

Improving Awareness and Social Connectedness through the Social Hue: Insights and Perspectives

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ABSTRACT

The ability to maintain a high cognitive function, autonomy and social support are key factors to promote “successful” ageing. The Social Hue is an envisioned peripheral awareness lighting system, which seeks to enhance social connectedness between the elderly and their caregivers. We adopted a participatory design approach to gain a shared understanding of the users’ context, their perspectives on ambient lighting technologies and wearable sensing, privacy concerns and acceptance of a system to promote social interaction. We obtained detailed accounts of our elderly participants’ social support structures and their interactions with their caregivers. Moreover, our exploratory results suggest important design requirements to realise the Social Hue system.

Author Keywords

ageing; loneliness; context awareness; ambient lighting; social connectedness;

INTRODUCTION

Social isolation and loneliness have been identified as risk factors diminishing the quality of life of the elderly because of their association with cardiovascular and infectious diseases, cognitive deterioration and depression [2, 35]. Social connectedness is characterized by a sense of belongingness based on the positive appraisal of having enough close contacts [42]. Within the context of this research, the elements of the caregiver network include family and friends who are living apart and independently. Although there are numerous benefits associated with successful ageing, opportunities for communication between the elderly and their caregivers might be limited. Factors such as geographic constraints,

work responsibilities and mobility-impairment might impede the timing and frequency of face-to-face visits between the target groups. This increases the likelihood of loneliness and social isolation among the elderly as posited in [16]. Epidemiological research has associated strong social ties as a fundamental component for maintaining the elderly’s psychological and physiological well-being [40]. Therefore, older adults with higher levels of social support have been found to better handle the mortality risks associated with these issues.

Recently, there has been a move towards embracing the use of technology to enhance the quality of life of senior citizens mostly in the context of home care. Ambient Assisted Living (AAL) exploits a set of ubiquitous and pervasive technologies to provide context awareness, facilitate independent living and improve the health and well-being of the elderly population. An extensive review of the literature has found that most AAL solutions have demonstrated success for enhancing the elderly’s mobility and autonomy. However, many AAL applications tend to focus on technical requirements such as reliability, accuracy and computational complexity, neglecting the elderly’s context, needs and expectations [3]. In this work, we attempt to bridge this knowledge gap through the incorporation of a user centered design approach, which could reduce development cost, increase ease of use and trust in our system.

Moreover, designing for conscious human interaction has been widely studied and as such we have chosen to examine the role of the unconscious in the development and deployment of AAL applications. The unconscious is explained by Bargh and Morsella in [1] as, “the unintentional nature of the behavior or process, with an associated lack of awareness not of the stimuli themselves, but of the influence or consequences of those stimuli.” This model of the unconscious has been viewed by designers as a fundamental factor for understanding the user’s behavioural processes [19].

Context-aware computing is defined in [32] as, “the ability of a mobile user’s applications to discover and react to changes in the environment they are situated in.” In this work, prop-

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erties such as sensing technologies and lighting features of a context aware ambient lighting system, the Social Hue [10] are evaluated. Consequently, we present the findings from the exploratory study conducting qualitative research into the perceptions, perspectives and attitudes of elderly persons and their caregivers toward the system and its application in daily life. The co-constructing stories design paradigm [6] was applied to determine whether the elderly and their caregivers perceived the envisioned system as a viable resource for enabling context-awareness and supporting social interaction.

The Social Hue is envisioned to create a sense of social presence by leveraging socially discrete and non-invasive pervasive technologies over mediated environments. Our work has three contributions to the gerontechnology community:

- A bird's eye view over the social situation of our users in context and their expectations and preferences for sensing and context-aware ambient intelligent solutions.
- Understanding how our proposed system could influence social connectedness, perception and unconscious human behaviour.
- Implications for designers in tailoring ambient lighting displays to support subtle context-awareness and social interaction.

RELATED WORK

To provide a theoretical framework, we briefly reviewed the state of the art of existing technologies to facilitate context-awareness for the elderly population. Subsequently, we explored a number of ambient intelligence studies to support context awareness and social connectedness in Ambient Assisted Living (AAL) domains. Also, the non-visual effects of lighting were explored since light has been proven to influence alertness, moods and visual perception [7, 15, 20, 46].

Sensing Technologies to Support Elderly Context-Awareness

Several studies have confirmed the use of sensors and actuators to improve the quality of life of the elderly who are living independently by providing notification to caregivers [4, 36]. Specifically, elderly remote monitoring systems employ wearable and ambient sensing technologies to unobtrusively detect health and emotional states, and identify patterns in activities of daily living [10, 25, 28].

In [30], Rashidi provided a list of typical wearable, mobile and ambient sensors deployed within the AAL context. These ambient sensors are capable of detecting a range of physiological, movement and environmental data including blood glucose (BGL), blood pressure (BP), respiration (R), cardiac activity (ECG), brain activity (EEG), muscle activity (EMG), eye movement (EOG), blood oxygen saturation (SpO₂), galvanic skin response (GSR), body temperature (T), acceleration, orientation, sound, light-intensity, humidity, floor pressure and door opening and closing [30, 34].

Context-aware systems typically employ one of two approaches using vision or wearable sensors [3]. Camera-based

sensors are usually considered intrusive and suffer from disturbances in the line-of-sight. To support unobtrusive sensing, sensors have been embedded into a variety of devices including: watches, glasses, smart textiles and jewellery [30, 45]. Although these devices provide endless possibilities for AAL, they are inordinately expensive while simultaneously challenged by privacy and security risks surrounding their deployment [34]. Specifically, most existing context-aware solutions in AAL are geared toward monitoring activities of daily living (ADL), indoor localization (i.e. locating the elderly or objects in a building), rehabilitation and detecting emergency situations [3] and as such overlook the critical privacy and dignity rights of the elderly population as discussed in [10, 12].

Our approach, on the other hand, investigates how sensing technologies can better support social interaction with less attention given to emergency and fall detection. In addition, this work places paramount importance on the consideration of users' needs and perspectives when designing context-aware solutions for enhancing end-user acceptance and adoption [34].

Ambient Displays to Support Context-Awareness and Social Connectedness in AAL Environments

Ambient displays are aesthetically pleasing displays for relaying context information in the periphery of the user's attention [23]. A number of studies have confirmed the success of using ambient displays to inform loved ones about the well-being of their elderly relatives [24].

The Digital Family Portrait [27] is an archetypal example showing the application of context-aware technologies to display a qualitative representation of a senior's daily activities. Similarly, the CareNet Display [9], informs the family members of elderly-context information including their calendar, activities, moods, medication, falls, meals and outings. Additionally, the Daily Activities Diarist [26] captures sensory information concerning the elder's activities of daily living, which is communicated to the caregivers through a narrative.

A study that demonstrates the benefits of light in social connectedness is the 6th Sense light sculpture, which shows presence between remote families [39]. A family member's movement in their home causes the other relative's 6th sense lamp to glow. Similarly, the SnowGlobe lamp [43] facilitates mutual awareness of movement between persons living in different homes. Movement of the remote user is reflected as a brighter glow and nudges are exchanged by shaking the device causing the other user's SnowGlobe to blink. The results show that both systems create social connectedness and enable interpersonal awareness.

In this work, we investigate how ambient displays can be used within users' environment to support mood-enhancement, connectedness and bidirectional context-awareness. It is noteworthy that previous awareness systems [9, 26, 27] reflected an unbalanced communication channel (i.e. only providing elderly-context information to caregivers and not vice-versa) with little progress made toward bidirectional awareness. Also, some ambient displays [39, 43] required explicit

interactions such as touch or a click to notify the remote person that the other person is thinking about them. Our goal in this work, is to provide with minimal cognitive effort, awareness information to illicit various perceptions of the remote user's context [12].

Physiological and Psychological Influences of Light and Colour on Social Connectedness

Light is a salient feature to stimulate visual perception. In particular, the non-visual effects of light and colour temperature demonstrate positive effects on alertness, arousal levels, body temperature, sleep and circadian rhythm as posited in [7, 46]. Melatonin (i.e. hormone that regulates sleep) and cortisol (i.e. an adrenal hormone released in response to stress and low blood-glucose concentrations) play critical roles in assessing the effects of light on circadian clock disruption [7], which may cause depressive symptoms and poor sleep quality.

Short-wavelength light is alleged to have greater emissions of blue light than natural light, which is known to suppress melatonin levels [37]. However, Pauley in [29] suggests that melatonin suppression can be ameliorated by deploying longer wavelengths of light toward yellow, orange and red. Also, bright light therapy has been proven to alleviate symptoms associated with mood and sleep disorders [33].

Added to the physiological effects, there is scientific evidence of the psychological effects of light and colour on mood and well-being. For example, [15] reports strong correlations between light exposure and quality of life together with social and emotional functioning in older women. Also, Jacobs and Hustmeyer [18] investigated the effect of red, blue and white light projected on a screen on GSR, heart rate and respiration measures. Their findings revealed that red light was significantly more arousing than blue or yellow light and green light more than blue.

Similarly, Gerard deduced from appropriate physiological measurements (GSR, respiration rate, frequency of eye blink, systolic blood pressure, heart rate, and EEG) that blue light was significantly less arousing than red or white light. Altogether, high arousal levels in response to the red colour can be attributed to associations of red with happiness and excitement and serenity with blue as posited in [17]. However, colour symbolism are based on a number of factors including culture and religion. For example, red is commonly negatively associated with blood, danger, violence and anger, as discussed in [14].

Colour hue, saturation and brightness have been shown to have positive effects on emotions. For instance, using the pleasure, arousal and dominance scale, Valdez and Mehrabian [41], have found hues such as blue and blue-green evoked more pleasant feelings while yellow and yellow-green were least pleasant. Red has been ranked at an intermediate value of pleasantness. Similar pleasantness ratings were obtained in [22], which investigated the impact colour on mood and worker performance.

In retrospect, the large majority of lighting experiments were conducted with relatively young people aged 18 – 35 years

as discussed in [21]. Thus, the vision problems of older adults, which influence their perception of light were often not considered. Despite these challenges, light's non-visual effects could be advantageous especially for elderly people, who tend to struggle with alertness and loneliness. Therefore, the design dimensions discussed in [31] such as variations in brightness, colour rendering, direction and patterns could enhance their experience.

THE SOCIAL HUE SYSTEM DESIGN

The Social Hue is a lighting system to support peripheral mutual context-awareness and enhance social connectedness between the elderly and their caregivers. The Social Hue technology has been proposed in [10, 11, 12] and this work seeks to gather deeper insights into the user requirements at the early design phase. The Social Hue consists of three components: (1) remote sensing (2) activity and emotion detection and (3) a glanceable display that resides in the participants living rooms and office spaces. In this case, the Philips hue lighting system renders aesthetic representations of the elderly's physiological information to the caregiver and vice versa. As discussed in [10], smartphone embedded sensors such as the accelerometer and gyroscopes are used for activity recognition and the electrocardiogram and galvanic skin response are used for emotion detection.

The Social Hue system follows a user centered designed process. The phases of the design and requirements elicitation process are described as follows: (a) brainstorming sessions with potential users for idea-generation concerning the lighting design space, (b) Social Hue service images were constructed to support conversations with the stakeholders regarding the envisioned ambient display and c) the co-constructing stories participatory design method [6] was applied to elicit feedback and suggestions about the design concept.

Concept Generation

Brainstorming sessions were conducted with 12 participants, including researchers from various disciplines such as electrical engineering $n = 2$, computer science $n = 3$, biomedical engineering $n = 1$, industrial design $n = 4$ and psychology $n = 2$. Our participants were asked to describe how ambient lighting could discretely support intimacy and context-awareness between the elderly and their caregivers and to freely think of the parameters that could influence the lighting space design. Conceptual ideas were generated using whiteboards and note-taking. Key lighting parameters to reflect intimacy and show context-awareness are demonstrated in Figure 1. These factors were considered in our service image design of the Social Hue ambient display.

THE USER STUDY

To evaluate, the users' needs, social context, expectations, perspectives and insights concerning peripheral ambient technologies on awareness and supporting social interaction, we conducted a qualitative user study. The aim of this experiment was to derive additional requirements for the Social Hue, explore the users' perception and acceptance of context-aware technologies and to explore the design implications of subtle

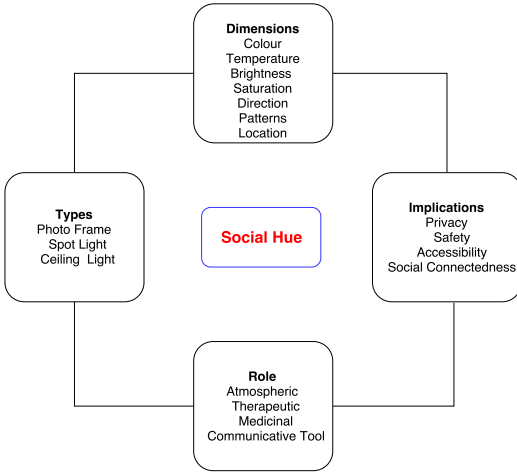


Figure 1: Lighting parameters to support intimacy and context-awareness.

ambient lighting displays in AAL environments as a means of enhancing interpersonal relationships between the elderly and their caregivers.

Participants

A total of 20 participants (mean age = 53.7 and standard deviation = 19.6) were briefed on the main objectives of the study and assured of the confidentially measures in place to secure anonymity. In keeping with the non-disclosure agreement, pseudonyms were adopted throughout this study. Thereafter, participants completed their demographic information and signed an informed consent on all aspects of the study. Participants were recruited through social media and personal networks. Overall, we recruited 10 caregivers (Group A) and 10 elderly volunteers (Group B) whose demographic information is presented in table 1.

To accommodate our Dutch and German elderly participants, this study was also conducted using the Dutch and German Languages.

Our caregiver sample reflected a gender balance while the females dominated the elderly sample by 20%. This is not astonishing given the evidence in [44] showing higher male mortality rates. Moreover, marital status was more varied among the elderly subjects, with 60% being single, divorced or widowed.

Sensitizing Phase: Co-constructing Stories Method

Our multidisciplinary team involved a range of professionals including a cognitive psychologist, a medical doctor, a computer scientist and an industrial designer. To set the stage for discussion and sensitize users to the positive and negative aspects of ageing, participants read a storyboard for 10 minutes, which displayed the social and health context surrounding an elderly parent Mrs. Visser and her son Steven, separated by geographical distance, which is narrated below.

Mrs. Audria Visser is a retired 75 year old store keeper who lives independently in an elderly apartment in Eindhoven,

Table 1: Demographic characteristics of participants

Group	Name	Age	Gender	Nationality	Marital Status
A	Abigael	53	F	Dutch	Divorced
	Alexander	31	M	Dutch	Married
	Johanna	48	F	Dutch	Single
	Abraham	54	M	Dutch	Married
	Aletta	25	F	Dutch	Common-law
	Addler	32	M	German	Married
	Emma	28	F	Belgian	Single
	Adam	27	M	Dutch	Common-law
	Catharina	27	F	Dutch	Common-law
	Antoon	42	M	Dutch	Single
B	Aldolf	66	M	Dutch	Married
	Eva	65	F	Dutch	Married
	Coby	60	M	Dutch	Divorced
	Agna	71	F	German	Married
	Aleit	66	F	German	Single
	Carla	82	F	German	Widowed
	Carlene	74	F	German	Widowed
	Adalwolf	71	M	German	Single
	Achmed	75	M	German	Married
	Esmeralda	77	F	Canadian	Single

The Netherlands. Her Husband Mr. Roy Visser, died five years ago. Mrs. Visser's only child, Steven Visser is 45 years old and is a software developer in Groningen. He is married to Tamoi Visser with children Elizabeth and Jonathan, 8 and 13 years respectively. Mrs. Visser suffers from mild hypertension and has bi-weekly visits from the doctor. She cooks, cleans, goes grocery shopping and occasionally does her own gardening. Mrs. Visser's social ties include her neighbours, her church family members and her lifelong friend Mrs. Karole Abbes who lives in a neighbouring community. Moreover, she is in contact with her sister Ms. Cheryl Aarts and her son Steven and his family. Mrs. Visser keeps in touch with her family via the telephone and has irregular visits from Cheryl and Karole. Distance and high job demands have restricted regular visits from Steven and his family limiting them to telephone conversations 1-2 times per week. Steven is worried about his mother's psychological and physiological well-being and desires to be more aware of her activities. Although his mother's hypertension is seemingly controlled, Steven is fearful that she lives alone and would like to be informed in the case of eventualities.

Next, participants were asked a number of questions geared toward eliciting real-life experiences by helping the participants to remember concrete accounts of their experiences with their relatives and elaborate on their social support structures. Participants also discussed their ideas concerning the factors for improving social connectedness, their willingness to provide physiological information to their relatives, their preferences for wearable sensing devices and the preferred

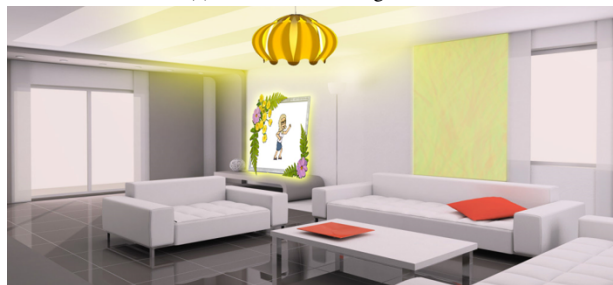
modality to receive awareness information. During this study, all responses were audio-taped.

Co-constructing Stories

The continuation of the sensitizing story was illustrated through Social Hue service images. The envisioned system illustrated a lighting social intervention strategy for Steven and Mrs. Visser. Service images were demonstrated using warm (yellow) and cold (blue) colour temperatures to exhibit key lighting features demonstrated in Figure 1. The proposed system displays movement and emotional information through its glow on the edge of a photo-frame, ceiling or wall or a combination of all three. Figure 2 illustrates a snapshot of the combination of lights in Mrs. Visser's and Steven's living room.



(a) Mrs. Visser's living room.



(b) Steven's living room.

Figure 2: Service image snapshot showing combination of lights in two remote living rooms.

Following the illustration, we investigated through in-depth interviews the preferences regarding the lighting temperature, colour, combination and location. Thereafter, we made inquiries concerning the perceived social connectedness and awareness benefits of the lights based on indirect and direct observation. This was done to evaluate the users' perception on the subtlety of the envisioned ambient display. Note well that there was no mention of the word unconscious throughout this experiment. Instead, phrases like "without dedicated attention", "in the periphery" or "in the background" were used to capture the users' perceptions of the notion of the subtle awareness. Later, we briefly examined the awareness and interpersonal benefits of light flickering in emergency phases.

On average, each session took 30 minutes for caregivers and 45 minutes for elderly participants.

Analysis

Audio-taped responses were transcribed, Dutch and German responses were translated to English by the principal researcher, a graduate assistant and a professor. We conducted a thematic analysis [5] to identify patterns in how stakeholders perceived their social interactions, their preferences for lighting characteristics, sensor options and their perceptions on subtle awareness and connectivity through ambient lighting. We adopted the QSR-NVivo software, to facilitate extensive coding and identification of themes.

FINDINGS

In this section, we discuss the major themes and concepts identified, which demonstrate the social context of our participants and their perceptions and acceptance of assistive technologies for social interaction and context-awareness.

Factors contributing to Loneliness and Social Isolation

Notably, the caregiver participants acknowledged loneliness and social isolation as serious problems of old age and were in favour of finding solutions to combat these issues. However, loneliness was not readily reported among the elderly participants. In retrospect, deeper insights into their subjective feelings of loneliness were acquired with further questioning from the investigator. These concepts will now be discussed.

Sickness

Almost all caregivers attributed sickness and cognitive disorders as causative factors for social isolation and loneliness among their elderly relatives.

For example, Emma communicated, "*When it is a close elderly relative you will always be worried about them. We think my grandma she is having a bit of a dementia and we are wondering if she can handle it alone. So we are thinking to move her to a retirement home....*"

In hindsight, those caregivers who were concerned about their elderly loved one's ill health were more in favour of the idea to place them in a nursing home.

Death of Friends and Family

All of the caregivers assumed the loss of friends and loved ones were contributing factors to loneliness and social isolation among the elderly.

For instance, Catharina mentioned, "*I think my boyfriend's grandpa misses his deceased wife and to hear some more people in the house he wouldn't feel so alone. Also, he used to walk with five friends but each year the group lessens when one of them dies. Now, he's alone and he doesn't have anyone to go with.*"

Denial

Denial was observed among a few elderly participants demonstrating the unpleasant realities of loneliness and social isolation.

Carla, aged 82, admitted after initial denial of experienced loneliness, “*Well, I feel alone sometimes. My two children have their own families and are not so far away. I use the phone more due to the distance. I don’t like this town a lot and I don’t have any real friends...*”

Adalwolf, aged 71, angrily painted his sister’s loneliness as follows: “*She is so stupid, she has retreated from life. When we drink coffee, she doesn’t come. She thinks it is repetitive and nothing comes of it. That is so stupid! Stupid! She is a hermit in her apartment.*”

However, further discussions with Adalwolf implied that he also could have been suffering from experienced loneliness. In addition, he demonstrated that independence is highly esteemed among the elderly and depicted his reliance on technological tools to support independence when he stated the following:

“My disease I must deal with. You have to deal it on your own, and cannot pass it further to someone else. I have 90% severe disability, and it is also not good to me. I have a device that helps me with daily living. I don’t want to be a burden.”

Social Support

In retrospect, several elderly participants suggested that they were able to reduce the feelings of loneliness through their involvement in a variety of sport and support groups. We will now describe the social structures of both user groups.

Support Groups

Social structures for caregivers generally included family, friends, college-mates and colleagues. However, Johanna solely mentioned, “*my family*” while Alexander, “*my work is my social life.*”

On the basis of the findings, maintaining communication and strong social networks were paramount for sustaining social relationships between the elderly and their caregivers.

Among the elderly participants, common social support were family, friends, religious groups and neighbours.

Esmeralda, aged 77, mentioned, “*I try to make myself busy at times. I am involved in church and I go to prayer meetings. My children call and visit me often.*”

Moreover, neighbours were deemed important for sustaining social interaction and mutual dependence in crisis situations.

Carlene, aged 74, stated, “*I can always ask my neighbours for help. With one of them I go on vacation sometimes.*”

Finally, involvement in sports e.g. gymnastics, swimming, biking and dancing were contributing factors toward infrequent loneliness tendencies among our elderly participants.

Feelings of Guilt

A few caregivers became emotional as they articulated their concerns. In particular, feelings of guilt emerged as some caregivers spoke about interactions with their frail elderly relatives. For example, Alexander indicated his discomfort by saying,

“I think I sometimes feel like a bad grandchild. The last time I was there was about a half a year ago and I only visit her twice per year because I am always busy.” - Alexander

Caregiver’s overestimation of loneliness

In general, the caregivers perceived their elderly relatives as sad, lonely and socially isolated, which are common ageism stereotypes of the ageing process as discussed in [38]. However, the elderly participants’ responses showed otherwise as the majority were very active and indicated that they did not have much in common with the Mrs. Visser’s lonely character.

For instance, Agna, aged 71, stated, “*My situation is not comparable to Mrs. Visser’s as I have a lot of friends. At any time I can call someone to do something together. I feel sorry for Mrs. Visser.*”

The Emergence of a Generation of Caregivers Among the Elderly

Some elderly participants indicated that they were responsible for taking care of their feeble elderly relatives and friends.

For example, Coby, aged 60, mentioned, “*I cannot relate to Mrs. Visser, as I am more involved visiting people with disabilities (De Zonnebloem) and the elderly in my apartment building.*”

Similarly, Aleit, aged 66, said, “*I can definitely relate to Steven’s situation as I worry for my mother as well. My mother has some illnesses, so I know how it feels...*”

Perceptions and Attitudes Toward Context-aware Technologies

Concerning the receipt of physiological updates, participants were generally concerned about the privacy implications and felt that sensory data was prone to false positives, which could cause unnecessary worrying.

Ethical issues associated with sensor Technology

Privacy and security were major concerns as it relates to the receipt and sharing of physiological information among the participant majority.

Abigael, a caregiver participant mentioned, “*It’s a matter of privacy. We don’t have to know every heartbeat, change in muscle tension or breathing rhythm if people want you to worry they would tell you worry. I think people should be able to decide by themselves what they want to share with the people around them.*”

While another caregiver, Addler mentioned, “*Is it that only my mother can see it? The light goes through the windows so, what about the neighbours wouldn’t they also be aware? Also, hacking, anyone could get access to my data and know what I am doing all day. Maybe also knowing nothing is happening so I am probably not at home could be a motivation for burglars to break in.*”

Who Should Receive Physiological Information?

One participant implied that nurses were deemed more adequate than family members concerning the receipt of physiological information.

Achmed, aged 75, communicated, *“I don’t know whether this is wise, I don’t know. If there is a nurse that needs to know exactly what is going on yes, but otherwise, no.”*

System Reliability

Some participants expressed concern regarding the accuracy and reliability of the sensors.

Abraham, a caregiver stated, *“With real time data you might see the fluctuations, which might cause unnecessary worrying.”*

Tension reduction and Defense mechanisms

Anna Freud posited in [13], that humans are driven towards tension reduction as a means of reducing emotional anxiety. In this user study, reality anxiety i.e. the avoidance or removal of one’s self from a threatening situation [13] was demonstrated by one caregiver participant. This anxiety often triggers the activation of defense mechanisms, which often occurs unconsciously to reduce psychological trauma. This was evident in the statement below.

“For me, definitely not because my mother is really sick. I don’t want to get a message repeatedly everyday saying, oh no, she is dying right now! Actually, that’s why I am distancing myself a bit because I don’t want to always know how she is feeling because I know she is feeling really bad and I would worry all the time....” - Addler

Acceptance

Wearable sensors were acceptable to most participants provided that they did not provide continuous sensing and measures to maintain privacy and confidentiality were in place. In addition, our analysis revealed the desire for an unconscious interaction with sensor devices.

Abraham mentioned, *“If it’s not really live updates only average values that are sent after a couple of minutes then maybe yes.”*

Catharina communicated, *“I can imagine you could wear it and get used to it and then maybe don’t feel it at all. Considering a watch or a bracelet you would always have to be careful if you take a shower or something. It would be fine to wear a sensor but I don’t want to consciously wear it the whole day.”*

A few participants were more appreciative of sensing devices to enable family members to be recipients of their physiological data-sets.

Johanna indicated, *“I would agree to wear it just to make my sister feel safer, I live alone and I am not elderly but anything is possible as I could have a heart attack...”*

Various elderly participants found sensor technology useful for the elderly with greater levels of frailty than themselves.

For example, Carla, aged 82, mentioned, *“Yes, they could possibly be advantageous especially if you really have a problem and you are no longer able to call an ambulance. But I would not be particularly captivated by them, as I’d feel even older than I already am.”*

Sensor Design Preferences

Sensor preferences were based on subtlety, unobtrusiveness and how well they could be integrated into daily life.

Embedded sensors

Sensor options such as rings, bracelets and smart undergarments emerged during the discussions. In addition, the provision of comfort, non-visibility and the ability to affect consciousness repeatedly presented themselves during the conversations.

Emma commented, *“Maybe something like a watch that collects the readings not something that stands out that I am wearing a sensor but something regular...”*

Addler quoted, *“I would choose something that is not obtrusive and something that I would have to wear anyway like a sock, shoe, pants, insole or something that is not visible and I wouldn’t notice as well. I would not wear the watch, which is a fashion object, I would rather choose my own fashion.”*

Preferences for Lighting Features

Colour preference was based on aesthetic appeal, the calming effects of warmer colour temperatures and the alerting effects of colder color temperatures. However, the unobtrusive nature of the light source was the basis for the preference among the participant majority.

Colour Temperatures

Six of ten elderly participants expressed their preference for warmer colour temperatures e.g. yellow for seniors’ living rooms while the others considered colder temperatures e.g. blue more suitable for the caregivers.

Esmeralda articulated, *“I prefer blue, because it is brighter than yellow, the yellow may affect Mrs. Visser’s eyesight. I like yellow for Steven, because he is younger and may have better vision.”*

Specific colours that were mentioned by both generations included; light green, orange and softer tones to evoke feelings of presence, happiness and warmth. Furthermore, subtle changes of light was also encouraged to induce a sense of remote presence, which in turn could trigger social connectedness.

Type of Light Sources

Three light sources were evaluated, namely a ceiling light, a wall spot light and an enhanced picture frame light. Caregivers generally preferred the picture frame light due to its inconspicuous nature.

“I prefer the picture frame, it is not as present as the rest, it’s quieter, and you can see if something is wrong but it doesn’t immediately announce itself...” - Johanna

Most caregivers appreciated the ceiling light while the vast majority described the wall light as invasive and overdone. However, Addler was concerned that the picture frame light would solely enhance the picture itself and not the loved one’s context information; thus impeding its awareness function. Consequently, he expressed his preference for the ceiling and wall combination. In addition, Adam another caregiver

advised that the wall light could be useful only for elderly mood enhancement. Similarly, the wall light was appreciated among some elderly participants for its illuminating effects and a few participants referred to its ability to augment visibility.

In contrast, some elderly participants highlighted the atmospheric and therapeutic benefits of the ceiling light to reduce loneliness.

Carlene, suggested that awareness information through the ceiling light could produce an empathetic response and reduce loneliness, when she stated,

“You are reassured, and you have peace of mind that you are not alone any more. If you see everything is all right with the family you are reassured.”

Additional places and lighting types were suggested such as beneath furniture and desk lamps to support subtle awareness in addition to being integrated one’s home environment.

Overall, both the elderly and their caregivers were more in favour of the ceiling and picture frame combinations to support mutual awareness and social interaction.

Design Considerations

We will now discuss the design considerations for the Social Hue.

Provide an On Demand Service

Notwithstanding the advantages of the light’s inconspicuousness some participants were still concerned about privacy violations and were interested in having more control of the lighting installation.

Alexander, highlighted the importance of installing an on-demand lighting system when he stated,

“So if you want you can ignore it and otherwise you can pay attention. I could see if the light is automatic inside your house then it can be intrusive even though it’s intended to be unobtrusive, understated and very unconscious but then it would feel more intrusive because you don’t have your own life any more, you have a shared life.”

Design based on user’s context

A number of participants suggested that colour temperature could be activated based on activities and context.

Addler stated, *“So blue light could be used if you have to concentrate on something such as reading. You could use the warmer colours with anything that could be social.....”*

The Value of the Unconscious

To improve connectedness some caregivers indicated that colour temperature could activate certain thoughts and memories from the past. In this case, existing knowledge of a loved one’s favourite colour could modulate the other person’s memory, perceptions, expectations and behaviours without being aware of it.

Aletta, a caregiver participant stated, *“if Steven likes green and something lights up in Mrs. Visser’s apartment with the*

colour green then this could facilitate connectivity because she knows that’s his favourite colour from childhood. She could possibly reconnect childhood memories of Stephen as a child through this method.”

In addition, some participants discussed that subtle changes in colour could evoke meaningful emotional information unconsciously and consequently improve connectedness.

Abigael stated, *“If there are small changes in light, that’s something you may not pick up consciously but if you connect a certain shade of the lighting colour to a certain feeling, that may evoke positive emotions that could improve connectedness. Even though it might not even be connected to the real activity that the family member is doing.”*

Risks and Emergency Management

The value of emergency notifications was a recurring theme in this study. To alert the users’ attention, red light was most preferred among the participants. Also, certain participants suggested better ways of supporting care coordination and management through intermediaries such as neighbour aid and medical intervention to provide assistance during emergency cases.

Abigael mentioned, *“given they are three hours away from each other then its better if she has a home alert system that could alert the medical personnel or a neighbour or friend who is living close by.”*

Attitudes toward Subtle Ambient Displays for Social Interaction

Our findings revealed mixed reactions toward the Social Hue. Some participants were certain about the social connectedness benefits of the envisioned system suggesting the pleasantries of light especially in winter months for mood enhancement, to increase social presence and create assurance. While others remained neutral suggesting that indirect updates could be less daunting for caregivers while it could simultaneously be distracting especially for those working at home. On the contrast, a few participants cynically indicated that the implementation of technological solutions to combat loneliness is reflective of a societal problem.

Cynicism

Aldolf, aged 66, sarcastically remarked, *“I think everyone is waiting on the applause for this improvement in the social aspect of the lonely elderly. You hear how extremely sceptical I am about this, particularly because I think its at the level of “giving the dog a pat”. If you give the dog a pat then the loneliness is gone again? I think human communication should have a higher quality than giving a pat, with or without nice light. So we have to attack the root of the problem....”*

Aldolf chronicled the root of the problem as follows: *“People should improve their own communication instead of having technological tools to do it for them.”*

Relevance to Frail Elderly

Most participants perceived that the light would be more relevant for the frail elderly to provide their children with awareness information.

Eva, aged 65, said, “*Not me. But I don’t know how my state will be 10 to 15 years from now. Now, I don’t need it. But I still live with someone. Many people are visiting me (my children etc.). I do not feel vulnerable now, no not yet...*”

Furthermore, participants commented on the mutual social interaction benefits through subtle cues and demonstrated the need for such a system.

“I think they would feel closer to each other because they know someone is watching the other and that would be a positive thing.” - Adam caregiver

DISCUSSION

In this section, we discuss the following: (1) the social context and its implications for designing subtle awareness systems for social connectedness, (2) the implications for designing context-aware technologies, (3) the implications for designing ambient lighting displays, (4) the role of the unconscious in design for social connectedness and (5) the limitations of the current study.

The Social Context and its Implications for Designing Subtle Awareness Systems for Social Connectedness

Our findings suggest that elderly participants were consistently in pursuit of social interaction through their involvement in volunteering services, sporting activities, visits and outings with family and friends. Therefore, our senior participants were much more socially involved than anticipated and in most cases defied the loneliness ageism stereotype conjectured by traditional gerontological theories [2, 35].

In contrast, denial of loneliness and projection onto others were observed among a few elderly participants. Moreover, our naive idea that there are three generations i.e. grandparents, parents and children was inaccurate as we observed the emergence of a fourth generation among our elderly participants who deemed themselves caregivers due to their responsibilities for taking care of their frail elderly loved-ones.

As confirmed in previous studies, caregivers maintained a busy work life; thus awareness of the need for social contact was insufficient to initiate a social behavioural change especially concerning their frail elderly relatives such as grandparents, aunts and uncles.

Considering physical barriers (i.e. being in different locations) to communication between the elderly and their caregivers, the Social Hue was generally perceived as a means not to replace face-to-face communication but as a tool to augment the users’ desire to improve social interaction. On the other hand, as suggested by most of our elderly participants our envisioned system would be more helpful for the frail elderly to reduce their loneliness, create deeper intimate connections and monitor their health.

Implications for Designing Context-aware Technologies

Taking an account of the perceived barriers to mainstream adoption and deployment of sensing infrastructure in AAL, we gathered detailed accounts of the participant’s acceptance and perceptions of such technologies to support ageing in

place. This we believe is a valuable design tool for researchers and practitioners to enable user-involvement and understand the challenges surrounding user-satisfaction with respect to sensing devices in AAL environments.

During the sensitizing phase, a few participants were sceptical regarding wearable sensors while the remaining participants recognized the value of these sensors for monitoring cases of fall-induced injuries or cardiovascular diseases for the frail elderly and to facilitate the involvement of family members in the care of their loved-ones living alone irrespective of their age. Consequently, our results confirm the studies of [9, 26, 27], which all depicted evidence of the benefits of contextual information. Therefore, our results can inform practitioners in the field of ambient assisted living on the perceived value of wearable sensor deployment and its relevance to the elderly and their loved ones.

Most participants saw the need for a balance to be struck between inconspicuousness and comfort for wearable devices. Revisiting the phrase “*I don’t want to consciously wear it the whole day,*” suggests that wearable sensors require conscious effort especially concerning switching on and off the devices and its ability to seamlessly integrate into everyday life is critical for preventing discomfort among users. This provides an opportunity for designers to consider how to seamlessly interweave sensor technologies into the tapestry of daily routines (e.g. in undergarments).

Moreover, the notion of privacy was considered threatening especially for the caregivers as they were generally concerned about the type of information they wanted to share with their elderly relatives. Thus, it is imperative that designers allow selective-content control as shown in [9], for elderly dignity preservation purposes and to respect the caregivers’ desire to live “separate” lives from their elderly counterparts [12].

The exchange of physiological information is a highly sensitive topic, which raised concern for some participants. Furthermore, securing the information alone was considered insufficient, as burglaries based on the receipt of awareness information were also a concern for a few participants. Considering the complexities involved in preventing unrestricted access by others e.g. burglars and hackers, it is critical for AAL practitioners to consider new and innovative ways for the seamless integration of physical and cyber security structures to protect against data violation and victimization in AAL environments.

Overall, presenting context information is extremely challenging when designing solutions to support the elderly who are living independently. For instance, sensor deployment increases the risks of missing detections and false alarms [8]. It is therefore critical to carefully select the sensors to support context awareness and to apply robust pattern recognition techniques to improve system reliability.

In addition, it is imperative that designers provide discreet and comprehensive representations based on average values to prevent worrying and distraction between both user groups. Furthermore, we suggest that designers consider an additional layer of abstraction into a format that ensures privacy preser-

vation of sensor data, which is of utmost importance within the AAL domain.

Implications for Designing Ambient Lighting Displays

Our work suggests that ambient lighting solutions for assistive environments need to be inconspicuous, accurate, reliable and therapeutic while providing bidirectional awareness information to caregivers and their elderly loved-ones.

In the case of assisted living, pervasive and ambient technologies should discreetly focus on both the caregiver's and their elderly counterpart's well-being and provide opportunities to strengthen social interaction. Moreover, exploiting existing lighting characteristics, such as colour temperature, location and lighting type among others provide unique opportunities for supporting emotional and awareness needs. Also, due to age-related visual decline, ambient lighting technologies should stimulate alertness and provide visual support for the ageing population.

Although participants were more in favour of warmer colour temperatures due to its atmospheric and therapeutic benefits, it was generally implied that colour temperature should be customizable, i.e. based on personal preference and the overall design of the living space.

The Role of the Unconscious in Design for Social Connectedness

Discussions with participants revealed that colour temperature could trigger a change in behaviour without being consciously aware of it. In essence, participants envisioned that perception of the Social Hue could support reflection or retrieval of preserved memories detailing past interactions with family and friends.

On a different note, illuminated awareness information through the Social Hue could reflect a symbolic interaction between the elderly and their caregivers. This symbolic interaction could trigger perception of awareness cues from a loved one's environment, which could influence unconscious behaviour e.g. prospective users can be led to be more mindful of each other and increase their social interaction.

On the other hand, the Social Hue is anticipated to trigger physiological responses e.g. changes in alertness and arousal levels, which is projected to reflect Bargh's and Morsella's view of the unconscious i.e. being aware of the stimulus with a lack of awareness of the influences/effects of the triggering stimulus. Furthermore, the Social Hue through its lighting features e.g. colour, location, brightness and saturation is projected to be a promising tool to reduce anxiety among its target users.

Limitations

There are a few limitations in this study. Firstly, increasing our sample size could make our results more generalizable to the population at large. Secondly, participants were relatively highly educated, which could influence their perceptions on ambient interventions to support awareness and social interactions. Thirdly, the study was conducted in individualistic

western societies, which might have culturally influenced the perception of our envisioned system.

CONCLUSION AND FUTURE WORK

This paper has explored the social context and perspectives of ambient technologies to support awareness and social interaction between caregivers and their elderly relatives. By adopting the Co-constructing Stories [6] approach, we were able to identify a range of social behavioural tendencies and perceptions on ambient technologies for awareness information and social connectedness, especially with respect to ambient lighting. Given the promising findings of our exploratory study, we demonstrate potential for designing subtle ambient interventions to support assisted living and improve social connectedness between the elderly and their caregivers.

From this study, it can be concluded that in designing tools for awareness and social connectedness in AAL, that designers should critically assess the social environment and methods for social interaction for both caregivers and their elderly counterparts. Moreover, the physical barriers to communication and the perceived barriers for adoption towards the value of context aware technologies and ambient displays should be taken into account. Furthermore, identifying the users' implicit needs such as unobtrusiveness of the sensing device or the "hidden" or "quiet" nature of the ambient display should be considered in AAL product design. In retrospect, our findings suggest that users were more in favour of a type of "invisible technology," which can be easily integrated in their daily lives. In addition, the contributions of the users' insights and perspectives of sensing infrastructure and ambient tools, could predict a range of anticipated behaviours with respect to product experience e.g. the system's capability to trigger reflection on past interactions and convey a sense of reassurance to the intended user groups.

In the future, by considering the acquired user and system requirements, we aspire to develop the Social Hue system and empirically assess its usefulness against the insights and expectations presented in this work.

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