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AmI in good care? Developing design principles for ambient intelligent domotics for elderly

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Abstract
The combination of ambient intelligence (AmI) and domotics has the potential to respond to elderly people's desire to live independent from extensive forms of care. Their slow adoption of technological aids shows reluctance, though. This article investigates their motivations to adopt ambient intelligent domotics, and proposes design principles specifically based on their preferences and experiences. Respondents appeared to be more acceptive of tangible problems they expected with AmI domotics than intangible ones. In addition, their opinions seemed to be profoundly influenced by the way they perceived their psychological quality of life, while their physical conditions did not seem to have noticeable impacts.

Keywords: *Ambient intelligence, domotics, obtrusiveness, elderly*

1. Introduction

The elderly population in the Netherlands is growing rapidly; in 30 years, 25% of all Dutch inhabitants will be over 65 years of age [1]. Generally, seniors live in their own homes until their physical or psychological conditions require them to have the assurance of continuously available care. Depending on their needs for the intensity of professional attention, they then move to domiciliary care, residential care or nursing homes [2].

Due to this growth of the elderly population, costs of professional care are expected to increase. As seniors traditionally use disproportionately much health care, the pressure on this sector will increase [3].

Simultaneously, however, the desire among elderly people in the Netherlands to live at home independent from extensive care increases. As a result, the percentage of seniors living in residential care homes is expected to decline from 9 to 5% in the next 20 years [4].

Development in the field of domotics, which aims at optimising communication between high-end electronic devices in the home environment for the benefit of its inhabitants, has produced household solutions that enable elderly to live independently up to higher ages [5].

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It has been implied in literature that a combination of domotics and the vision on environmental reasoning technology known as ambient intelligence could strongly improve domotics' functionality [6]. AmI comprises a vision in which technology is integrated in and aware of environments, and able to make reasoned decisions [7].

Intelligent technology integrated in everyday objects, aware of its surroundings and users' conditions, could considerably enhance the effectiveness of regular elderly domotics and enable new solutions [8]. For example, simple alarm buttons worn by users could be enhanced to measure physical discomfort and automatically alert emergency services.

Both the availability and the usability of domotics for elderly are limited [5]. This may delay the diffusion of assistive devices. Many of the issues encountered with regular domotics could be solved through AmI approaches, but such devices would come with their own acceptance problems [9].

1.1. Design principles

Literature stresses that due to ambient intelligence's vast capabilities and the impact it could have on users' lives, people should not be regarded as passive users but as active co-creators. Aarts and Marzano [7] argue that AmI design involves 'human culture in its broadest sense: different value systems, individual likes and dislikes, sustainability, codes of ethics, conduct and communication'.

In general, seniors have more problems adopting technology than younger people, especially because of their lack of experience with it and their decreased physical and psychological abilities [10]. As a result, domotics are often among the first technological aids they adopt. Since ambient intelligent domotics are often considered aids for people with disabilities, especially seniors should be taken into account when proposing design principles [11].

In a user-centered design approach, models or guidelines would be used as fundamentals to build from users' expectations instead of technology's capabilities. While principles regarding the ethical, behavioural and technical aspects of AmI exist, all are based directly on theoretical viewpoints, instead of users' experiences and preferences [12–14].

The motivation for conducting this study arose from the aspiration of creating principles for the design of AmI domotics, based on elderly users' preferences and expectations towards them.

While AmI domotics, by definition, would be designed to be all-encompassing but not noticeable, in reality they would require a considerable level of attention: users have to interact with the devices; systems may address users when necessary; sensors continuously collect data; homes have to be redecorated to accommodate all equipment.

Consequently, AmI domotics, while significantly enhancing users' mobility, would come with their own acceptance problems [9]. In the field, these are typically referred to as *obtrusiveness* issues, a term that is interpreted as 'protruding' or 'undesirably noticeable'. These issues could severely delay or disturb the diffusion of AmI domotics.

Through interviews conducted with elderly people, the obtrusiveness issues they perceived with regard to AmI domotics were incorporated into the design principles.

2. Theoretical framework

2.1. Obtrusiveness

Hensel et al. [9] recognise that the terms obtrusiveness and intrusiveness are often, but inconsistently, used in literature on AmI. Aiming to generalise these terms, they proposed a framework that distinguishes eight dimensions of obtrusiveness that users may experience:

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1. Physical dimension; physical discomfort, such as space obstructions, noise, or aesthetic incongruence;
2. Usability dimension; lack of user friendliness and accessibility;
3. Privacy dimension; invasion of privacy and violation of personal space;
4. Function dimension; lack of perceived reliability and effectiveness, including systems' malfunctioning or incorrect assessment of situations;
5. Human interaction dimension; lack of human response in emergencies and the fear of detrimental effects on relationships;
6. Self-concept dimension; symbol of loss of independence, which may lead to embarrassment;
7. Routine dimension; interference of daily activities and acquisition of new rituals; and
8. Sustainability dimension; concern about affordability or future abilities.

2.2. Five layers of ambient intelligence

The impact the aforementioned obtrusiveness dimensions have depends on the degree to which AmI is implemented in users' environments. Aarts and Marzano [7] distinguish five cumulative implementation layers through which they expect ambient intelligent technology to be incorporated in society, each one more technologically sophisticated than its precursor:

1. Embedding: sensory equipment necessary for ambient intelligent services is physically embedded in environments to such extent, that users hardly notice its presence;
2. Context-awareness: equipment is aware of environments' as well as users' characteristics, and combines these to provide more extensive information;
3. Personalisation: equipment uses environmental information in conjunction with user profiles to determine its actions and provide advice;
4. Adaptation: equipment uses environmental information to determine its actions and automatically adapts to it; and
5. Anticipation: equipment analyses environments and adapts beforehand to prevent undesirable situations from occurring.

2.3. Obtrusiveness per implementation layer

Not all obtrusiveness dimensions are expected to be experienced to the same degree in all implementation layers of AmI. Some may be continuously present in all layers, but most will become more or less aggravated in later ones due to increased infringement or user-friendliness.

By interpreting the literature elaborating upon obtrusiveness, we have mapped the dimensions identified by Hensel et al. [9] to the five layers proposed by Aarts and Marzano [7]. Figure 1 shows the degree to which obtrusiveness is an issue in each of the five layers. A lighter shade of grey indicates a less prominent obtrusiveness issue, while a darker shade signifies a more heavily represented one. The dimensions are interpreted as follows:

1. Physical dimension: the physical presence of sensors and equipment is present from the first layer, but does not increase in later ones;
2. Usability dimension: while it could be argued that more complex systems in later layers may require more user intervention than simpler ones, it can be expected that usability issues will gradually diminish as later systems occupy more intelligent reasoning systems.

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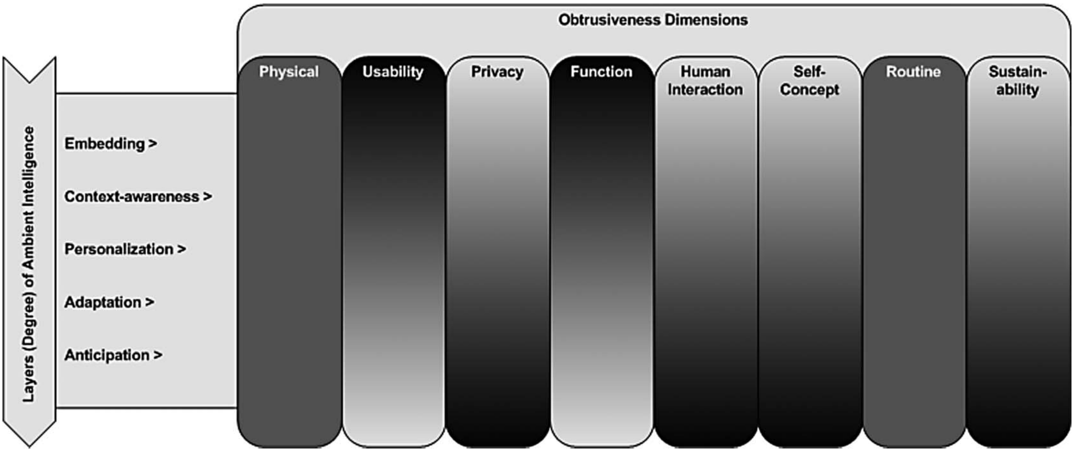

Figure 1. The impact of obtrusiveness issues in each of the five layers.

3. Privacy dimension: from the first layer, privacy infringement may be an issue, as sensors and cameras may have to be placed in users' houses. However, as in subsequent layers these start to gather more specific information and tie them to personal or historical records, the perception of privacy infringement is expected to worsen (even as the sheer amount of data gathered may decrease due to more efficient recording);
4. Function dimension: in early layers users may expect too much from systems and, as they are disappointed with their results, distrust them. As systems grow more complex, users are expected to experience less functional disappointment with them. While it can be argued that more complex systems may malfunction more often, it may be expected that due to their more personal and adaptive approach, users will perceive systems' reliability and effectiveness as being better than those of earlier systems.
5. Human interaction dimension: as devices become more capable and intelligent, human caregivers become unnecessary. Consequently, relationships with carers and family may lose intensity;
6. Self-concept dimension: when ambient intelligent domotics become more capable, users may feel more dependent. Their sense of self-concept and confidence may diminish;
7. Routine dimension: in the first layers, users may have to accommodate requirements of domotics in their daily activities, and perceive that as obtrusive. In layer phases, domotics may perform so many actions that users may experience this as interfering with their routines; and
8. Sustainability: when costs increase, it may become more difficult to maintain domotics. Additionally, if users' conditions deteriorate to such extents that domotics can no longer assist them, they may have to give up tools they've grown used to.

2.4. Senior technology acceptance and adoption model

The reasons why people choose to accept technology in their lives has been extensively studied [15–17]. One of the most accepted models in this field, the Technology Acceptance Model by Davis [16], has been extended to explain technology acceptance by elderly people; this adaptation is known as the Senior Technology Acceptance & Adoption Model (STAM) by Renaud and Biljon [18].

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The model consists of three phases: an *objectification* phase in which people's intentions to use new technology are determined; an *incorporation* phase in which people actually use and experiment with the devices; and finally the *conversion* and *non-conversion* phases, in which people either accept or reject them.

In this study, people's intentions to use technology, and thus the *objectification* phase, are the objects of study. Renaud and Biljon [18] have determined perceived usefulness and user context as the two influencing factors on that aspect. Perceived usefulness comprises the effectiveness and worth people allocate to new devices. User context consists of demographics, personal beliefs and mostly social factors that influence technology adoption. The way in which these factors were taken into consideration in this study will be elaborated upon in the following sections.

2.5. Quality of life

Quality of life is a term common in the fields of psychology and medicine, and comprises the well-being people perceive in their own lives. It is a subjective indicator of one's physical and psychological health situation.

Felce and Perry [19] define it as someone's life conditions and his or her personal satisfaction with them. They propose an all-inclusive model to depict quality of life, distinguishing five different domains of physical and psychological satisfaction.

The model by Felce and Perry [19], however, incorporates a very broad concept of quality of life, not specialised for any group. As some of the aspects they mention, such as job satisfaction and education, are of lesser relevance to elderly people, the model was adapted by emphasising the elements elderly people themselves indicated valuing in their lives in a study by Xavier et al. [20].

It comprises five areas of physical and psychological well-being:

1. Health: people's physical conditions and bodily constraints;
2. Active well-being: people's abilities to partake in activities and their satisfaction with their efforts;
3. Material well-being: people's satisfaction with their assets, including financial and physical possessions;
4. Social well-being: the importance of and satisfaction with social relationships people experience; and
5. Emotional well-being: people's self-concept, confidence, and the extent to which they feel they are contributing to society.

2.6. Adoption of AmI domotics

As will be described more extensively in the section on the research design, a qualitative approach with 21 respondents was used. As such, no hypotheses could be tested. We did, however, have certain expectations with regard to the outcomes of the data analyses, as will be elaborated upon below.

Following the STAM theory as described earlier, it was assumed when conducting this study that the way people perceive their quality of life influences their stances towards technology adoption and ultimately their acceptance [18]. The conditions assembled in the psychological and physical well-being terms influence the two determinants of the STAM that define people's intentions to use technology.

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People's psychological well-being, comprised of people's social attitudes and emotional stability, largely determines their user contexts. The more positive their emotional well-being and attitudes towards care and domotics, the more likely they are to accept new solutions.

People's physical well-being, consisting of general health and specific physical constraints, influences people's attitudes towards perceived usefulness; the more constraints people experience, the greater their need for supportive aids.

The research design used was aimed at finding both elderly people's attitudes towards domotics' obtrusiveness dimensions, and how they perceive their lives' quality. With the results of these questions, insight was gained into people's perspectives towards domotics, and to what extent these are influenced by their quality of life.

3. Research design

In order to determine the attitudes of elderly people towards ambient intelligent domotics, empirical evidence was sought; conclusions were drawn from just single measurement moments.

3.1. Research Group

The research group consisted of 21 seniors in various conditions of mental and physical ability. Because of this, we chose to conduct single face-to-face interviews in places comfortable to them, preferably respondents' homes.

Respondents were selected via a quota sample; as people's health was believed to relate to the care-intensiveness of their residence, seniors (over 65) from various types of elderly living environments were selected to form three subgroups. A fourth group consisting of younger people (under 65), whose members were completely independent and who did not yet experience the physical deterioration of aging, was interviewed as well. Quota sampling was preferred over more random selection methods, as seniors' conditions often made it difficult to participate (e.g. due to concentration problems).

The following subgroups, based on living environments, were distinguished:

1. Independent-living elderly ($n = 5$): this group of elderly still lives at home and does not receive professional care;
2. Elderly in domiciliary care homes ($n = 5$): people living in domiciliary care live in houses located closely to residential care homes, and only get help with activities of daily living, such as bathing or cooking;
3. Elderly in residential care homes ($n = 6$): this group of people, living in residential care homes, is more dependent than the previous group and needs professional help on a daily basis.
4. Prospective elderly ($n = 5$): people aged between 50 and 65 are surveyed to investigate to what extent generational differences influence attitudes towards AmI.

The data extraction methods described below were issued consecutively during sessions in respondents' homes; these took from 60 to 90 min and were never interrupted or suspended. Respondents were briefly informed about the research project and assured of their anonymity before being asked for their consent. In order to analyse the results, the interviews were audio recorded.

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3.2. Methods

The quality of scientific research to a great extent depends on the reliability and validity of the methods used to conduct the study. Reliability is generally understood as the accuracy of the research methods, while validity authenticates their appropriateness to the research questions [21].

In order to ensure the reliability and validity of the results, Golafshani [21] argues the usage of triangulation, or using multiple methods to confirm the results. While in the stricter sense triangulation is interpreted as applying three methods to measure a single phenomenon, it has been defined by Denzin [22] as 'the combination of methodologies in the study of the same phenomenon'. In this study, we applied two methods to study both respondents' quality of life and their attitudes towards ambient intelligent domotics.

3.2.1. Vignette method. A vignette method was used to find people's attitudes towards AmI domotics. The approach of the method consists of having respondents judge certain hypothetical scenarios, or vignettes [23]. These exist of short stories describing a situation, providing any information that is considered influential. Respondents are to evaluate or judge these vignettes, based on their personal preferences in the situations described.

In this study, eight vignettes were used – one for each obtrusiveness dimension – of which the answers depicted various layers of AmI. Vignettes comprised situations that featured common problematic activities in seniors' daily lives (e.g. considering safety or mobility); respondents were asked to indicate to what extent they would like (ambient intelligent) domotics to aid them in those situations.

Below is an example of a vignette as it was used in the study.

You're home alone; you slip and fall in the bathroom and sprain your ankle. Without help you're unable to get up and so you're forced to keep lying on the ground.

- *Since you do not have devices in your home you can't do anything.*
- *You wear an alarm button around your neck that you press for help.*
- *Integrated within your watch is a device that automatically detects your accident and sends out a request for help.*

3.2.2. Nottingham health profile. Various validated tests for the identification of people's perceived quality of life were assessed, and the Nottingham Health Profile (NHP) proved most applicable for this study [24]. It is able to identify both physical and psychological aspects of people's attitudes towards life and is still short enough to ensure it can be filled out by elderly respondents. It has been thoroughly validated and is available in the Dutch version by Oudhoff et al. [25].

The NHP consists of 38 questions classified by six categories, each of which has a weighting of 100. The 38 questions that have to be answered are short statements to which respondents either agree or disagree.

3.2.3. Semi-structured interview. Finally, to identify both respondents' attitudes towards AmI domotics and their perceived quality of life, a semi-structured interview was used. This method was chosen because of the freedom in questioning and the free association during the conversation it offered. Respondents can freely discuss subjects, going back and forth through subtopics and referencing earlier answers [26].

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During the interview, subjects relating to domotics, including usability, aesthetics, reliability and trust were discussed in the context of seniors' daily problems, such as safety and mobility. Respondents were able to expatiate on the subjects and add more nuanced commentary, if they wanted to.

3.3. Reliability and validity

As described before, a triangulated approach was used to ensure the study's reliability and validity. During conduction, however, examples in the vignettes often had to be adjusted to actual situations of elderly respondents, to ensure they could refer to the questions. Consequently, the vignette study's results were only reliable to a limited degree and analysed with considerable reservation. During the analyses and interpretations, qualitative data has been relied on; quantitative data was only used to confirm discovered patterns.

4. Results

4.1. Data analyses

In order to analyse the qualitative data collected during the interviews, a method known as the Constant Comparative Analysis was used. Originally developed by Glaser and Strauss [27], the focus of this method centres on the comparison of all interview elements as they are gathered in order to create conceptualisations or discover relations among them. As Hart et al. [26] add, patterns can thus be discovered in the data that allow for abstractions and generalisations in later phases of the project. A three-step approach proposed by Boeije [28] was used to conduct the analysis; this standardised method consists of comparing phrases within a single interview, within research (sub)groups and between (sub)groups.

Because of the compromises taken into account regarding the vignette study, mainly qualitative data was used to discover patterns. The quantitative data was analysed with descriptive statistics to confirm those.

4.2. Patterns

The quantitative and qualitative datasets were analysed to find patterns regarding the impact of people's perceived quality of life on their attitudes towards ambient intelligent domotics.

From the results of the interviews, patterns regarding their perceived quality of life and people's living environments can be examined. Especially with regard to physical constraints, it is clear that the more care-intensive environments people inhabit, the worse their physical conditions are. A weaker pattern was found with regard to people's psychological well-being and their living environments; it showed that people in more care-intensive environments are less emotionally and socially content than others.

Results show that the prospective group of 'upcoming' elderly was by far the most progressive one regarding ambient intelligent domotics. The other groups were mostly divided or, in the case of the independent group, mostly conservative in their answers. Generally, people appeared to be more progressive towards 'tangible' issues, such as domotics' physical presence or usability than towards 'intangible' issues, concerning disturbances of their routines or self-perception.

Regarding the influence of well-being on their attitudes towards domotics, it appeared that elderly people's psychological state of mind was of greater importance than their physical conditions. The strongest patterns were observed with the more 'tangible' obtrusiveness

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dimensions. Expected problems with people's self-perception or disturbances of their routines were not as strongly related to psychological or physical well-being.

Figure 2 illustrates people's attitudes towards domotics. Conservative answers are mapped onto earlier ambient intelligent layers (*embedding* or *context-awareness*), while progressive answers are mapped onto later layers (*adaptation* or *anticipation*); the density of the rectangles' shading indicates how many people gave a certain answer. Evidently, many people responded protectively to questions concerning 'intangible' items, such as routine disturbance or privacy infringement. On 'tangible' issues, including domotics' sustainability or their physical appearance more people answered progressively.

The relation between their attitudes and their psychological well-being shows that respondents who answered conservatively had more pessimistic, passive attitudes that were often exemplified by loneliness or indifference. By contrast, people who answered progressively were more likely to have optimistic, active attitudes, instead. As mentioned earlier, no similar patterns concerning physical conditions were found.

The specific well-being patterns found for each obtrusiveness issue are summarised here:

1. Physical dimension: the physical presence of domotics did not seem to be a major obstacle in their acceptance, since almost half of the respondents indicated eagerness to adopt them. Quite strong patterns were found relating their attitudes to people's psychological well-being, but no physical ones were found;
2. Usability dimension: respondents were uncompromising in their attitudes towards usability issues. Except for the group of prospective elderly most respondents lean towards conservative answers, indicating they expected problems with usage. Strong psychological relations were found in the data, but only slight physical ones;
3. Privacy dimension: many respondents were protective of their privacy; members of the prospective group less so than others. Strong psychological patterns were discovered, indicating that 'happier' people were more acceptive of privacy infringements. Only slight physical relations could be found;
4. Function dimension: respondents seemed to be divided over this issue and did not share many answers; many were not very willing to rely on domotics. Interestingly, some prospective group members indicated accepting domotics if the functionality would be

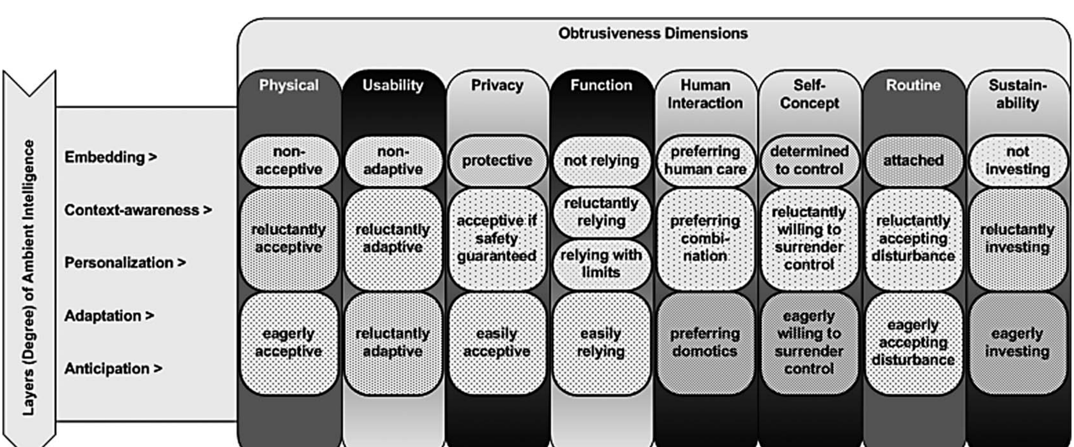

Figure 2. Respondents' attitudes towards AmI domotics, divided by obtrusiveness aspect, mapped to the implementation layers of AmI.

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limited. Only slight psychological patterns were found in the data, and hardly any physical ones;

5. Human interaction dimension: people generally preferred domotics over human care because of the unlimited availability of technology. Strong psychological relations were found among them, indicating that more self-conscious people preferred domotics. Physical patterns were hardly found;
6. Self-concept dimension: respondents were divided over this issue; they either wanted to stay completely in control or did not mind having decisions getting taken out of their hands. Only slight psychological and physical patterns were found in this data;
7. Routine dimension: most respondents indicated being very protective towards their daily routines and did not welcome disturbances by domotics. Consequently, only slight psychological and hardly any physical patterns could be discovered; and
8. Sustainability dimension: people indicated eagerness to invest in care, whether domotics or human care. Especially members of the prospective group did not mind commercial exploitation of domotics. Slight psychological and physical patterns were found in the data.

5. Discussion and conclusion

The purpose of this study was to determine elderly people's attitudes towards ambient intelligent domotics, taking into account their perceived quality of life. Based on this design principles were to be proposed.

Results show that people's psychological well-being has a strong influence on their attitudes towards the acceptance of domotics. No similar pattern could be distinguished that related respondents' physical conditions with their willingness to adopt ambient intelligent solutions.

The psychological findings in this study are similar to the predictions of the Senior Technology Acceptance & Adoption Model, introduced in the Section 2. Social pressure is believed to have a major effect on people's acceptance of new devices; Venkatesh and Davis [17] argue that 'people may choose to perform a behaviour, even if they are not themselves favorable to the behaviour or its consequences, if they believe one or more important referents think they should'. With regard to elderly people, Renaud and Biljon [18] state that 'friends and relatives, especially the opinion of children and grand-children impact the behaviour [sic] of the elderly mobile phone user'. In a more technology-oriented sense, they argue that elderly people's mental abilities to comprehend the concept of a specific device influence their adoption of it.

In a more general psychological sense, Ajzen [15] reasons that people's attitudes and beliefs largely determine their intentions to perform actions, as 'these salient beliefs [. . .] are considered to be the prevailing determinants of a person's intentions and actions'. The influence of these beliefs on technology adoption have to date not been irrefutably demonstrated but the literature on technology acceptance is in line with the Theory of Reasoned Action, so there is no reason to assume otherwise.

The physical results of this study do not match the expectations based on the Senior Technology Acceptance & Adoption Model. Potential users' physical abilities are not generally considered in technology acceptance models, but they are believed to influence the perceived usefulness attributed to devices. People's impaired abilities may restrict them from using new technology [18]. However, devices that assist in caring and as such improve people's well-being are believed to positively influence their perceived usefulness; this expectation corresponds with discourse in the literature [8,6].

No findings were discovered in this study that could confirm the expectation above; it appeared that respondents in good physical health were generally less willing to accept domotics,

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but there was no pattern that confirmed the idea that people in bad physical conditions were more adaptive to them. This may be a result of people reasoning that their impaired abilities make usage of technology difficult or impossible. Often-heard comments in this study concerned people's willingness to try new technology and their frustration of not being able to. As one visually impaired respondent put it: 'I would like to use a mobile phone, if only I could'.

Regarding their attitudes towards AmI, people seemed to be more progressive towards the tangible areas of obtrusiveness than the intangible ones. With the tangible subjects, such as the physical presence of domotics or their cost, respondents were willing to accept a higher intensity of obtrusiveness. Simultaneously, people were more conservative in their tolerance of infringement on intangible aspects, such as disturbances to their daily routines or breaches of their privacy.

The reasons for this difference in attitude may be found in various reasons. First, the consequences of intangible obtrusiveness issues on people's lives may be more considerable than tangible ones. Because of this, people may have been more conservative in their answers on these issues. Second, respondents may have had more outspoken opinions on the more 'tangible' aspects they are more comfortable with. Finally, people may not have been as willing to share their thoughts on the more personal 'intangible' aspects than on the 'tangible' ones.

5.1. Design principles

Literature stresses the importance of involving potential users in the development of AmI [7]. To this end, the design of development guidelines based on users' preferences is advocated for [29]. Because of the applicability of AmI domotics for elderly users, and this group's slow technology adoption, a set of design principles for AmI domotics specifically based on seniors' preferences and experiences is required.

These design principles have been extracted by analysing the interviews through the Constant Comparative Method, by interpreting and assembling the opinions most often shared. These were reduced into concise statements to guide the development of ambient intelligent domotics.

These design principles are summarised below.

Ambient intelligent domotics

1. *should be embedded, invisible, tranquil and aesthetically conforming;* domotics should blend in with the environment and not disturb users without necessity;
2. *should function autonomously;* domotics are expected to operate by themselves, asking user input only when required;
3. *should be operable intuitively and unambiguously;* domotics should be operable through means natural for elderly users, through definitive, unchanging interfaces;
4. *should have distinctive and limited functionality;* domotics should have clear and limited functions and not be all-encompassing;
5. *should not be controlled or influenced by, nor substitute human relationships;* domotics should operate technically, without intervention by humans. At the same time, they should not aim at replacing human relationships;
6. *should act subordinately and unpretentiously;* domotics should leave users feeling they are in control and act helpfully;
7. *should gather private information moderately and manage it discreetly;* people are concerned about their privacy and thus domotics should only collect personal data when necessary; and

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8. *should communicate clearly about capabilities and sustainability;* domotics should not exaggerate their abilities, nor misinform users about their own capabilities.

5.2. Applicability

Currently, AmI domotics, aware of and attending to their users and surroundings, cannot be technically realised. Technologically less sophisticated forms of domotics are available, however, including safety and burglar alarms. Since these appliances are among the domotics most often found in seniors' (care) homes, many questions in the research that led to this article concerned alarm systems.

The development of AmI domotics allows for a division of alarm systems in two types: 'active' alarms, which are the classical alarm buttons that require user intervention, and 'passive' alarms, which operate independently by monitoring users' activities or health [5].

Active alarms could benefit from the guidelines proposed above, if developers would take into account the principles on aesthetics and intuitive operability. Respondents in this study often indicated disliking alarms' appearances and how they stood out in their homes. Alarms with designs more aesthetically conforming to their preferences could increase people's acceptance of them. Regarding operability, developers should aim at designing interfaces in which all buttons have distinct functions, as respondents indicated preferring such 'mechanical' interfaces to more efficient multi-functional ones.

In most scenarios about the possible working of passive alarms, cameras are used to observe people and monitor anything from simple movement to deviations from their daily routines, in order to detect distress situations. When confronted with this idea, respondents in this study clearly indicated wanting guarantees regarding their privacy. Thus, in designing these systems, developers should not only focus on ensuring the technical safety of the devices, but also on presenting them to users in the least protruding way. This could be done by aesthetically integrating the cameras within the home environment, or informing users about their techniques and reassuring them that they're not being watched by human supervisors.

5.3. Limitations

Even though many precautions have been taken into account, some limitations should be applied when interpreting the results of this study.

First, the methods may not always have identified the intended phenomena. As described earlier, the vignette method's results were applicable only to a limited degree. The negative effects this had were reduced by using a triangulated approach.

Second, the conditions in which the interviews and tests were conducted may have inadvertently influenced respondents' attitudes. These effects were limited by conducting the interviews in places comfortable to respondents (usually their homes) without the social pressure of other people.

Finally, the composition of the research group makes generalisation difficult. The limited number of respondents, as well as their social backgrounds and geographical locations, makes it difficult to generalise beyond a theoretical level, outside of the study participants.

5.4. Further research

The design principles proposed in this article serve as user-focussed guidelines for the further development of ambient intelligent domotics. Additional research on the impact AmI domotics may have on users' lives is required. Further research should aim at confirming

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people's attitudes towards the obtrusiveness issues identified in this study, as well as the relations between these and people's psychological and physical conditions.

The findings reported in this document should be validated by similar research studies to ensure their reliability; especially findings that do not concur with other literature in the field, such as the absence of relations between respondents' physical conditions and their attitudes, should be investigated. The design principles should be tested with research groups consisting of other population groups to ensure their generic applicability.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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