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Don't be afraid! Design of a playful cleaning robot for people with dementia

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Abstract. Robot technologies for care homes and people affected by dementia has become a popular research field. However, such technologies have not become mainstream in care homes yet, due to specific issues related to the well being of their residents. For instance, although existing robot vacuum cleaners can provide meaningful support to hygiene practices in care homes, their appearance and loud noise can negatively affect residents. Building on these insights, we developed a playful alternative design. Through a user study conducted in a care home, we have found that a robotic vacuum cleaner can be accepted by residents affected by dementia, when it has a playful appearance and movement pattern, to elicit positive feelings and provide predictability of its actions.

1 Introduction

In 2018, around 9.1 million people over 60 were diagnosed with dementia in EU states [11]. Dementia describes a variety of brain disorders which progressively lead to brain damage, causing deterioration in memory, thinking, behaviour and the ability to perform everyday activities [11]. Many of these individuals can still live at home, but when reaching a later stage of the disease, most will eventually move to a residential care facility.

Dementia affects not only its victims, but also caregivers and families, causing physical, psychological, social, and economic challenges [15]. Moreover, the number of people working in elderly care is decreasing. The job requires long working days and shifts, physically hard labour, often at relatively low wages and with too little time for caring for residents [18, 4, 10]. According to Riek [17], there is a substantial health-care shortage, because far more people need care than healthcare workers are available to provide. Therefore, researchers in healthcare robotics have proposed multiple robotic solutions for providing health

Fig. 1: Our Sanne prototype moving across the shared room during tests. Left in the door: one researcher steers Sanne through the room. On the opposing side of the room, another researcher takes field notes.

support. Amongst other things, robots may help people with cognitive impairments, support caregivers, and aid the clinical workforce [17].

A common and time-consuming task in care homes and hospitals is cleaning the floors. In the care home where we conducted our study, a robotic vacuum cleaner had been trialled. The caregivers reported that the residents, most of whom are at later stages of dementia, were overwhelmed by the robot, because they could not perceive it easily due to its dark colour, and felt unsettled by its unpredictable movement pattern and noise level. Therefore, the cleaning robot could not be used any further.

The project reported here focuses on developing a mobile cleaning unit with a playful design, to be used at care homes for people with dementia. We investigated the design of a robotic appliance, which has the functional purpose of cleaning the floors autonomously, but also a social purpose for residents. We aimed at a vacuum cleaner that does not elicit the feeling of being overwhelmed and may even lead to amusement. We designed our robot in the form a toy cat, so that it could serve as a pet-like companion (fig. 1). Residents' reactions to the robot were investigated through in-situ observations in two care homes. The focus of our analysis was: *whether a playful, zoomorphic design for such a robot, with a playful moving pattern, will be accepted by people with dementia, without them getting scared or overwhelmed*. In our study, we define residents' acceptance as a positive user experience, characterised by an open, possibly playful attitude towards our prototype [13]. In the following, the user study and findings regarding the reaction of residents are described.

2 Background and Related work

The estimated number of cases of dementia will almost double by 2050, growing from 1.57 to 3.00% of the European population [8]. Studies show a positive effect on cognition through preventive interventions, a healthy diet, physical exercise, and cognitive training [15]. Nevertheless, there is no cure or disease-modifying treatment for dementia yet.

Although dementia mainly affects older people, it is not a normal part of ageing [15] and comes with different challenges for each patient. Dementia has different stages, characterised by different signs and symptoms. The late stage of the disease comes with behaviour changes and difficulties in recognition of humans and objects, causing an increased need for assisted self-care [15]. The participants of our study were almost all in this later stage, therefore their needs have to be considered when designing technology for care homes.

According to current literature [3], ageing adults affected by dementia experience changes in their perception of the environment and corresponding behaviour. This occurs in different ways, in some cases people may lose control of their emotional responses to environmental stimuli, leading to erratic behaviour and emotion, or show indifference to their surroundings [21].

In the study of dementia, it was found that laughter and humour can bring significant benefits to people affected [21]. Laughter has been acknowledged as a supportive method to complement clinical treatment, improving quality of life. Another important aspect for well-being is the use of familiar objects to sustain daily practices [3, 6]. Dementia causes cognitive impairments, which hinder people from understanding the function of new unfamiliar objects. Nevertheless, when interacting with own objects and perceptually similar ones, people are able to spontaneously relate to and use those objects in their daily practices [3], whereas perceptually unfamiliar objects were not easily understood by the same study participants [3]. It seems that by using certain objects for many years, people internalise their physical use and context [3, 5], so that despite of dementia they can still actively relate to these. This can be explained as an effect of implicit memory, an unconscious memory generated by previous experience of repeated task performances, not linked to specific episodes [9]. Repeated exposure to objects results in perceptual priming that is resilient to cognitive impairment and can support people affected by dementia in performing their daily practices [9]. Thus, the design of novel technologies and artefacts for residents in care homes should take into account perceptual familiarity, so that novel artefacts fit with residents' previous experiences and sociocultural context.

When designing a mobile robotic unit, we have to be careful to not trigger fear of falling [2]. Falling is acknowledged as "the second leading cause of death from unintentional injury" [2]. Dementia is known for leading to unconscious wandering, agitation, and perceptual difficulties, which in combination with the physical fragility associated with ageing might cause people to experience serious injuries [6]. As a consequence, ageing people affected by dementia, manifest a strong fear of falling [2, 6].

The design of assistive robots for care homes typically includes automated mobile units, which are in charge of carrying things around, monitoring safety, engaging people in physical exercise, even including exoskeletons and wearable devices aimed at improving physical mobility [17]. Thus, no matter whether care home residents will actively use such robots, or just encounter them in their daily environment, fear of injuries should be considered as a key factor in such designs for the residents' safety.

Building on these insights, we aimed at designing a mobile floor cleaning unit, which could be perceived as nonthreatening, in relation to three main aspects: humour, familiarity of objects, fears of falling and injuries.

3 Designing Nonthreatening Robotic Cleaners

The work presented here is part of a larger research project on care home technologies. In this context, interviews and observations at care homes were conducted. The researchers also visited the cooperating two care homes of OK-Fonden in Odense, Denmark [3]. Here, the inspiration and motivation for the reported work was gathered. This was complemented via a number of (online) interviews and meetings. When the design was finished, the pandemic situation allowed to test the prototype at the care homes of OK-Fonden.

3.1 Development Process

This research followed the Human-Centred Design approach (closely related to User-Centered Design), which aims to create usable and useful systems and products by focusing on users, their needs, and requirements [12, 19, 16]. During the initial stage of the project, the setting, the care staff and a clinical clown, whose role is to activate and engage the residents, were observed. The goal was to gain a first-hand understanding of the user group and context of use. This yielded insights into the daily life in the care home, the activities, behaviour and challenges for residents and staff. It revealed the omnipresent problem of keeping the floors clean and the mentioned problems when using a vacuum cleaning robot. This robotic vacuum cleaner was hard to perceive for residents due to its dark colour and minimalist round shape, which, according to the staff, made it look like a black hole moving across the floor. Moreover, its movement pattern was unpredictable for the residents, making them restless. Therefore, the acquired robotic vacuum cleaner was discarded after only a few months, because of its negative impact on the residents.

The clinical clown was a source of inspiration for investigating patterns of movement and appearance of our robotic vacuum cleaner. She dresses as a cow and uses a slow and predictable as well as playful movement pattern to approach people. This was reported as being especially important for residents with dementia, who are not frightened by such a slow and playful approach pattern.

[3] https://ok-fonden.dk/

After discussing requirements among the researchers, it was decided to design a playful interactive mobile cleaning unit. Given the positive effects documented of laughter and humour on people with dementia [21], we experimented with a playful, zoomorphic look for our prototype, to elicit positive emotion and laughter. The concept prototype is nicknamed “Sanne”, short for ’sanitizing unit. Interviews with management and staff members of the care home, the board of OK-Fonden and a hygiene expert of a hospital, provided feedback to this idea as well as additional insight into residents’ and stakeholders’ needs. Staff argue that residents are cognitively and emotionally affected by colours; red and orange are stimulating due to its high contrast [7, 1], while white and black can be hard to perceive. On the other hand, blue and green were described as pleasant and relaxing, but easily ignored by residents. Therefore, it was suggested to colour our prototype red and orange to make it easily visible for residents. Potential shapes of the cleaning unit were also discussed. A staff member reported that the residents of this care home felt uncomfortable and ’unnatural’ while interacting with a toy resembling a seal, which sparked the idea to use the form of a domestic animal, which should be familiar to residents and can be expected of moving around (cp. [6, 3]). The size of the cleaning robot was also decided in collaboration with the staff. According to a hygiene expert, the floor itself is considered potentially infectious and unhygienic, and thus the body of the robot (especially the head that might be touched by residents) needs to be at least at 20-30 cm height, to avoid contamination. On the other hand, the robot should still be able to drive under furniture (fig. 1).

During the design process, the stakeholders continued to contribute feedback and ideas. After the first digital sketches, use cases and user scenarios were created, also considering potential challenges. Hence, a short video of animated sketches was created and distributed, to gain additional feedback. Finally, the first prototype was created based on our understanding of the users, tasks, and environment [16].

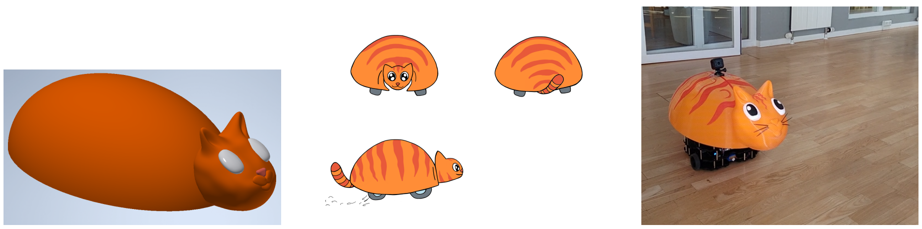
As mentioned, the shape of a cat was chosen as a familiar pet. The robot cat was intentionally designed to look toy-like, to avoid deceiving the residents about its nature as an inanimate object. Orange was picked because of its activating nature, and being easy to perceive to reduce the risk of tripping.

3.2 Proof of Concept Prototype

Our Sanne prototype was developed with the TurtleBot [4], a modular robotic unit widely used in teaching and research environments, due to its small size and flexible design. We selected the TurtleBot, mainly because it was within the desired size limits, price tag, and it can support a fast, modular prototyping process. The TurtleBot is equipped with a raspberry Pi, raspberry pi Camera, and 360° 2D LiDar among other sensors. These will be vital for further development, e.g. autonomous navigation in the care home environment.

[4] https://www.robotis.us/turtlebot-3-waffle-pi/

A 3D-printed cover with the design of an orange cat was mounted on top of the TurtleBot. This first prototype weighs around 3 kg, is 80cm long from head to end, 40cm wide and around 40cm tall,so to be able to move under furniture, while avoiding contamination from the floor, as pointed by the hygiene expert. Moreover, the staff should be able to move it, if stuck in furniture and in case of malfunction. For research purposes, Sanne had a camera mounted behind her ears, so to record reactions of residents and staff.



(a) 3D sketch of prototype

(b) Animated prototype for videos

(c) 3D-printed prototype used in the study

Fig. 2: Different stages of development of the Sanne prototype

Currently we are still experimenting with acceptable movement patterns, regarding speed and quality of movement when approaching residents, so to be seen, and to avoid scaring and intruding in residents' activities. In the tests, Sanne slowed down when approaching residents and moved faster when further away. In addition, a 'wiggling' movement was used when Sanne was close to residents, by driving back and forth and sideways, to make Sanne look playful and attract residents attention. This pattern was inspired by the clown's movement.

For the study, we utilised a Wizard of Oz setup, which is a common method used for exploring how humans react to autonomously moving objects and robots before having fully functioning prototypes [14, 20]. This means that we remote-controlled the movement of Sanne, enabling us to flexibly react to emerging situations and adjust on-the-spot to the residents' needs.

4 The Study

The evaluation of our proof-of-concept prototype was conducted in the field, that is at our partner care home. Our study focused on the perception of Sanne, residents' acceptance towards our robotic prototype, and on movement patterns suitable for a care home. We tested the mentioned movement pattern while observing the residents' reactions in relation to their current activity level.

We conducted our test in two care homes of OK-Fonden, in 6 different house units. In total, 30 residents (16 female, 14 male) participated in our study. Their age and names were not recorded, as for our study the state and effects of the dementia disease were more relevant than personal information. The process of the study was approved by the OK-Fonden management. Informed consent was obtained from the patient's relatives for their participation. For presentation here, participants have been anonymized via drawings based on the recorded video. Our tests took place on three days at different times and lasted 30 to 70 minutes. To investigate if and how the residents' activity level might influence their perception of Sanne, we showed them our prototype before and during lunch, which qualify respectively as low and high activity levels. In total, 2:50 hours video footage were gathered in total. One camera was mounted on top of the robot's head, approximating Sanne's field of view, to record close-ups of the residents. A second camera was installed in the room, to record the space and document other eventual interactions between the residents and how Sanne might affect these.

As the researchers did not speak Danish fluently, a staff member of the care home was present to help communicating with the residents and intervene in any unexpected situation. The researchers wore a care staff uniform, to blend in and not raise too much attention. They also had to wear a face shield and keep distance from the residents and were tested negative, due to hygienic restrictions related to the Covid-19 pandemic as shown in figure 1.

One researcher controlled the robot via a remote control, according to the Wizard-of-Oz method, to simulate that the robot was moving autonomously. This researcher stayed in the background and tried to hide the remote control, to avoid that the residents might notice it. A second researcher stayed close to the residents, to take notes of their reactions and their words 1. The present care staff were sitting or standing next to the residents, talking to them or supporting them in daily activities.

Later, we conducted a series of follow-up semi-structured interviews, the first with the staff of the care home and the second one with its management. Both interviews lasted 30 minutes and were recorded. These interviews focused on the tests and staff's regular daily practices and challenges. The aim of these interviews was to gain an understanding on whether the care givers noticed any unusual moods or reactions, caused by Sanne's presence in the home. Since Sanne is supposed to ease the daily work of the care staff in keeping the home clean, we asked them how they perceived Sanne, to comment on her potential and which difficulties they could foresee. The interview with care home management focused on the general concept of Sanne and how the user tests were experienced.

5 Findings

The recorded video footage provided the key data for our analysis. It was cut, labelled, translated, and categories were assigned to identified occurrences, such as: residents' reactions to Sanne, their activity level, and how they became aware of Sanne during the test. In total, 37 situations were identified, analysed (also referred to as reactions), and organised into a logbook. We focused especially on occurrences in which the residents noticed Sanne and were led to act in different ways than usual.

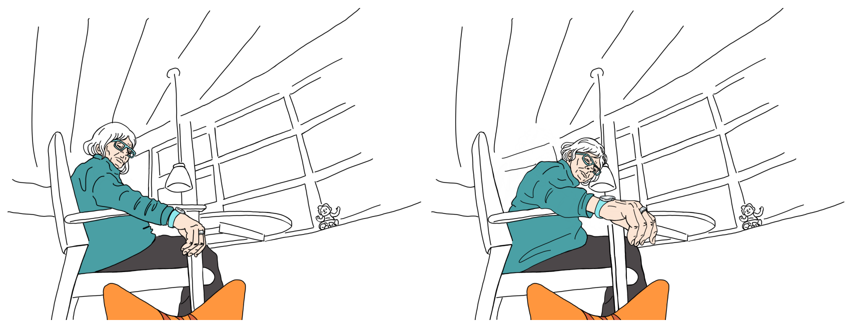


Fig. 3: Positive reaction, luring with hand

5.1 Reactions to Sanne

The residents' reactions were categorised into positive, neutral, negative, and non-reaction. *Positive reactions* towards the robot include situations in which the residents showed interest in Sanne by asking questions, talking about or to her, smiling at her and luring Sanne to come closer or touching her (fig. 3). Situations where residents only noticed and visibly accepted her presence or commented briefly, but did not further interact or relate to Sanne, were categorised as *neutral reactions*. Negative verbal comments, a perceptibly worsening mood or a rejecting gesture were categorized as *negative reactions*. Situations, in which residents could not perceive Sanne because of their activity level or health condition, as well as situations where they did not show any interest, ignoring Sanne, were labelled as *non-reaction* (both types are counted as non-reaction as it is not always possible to tell whether Sanne was intentionally ignored or not visible from the point of view of the resident).

16 out of 37 reactions were positive, only one was negative. 11 residents reacted neutral, and in 9 situations, no reaction was discernible (table 1).

The four reaction types were subcategorised according to the kind of reaction (table 1). Residents who reacted positively, were either talking to or about Sanne, luring and/or touching her. In three situations, Sanne was touched by residents, they either scratched her head or touched her ears. Before every touching situation, the participants talked to Sanne or lured her. While talking to her, some participants altered their voice to reach a higher tone, reminding of the tone used while talking to children or pets. Luring the robot was done either by whistling, reaching with the feet towards Sanne, or via a hand luring gesture (fig. 4).

Reaction	Situations	Sub-type	Situations
Positive	16	Talking	5
		Talking and luring	5
		Luring	3
		Talking, luring and touching	2
		Talking and touching	1
Neutral	11	Observing	7
		Listening and agreeing	3
		Listening	1
Negative	1	Kicking	1
Non	9	Not interested	5
		Not possible	4

Table 1: Occurrences of reactions to Sanne and sub-types of reactions

Fig. 4: Close up on lure gesture with hand

Residents who showed neutral reactions either just observed Sanne or listened to a caregiver, or employee talking about her and agreed to what was said. In three of the 11 neutral situations the conversation sounded like this:
Caregiver: Look, the cat is coming over there.
Resident: What is it doing?
Caregiver: It's supposed to wash our floors, wouldn't that be nice?
Resident: Yes, of course!

The one negative situation observed was labelled as such because the resident followed Sanne and kicked her (fig. 5). Nevertheless this situation was ambiguous, as he did not show visible rejection, fear or anger and continued to follow Sanne. The resident appeared negative concerning our study in general, as he also kicked a researcher to clear his way. Kicking is usually done to show dislike or to keep something at distance, and was therefore categorised as negative.

In some cases, no reaction was observed, this happened typically when residents were focused on other activities and did not notice Sanne. Some seemed to see her, but did not appear interested, so that it was not possible to determine if they would accept her or not.

5.2 Attention

As another key finding, we consider how the residents became aware of Sanne's presence. During the user study, at least one caregiver or employee of the care home was present, which led to conversations about Sanne. To determine whether Sanne will be able to drive through the care home by herself without needing somebody to introduce her or to make the residents aware of her, we analysed how many people were able to perceive her without any help. There are four different categories of the attention level (fig. 6).

From 37 situations, 26 residents were able to notice and reacted to Sanne *independently*. In those, no help was needed from a caregiver, employee, or other resident to perceive the robot and to react. *Semi-dependent* were residents who either needed help to shift their attention towards Sanne or to react. Only three residents needed this partial help.
1. *Caregiver: Look who is coming here!*
Resident: Oh yes, is it walking on wheels?
2. *(Resident observing Sanne on the floor)*
Caregiver: Do you think its cute?
Resident: Yes.

The category *Dependent* summarises the situations where residents needed help to notice Sanne and react to her. The caregiver or employee lead the conversation about the robot, and it is not clear whether the resident would have noticed Sanne without any help. Situations like this were observed four times.
Caregiver: Look there! Resident: Ah.
Caregiver: What do you think about it, is it nice? Resident: Yes.

The last category describes situations, in which the residents did not pay any attention towards Sanne, in spite of the effort of a caregiver or other residents.

Fig. 5: Negative reaction, kicking

This lack of attention was observed four times and assigned to the reaction category *Non* and subcategory "Not possible".

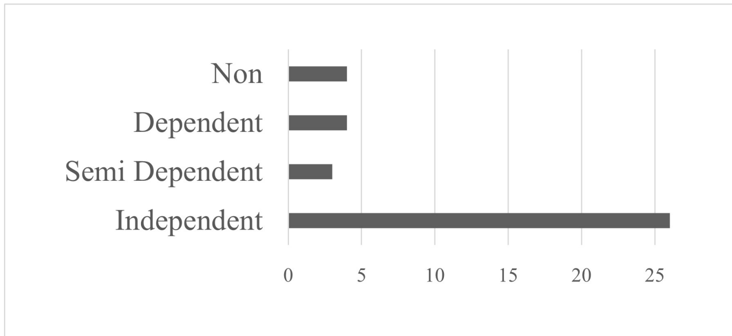


Fig. 6: Attention towards Sanne

5.3 Influence of Activity Level

The third aspect of our analysis deals with whether the activity level of the residents might have influenced their reaction to Sanne. Activity levels were categorised in low, middle, and high. A *high activity level* is represented by situations in which residents are busy during a meal, talking to somebody, or focused on an activity such as handicraft. Instances in which residents were watching TV, reading a magazine, walking through the care home, or having a small snack or drink, were categorised as a *middle activity level*, as these did not require intense focus from the residents. Situations where people were only sitting or standing somewhere were categorised as *low level activity*. The prototype was tested before lunch (low to middle activity level) and during lunch (high activity level). From 16 positive reactions to Sanne, only one resident had a high activity level, while 11 residents had a low level. Six of the 11 neutral reactions happened during high activity levels. In general most (19 of 37) situations were observed during the residents had a low activity level (fig. 7), including also the largest number of positive reactions.

6 Discussion

A main key finding from our study is that **73% of observed residents showed to have accepted Sanne**, which means that at its current state, our prototype was accepted and tolerated by most residents. Only one negative situation was observed and 24% of observed situations had no discernible reaction to the robot (non-reaction). These cases of no reaction were considered a positive finding, since the residents did not appear scared or annoyed, but simply went on with

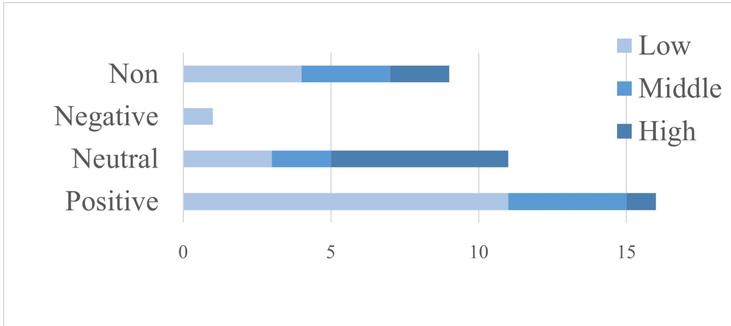


Fig. 7: Activity level

their activities, ignoring Sanne. The observed negative situation was, as reported by the caregivers, explainable with the fact that the resident never liked animals in his life. Moreover, by previously kicking one of the researchers, this resident indicated to be annoyed by anyone or anything standing in his way. Even though some residents might not like cats or the chosen colour for Sanne, we can argue that our prototype did not cause any fear, disturbance, or anxiety. Since Sanne is primarily intended to clean the floor, and only secondarily to provide an opportunity to interact or play with her, the residents do not necessarily have to respond and should be able to ignore her. Our research question *"Can a playful robotic vacuum cleaner, like Sanne, be accepted by people with dementia?"* can, therefore, be answered positively at this current state of development.

Another key finding is that **Sanne is perceived as cat-like**, indicated by 11 out of 16 positive reactions ending with touching her. The behaviour of luring and touching could be counted an implicit behaviour, comparable to a playful interaction with pets. Nonetheless the residents clearly appeared to be aware that Sanne is not a real living cat, as some commented on her body being hard and knocking on her head, showing that the design of Sanne evokes behaviours that allude to cats as well as toy pets, without misleading people affected by dementia.

70% of the residents were able to react to Sanne independently. This shows that the robot could be used in an everyday situation, moving around the care home without needing help from caregiver to be introduced or be supervised during interactions. In this way, our prototype should be able to fulfil the purpose of keeping the floors clean and relieving care staff of this task, as the residents could perceive, accept, and some even liked to interact with Sanne, opposite to what happened with the previous commercial robotic vacuum cleaner.

58% of residents with a low activity level reacted positively to Sanne. The most significant reactions to Sanne occurred during low activity levels. When residents were focusing on a task and thus had a higher activity level, they only reacted neutral or very briefly to the robot. This shows that people can easily ignore Sanne, which might fit the purpose of cleaning the floors without causing unnecessary distraction. Finally this finding can provide clues for caregivers to find a suitable time to use the robot for actively cleaning the floor (for example during lunch or another activity) and for using it as an entertainment and talking point for residents.

6.1 Future Work

According to our study, Sanne might become a source of danger to those residents who have difficulties to attend to more than one thing at a time, or to anything that is not in their line of sight, a known issue for late stages of dementia [2]. In one instance, a resident was walking up and down the hallway and did not notice the robot on the floor, if the researchers would not have controlled the robot, a tripping incident might have occurred. Therefore, further investigation is required to develop a safety protocol for Sanne, fine tuning her movement pattern, establishing a safe distance and acceptable warning signals for residents in transit.

The observed negative situation revealed that Sanne should be able to react to residents' rejections. Actions like kicking or utterances like *"Go away"* can be interpreted as warning signals, which Sanne should be able to detect and to shut off or drive away in response, avoiding further annoyance.

At the current stage of our research, it is not possible to make any claims on the noise level of Sanne, as the tested prototype did not yet have a vacuum cleaning function. According to experiences reported by the caregivers with their previous cleaning robot, loud noise can negatively affect the residents, therefore, it is our plan to further investigate this aspect during in-situ workshops.

As the residents touched Sanne in 69% of the positive reactions, the tactile properties of the shell material should be further explored. Currently Sanne is made of 3-D printed plastic, which is not particularly pleasant, hence we aim to find a soft-feeling material, which invites touch but is also hygienic, so that it does not summon more work from the care staff for disinfecting the robot.

7 Conclusion

In our study, we explored the design of a non-threatening robotic vacuum cleaner for care homes, addressing in particular the needs of people affected by late stages of dementia. Our study was conducted through a Human Centred Design methodology. Therefore, we engaged in a close partnership with two care homes located in Odense, Denmark.

Our study demonstrates that people at late stages of dementia can accept a robotic vacuum cleaner, if it carries playful qualities in its appearance and movement pattern. Based on our conversations with staff, we gave our prototype, which we call Sanne, the appearance of an orange red-striped cat and a movement pattern, which supports visibility and predictability, avoiding fright and tripping.

Our results show that residents responded positively to our prototype, as most of them tried to engage with our prototype to play as if it was a pet or a cat-like toy. Only one negative response was observed, which was a rejection, but not accompanied by fright or accidents. Other residents simply ignored Sanne, as she was not in their field of view or they were engaged in activities. We consider non-responses as positive, as people are entitled to interact with Sanne or not according to their wish. These occurrences mean that there might be a risk of tripping, therefore, our next step in development will focus on exploring a safety protocol to avoid accidents while Sanne is cleaning the floor or simply sharing space with residents.

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