“I still Need my Privacy”: Exploring the Level of Comfort and Privacy Preferences of German-speaking Older Adults in the Case of Mobile Assistant Robots

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Abstract

With an ageing population, more and more older people are expected to remain in their living environment. Mobile robots, whose market is expected to increasingly grow, could assist them for specific tasks. Existing studies, however, show that potential users have privacy concerns. In this paper, we therefore aim at understanding factors influencing these concerns and exploring their preferences with regards to different aspects related to informational privacy. In a quantitative study with 1090 German-speaking older adults, we show that female and non-owners of robots tend to express more concerns about their privacy than others.

Key words:

Mobile home assistant robots, privacy, privacy concerns, preferences

1. Introduction

Our society is ageing: the share of the older population (i.e., aged 65 and over) has almost doubled over the last past 50 years in the EU [1].

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Allowing older adults to stay in a familiar environment has been shown not only to positively impact their health conditions and foster their autonomy, but also to be a cost-effective solution [2]. Deploying mobile assistant robots to monitor both the health and behaviour as well as assisting elderly can contribute to ensure their safety. Assistant robots allow users to live alone, but simultaneously can infringe users' social, physical, and informational privacy [3–11]. While older adults are ready to trade their privacy against potential benefits [12–18], they express privacy concerns [19–22].

In this paper, we hence present the results of an online questionnaire involving 1090 participants over 65 distributed in German-speaking countries (i.e., Germany, Austria, and Switzerland). Our study investigates the participants' levels of comfort and preferences when considering different aspects related to (1) data collection, (2) data processing, (3) data sharing, and (4) control and transparency. Both our sample choice and the addressed topics are grounded in our plan to develop user interfaces for older adults to express their informational privacy preferences.

We adopt the following scenario in our study. A mobile robot is deployed in the home of an older person. It can follow her and remain in proximity to assist her. It includes approaching her in case of a fall or reminding her to take her medication [23, 24]. The robot is equipped with on-board sensors extendable by external ones. It can recognise user's current location and position (e.g., siting, lying, standing). It can further recognise emergency situations and send an alert to a remote health service. Note that such deployment can include additional components, such as engaging conversations (e.g., [25, 26]), recognising facial emotions (e.g., [27, 28]), establishing video connections (e.g., [29, 30]), or helping users walking or carrying objects.

The rest of this paper is organised as follows. We discuss the concept of privacy in Sec. 2 and existing works in Sec. 3. We present our methodology in Sec. 4 and our results in Sec. 5. We conclude this paper in Sec. 6.

2. Privacy as a Concept

2.1. Definitions and Taxonomies

There exists a myriad of definitions of privacy and associated theories. In 1763, Pitt claimed that "[his] home is [his] castle" and hence supported the right to privacy against intrusions into individual properties. In 1890, Warren and Brandeis described privacy as "right to be let alone" [31]. More recent definitions and theories include those of Westin in 1968, Altman in 1975, Gavison in 1980, Moore in 2003, and Nissenbaum in 2004. In [32], Westin defined the concept of *information privacy* as "[. . .] the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extend information about them is communicated to others". His definition is completed by Altman's theory that considers privacy as a process, in which boundaries are defined and interactions are regulated [33]. Gavison expressed a similar idea of limited accessibility [34]. In contrast, Moore defined privacy as "control over access to oneself and information about oneself" [35]. He therefore did not limit privacy to the *determination* of the modalities under which information should be communicated as defined by Westin, but introduces the explicit notion of *control*. Nissenbaum finally proposed the theory of *contextual integrity* [36].

Different efforts have been made to structure these different definitions. For example, the concept of privacy is divided into four dimensions in [37]: (1) physical privacy, (2) psychological privacy, (3) social privacy, and (4) informational privacy. The first dimension relates to physical accessibility and personal space. The second concerns the ability to develop one's own values and control the conditions under which thoughts are shared. In comparison, the third one considers the control of social contacts. The fourth one builds upon Westin's definition about personal information. The same structure has been adopted in a taxonomy dedicated to robotics [5, 38, 39]. These taxonomies hence highlight that privacy is a multidimensional concept.

2.2. Privacy and Mobile Assistant Robots

Building upon the above dimensions, we consider our specific scenario and discuss the corresponding privacy dimensions.

2.2.1. Informational Privacy

Mobile assistant robots are equipped with different sensors. They hence collect, process, and transmit information about their environment and people located in physical proximity. Note that information about visitors are also collected [8]. Robots can gain insights about users' characteristics and are able to observe their behaviour over time [9], including their daily routines, health issues, or changes in both physical or emotional well-being [10]. They are aware of emergency situations and further get information about users' living environment including displayed objects and floor maps [9]. Therefore, the robots endanger older adults' *informational privacy* [5] and raise three different privacy concerns based on [40]: (1) direct surveillance, (2) increase access, and (3) social meaning [39, 41]. The deployment of robots increases the access by means of technology to what is happening inside their home. The social interactions between users and robots also impact how information is shared with technology. E.g., the robots' appearance influences how people reveal information to them [7, 11].

2.2.2. Physical Privacy

Mobile robots can also endanger older adults' physical privacy [5–7, 10]. Note that their presence is however not required to be a threat to privacy, as sensors can capture data even behind walls [10]. Users' personal space can be invaded by the robot when they are in embarrassing situations. The same can be perceived when robots maintain a constant gaze [7]. These examples illustrate potential issues related to access management and boundary regulations—both topics included in Altman's theory as well as in Gavison's and Moore's definitions.

2.2.3. Social Privacy

Robots can also violate older adults' social privacy [5, 10] and their right to be let alone. Depending on the robots' appearance and interaction capabilities, the human-to-machine relationships can be comparable to human-to-human social relationships. Therefore, older adults should be able to choose their own company and their need for solitude should be respected.

In absence of protection mechanisms, robots can therefore threaten the users' privacy, specifically its informational, physical, and social dimensions.

3. Related Work

Besides the above discussions on privacy threats, the state-of-the-art addresses the acceptance of robots and solutions to address these threats.

3.1. Acceptance of Robots

The acceptance of different robots by different age groups in various scenarios has been extensively evaluated. When focusing on older adults only, the robots *Paro* [42], *Karotz* [43], *Kompaï* [20, 44], *VGo* [45], *Giraff* [46], and *Double* [47] have been evaluated. A study based on a robot picture has been conducted in [19]. The general acceptance of home service robots has been investigated in [48, 49], while the attitudes of potential users have been analysed in [21, 50]. A citizen panel has explored their expectations and concerns [22]. An analysis of encountered challenges has been proposed based on a literature review in [51]. Additional acceptance models including privacy concerns as a factor have been developed in [24, 52, 53]. They do not exclusively consider older adults, though.

3.1.1. Privacy Concerns

During some of these studies, participants expressed their concerns about privacy issues related to the robot's deployment [19–22]. For example, the older adults' main concern was the robot's camera in [19], while the participants indicated that they would feel observed and followed in [20]. According to [21], the participants even rejected the idea of the robot continuously monitoring their activities. Note that two studies based on interviews dedicated to privacy concerns have been conducted in [54, 55], both however do not focused on older adults only. Conversely, the results of other studies indicate that their participants had little to no concern about privacy [45–47]. In [45], the participants however indicated that they were willing to control who could contact them through the robot. In contrast, the participants [47] did not seem opposed to their family members being able to contact them anytime. Additional works have been conducted to study the impact of concept videos [56] and interpretive framing [57] on privacy concerns.

3.1.2. Consequences of Privacy Concerns

As shown in [58], participants exposed to a stationary camera, a stationary robot, or a mobile robot have demonstrated privacy-enhancing behaviours, such as covering the camera. In [43], two participants have even renounced to use *Karotz* because of their privacy concerns.

3.1.3. Utility-Privacy Trade-off

Despite these privacy concerns, different studies show that older adults are willing to accept new technologies if their utility outbalance these concerns (among other factors) [12–18]. In the case of robots, participants in [16] have generally prioritised autonomy over other values, such as privacy, but not always over safety. Such prioritisation should however not be seen as a motivation to neglect older adults' privacy concerns [17].

3.2. Addressing Privacy Threats

Different works including [41, 59–62] have proposed guidelines and recommendations for the design of privacy-preserving robots. A taxonomy of corresponding solutions is proposed in [5]. It includes solutions to control both conditions under which the robot can touch people and its navigation to respect the users' personal space [5]. Studies, such as [18, 63–65], have studied users' comfort when interacting with robots. To restrict the robot's perception, the utilisation of sensors that are more privacy friendly [66, 67], the recognition of the sensitive locations (e.g., bathroom, bedroom) [68], elements (e.g., naked people, faces) [65, 69], situations [65], or a combination of all [70] have been proposed. In addition to detect them, a wide range of solutions have been proposed to hide them using various techniques, such as [71–78]. Some solutions [73, 79, 80] allow users to select the objects to be hidden. Their preferences have been further explored in [81].

Besides controlling and redacting collected information, additional aspects of informational privacy have been considered in [9, 82, 82]. In [9, 82], participants' preferences in terms of data storage, retention, and deletion have been explored based on a sample of 12 students and university staff in the UK and 97 participants including 38 older adults in the UK, the Netherlands, and France, respectively. Our study shares thus similarities with both studies, but we focus on older adults as compared to [9] and address German-speaking participants as compared to [82]. Moreover, we include novel aspects related to, e.g., location prediction and data processing, not yet covered in these studies. Since, to the best of our knowledge, no dedicated solutions allowing both transparency and control over these dimensions are available yet, we further explore these aspects in our survey.

4. Methodology

Both ethics committee and data protection officer approved our survey.

4.1. Survey Design

In our study, we first determine our participants' profiles and their current relationship with robots. This includes collecting their demographics, their familiarity and interests in robots, and their preferences in terms of robot appearance. We therefore collect information about our participants regarding different factors that we assume may have an impact on their later answers. We further address different aspects related to informational privacy and especially to data collection as introduced in Sec. 2.1. This includes verifying in which situations and locations our participants would not like the robot to collect information about them, thus establishing a link between informational and physical privacy. We further consider participants' level of comfort and preferences in terms of data processing, data sharing as well as control and transparency. We have verified their attention by letting them compute a simple addition. Participants who did not correctly answer this question did not pursue the study and their answers were discarded.

4.2. Survey Implementation

We have advertised the study to be about "robots and people" to avoid priming participants. Answers were anonymously collected and processed in compliance with the GDPR. Participation was voluntary and took about 30 minutes in average. We tested it with a convenience sample to estimate the time needed and verify that the questions were clear and understandable. It resulted in the correction of few minor language errors.

4.3. Survey Distribution

To avoid social bias, our survey has been distributed by a German panel provider certified ISO 26362. The participants' contributions were monetarily rewarded. 1710 participants contributed out of which 1090 provided complete answers, which we consider in the following.

4.4. Survey Limitations

Our goal is to explore different elements that we assumed to be relevant for the design of new privacy-preserving solutions. Our study is therefore a first step in this direction due to the following limitations. Like other online questionnaires, the provided answers are a representation of the participants' opinions and may not reflect their actual behaviours. Moreover, these answers depend on the provided information and the formulation of our questions. While we have made the choice to cover different aspects of privacy for exploratory purposes, this has requested us to limit the depth of our exploration for each specific topic in order to limit the participants' fatigue (our questionnaire counts already up to 57 questions). We have thus asked the participants to assume that the robot can assist them in their daily tasks at home. By using this description, we have therefore left a certain space for interpretation open, as the participants could imagine different contexts including different robot designs, assistance tasks, and services. Consequently, these exploratory results should be verified and extended by additional studies with narrower focuses to close this interpretation gap in the future. Another limitation is that almost all participants have not experienced assistant robots yet. Their answers thus also reflect what they imagine. A solution would be to conduct additional real-world experiments. Finally, their participation to an online panel may suggest that they have better digital competences than others.

5. Results

Sec. 5.1 to Sec. 5.3 focus on characterising and clustering our participants based on different factors that we assume to be a priori relevant to their privacy concerns and preferences analysed in Sec. 5.4 to Sec. 5.8.

5.1. Demographics, Background, and Living Conditions

78% of our 1090 participants are between 65 and 74, while 21% are 75 or older. 67% are men. Almost all our participants are living in an apartment or a house (99%). 70% do not live alone and 76% do not have a prior background in computer science or robotics.

5.2. Ownership and Interest in Different Robots

14% of our participants own a cleaning robot, while 5% own a robotic lawn mower, and 1% own an assistance robot. Among the participants not yet owning a certain type of robot, we have asked them to indicate

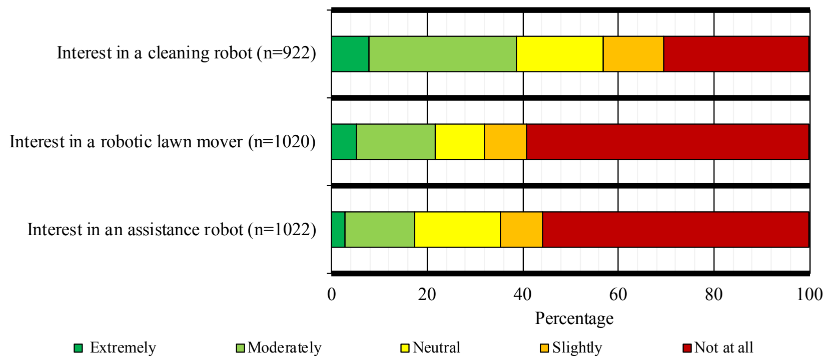

Figure 1: Expressed interest for different kinds of robot

their interest in owning such a robot in the future (Fig. 1). Overall, the participants are more interested in owning a cleaning robot.

A Mann-Whitney U test shows a statistically significant difference between the owners and non-owners of cleaning robots in their expressed interest in both robotic lawn mowers and assistance robots ($U = 45,038$, $p = 0.000$ and $U = 48,835$, $p = 0.001$, respectively). Similarly, there exists a significant difference between owners and non-owners of robotic lawn movers in their interest in assistance robots ($U = 19,121$, $p = 0.010$). A Kruskal-Wallis H test confirms a significant difference between the three groups of participants, i.e., owners, non-owners, and not knowers, in their interest in robotic lawn mower ($p = 0.040$). A pairwise comparison (Bonferroni corrected) shows that a significant difference only exists between owners and non-owners ($p = 0.050$). When comparing the mean ranks for all these cases, we observe that owners show a higher interest than non-owners.

We have also tested whether there exists a significant difference in the participants' interests based on their gender. Our results show that this is only the case for their interest in cleaning robots ($U = 84,288$, $p = 0.002$), for which female participants expressed a higher interest.

5.3. Preferences in terms of Robot Appearance

We have next elicited the participants' preferences in terms of appearance, as the robot design may impact information disclosure patterns [7, 11]. To this end, we have asked the participants to "[assume] that a robot can assist [them] in [their] daily tasks at home" and submitted four pictures of different robots to the participants: (1) a machine robot: *Home Security Robot* by 7links, (2) a semi-humanoid robot: *Pepper* by SoftBank Robotics, (2) a dog robot: *Wirless Robot Puppy* by Yeezee, and (4) a cat robot: the *Silver Companion Cat* by Joy for All. We have chosen these robots due to their diverse forms and their current availability to the public via, e.g., online retailers. We have especially added both cat and dog robots, as participants may prefer one of them like for real animals. We have then asked them to rank these designs according to their preferences and indicate the reasons behind their ranking (Tab. 1). Like in [20, 82], our participants are divided in terms of preferred robots, especially between human-like and machine-like robots. When considering their fist choice, 54% selected a robot which is a representation of an existing being, while 46% selected the machine robot. A reason given for the machine robot choice is that a robot should have a mechanical appearance. A similar opinion has been expressed by one out of 11 participants in [20]. However, our results seem different from those obtained in [83], where videos about the machine robot *Roomba*, the semi-humanoid robots *Nao* and *Pepper*, and the humanoid robots *Ishiguro* and *Erica* were shown. The participants preferred *Pepper* against the other robots including *Roomba*. The difference might, however, be explained by the different presentation format, information provided, and compared robots.

In a different question, we further asked our participants whether they would like the robot to exhibit human emotions. 70% indicated not to

Robot design	First rank %	Three most cited reasons	Citation %
Machine	46	Machine stays machine	60
		Practical	17
		Appearance	14
Human	35	Appearance	25
		Similar to self	22
		Gut feeling	20
Dog	11	Love for dogs	39
		Emotional	21
		Cute	21
Cat	8	Love for cats	39
		Emotional	26
		Gut feeling	21

Table 1: Distribution of ranked robot designs and corresponding reasons

want it. While a direct comparison is difficult due to different contexts and samples, participants would wish the machine robot *Care-O-bot* to include more human traits [82]. Younger participants [84] and a mixed sample in terms of age [85] also confirmed this trend, but highlighted that there should still be differences between robots and human beings.

5.4. Physical Closeness, Privacy-relevant Locations and Situations

We are interested in learning more about the participants' attitudes towards the resulting physical closeness and identifying situations, in which they would feel their physical privacy to be endangered. We indicated to the participants that "the assistance robot would remain in [their] proximity at home to assist [them] in [their] daily tasks". 31% of our participants indicated that they would overall feel moderately to extremely comfortable to have a robot around them at home, while 24% indicated not to feel comfortable at all. As expected, the participants' answers are divided when considering their level of comfort when imagining a robot in their vicinity.

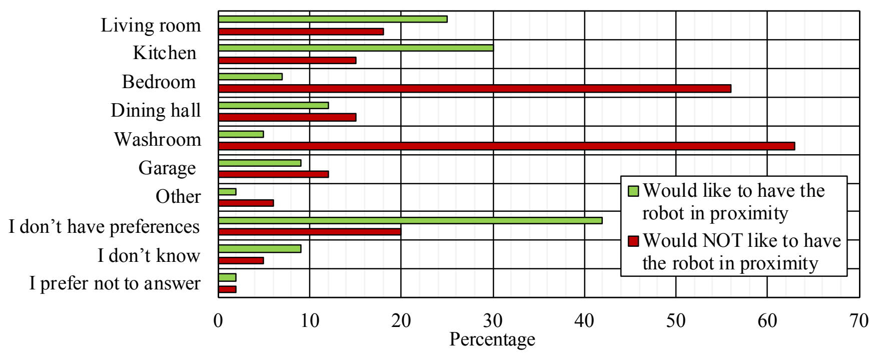

Figure 2: Locations where participants would like/not like to have a robot in proximity

The participants having selected different robot designs have expressed statistically significant different levels of comfort when considering the physical closeness of an assistant robot ($p = 0.000$). The participants having ranked the human robot first chose higher levels of comfort than those who chose a machine robot ($p = 0.000$) or a cat robot ($p = 0.007$). A possible explanation for this result is that these participants may feel more comfortable in this physical proximity with a robot with similar human characteristics as wished in [82]. Since both questions were disjointed, it is not sure whether these participants had their indicated preference in mind when answering the following questions, thus requesting an additional investigation.

42% of our participants do not have any preference about the locations where they would especially like to have a robot in proximity (Fig. 2). 30% indicated that they would like to have the robot in their kitchen and 25% in their living room, as it would be particularly helpful there and they spent most time in these locations. Conversely, both bathroom and bedroom are locations in which they would especially dislike to be accompanied by a robot. This finding is in-line with those of [55, 76]. Most participants justified their choices by privacy-related concerns. They perceive a robot

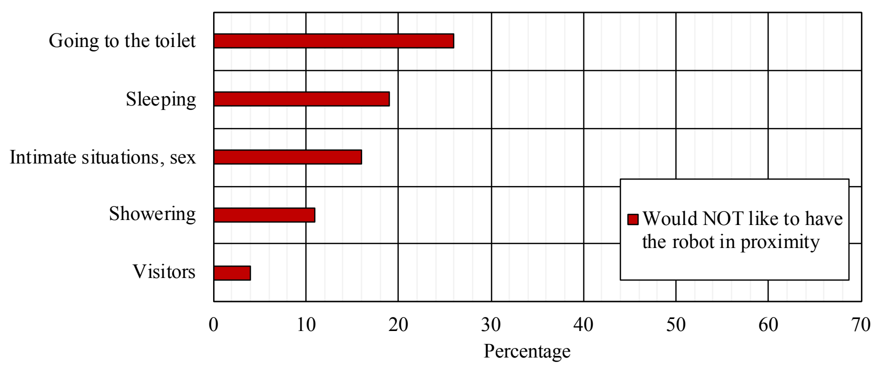

Figure 3: Situations in which participants would dislike to have a robot in proximity

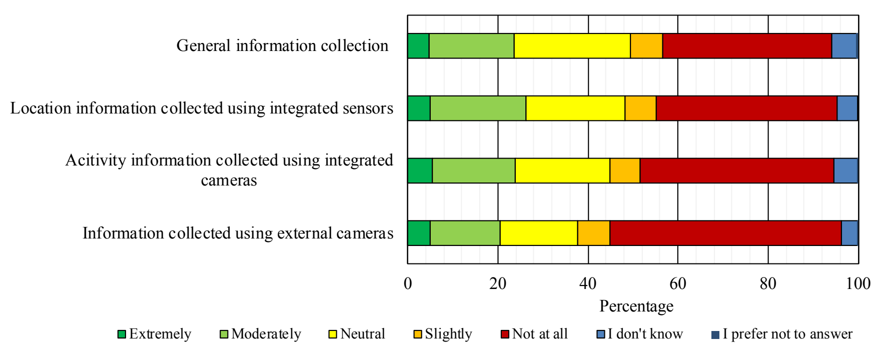

Figure 4: Comfort of robots collecting information

as a monitoring device capable of capturing sensitive and intimate data. Moreover, participants fear that a robot could determine their everyday lives and they would feel observed and restricted in their personal freedom. Besides, 3% of our participants do not want third parties to be able to access their data. Similar concerns have been raised in [9]. Participants do not trust the measures implemented to secure their data.

Participants would further prefer go to the toilet, sleep, have sex, or shower alone (Fig. 3). There is an overlap between our results and those in [58] that further include blowing their noise or doing personal finances.

5.5. Data Collection

We next focus on the participants' comfort when considering the collected data. Note that cameras are identified as a source of concerns in [86], while it is not the case in [82].

5.5.1. General Comfort

Fig. 4 shows how comfortable our participants indicated to be when the robot would collect information about them (e.g., their locations or activities). 31% would not be comfortable at all, while a total of 24% would feel moderately or extremely comfortable. Note that owners of cleaning robots indicated to be more comfortable than non-owners ($U = 71,130$, $p = 0.002$). The level of comfort is further significantly different between participants having chosen different robot designs ($p = 0.000$). Participants having preferred a human robot indicated to be more comfortable than participants having selected the machine ($p = 0.002$) or the cat ($p = 0.000$).

5.5.2. Collection Modalities

Fig. 4 also presents the level of comfort when the robot would collect information about their location using its integrated sensors, their activities with its integrated cameras, and in presence of external cameras. A Friedman test shows differences between the particular techniques used to collect these data. ($\chi^2 = 75.444$, $p = 0.000$). A post-hoc analysis conducted with Wilcoxon signed-rank tests with a Bonferroni correction further shows significant differences between the integrated sensors vs. integrated cameras (Z=-3.052, p=0.002), external vs. internal cameras (Z=-5.822, p=0.000), as well as integrated sensors vs. external cameras (Z=-7.864, p=0.000). A comparison of the mean ranks confirms that our participants would feel less comfortable in presence of cameras (both integrated as well as external) than integrated sensors. Overall, the lowest level of comfort is reached for external cameras. A possible explanation is that the participants value the information extracted by the mentioned sensors differently and that they are more sensitive to the collection of activity information than their location. To be able to better understand these aspects and decouple the impact of these different factors, a follow-up study is necessary.

Significant differences between different participants' groups exist. This is the case when we group the participants by (1) gender, (2) ownership of a cleaning robot, or (3) their preference in terms of robot design for all considered collection modalities. In more details, female participants selected a significantly lower level of comfort than male participants when considering the collection of location information using the robot's integrated sensors ($U = 135,112$, $p = 0.001$), the collection of information about their activities with its integrated cameras ($U = 138,406$, $p = 0.000$), and when external cameras would be installed to help the robot to navigate ($U = 144,721$, $p = 0.000$). Similarly, owners of cleaning robots would be more comfortable than non-owners ($U = 73,645$, $p = 0.004$; $U = 73,420$, $p = 0.001$; and $U = 76,167$, $p = 0.000$, respectively). Against our expectations, we also observe a significant difference between participants having selected different robot designs as their favourite for all considered collection modalities ($p = 0.000$ for each modality). Like in the previous questions, there is a significant difference between the ones having chosen a human robot as preferred design and all other groups. For all collection modalities, participants having chosen the human robot indicated a higher level of comfort as compared to each other individual group. Again, these differences suggest that this factor should be further examined in the future.

5.5.3. Location Prediction

To improve its assistance function, the robot could integrate a function to predict the user's future location. We assume that the participants may feel less comfortable when the robot would be able to predict it as compared to just collecting it. According to our expectations, 43% of our participants indicated that they are not comfortable at all with this functionality. Despite a different sampled age group, a similar concern about the robot being able to learn and make further inferences is expressed in [54]. However, no significant difference exists between the level of comfort indicated when considering the collection of this information and its prediction, but significant differences between the participants' groups exist. The expressed level of comfort is different based on gender ($U = 127,812$, $p = 0.000$), the ownership of a cleaning robot ($U = 70,361$, $p = 0.003$), and their favourite robot design ($p = 0.000$). Again, the level of comfort is higher for male participants, owners of a cleaning robot, and participants preferring a human robot rather than all remaining robot designs ($p = 0.000$ for all designs).

5.6. Data Processing

We assume that the modalities of data processing may impact the participants' degree of comfort. In the case of local processing, 25% indicated not to be comfortable at all with this solution, while a total of 37% indicated to be moderately to extremely comfortable with it. In contrast, 70% are not comfortable at all with their data being transmitted and processed online and 6% are overall comfortable with it. A Wilcoxon signed-rank test shows a significant difference between both processing modalities ($p = 0.000$), our participants being significantly more comfortable with the local processing option. This observation is confirmed by their answers indicating that they would like to have "all" their data locally processed. We only observe a significant difference between gender ($U = 127,537$, $p = 0.000$), ownership of a cleaning robot ($U = 71,169$, $p = 0.000$), and the preferred robot design ($p = 0.000$) for local processing. Female participants and non-owners of a cleaning robot expressed lower level of comfort, while participants preferring a human robot indicated significantly higher level of comfort than those preferring a machine ($p = 0.002$), dog ($p = 0.012$), and cat ($p = 0.004$).

5.7. Data Sharing

We now focus on information sharing with different parties. Our analysis is closely related to the participant's statement in [9]: "However, sharing my info with non-friends may not be pleasant", but goes beyond it.

5.7.1. Data Sharing with a Health Service

We assume that the robot can identify users' location and current position (standing, sitting, or lying) to monitor their health status and transmit these data to a health service. Most participants (63%) do not like the idea of this information sharing. Among the ones supporting it, most would prefer to share these data only in case of emergencies (70%), while 22% would prefer periodical sharing and 8% continuous sharing, respectively . Most participants indicated that information about themselves should only be transmitted in dangerous situations to be able to get help. Among the participants having indicated that they would like to share these data, only a total of 37% would feel moderately to extremely comfortable.

Having anticipated the participants' answers, we next focused on sharing the same data but for detecting emergencies like falls. Specifying the data sharing purpose leads to an increase of 19% of participants willing to share

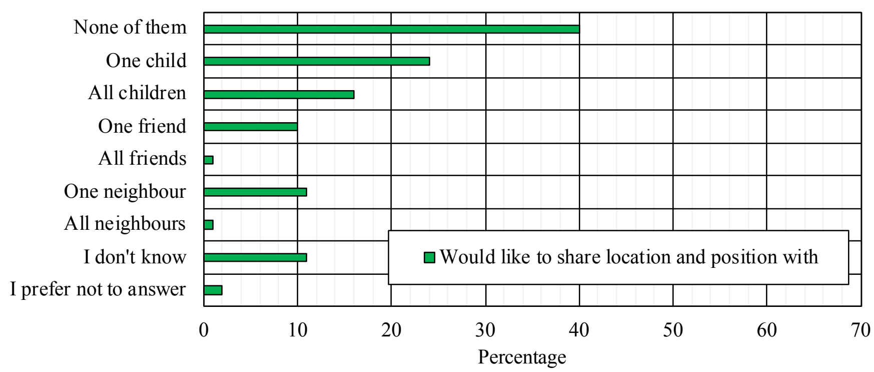

Figure 5: Categories of people to share location and position information with

their data. This however means that 44% still do not appreciate the transmission of their data even in such cases. A total of 46% of the participants wanting to share these data would feel moderately to extremely comfortable to share them. 20% would feel uncomfortable, though.

5.7.2. Data Sharing with Trusted People

We further assume that our participants might like to share information with trusted people. We expect that participants may trust these people more than an anonymous health service. Conversely, they might prefer using an independent health service instead of bothering these people. Note that different preferences have been observed when family members could start a video stream. In [47], the participants did not express concerns about it, whereas those in [45] wished to control it. Participants have also shown concerns about sharing health-related data with family members in [16].

We hence asked our participants with whom they would like to share both location and current position apart from the health service. 40% would prefer not share these data with any other people (Fig. 5). In contrast, 24% would share them with one of their children and 16% with all their children.

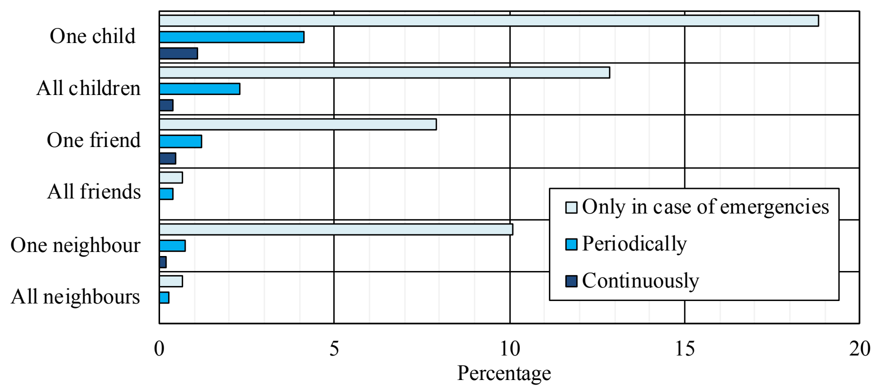

Figure 6: Frequency of sharing location and position with different people

The option of sharing these data with one friend or one neighbour appears to be a viable solution for some participants. Most participants indicated that the proximity of these people is determinant. Other factors like trust and current family situations have also influenced their choice.

Most participants having indicated that they would like to share these data with others confirmed that they would like to share these data preferably only in case of emergencies (Fig. 6). Still a minority would choose to send these data either periodically or continuously. However, not all participants indicated to feel comfortable with this sharing (Fig. 7). In all considered cases, fewer than 40% of our participants having chosen this option would feel extremely or moderately comfortable in sharing them.

The results hence confirm that our participants would prefer to have a transmission of their location and current position only in case of emergency. This result is aligned with the privacy-utility trade-off identified in [12–18]. The level of comfort, however, remains lower as expected in case of emergency detection. The same applies to data shared with one of their children.

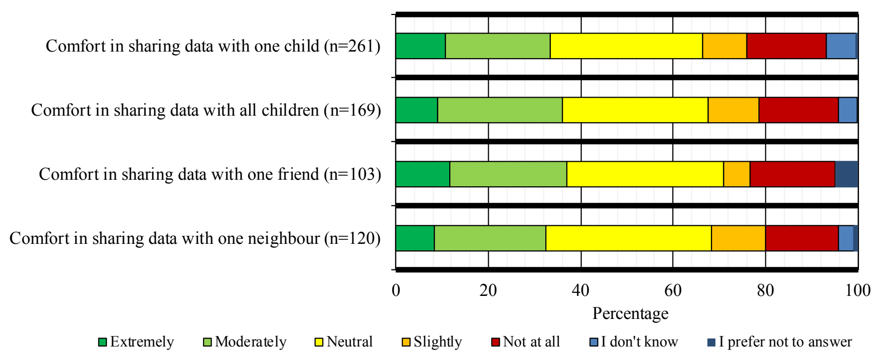

Figure 7: Level of comfort when sharing location and position with different people

5.8. Control and Transparency

We finally explore control and transparency preferences motivated by the fact that the consent of older adults should be informed [8]. Its importance has been confirmed in [18], where the values of the knowledge of the nature of the collected data, their purpose, interpretation, storage, but also the capability to control the access, review, or delete collected data have been investigated. The topic of data storage has been addressed in [9, 16, 82]. Overall, the participants indicated in [9] that they wish no sensitive data to be stored except if their utility outbalance their concerns. In [82], the participants further wished to control the nature of the stored data, while participants wished to access the stored data in [9, 16].

Our results confirm the aforementioned qualitative findings. Most of our participants want to be able to (1) select the specific type of information that is collected about them (such as health or location information), (2) see and review the different types of collected information, (3) see and review shared information, and (4) know the information storage duration (Fig. 8). In comparison, only 49% are interested in seeing their predicted location.

A Cochran's Q test confirms a significant difference between these an-

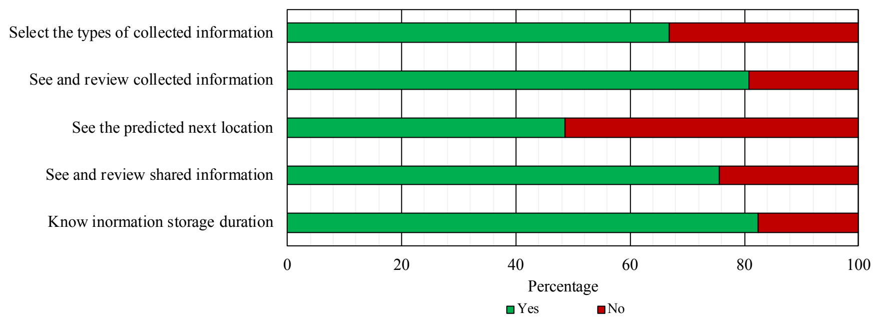

Figure 8: Willingness to select, access, know, or review different data

swers ($\chi^2 = 703.777$, $p = 0.000$). Only the difference between the participants' willingness to see and review collected information vs. the knowledge of the information storage duration is not significant ($p = 0.256$). For all other pairs, the differences are significant with $p = 0.000$. Our participants are thus more interested in seeing and reviewing the collected information than selecting the types of information to be collected. Likewise, they are more interested in seeing and reviewing collected than shared information. Many participants also indicated that they would like to know the information storage duration. These results are surprising because we expected that the participants would be more willing to control than see and review what has been collected or shared. A possible explanation could be that the participants could feel more confident in seeing and reviewing that actually taking a decision as it would require more knowledge.

5.9. Summary and Discussion

While having the limitations of our study detailed in Sec. 4.4 in mind, the majority of our results are in-line with our expectations and reflect previous results. For example, this is the case for the influence of the participants' gender on their answers. As shown in other contexts, e.g., in [87], female participants tend to express more privacy concerns. About the observed differences between owners and non-owners of cleaning robots, we assume that they are due to the fact that the former have already accepted a robot in their environment. For us, the most surprising is the differences observed based on the participants' preferred robot design. When significant, participants having selected the human robot as their favourite one felt overall more comfortable than at least one other participants' group. Since we did not ask the participants to imagine the robot having this exact design across our questions, it is difficult to elaborate on a possible explanation.

When considering our sample as a whole, our results indicate that only about a quarter of our participants would feel comfortable about the collection of their location and activity. We further observe a difference in their claimed level of comfort depending on the data collection modalities. Our participants would also overall prefer local data processing. Many of them are not willing to share their location and current position with a health service even to help detecting emergencies and with any other potentially trusted people. Most participants are however interested in seeing and reviewing their information and knowing the associated storage duration. This suggests a need for transparency solutions as recommended in [8, 41, 88], which should however be confirmed in practice since such solutions would require users to invest additional resources. In comparison, the selection of the types of information to be collected as well as seeing their next location as predicted by the robot appear to be less attractive to them. A majority of our participants however indicated to feel uncomfortable with the robot being able to predict their next location. It could therefore be interesting to further investigate whether providing transparency and supporting explainability would impact the resulting level of comfort.

6. Conclusions

We have explored the attitudes towards mobile home assistant robots of a sample of 1090 older adults in German-speaking countries. We have quantified the participants' level of comfort and preferences when considering different options regarding the data collection, processing, and sharing—all aspects related to informational privacy. We have further compared their willingness to control or see and review different information types.

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