: the (sometimes incoherent) motion of the robot and the use of the app. The participants often had to learn the *know-how, to co-exist with* the robot, and *to accommodate it*: not the opposite – the robot did not necessary accommodated them, although it was its purpose. On the other hand, [84] talk about *unfamiliarity* of the users with a new technological machine makes it *more difficult to cope with it* – this does not mean that the machine lacks technological advancement, but perhaps *it is not designed in a familiar way for the users*.

Finally, we have noticed that the robot, through its motion, did not only trigger negative feelings but also feelings of personification: the participants associated the *motion feedback* of the robot with *aliveness*. The movement of the robot put the robot somewhere in between a static object, and a fully autonomous object: it was something that could move by itself, be self-propelled, i.e., it could change its location without a necessary and continuous intervention of a human or another object. Nevertheless, this idea of *aliveness* as a *familiar characteristic* has been earlier noticed, based on "autonomous motion, or reactivity" [44]. These feelings of personification can be translated as awaking *positive emotions* in the elderly. However, making sense of the *motion* itself as *feedback,* and how it can be understood through the lens of familiarity remains to be discussed. We explore this next.

B. Making Sense of the Motion as Feedback

The second set of questions addressed in this paper is: *How is a motion made sense of and understood by the users when interacting or engaging with a semi-autonomous robot, in their homes? If the motion is illustrated as a type of feedback – what did we learn from their experiences?*

Humans are usually *familiar* with their own *movement,* with seeing things that move around outdoors: bicycles, cars, trains, ships, airplanes. However, one is not yet familiar with semi-autonomous *things* that move within a home. This phenomenon has been discussed within Robotics and Human-Robot Interaction (HRI), but it still remains to be explored within HCI. A *home* is not a static linear environment, but rather things happen in a dynamic and non-linear fashion: people in the home move objects around: a chair is moved to another place, a bag is placed on the floor, a sock is forgotten on the floor and so on. A robot, whose main surface of navigation is *the floor,* may encounter these objects and treat them as *obstacles*: both in its wayfinding and in its navigation. Familiarity is also a form of engagement, or what Heidegger calls *involvement* [83]. One becomes familiar with the technology through repeated, everyday exposure to it [59][60]. But a semi-autonomous robot that moves within the home seems to be still unfamiliar so far: perhaps because we are not yet exposed in our daily lives to robots that move semi-autonomously in our homes. Turner (2011) talks about the inclusiveness of technology, that it must fit users' everyday lives [58]. *Did the robot fit the participants' everyday lives?* The elderly in this study were willing to adopt a robot in their homes, out of curiosity, willing to learn more about such semi-autonomous robot technologies, to become familiar with it, but also perhaps they sought out some sort of practical coping, that ameliorate some of the direct consequences of aging, such as bending while doing cleaning work. Housekeeping, for instance, seems to be considered not only a physical task, but also a goal-oriented task that requires some degree of cognitive functioning [3].

However, the authors refer to information retrieval only as a *text regarding* these types of feedback, not as a *motion* [42][46]. The human is considered here as an interpreter of the *motion as feedback*. *Motion feedback*, similarly to visual feedback, can also be translated into *positive, negative, homeostatic feedback*, or *archival feedback*. Based on our study, we have observed that the *motion as feedback* can be mapped out to four situations: (1) when the robot is still, (2) when the robot goes from a still state to motion, (3) when the robot goes from a motion state to a still state, and finally, (4) when the robot is in motion. We ground our mapping on empirical examples from our data to illustrate motion as feedback, but we do not argue that other ways of are not possible. Besides *polarity feedback, homeostatic feedback,* and *archival feedback*, we introduce the notion of *transition feedback*. *Transition feedback* emerged during our mapping of *motion as feedback.* Transition feedback refers to *motion as feedback* when the robot changes its state from *still to motion* (2), or from *motion to a still state* (3). Next, we map *polarity feedback, homeostatic feedback, and archival feedback* to *motion as feedback*.

1) When the Robot is Still

When the robot stands still, the *motion as feedback* can be translated into homeostatic feedback: the robot does not perform any change in its motion state. The homeostatic feedback can be either positive or negative, depending on if the user has previously pressed the button to start it, or not. For instance, if the user presses the CLEAN button, which means that the change of the robot should be changed from still to motion, but the robot remains still, the feedback is negative.

2) When the Robot Goes from a Still to a Motion State

The transition between the still state to a motion state of a robot can be translated as positive or negative feedback, depending on the correspondence between the user's input and expectations. Positive feedback is given when the user presses the CLEAN button, and the robot moves around cleaning. This is also transitioning state feedback, as the robot changes its state. An example of negative feedback for this situation is when the robot starts moving around by itself, without being enacted by the user.

3) When the Robot Goes from a Motion State to a Still State

The robot turns back to its charging station when the user presses the HOME button can be translated into positive feedback, as the robot responds to the user's input. At the same time, this can also be translated into transitioning feedback since the robot changes its state, from motion to a still state. A second situation is when the robot turns back to its charging station when it is almost out of battery. This motion feedback can be translated as positive archival feedback since the robot acts accordingly to its resources, e.g., needs to be charged. However, from the point of view of the user, this can be translated as negative feedback, since the robot does not meet the expectation of the user: to be in motion once that the user has pressed CLEAN. It can also be translated into *transition motion feedback* since it is changing its state. A third situation is when the robot remembers the path and turns back to its charging station after finishing cleaning. This can be translated as positive archival feedback because it remembers its way back, based on a logged history or a previously created map. A fourth situation is when the robot gets stuck and enacts the users through indirect or invisible feedback to do facilitation work. In other words, the robot gives a negative *transition motion feedback* to the user by changing its state, from motion to a still state.

4) When the Robot is in Motion

We could see in our findings that when the user presses the HOME button, but the robot does not go back to its home station, and yet here the *archival feedback* was missing. This can be translated as negative homeostatic motion feedback. We can say that when the user presses the HOME button and the robot returns to the home station, the user understands the robots' navigation to the base station as immediate positive feedback: it responded to the user's action. Another situation is illustrated when the motion of the robot is incoherent: it only cleans a small surface, without navigating the whole area. This can be translated as negative homeostatic motion feedback. When the robot is in motion, and the motion feedback is manifested through the noise, it can be translated into positive homeostatic feedback. However, in the view of the user, this is translated as negative feedback since the noise itself creates feelings of annoyance, disturbing the user.

When the robot remembers the map of the rooms when is not running for the first time in the area (coherent navigation), the motion of the robot can be translated into positive archival homeostatic motion feedback, since the robot remembers the map of the room and can navigate accordingly. Opposite to this situation is when the robot escapes a room previously navigated, i.e., the navigation path of the robot does not respect the boundaries. This can be translated as negative motion feedback.

We illustrate some examples of positive, negative, homeostatic and archival motion feedback in Table IV.

C. Familiarity with the Motion as Feedback

Based on this study, we have observed that the *familiarity*, or for that matter *unfamiliarity,* of the *motion as feedback* can be based on already established notions of the polarity of feedback, homeostatic feedback, and archival feedback. However, these notions were used so far in relation to textual or visual feedback [55][60]. We have classified motion as feedback, based on the motion state of the robot and empirical examples from our data: 1) motion as feedback when the robot is still, 2) motion as feedback when the robot is transitioning from a still state to a motion state, 3) motion as feedback when the robot is transitioning from a motion state to a still state, and 4) motion as feedback when the robot is in motion. To the already existent types of feedback, we have observed that for semi-autonomous robots, transitioning feedback for situation 2) and 3) is a new type of feedback. We have mapped and illustrated the four situations based on the robot's states and their corresponding feedback (Fig. 8 on the next page).

Further, [85] compared and synthesized the design principles from Schneider (1999) [37][38], from Constantine & Lockwood (1999) [86], and from Nielsen (2005) [87]. The author found out that the principles related to error handling and error recovery, based on the three named guidelines are necessary for any type of interactive system [85, 45]. Specifically, the author means that errors should be avoided [85, 45]. If we translate this to the familiarity of *motion as feedback,* it implies that any feedback that can be translated as a form of *negative feedback* illustrates some sort of *unfamiliarity*: either of the robot as a response to a user action, or of the *emotions* triggered in the user. The authors say: "in other words, the environment would behave in a manner familiar to the user as if they were not actually using a computer system." [85, 45]. We can observe that negative feedback occurred in all types of situations. This means that the semi-autonomous robot did not respond or act in a *familiar* way. Further, according to the authors the concept of UNDO, of *archival feedback,* which we translated as a way for the robot for going to a previous state, is "unnatural" and conflicts "with the principle of familiarity" [85, 45]. We observed this type of *archival feedback* in situation 3) when the robot transitioned from a motion state to a still state, and in 4) when the robot maintained its motion state. For *motion as feedback*, this idea that the archival feedback is unnatural and conflicts with the *familiarity* concepts seems to do not always hold. We argue rather that there are situations when the robot acts in a familiar way for the user. Here are our arguments: the robot turns back to its charging station when the user presses HOME button – this is in line with the user's expectations; the robot turns back to its charging station when it is almost out of battery – the robot is at least in line with the needs of its system for more resources; the robot remembers the path and turns back to its charging

TABLE IV. MAKING SENSE OF MOTION AS FEEDBACK

Robot state	Example of situation	Motion as negative feedback	Motion as positive feedback	Motion as homeostatic feedback	Motion as archival feedback
1) The robot is *still*	The robot stands still.			X	
	The user presses the button, but nothing happens.	X		X	
2) The robot is transitioning *from a still state to a motion state* (transition feedback)	The user presses the CLEAN button and the robot moves around cleaning.		X	X	
	The robot starts moving around by itself without being enacted by the user.	X		X	
3) The robot is going *from a motion state to a still state* (transition feedback)	The robot turns back to its charging station when the user presses HOME button.		X		X
	The robot turns back to its charging station when it is almost out of battery.	X	X		X
	The robot remembers the path and turns back to its charging station after finishing cleaning.		X		X
	The robot gets stuck and enacts the users through indirect or invisible feedback to do facilitation work.	X		X	
4) The robot is *in motion*	Motion feedback manifested through noise.	X	X	X	
	The robot remembers the map of the rooms when is not running for the first time in the area (coherent navigation).		X	X	X
	The motion of the robot is incoherent (it only cleans a small surface, without navigating the whole area).	X		X	
	The robot escapes (e.g., the navigation path of the robot does not respect the boundaries).	X		X	

station after finishing cleaning – the robot is acting in a familiar way to user's expectations, it acts accordingly after finishing its job.

Further, in this section, we have followed Turner (2011), of making sense everyday examples of interacting with technology, the readiness of coping with it in everyday life situations [58]. This sense-making lead us to a mapping between polarity feedback (positive or negative), homeostatic feedback, and archival feedback to motion as feedback. In addition, we observed that doing this mapping by using the states of a robot, still and in motion, and their corresponding transitions, we could define the *transition feedback type*. We have also observed that different feedback for different states can trigger *emotions* (positive or negative) in the user. If we follow the idea that the interaction is a form of dialogue' with the technology, we are still concerned that current design remains *unfamiliar* to the user in specific situations, regardless if the user is experienced or not. To come back to Suchman's (1986) idea that a "*tool must communicate*", and that "*the artifact should be self-evident*" [44, 14-15], it seems that our *artifact, tool,* and *machine,* the robot, was not able to communicate in a number of situations that we illustrated based on our empirical data. This problem of *unfamiliarity,* as opposed to *familiarity,* reveals a deeper underlying problem: "*the problem of deciphering an artifact defines the problem of the designer as well*." [44, 14-15].

If the robot does not follow a *familiar* way of navigating a space, responding to the user's expectations, this may lead, in the case of the elderly and their use of a safety alarm robot, to additional falls for them. A concrete example is when the robot *transitions* from a still state to a motion state, without giving any *feedback* to the user, besides the feedback in the form of *transition motion feedback*, and noise as homeostatic feedback. Falls amongst elderly is a well-known problem [88]. The situation presented above may lead the user to additional falls if the user is not aware of the *transition and homeostatic feedback*. Introducing a robot that does not respond accordingly, by giving negative feedback, being it homeostatic or archival, may have negative consequences on the user. Further, the report about falls amongst the elderly shows that fall may lead to fear of falling, and other negative physical and mental health consequences [88]. The literature also shows that falls amongst elderly people (≥65 years old) are very common, and hospitalized due to fall injuries seem to occur five times more than due to other causes [89]. Another problem with the *motion as feedback* is when the robot escapes. In the situation of the use of a robot in the home, e.g. a safety alarm robot for the elderly, such a type of negative and homeostatic feedback may lead to a non-detected fall. The situation of the robot getting stuck, as negative and homeostatic motion feedback, may also lead in a real situation to a non-detected fall, and in other implications for the user: bending over to move the robot.

Lastly, we can say that looking at the *motion as feedback* with the help of *familiarity concept* contributed to understand the potential challenges and implications when introducing a robot in the homes of the independent living elderly. Moreover, it also contributed to map and discusses *motion as a positive, negative, homeostatic, archival,* and *transition motion feedback*.

VIII. CONCLUSION AND FUTURE WORK

In this paper, we have presented *motion as feedback* through empirical data from an explorative study of semi-autonomous robots used in domestic settings. We started the

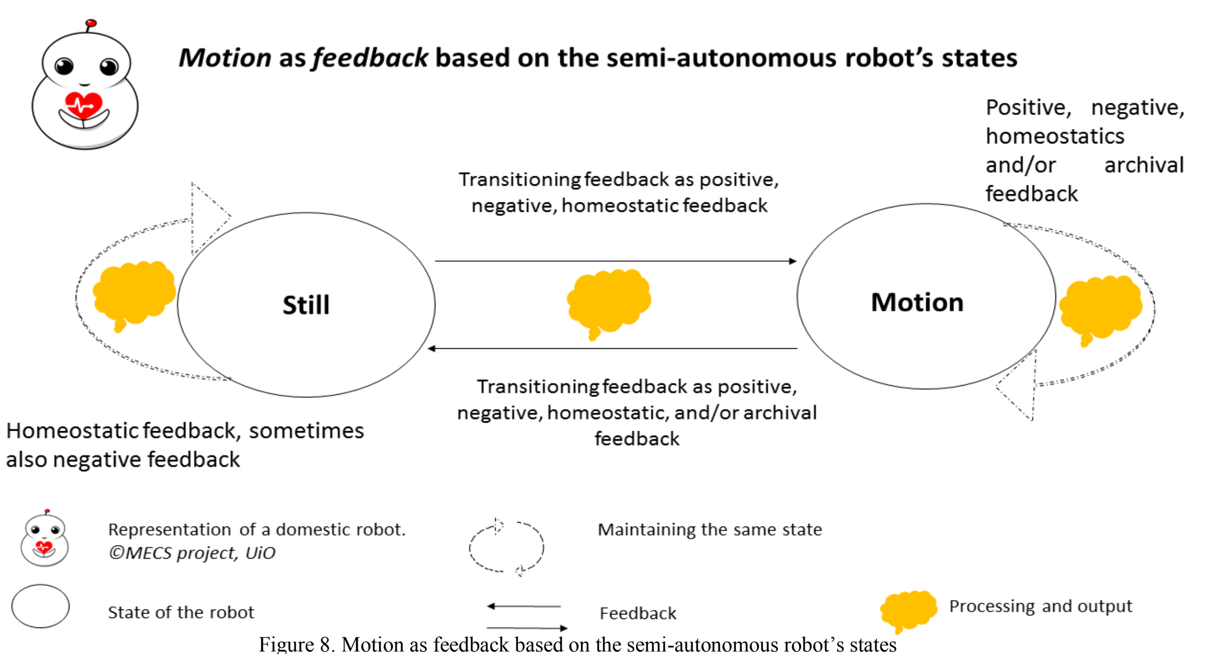

Figure 8. Motion as feedback based on the semi-autonomous robot's states

paper by stating our research questions, introducing some terminology and the background for this study. In Section II, we gave an account on the state-of-the-art. Section III introduced the reader to the concept of feedback within HCI, where it often is understood and designed as visual, auditory, haptic, or textual. We drew attention upon the significance of the use of natural language when interacting with computers, or designing feedback, dating back to the work of Suchman (1985) [41][44]. We elaborated on *polarity-, homeostatic,* and *archival feedback* based on the existent literature. We briefly described *motion as feedback* based on robot navigation. We have framed *feedback* from a smartphone app and semi-autonomous robot technology, to be able to discuss robot's *motion as feedback*, and differentiate it from *feedback* received from stationary technology, we have framed feedback from smartphone app and semi-autonomous robot technology.

Further, in Section IV, we have elaborated on our theoretical foundations, explaining the *familiarity* concept. Section V illustrated in detail the methodology and methods for this study, including the ethical aspects. In Section VI, we have presented our findings structured in: the user receives feedback from a smartphone technology; the user receives distributed feedback from a robot - mediated via an app; and motion as feedback and its implications for the user. Finally, in Section VII, we discussed the *motion as feedback*: the role of *familiarity* for the *emotions* triggered by the *engagement* with the technology, discussing how *feedback* can support *familiarity* with technology; and making sense of the motion as feedback, based on polarity-, homeostatic-, and archival feedback. The *transitioning feedback* emerged here. We continued by discussing *familiarity with the motion as feedback.* We argue that having *familiarity* in mind when designing new technologies, can make it easier for the user to *know-how* to use the technology.

Our conclusion is that a semi-autonomous robot technology can become more *familiar* to the user if it triggers (more often) positive feelings in the user (than negative feelings). Finally, from a System Engineering perspective, following HCI requirements derive from the findings: if its motion is coherent, if its navigation is appropriate to the situation (e.g., going back to the charging station when it is out of battery, not getting stuck, remembering the map of the rooms to be navigated, without "escaping"), and if its motion is not disturbing or interrupting the user (e.g., when taking a phone call, or when eating). Taking a *being-with* approach to *familiarity* for semi-autonomous robot technology to make sense of the robot's motion helped us in being able to distinguish amongst *motion as positive, negative, homeostatic, archival,* and *transitioning feedback*. This approach changed how we view that the participants *engaged with* the technology: it changed their routines at home through the enactment of facilitation work, their schedule, their relationship with the technology itself and with others that live or visit the same home – once part of the home or one's daily's live, it became a subject for discussion suddenly. It was part of their everyday lives. However, we can conclude that through *making sense of motion as the feedback,* we may observe that the semi-autonomous robot was *part of,* but *not* yet *integrated* within their homes and their daily lives. The robot did not accommodate the participants, but rather, the participants had to accommodate the robot. *Familiarity* was defined as an intimate, close, and friendly state, or interaction [81]. However, we showed through this study that while using *familiarity* as a lens *to analyze* the participants' experiences with the semi-autonomous robot technology, the relationship between the participants and the robot remains *unfamiliar* in many situations. The robot still remains in many situations un-familiar to the participants, the *know-how* relationship is not fully developed, and the participants do not always have tacit knowledge on how to interact with it. Finally, the *co-existence* with such robots in domestic settings is not fully developed yet. We can conclude that familiarity *per se* plays a central role in individuals' relationships with technology [56].

Coming back to the State of the Art described in Section II, this study supports the findings from the ACCOMPANY project and Care-O-Bot robot [13][14][15][16]: many of the elderly need support with the ADL. Specifically, the need for support with the housekeeping related needs was nevertheless present also in this study, along with the findings from [19]. However, some of the studies made with the robots used in Robot-Era Project [3], ACCOMPANY [13][14], MARIO, EURON RoboEthics Roadman, EP6, ETHICBOTS, BREATHE, or ICT & Ageing Project [18] were centering their focus around the functionalities of the robot, and the user acceptance of the robots. These robots were also specifically designed for home care of the elderly. The studies made on the companion robots: PARO [21][22][23], AIBO, Furby, NeCoRo [21][22], Pepper and NAO [25], or Giraff [26] focused nevertheless on how a robot may impact the elderly's behavior across time. Many of the studies used quantitative statistical data for the evaluation of the robots. While this is nevertheless important, our study provides an example on how existent robots on the market can be used instrumentally in explorative interpretative qualitative studies for understanding more about the participants' everyday experiences, and how their daily activities may change when introducing such robot in their homes. The study is primarily about the lived experiences of the participants. These experiences are instrumentally used as a foundation for understanding more about design, design of robots for their use at home, design implications of feedback, and motion as feedback distributed or not via an app.

We suggest as future work to elaborate further on the relationship between motion*, transitioning motion feedback,* and the role of *familiar feedback* in *engaging* with technology, rather than *interacting* with it. Further, one could explore more the affordances of motion as feedback, following the definition of affordances as given by [90], or as seen in HCI. Introducing moving technologies in the home lays the foundation for further explorations. One way to build further on this study is by conducting a quantitative statistical study on the acceptance of the robots in the home, on the movement types of robot, or by using the concept of animacy as shown in [48]. Exploring the abstract concept of *feedback* as a coordination mechanism and/or as a boundary object is also of high interest and relevance for those interested in theoretical anchored explorations. Another way for continuing this study is by conducting a qualitative interpretative study by analyzing the division of work tasks and types of work performed by the human and the robot. Here we encourage the analysis of work tasks and types of works to be done by borrowing established concepts used outside of HCI field, such as Computer Supported Cooperative Work. Nevertheless, studying the boundaries between when the interaction between the human and a robot becomes a cooperation between the human and the robot is of high relevance, especially now with faceless interaction devices: conversational based devices on face- or faceless interactions based mainly on speech, such as, e.g., Sophia the Robot, or with Google Home Mini.

Finally, this study was conducted to understand the potential challenges (e.g., robot motion as feedback is not understood by the participants, the robot motion enacts the participants to do facilitation work, the robot escapes, etc.) that may occur when introducing a robot in the homes of the independent living elderly. Introducing modern technologies in the homes of the elderly, such domestic robots requires scrutiny of the design of current and eventual future technologies that will be used by them. Understanding which challenges the elderly encounter *when* they interact with a semi-autonomous robot, in their everyday lives in domestic settings, contributes to our understanding on potential challenges on the future home care robots for the independent living elderly.

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