Social Hue: A subtle awareness system for connecting the elderly and their caregivers

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***Abstract*—In this position paper, we propose an unobtrusive solution for improving bonding relations between the elderly and their caregivers, through the *Social Hue*. The *Social Hue* is a bidirectional application that is based on the Philips Hue light. To create social presence, activity and emotional states will be detected through sensors and will be transformed into ambient lighting into the elder's home and vice versa without overt communication from participants. Findings are expected to provide a deeper insight on the notion of subtle awareness in relation to social connectivity between the elderly and their caregivers.**

I. Introduction

According to the UN population projections, the global share of older persons (aged 60 years or over) is expected to increase from 841 million people in 2013 to more than 2 billion in 2050 [1]. Basically, there are insufficient resources (such as nurses), which induce costs; thus independent living is forced. In addition, it has been observed over the last decade that the trends associated with ageing societies in developed nations have been frequently argued to impose serious challenges for economic growth in Europe [2]. Therefore, aged European societies tend to have high public and private expenditure to cover the cost of health care and other social interventions.

Despite these challenges, a growing number of the ageing population is in favour of independent living, which can be addressed by several means including public policies, social and legal interventions, financial support and city planning among others. One remarkable policy for supporting ambient assisted living in Europe is the Ambient Assisted living Joint Programme. This programme aims to develop innovative technical solutions through the funding of widespread national projects that involves the corporation of institutions such as, research bodies and elderly care organizations [3].

A. Social Isolation and Loneliness in the Ageing Population

Social isolation and loneliness are common problems associated with increased mortality [4], [5]. Social isolation refers to the objective state of infrequent or the non-existence of communication with others, whereas loneliness ascribes to the subjective state of repugnant emotions affiliated with social isolation, less contact than desired and the deprivation of companionship [6]. However, in assessing the correlation between loneliness and social isolation, the authors in [6] suggested that the concepts do not coincide. For example, some persons may have few social contacts and feel lonely whereas others might not due to their preference for reduced social interactions and privacy.

Research in [7] highlights a number of health risks associated with loneliness and social isolation including cardiovascular diseases, elevated blood pressure and cortisol, cognitive deterioration, heightened inflammatory response to stress, depression and infectious illnesses. Therefore, older adults with weak social ties are prone to develop various cardiovascular and mental illnesses. It is generally agreed that social ties often play an advantageous role in the maintenance of the elderly's psychological and physiological well-being. Furthermore, socially active senior citizens are often physically and mentally healthier when compared to those who are socially isolated [8]. Consequently, strong social ties play a critical role in maintaining elderly well-being.

B. Research Objectives

In this research, we hope to utilize the notion of peripheral awareness [9] through lighting to induce social presence [10] and assist the elderly living independently. As a result, we are interested in understanding how pervasive ambient lighting solutions can improve bonding relations between the elderly and their caregivers without their direct attention. We have taken a subtle approach, as a result of our own curiosity and exploration of a number of ambient display studies for connectedness [11], [12], which assumed conscious explicit communication. Moreover, following Bargh and Morsella's [13] definition of the unconscious ie., the "lack of awareness of the influences or effects of a triggering stimulus and not the effect of the triggering stimulus itself," we believe that the notion of the unconscious is almost forgotten and we assume its relevance in design interventions for social interaction.

We hope to utilize the user-centric *Social Hue* application by subtle means to create social presence through the emotional and activity states of elderly persons and vice versa for their caregivers. To communicate emotional states, there is a positive correlation with colour and moods as shown in [14]. For instance, red is frequently associated with excitement, blue with peace and comfort, orange with distress and black with power or despondency. In this position paper, we advocate the use of unconscious perceptual processing to improve bonding between caregivers and their elderly relatives, and we describe the design of a subtle awareness system through coloured connected lighting.

We have devised a number of research questions, which shall be examined throughout the duration of this study.

1) Can subtle awareness systems improve the bonding relations between the elderly and their caregivers?
2) How do we measure the effect of the light as it relates to bonding?

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3) Subtle awareness may not give clear discrete signals thus; how do we know that changes in communication patterns are associated with the unconscious?
4) In recording the activities and emotional states of the elderly and their caregivers, how do you make them feel comfortable with a system that knows their position?

This paper is organized as follows: a summary of the state of the art in the field of ambient awareness applications is presented in section 2. Section 3 describes the components and design of the *Social Hue* application. Our planned research approach is discussed in section 4. In section 5, we present our conclusions and future research directions.

II. State of the Art

Several studies have shown how sensing and communication technology can be applied to support independent living among the elderly and also provide awareness of their activities and emotional states in real time to their caregivers. Additionally, the use of social networking sites, Skype and mobile phones could enhance the bonds between the elderly and their caregivers. However, senior citizens who are less technically inclined may feel anxious and less confident while using social media solutions [15].

A. Elderly Monitoring Systems

Researchers in [16], [17], [18] have designed elderly monitoring systems using pervasive technologies such as sensors and actuators, which can be used for emergency detection and notification to the caregivers. However, emergency detection is not the primary focus of this research as our main objective is to utilize sensing technologies to support social bonding through subtle awareness. Primarily, wearable sensors facilitate accurate and real-time monitoring of physiological signals, movement and emotional states as shown in [19]. However, like the researchers in [20], we believe that further work must be done to achieve motion artifact reduction, which is a common problem of wearable sensors. However, this could be addressed by integrating sensors into intelligent textiles as shown in [21]. In summary, the use of wearable sensors can enable the unobtrusive collection of health and well-being information while providing flexibility and convenience. In turn, this increases the possibilities for reducing the cost of formal care for the elderly population.

B. Ambient Displays supporting Conscious Explicit Communication

In an effort to support awareness and connectedness between the generations, a number of studies explored the use ambient displays to enable feelings of presence and communication. For instance, the Digital Family Portrait [22] provides from available sensor input, a qualitative sense of an elder person's daily routine to their caregivers in a remote location. This information is displayed using qualitative icons to preserve his/her privacy. Similarly, the CareNet Display [23] augments a photograph of a senior citizen related to their daily routine and provides a mechanism for caregivers to monitor activities such as meals, falls, moods, activities, medications and calendar. Unlike the Digital Family Portrait [22], the CareNet Diplay [23] facilitates selective-content-control thus; enabling the elder to disclose information to whomever they want.

As it relates to light as an activity display, the LumiTouch [24] device aims to communicate emotional content through presence detection in the form of picture frames and light patterns. LumiTouch is an asymmetric (touch-to-light), bidirectional channel of communication, which might be useful for the sick or elderly who are incapable of actively communicating over an extended period. However, this asymmetric participation might be problematic, as one person might play an active role in the communication channel whilst the receiver passively perceives ambient information thereby obstructing immediate responses. Like the LumiTouch ambient display, the 6th Sense [25] light sculpture was designed to induce a sense of presence and support closeness.

Other studies showing the application of technology to support connectedness and activity awareness include the GustBowl [26], the Family window [27], and the Tlatoque situated display [28]. The GustBowl [26] application facilitates two-way communication between a mother and son by detecting the presence of objects thrown into a bowl. The GustBowl records movement via a wobble, takes snapshots of the object and transports the information over the Internet to the family member's home. As a consequence, through its wobble and picture the GustBowl enables sentiments of connectedness and presence, while suggesting that the son has arrived home. The Family window [27] is an always on video-media space that enables the asynchronous sharing of information through handwritten messages and time-shift recording. Consequently, time zones and work schedules are taken into consideration resulting in the access of recorded activities at the receiving family member's own convenience. Privacy is also taken into consideration as caregivers can control what was visible at the receiving end by opening and closing blinds (modelled as real-world window blinds) within the Family window application. The Tlatoque 2.0 situated display in [28] is designed to seamlessly integrate elders into social networking sites used by their caregivers. This application provides a platform for enabling older adults to become users of social networking sites and experience awareness of their caregivers' lives and interest. However, its automatic sharing capability raises privacy concerns for caregivers; thus creating a loss of content-control. Although, the Tlatoque application has shown a number of benefits, we are still interested in exploring the implications of social connectedness by subtle means i.e., through the peripheral display of activities and emotional states of the elderly and their caregivers.

Each of the works examined above, was designed to foster feelings of connectedness and awareness between the elderly and their caregivers by conscious explicit means. We assume this might be intrusive to the caregivers who may feel they are loosing autonomy of their own lives through conscious awareness and interactions over a mediated environment. However, we propose an unobtrusive solution, which unconsciously stimulates feelings of connectedness and awareness between the generations. Moreover, to avoid invasion of privacy we propose an on demand service that will allow experimental subjects the right to turn on or off their hue lamps at their own convenience. Unlike the previous unidirectional studies, this research shall employ a bidirectional approach to promote physical satisfaction through subtle awareness that people are around.

III. *Social Hue*

The *Social Hue* platform will be integrated within the ambient intelligent home environment by combining movement and psycho-physiological sensors, communication media and storage devices to remote locations. We hope to facilitate bidirectional social presence between the generations by unobtrusive means.

A. *Concept Design*

The proposed design is based on Damasio's somatic marker hypothesis [29], in which we evaluate experiences according to the reactions they elicit from our physiological signals (somatic markers), which represent affective states in response to stimuli. This further guides adaptive behaviour unconsciously and hence when a similar experience occurs, the memory of the original experience is triggered. Therefore, we believe somatic markers will play a vital role in assessing the affective states in response to the *Social Hue* application.

To recognize a participant's emotional and activity states we will use portable/wearable devices to capture signals, which are autonomous to the body such as: electrocardiogram (ECG); blood pressure (SpO2) and galvanic skin response (GSR). We believe that autonomous bodily reactions directly correlate to the notion of the unconscious coextensively running as a background process of the mind and body that they are unaware of as discussed in [31].

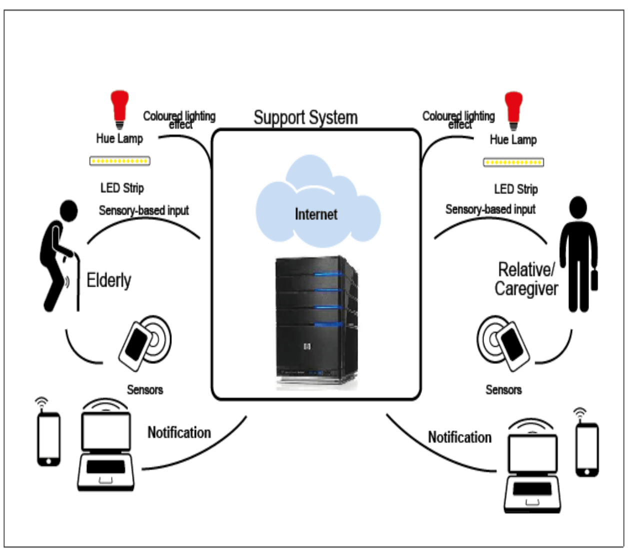

Fig. 1. *Conceptual Design.*

The bidirectional aspect of our proposed research is illustrated in our Conceptual Design (Figure 1), where both the caregivers and their elderly relatives will be monitored using activity and emotion sensors. Sensor-based input from these wearable sensors shall be relayed to a server within the Support System that analyzes the data to detect activity and emotional states. Subsequently, both the elderly and their caregiver will passively receive the processed information in the form of light changes. Table 1. shows a sample classification of states. Note well that emotions will be classified according to the discrete model of emotions as shown in [32]. Assuming you have n possible activities and m possible emotions, then the number of possible states is equal to $n * m$. Each state will be mapped to a set of subtle lighting patterns and colours and the light patterns within a particular set will be randomly generated. This information will be rendered using the Philips Hue light to improve social connectedness. During this phase, we shall utilize the notion of peripheral awareness ie., information that is not in our direct attention to induce feelings of social connectedness in a mediated environment using the Philips Hue Light. Moreover, we will apply the principle of *information decoration* [30] through lighting to make data available at all times to participants but this data can be ignored.

TABLE I. TABLE SHOWING A SAMPLE CLASSIFICATION OF STATES

Activity states	Emotional states
Low	Anger
Moderate	Disgust
High	Sadness
	Fear
	Happiness
	Surprise

B. *System Architecture*

The components and the data flow within the system is demonstrated in Figure 2.

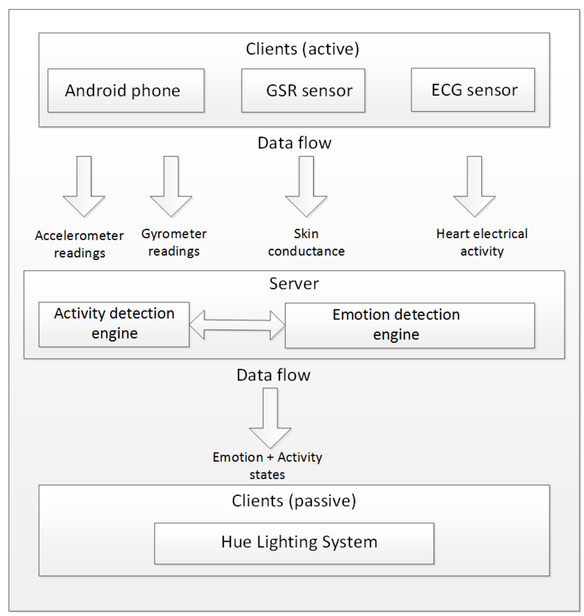

Fig. 2. *System Framework.*

The system models a client-server architecture. The sensors (Accelerometer, Gyroscope, Electrocardiogram (ECG) and Galvanic Skin Response (GSR) sensors) act as active clients, which collects and sends sensory data to the server. They are said to be active since they will collect and filter data, and subsequently initiate communication with the server. The server consists of two modules: *Activity detection engine*, which analyzes accelerometric and gyrometric data to detect a participant's levels of activity and an *Emotion detection engine* that analyzes skin conductance and electrocardiogram data to detect a participant's emotional states. The activity and emotional states detected by the server serve as inputs to the Hue lights to display lighting characteristics to stimulate subtle presence. The Hue lighting system will act as a passive client, which will only wait for commands from the server in order to display a particular lighting characteristic. The data flow from the active client to the server consists of complex raw sensory data to be processed, while data flow from the server to the passive client is a set of simple commands.

1) Implementation Details: The accelerometer and gyrometer clients have been developed using the Android programming language since the in-built sensors of Android mobile phones are being used to collect accelerometric and gyrometric data. The server will be built using the C++ programming language and the data analysis within the server will be done with Matlab and C. The Shimmer wearable sensors for the electrocardiography and galvanic skin response provide a JAVA/Android API, which facilitates streaming of sensory data to the server for analysis. Finally, the GU10 Philips hue light output is a wireless LED light bulb with functional white light and 16 million colors including all shades of white from warm to cold colour temperatures. Furthermore, this light is software upgradeable and can be controlled via commands from a server to regulate its colours, brightness and all related functionality.

C. Feasibility and Risks

It is important to note that there are many risks associated with this project. As mentioned earlier, physiological sensors and motion sensors will be deployed to detect gait and unusual periods of inactivity. Also, the elderly are vulnerable and are easily compelled into giving up control and privacy [33]. Thus as part of our research, we asked the following questions:

1) What is the threshold for the elderly to share their information?
2) Under which conditions is it ethical to install cameras, psycho-physiological and motion sensors?

In addition, the use of physiological sensors might complicate our design as it is difficult to capture physiological information without being obtrusive. For example, ECG can only be measured on the body and galvanic skin response sensors need a skin connection in order to work efficiently. As a result, the elderly might be apprehensive with respect to wearable devices and we may need to develop a ritual to seduce them into wearing these devices. This is an open problem, which is difficult to design and hence will be further investigated throughout the tenure of this research.

Nevertheless, we believe that despite its complex nature this project will be successful due to the following reasons:

1) its focus on bridging the gap between formal and informal care services as it relates to elderly care;
2) the existing body of knowledge and ongoing studies pertaining to lighting and colour as social interventions for improving moods, which may positively correlate with decreasing loneliness;
3) its novel nature of using subtle awareness by way of coloured lighting to support bonding relations between the elderly and their caregivers.

IV. Methodology

A. Participants

We will conduct a longitudinal study, applying the between-subjects design methodology to caregivers ($n = 45$) and elderly persons ($n = 45$) from ageing societies such as the Netherlands, Belgium and Germany. Throughout this study, we make the following assumptions:

1) Mainly elderly and their caregivers are living apart.
2) The user-group includes the elderly (above sixty years) who are able to live independently and caregivers (eighteen - sixty years) who often worry about their elderly family members living at home alone.

B. Procedure

Methodologies from interaction design will be applied in the design process, which is illustrated in Figure 3.

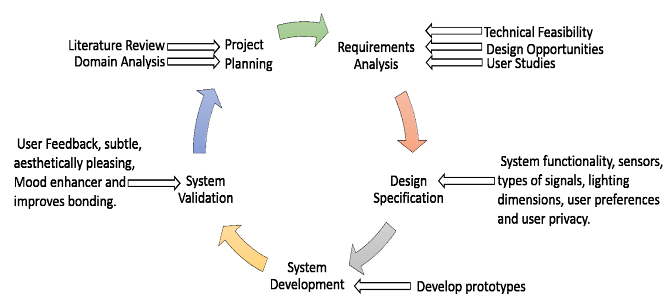

Fig. 3. *Social Hue Design Life Cycle.*

1) Stage 1. Project Planning and Requirements Analysis: A user centered approach shall be adopted to investigate the applicability and preferences for designing the *Social Hue* system. This process is iterative and will be refined continually according to user needs. Participants of this initial phase shall include: elderly volunteers, expert designers, caregivers, elderly care organizations and medical personnel. A series of interviews, domain analysis and observation sessions shall be conducted to identify end-users' needs. We shall examine during the requirements analysis stage: lifestyle, communication patterns and habits, which might be useful to design the Social Hue intervention. Moreover, a literature study on social relationships, unconscious channels, colour and mood determinants, lighting as an activity display and psycho- physiological measures shall be conducted to form part of the theoretical framework for designing the *Social Hue* application.

2) Stage 2: Human Activity Recognition: The elderly and their caregivers will wear an android mobile phone contained in a waist-belt for eight hours (8). The android mobile device is embedded with both a gyrometer and an accelerometer that records their accelerometric and gyrometric data, through an android logger application we developed. We have made this application (Accelerometer Gyrometer Logger) available on Google Play store. Sensory readings will be sent to an activity detection/recognition engine to analyze and classify their activities. The activity detection engine employs a Support Vector Machine (SVM) classifier proposed by [34]. The SVM classifier will be trained with our own training data and the public training data made available by the authors of [35]. The various activities detected such as walking, running, cycling, sitting, standing, laying will mapped to low activity states (laying, sitting), moderate activity states (standing, walking) and high activity states (running, cycling). These states will serve as inputs to the Hue lighting system, which will generate lighting characteristics (colour, temperature, brightness and composition) that simulate a subtle presence of activities. Using the principle of peripheral awareness the hue light characteristics generated from a caregivers' activities will be shown to the elderly (and vice versa) in a controlled environment. During this phase, we believe it would be useful to determine what people feel based on the input from the activity recognition engine. For example, speed and irregularity of movement could induce a subtle presence and suggest that something is wrong with either the elderly participant or their caregivers. We assume throughout stages two to three that this subtle presence could induce unconscious emotions and trigger communication between the caregivers and their elderly relatives to create an assurance of each other's health and well-being.

3) Stage 3: Human activity recognition + Human emotion detection: In this phase, Shimmer GSR sensors will be deployed to measure and record the skin conductance of caregivers and the elderly. As shown in [36], [37] skin conductance is closely related to arousal levels, which is closely aligned with the Circumplex Model of Affect as described by Russell in [38]. The recorded data will be analyzed by the emotion detection engine to classify the moods based on discrete emotions such as sadness, fear, happiness etc. These emotional states combined with the activity states will serve as inputs to the Hue lighting system, which will generate lighting characteristics that simulates a subtle feeling these combined states. As mentioned earlier, we will apply the principle of peripheral awareness the hue light characteristics generated from a caregiver's activities and emotions will be shown to the elderly (and vice versa) in a controlled environment.

4) Stage 4: Evaluation: To investigate the notion of subtle awareness based on activities and emotional states, our control strategy includes three settings: randomized lighting colours and patterns that are not associated with either human activity or emotional states; a monochrome lighting system that has no change in lighting characteristics and our *Social Hue* application that changes based on input from the activity and emotion detection engines as explained in stages two to three.

Objective and subjective measures of emotions will be deployed throughout this experiment. Like the researchers in [37], we believe that physiological signals would be more useful to measure emotional experiences than self-reports. Therefore, GSR and ECG sensors will be deployed to measure the skin conductance and the heart's electrical activity in response to the light. In evaluating the usefulness of the *Social Hue* we hope to investigate the following:

- How does the experimental subjects perceive the *Social Hue* application?
- Did the participants notice the changes in colour and light patterns?
- When they noticed the lights, what were their perceptions of their caregiver's moods and actions?
- Does it trigger social behaviour? For example, do we see an increase in phone calls?
- What are the levels of engagement of the participants before and after the implementation of the *Social Hue*?
- How does the lighting affect loneliness? It might be the case that the elderly are fascinated by the lighting experience and may not feel lonely.
- What are positive moods and how are these moods affected by light?

In evaluating our prototype as it relates to loneliness and connectivity, we shall employ subjective validated scales such as the UCLA loneliness questionnaire [39] and the Inclusion of Other in the Self scale (IOS) as detailed in [40]. We speculate that subjective investigations will be useful in deciphering the role of conscious awareness throughout this research. Thereafter, we can compare perceived experiences with actual physiological data to gain further insight on the unconscious perceptual processing of the effects of the *Social Hue* and not on the light itself.

V. Conclusions and Future Directions

The aim of this project is to induce social presence through subtle awareness using a covert lighting application namely the *Social Hue*. Our end-users shall play a vital role during all stages of the design of *Social Hue* application; thus leading to several iterations of the product according to end-user specifications.

Throughout this study, there is need for classification and pattern recognition algorithms to ensure high-level information about activities and emotions, which are based on low-level sensory data. Therefore, we could map different dimensions of the data to different elements of light without understanding what the emotion is. However, through emotion classification and feature selection we shall be better able to tailor our system make informed judgements of the activity and emotional states of the participants.

We envision that by way of a literature review, conducting experiments, and evaluation methods we shall gain deeper insight to the implications of using the *Social Hue* as an subtle means to reduce loneliness and stimulate feelings of presence. However, in the worst case scenario it is quite possible that people could note in their consciousness the changes in light patterns and colours, which is likely to negate the effect of the unconscious experience.

The *Social Hue* is expected to bring added value by its discrete communication features. Furthermore, it is a potential niche for the elderly market, where we believe socially integrated ambient displays can improve connectedness and will be beneficial to its users and also reduce the burden on the formal care industry.

Finally, in stages two to three of the experiment, pre-recorded sensory data will be analyzed and fed as input to the Hue lighting system and the responses will be measured. Our long term research goal, is to create a subtle awareness system in a real time home environment. In the future, we will stream data from the sensors to the server, which will analyze and send commands to the Hue lighting system in real time.

Therefore, we will be able to measure quantitative emotional and activity responses in real time.

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REFERENCES

[1] United Nations, Department of Economic and Social Affairs, Population Division (2013), *World Population Ageing 2013.* New York.

[2] J. Crespo Cuaresma, M. Lábaj,and P. Pruzinský, *Prospective Ageing and Economic Growth in Europe.* Vienna University of Economics, 2014.

[3] *Ambient Assisted Living Joint Programme* http://www.aal-europe.eu/about/objectives/ Accessed on April 14, 2014.

[4] J.H. Sheldon. *The Social Medicine of Old Age. Report of an Enquiry in Wolverhampton.* The Social Medicine of Old Age. Report of an Enquiry in Wolverhampton. 1948.

[5] P. Halmos, *Solitude and privacy: a study of social isolation its causes and therapy.* Vol. 15. Psychology Press, 1998.

[6] G. C.Wenger, R., Davies, S. Shahtahmasebi and A. Scott, *Social isolation and loneliness in old age: Review and model refinement.* Ageing and Society, vol. 16, no.3, 1996, 333-358.

[7] A. Steptoe, A. Shankar, P. Demakakos and J. Wardle. *Social isolation, loneliness, and all-cause mortality in older men and women.* Proceedings of the National Academy of Sciences vol. 110, no. 15 2013, 5797-5801.

[8] R. Cornejo, J. Favela and M. Tentori. *Ambient displays for integrating older adults into social networking sites.* In Collaboration and Technology, Springer Berlin Heidelberg, 2010, 321-336.

[9] J. Grudin, *Partitioning digital worlds: focal and peripheral awareness in multiple monitor use.* In Proceedings of the SIGCHI conference on Human factors in computing systems, ACM, 2001, 458-465.

[10] F. Biocca and C. Harms, *Defining and measuring social presence: Contribution to the networked minds theory and measure.* Proceedings of Presence, 2002, 1-36.

[11] P. Dadlani, P. Markopoulos, A. Sinitsyn and E. Aarts, *Supporting peace of mind and independent living with the Aurama awareness system.* Journal of Ambient Intelligence and Smart Environments, vol. 3, no. 1, 2011, 37-50.

[12] V. J. Khan and P. Markopoulos, *"Busy families' awareness needs."* International Journal of Human-Computer Studies, vol. 67, no. 2, (2009) 139-153.

[13] J. A. Bargh and E. Morsella, *The unconscious mind.* Perspectives on psychological science, vol. 3, no. 1, 2008, 73-79.

[14] L.B. Wexner, *The degree to which colors (hues) are associated with mood-tones.* Journal of applied psychology, vol. 38, no. 6, 1954, 432.

[15] J.E. Chung, N. Park, H. Wang, J. Fulk, and M. McLaughlin, *Age differences in perceptions of online community participation among non-users: An extension of the Technology Acceptance Model.* Computers in Human Behavior, vol. 26, no. 6, 2010, 1674-1684.

[16] B. D. Ruyter and E. Pelgrim, *Ambient assisted-living research in carelab.* interactions 14, no. 4, 2007, 30-33.

[17] M.A. Hossain and D.T. Ahmed, *Virtual caregiver: an ambient-aware elderly monitoring system.* Information Technology in Biomedicine, IEEE Transactions on vol. 16, no. 6, 2012, 1024-1031.

[18] P. Tseng and L. Lu, *The Elderly Care System.* Journal of Computers, vol. 24, no. 2, 2013.

[19] P. Shyamal and H. Park and P. Bonato and L. Chang and Mary Rodgers, *A review of wearable sensors and systems with application in rehabilitation.*Journal of NeuroEngineering and Rehabilitation, vol. 9, no. 1, 2012.

[20] Y.S. Yan and Y.T. Shang, *An efficient motion-resistant method for wearable pulse oximeter* Information Technology in Biomedicine, IEEE Transactions, vol. 12, no 3, 2008, 399-405.

[21] M. Chan and D. Estève and J-Y. Fourniols and C. Escriba and E. Campo, *Smart wearable systems: Current status and future challenges.* Artificial intelligence in medicine, vol. 56, no 3, 2012, 137-156.

[22] E.D. Mynatt, J. Rowan, S. Craighill and A. Jacobs, *Digital family portraits: supporting peace of mind for extended family members.* In Proceedings of the SIGCHI conference on Human factors in computing systems, ACM, 2001, 333-340.

[23] S. Consolvo, P. Roessler and B.E. Shelton, *The CareNet display: lessons learned from an in home evaluation of an ambient display.* In UbiComp 2004: Ubiquitous Computing,Springer Berlin Heidelberg, 2004, 1-17.

[24] A. Chang, A.B. Resner, B. Koerner, X. Wang, and H. Ishii. *LumiTouch: an emotional communication device.* In CHI'01 extended abstracts on Human factors in computing systems, ACM, 2001, 313-314.

[25] K. Tollmar and J. Persson, *Understanding remote presence.* In Proceedings of the second Nordic conference on Human-computer interaction, ACM, 2002, 41-50.

[26] I. Keller, W. van der Hoog and P.J. Stappers, *Gust of me: reconnecting mother and son.* Pervasive Computing, IEEE, vol. 3, no. 1 2004, 22-27.

[27] T.K. Judge, C. Neustaedter, Tejind and A.F. Kurtz, *The family window: the design and evaluation of a domestic media space.* In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, 2010, 2361-2370.

[28] R. Cornejo, M. Tentori, and J. Favela. *Ambient awareness to strengthen the family social network of older adults.* Computer Supported Cooperative Work (CSCW). vol. 22, no. 2-3 2013, 309-344.

[29] A.R. Damasio, D. Tranel, and H. Damasio, *Somatic markers and the guidance of behavior: Theory and preliminary testing.* Frontal lobe function and dysfunction, 1991, 217-229.

[30] B. Eggen and K. Van Mensvoort, *Making sense of what is going on 'around': designing environmental awareness information displays.* In Awareness Systems, Springer London, 2009, 99-124.

[31] M. Rauterberg, M, *Emotions: the voice of the unconscious.* In Entertainment Computing-ICEC, 205-215, Springer Berlin Heidelberg, 2010.

[32] P. Ekman, *An argument for basic emotions.* Cognition and Emotion, 6, no. 3-4 1992, 169-200.

[33] S. Petronio and S. Kovach, *Managing privacy boundaries: Health providers' perceptions of resident care in Scottish nursing homes.* 1997, 115-131.

[34] D. Anguita, A Ghio, L. Oneto, X. Parra, and J.L. Reyes-Ortiz, *A public domain dataset for human activity recognition using smartphones.* In European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, ESANN, 2013.

[35] J. L. Reyes-Ortiz, D. Anguita, A. Ghio and L. Oneto, *Smartlab - Non Linear Complex Systems Laboratory* DITEN - Università degli Studi di Genova, Genoa I-16145, Italy. activityrecognition '@' smartlab.ws www.smartlab.ws

[36] P. J. Lang, M.K. Greenwald, M.M. Bradley and A.O. Hamm, *Looking at pictures: Affective, facial, visceral, and behavioral reactions.* Psychophysiology, vol. 30, no. 3 1993, 261-273.

[37] L. Ivonin, H.M. Chang, W. Chen and M. Rauterberg, *Automatic recognition of the unconscious reactions from physiological signals.* In Human Factors in Computing and Informatics , Springer Berlin Heidelberg, 2013, 16-35.

[38] J.A. Russell, *A circumplex model of affect.* Journal of personality and social psychology, vol. 39, no. 6, 1980, 1161.

[39] D. Russell, *UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure.* Journal of personality assessment, vol 66, no. 1, 1996, 20-40.

[40] A. Aron, E.N. Aron and D. Smollan, *Inclusion of Other in the Self Scale and the structure of interpersonal closeness.* Journal of personality and social psychology, 63, no.4, 1992, 596.