2019 IEEE World Haptics Conference (WHC)
Tokyo, Japan
9-12 July 2019

Multi-modal Design to Promote Social Engagement with Dementia Patients

Elaine Czech[1], Mina Shibasaki[1], Keitaro Tsuchiya[1], Roshan Peiris[1], and Kouta Minamizawa[1]

Abstract— **Haptic technologies applied as a means of fulfilling the social needs of dementia patients is an unexplored area of research. Patients with dementia face many limitations that prevent them from engaging with others. For example, as dementia progresses, it becomes more difficult to communicate verbally. We propose a multi-modal system that is personalized and incorporates both active and passive haptic elements can bridge the communication gap between verbal and non-verbal communicators and improve interpersonal relationships. We applied a community-centered design methodology to develop our technological solution so that it would be functional and appropriate for our target audience. We tested our solution, a book which incorporated haptic technologies, with our target audience, and our preliminary analysis of their feedback suggests that there are many opportunities in which multi-modal systems can be used to improve the social engagement of dementia patients.**

I. Introduction

According to the World Health Organization by 2050, there will be an estimated 115.4 million people diagnosed with dementia in the world [7]. As people with moderate to late-stage dementia lose their ability to verbally communicate, their interactions with peers, family members, and care staff becomes challenging. The inability to socially interact not only has a negative impact on the person with dementia [12] but also has a negative impact on those around them [8]. Therefore, to improve the social well-being of dementia patients and those within their social network it is important to investigate non-verbal methods that can encourage social engagement. In this paper, we explore the application of haptic technology as a catalyst for social interaction between moderate to late-stage dementia patients and their families and care staff. To determine an appropriate application, we adopted a community-centered design approach [15] and collaborated with not only the older individuals but also their families and the care staff. We developed a multi-modal system incorporated into a book that would stimulate the user's auditory, visual, and somatosensation senses. Our research demonstrates that using multi-modal design is beneficial to not only dementia patients but all stakeholders within the nursing home community as the multi-modal design can be more personable.

II. Related Works

Conventional means of social interactions can be difficult for people with dementia. However, researchers of dementia have used Human-computer interaction (HCI) and haptics to conduct extensive explorations into touch as a way of stimulating the brain and as a form of communication.

A. Senses, memory, and dementia

According to Kontos [11], the concept of one's personhood relies on social interconnection. However, as Ellis and Astell [8] found, caregivers tend to rely mainly on verbal communication to engage with dementia patients and therefore conclude that non-verbal patients are unreachable. However, beyond verbal communication, there are many different ways dementia patients communicate and make sense of the world around them [8], [11], [13], [20]. Even as verbal cognition declines, patients retain primary motor and sensory areas of the brain [19]. Therefore, many popular dementia interventions rely on multi-sensory stimulation as it allows the brain to make more cognitive connections and improves memory [2], [10], [18], [20]. Dementia patients rely on their senses to be their way of communication and to help them gage their emotions [11]. Additionally, various studies have shown that touch can help calm patients with dementia and help them process situations more positively [13], [20]. The patient's positivity and calmness make it easier for those around them to interact with them.

B. Haptics and social connections

In HCI and haptic research, many works have shown the effectiveness of haptics as a means of enhancing communication [4], [6], [14], [17], [18]. Various haptic solutions attempt to deal with proximity issues which prevent physical contact [4], [6], [18]. In the project HugMe [6], one user touches or hugs an inanimate object, and their physical interaction is transmitted through vibrotactile actuators embedded in a jacket another user is wearing. The purpose of the project is to enhance physical intimacy between people in remote locations. Other solutions try to take this a step further by using haptics as a way of communicating emotions [14], [17]. These solutions try to not only serve as a supplement to verbal and visual communication but also try to become a form of communication. Obrist et al. [17], developed haptic descriptions which invoked certain emotions in users with the potential to allow people to communicate through emotions. While such research is promising, there is still need for further exploration into using haptics as a means for non-verbal communicators to engage with verbal communicators. Furthermore, many of these explorations are inaccessible to dementia patients as they require the user to be an active user.

[1]Elaine Czech, Mina Shibasaki, Keitaro Tsuchiya, Roshan Peiris, and Kouta Minamizawa are all associated with the Media Design Department, Keio University, Yokohama, 223-0061, JAPAN czech_el, mina0415, keitaro.tsuchiya, roshan, kouta @kmd.keio.ac.jp

978-1-5386-9461-9/19/$31.00 © 2019 IEEE

C. Adapting technology for dementia

Technologies which require the user to be an active participant without intuitive visual cues (e.g., pushing a button to turn on a device) are inaccessible to dementia patients [18]. Wearable devices [6] are one potential solution, as they can allow for passive interactions. Studies on dementia patients show that patients retain procedural and emotional memories [20]. Thus, devices potentially can remain accessible to dementia patients over time if they involve movements that are innate or trigger an emotional response [2]. The Messaging Kettle [5], while not an application of haptic technologies, demonstrates that embedding technology into a habitually used item improves accessibility for older users.

Research on physical touch and dementia patients, as well as various applications of haptic technologies, show the potential of haptics for non-verbal communication. Furthermore, research also reveals methods by which technology can be applied to remain accessible to dementia patients. Based on this research, we believe that applying haptic technologies in a way that is accessible for dementia patients could be used to bridge communication between non-verbal and verbal participants. To find an appropriate solution and develop methodologies to help other haptic researchers, we took a participatory design approach to our target community.

III. Background

To developed a design methodology for a solution that would address the needs of our target community, the social network of a dementia patient, we used a participatory design approach. First, we identified the needs of the community by observing and interviewing members of older individuals' social networks. Then, we addressed the issues raised by the community through a design workshop with field experts.

A. Identifying Needs

We decided to observe and interview people from the United States and Japan who make up the social network of not just dementia patients but older individuals in general. We observed older adults (25) in an assisted living home, Hyldemoer Hutte[1], who were in their late 70s to late-90s, were all independently mobile and required minimal to moderate care. We also held a set of small group interviews with older individuals (16) from the United States. The participants' ages ranged from the early 60s to mid-70s, and all lived independently without assistive care. Our participants from the United States provided us with knowledge and experience concerning peer interactions as well as family members' perspective on the life of older adults, as many of the participants cared for, or were currently caring for family members. Simultaneously, we conducted interviews with nursing/assisted living home care staff in both Japan (6) and the United States (2). For our observations, we compiled notes on the topics of conversation, the residents' body language, and the residents' overall appearance. All interviews were video recorded and transcribed. Then we thematically analyzed [3] the texts from our observations and interviews into four categories: **interpersonal relationships, reminders/artifacts, motivation, and ability**.

While we did not focus our observations and interviews on dementia patients, we found that the dementia patients expressed needs within all of the four themes. In particular, the dementia patients (6% of those observed), to some degree, expressed feelings of shame and isolated themselves to avoid social interactions. For family members and care staff (50%), because they could not verbally Communicate with dementia patients, they did not feel their interactions were meaningful. Family and care staff, to varying degrees, also mentioned an importance of memorialize people as a way to sustain and build relationships. To achieve our ultimate goal of designing a solution by which dementia patients could engage with others socially, we concluded we needed to create a design which addressed a broad spectrum of abilities. For our solution to be considered successful, we would need to have the potential to engage all members of the dementia patients social network as well as address the four themes. To address the identified needs, we solicited design input from health care experts who make up an important part of the dementia patients social network.

B. Addressing Needs

For our initial ideations, we performed a 2-part workshop with Mediva Inc.[2], a health care consulting and medical service operation company based in Tokyo, Japan. The purpose of the workshop was to develop a variety of solutions that were not just tailored to dementia patients but for older individuals and their social networks.

In the first part of the workshop, we presented an overview of the findings and had participants created storyboards considering how they would promote a positive frame of mind and enrich social interactions for older individuals. We analyzed the storyboards by creating a series of concept posters which allowed us to visually categorize each idea. We categorized each design based on which positive aging elements, as described by Nassir, Leong and Robertson ([16]), they addressed and how the design affected the members of the older individuals social network. This process resulted in the categorization [3] of the concept posters into four themes: **creating empathy, memorializing people, self-motivation, and expanding ability**. For the second part of the workshop, we performed a design sprint and everyone wrote down or drew as many ideas as possible on post-it notes that fit under the four themes. Through group discussion, we were able to address potential issues that could arise with each design, particularly issues of accessibility.

From the design solutions that emerged in our two-part workshop, we decided to develop a haptic book. While several of the other designs promote interpersonal relationships and community building, they relied heavily on operating new technologies which we felt might prove difficult for some dementia patients. Conversely, a book is a familiar item

[1]Hyldemoer Hutte Nursing Home, `https://www.hyldemoer.com/`

[2]Mediva Inc.`http://worldwidemediva.com/`

that is habitually used over a person's lifetime and typically nursing/assisted living homes have a public library space; therefore, a book is an item that can be easily shared by members of the dementia patient's social network. Furthermore, using a book would allow us to memorialize people through their stories, a theme that initially arose during our observation/interviews. Also, sharing stories is one way to build feelings of empathy which is essential for developing or improving social bonds [9]. We decided to design our book to include stories from various participants connected by an over-arching theme. An anthology, as opposed to a single person narrative, was created to help users more easily find relatable content for which to generate empathy.

IV. Multi-modal System Design

Using the book format allowed us to invoke both passive and active haptic experiences. To make the content captivating and accessible, we wanted to involve as many senses as possible. Multi-sensory stimulation would not only serve to help dementia patients [11], but would also help other older individuals who may have weakened senses [18]. We decided to tell each participant's story over four pages using a multi-modal system (Fig. 1 [Top]). The first two pages would be a straight-forward telling of the story and would stimulate the user's auditory and visual senses, while the next two pages would be an abstracted version of the same story and stimulate **somatosensation, visual, and auditory senses** (Fig. 1 [Bottom]).

A. Somatosensation

Unlike most technologically enhanced tools, a book relies on a more tactile interaction and draw upon one's procedural memories [1]. When using a book, one flips the pages to reveal new content; thus, we decided to mirror this effect by using a hall sensor per page which would be triggered by magnets attached to each page. Thus, as each page was turned, the content of the opened page would automatically play and the user would not be required to perform any additional action beyond how they would normally interact with a book. All technological elements were embedded in the book's cover base in order to keep the format of the book as familiar as possible. We decided to invoke the somatosensation sense further with the abstract experience of each story. The abstract experience included both a tangible element and a corresponding vibrotactile sensation. A VP2 actuator[3] transmitted the vibrotactile sensation. For example, the actuator played the sound of a cat purring, which was felt when touching the tangible element, felted wool. We hoped the active haptic vibrations from the actuator coupled with the passive haptic sensation from touching the tangible item would provide greater sensory simulation.

B. Visual

To make the stories more engaging, build empathy, and create context we added various visual elements. For many older individuals, visual senses are impaired; we attempted to address this limitation by using contrasting color elements and enlarging images and text. With each straight-forward story pages, we included a text transcript with a picture of the storyteller. The transcriptions were made so that end users could listen to the stories and read along, while the photo was included to help the user develop empathy for the storyteller. For the abstract experience pages with the tangible element, we included a picture related to that item. In the case of the cat, we included a picture of the storyteller's cat. We felt a visual element would add context to the abstract haptic experience and a sense of reality.

C. Auditory

We included audio recordings of each story for two reasons: 1) Although we enlarged the transcribed text of each person's story, we felt being able to hear the stories would provide another way for those with visual impairments to engage with the contents. 2) We felt that hearing the participant tell their own story would help to increase empathy as well as empower the participant. By telling their own story, the participant controlled the narrative. Audio elements were also used to convey the vibrotactile sensations; when the user felt the vibration of the cat purring, they would also be able to hear the purring. Audio files of the participants' stories and the haptic audio files were played using a DFPlayer Mini and played through the VP2 actuator. The system was operated by an Arduino computer (Uno then Pro-Micro) and powered using a 5000mAh mobile battery.

Fig. 1. [Top] Hardware set up of our book prototypes. [Bottom] Users can listen to the storyteller share their story on one set of pages. Then experience the story through passive and active haptic sensations.

V. Haptic Remembrance Book 1: Content Creation

With our design methodology, we created the first prototype of our book (Fig. 2). The purpose of this prototype was to gauge reception and improve the design.

[3]Acouve Laboratory Inc., `http://www.acouve.co.jp/product/pd_vp2.html`

1) Multi-modal Content and Participatory Design: Two independent adults, a male and a female both over the age of 60, without any significant physical or mental limitations, consented to participate in the prototype. We predetermined the book theme as pets. For the straight-forward pages **auditory** component, we prompted both participants to provide a 30-second story recording. As for the **visual** components, we asked participants for a photo of them with their pet and another photo of only their pet. The female participant provided a story and photo of her dog. While the male participant provided a story and photo of his cat. In consideration of how end-users would receive the content, we cleaned up the participants' audio recordings in Audacity and transcribed the recordings. Based on the photos of their pets, we created the **somatosensation** and **auditory** elements for the abstract expression pages. We chose and designed corresponding haptic audio and tangible items without prior consultation with participants. As mentioned previously for the cat, we included a haptic sensation of a cat purring. For the dog, we included a felted wool tangible item with the sound and feel of a dogs nails tapping on wood.

Fig. 2. [Left Images] Transcribed story with photo of storyteller. [Right Images] Tangible item with photo of storyteller's pet.

2) Demonstrating and Feedback: We exhibited this prototype at the Keio Media Design Forum in Japan (Fig. 3). We demonstrated the book to over 20 visitors of varying ages (younger than 10 to over 60) and backgrounds. During our demonstrations we hoped to learn whether users felt the device was suitable for our target audience and if the content resulted in social engagement. Adult users felt the design was appropriate for our demographic although concerns about visual and auditory limitations were raised. All users were intrigued by the application of vibrotactile actuators and felt it added to the book's content. Notably, those who found the content relatable shared personal anecdotes (stories and pictures) and engaged longer with the prototype. Two separate females, in their 20s, visited our demonstration more than once. One female user in her 20s said, *"My grandfather had Alzheimer's disease and I think this could have an incredible impact on that community!"* We also demonstrated the book to various residents and care staff in both the United States and Japan (Fig. 3). Their reactions were similar to those received during the Forum exhibition. Individuals with pets were excited to share their own stories, while those without were more intrigued by the technology. We concluded that indeed the book was an appropriate device and that the novelty of the technology was enough to create social engagement. However, it was the content which helped sustain conversation.

Fig. 3. [Above] Demonstrating to visitors at Keio Media Design Forum. [Below] Demonstrating book to nursing home residents in the United States and Japan.

VI. Haptic Remembrance Book 2: Content Creation

Considering the feedback received from our demonstrations, we decided to enlarge the pages of the book from approximately 5.5" x 8" to approximately 8.5" x 11" and reduce the base containing the technology. We also made efforts to increase the volume level in our program. Besides these changes, the book's functional layout and technology remained the same. However, significant changes were made concerning content creation since we wanted to assess the reactions that the people living in close proximity would have towards each others stories. Therefore, for this prototype we collaborated with five residents living within the Lourdes Senior Community[4]. For ethical considerations, we had all participants (residents or their power of attorney, family members, and care staff) sign both a participation consent form and a video/image release.

1) Multi-modal Content and Participatory Design: To gather content for the book, we interviewed five residents, two females and three males, ages ranging from 75-100, and of varying degrees of physical and mental capabilities (Table I). Since the purpose of the book was to foster social engagement, we did not feel it was essential to gather participants with only dementia. We decided to not predetermine the books theme for this prototype. We used the recordings from our interviews to create the **auditory** elements for straight-forward pages. During each interview, we asked the residents to share their passions and interests. Then we edited the interviews into concise 20-25 second stories

[4]Lourdes Senior Community, `https://www.lourdesseniorcommunity.org/`

using Audacity. Once this was done, we transcribed each clip. For **visual** components of the straight-forward pages, we either paired the story transcription with a portrait of the storyteller or an image provided by the family members. One participant, Margaret, 96 years old, who suffered from limited vision and mild-moderate dementia, loved her cats; and due to her dementia, she recorded her story with her daughter (Fig. 4 [Right]). Her daughter also provided us with a photos of Margaret holding her cat and of Margaret's three cats.

	Age	Condition
Marie	100	Short-term care, recovery
Margaret	96	Long-term care, visual impairment and mild dementia
Jeff	89	Long-term care, bed-bound
David	75	Multiple Sclerosis
Saul	100	Short-term care, recovery

TABLE I

PARTICIPANTS (PSEUDONYMS USED TO PROTECT THEIR IDENTITIES)

We consulted with all residents on the type of **visual**, **auditory**, and **somatosensation** they wanted for their abstract pages. More lucid residents, such as David, 75 years old, who was living with multiple sclerosis and had some muscle weakness, were active in the design process. Since David's drawings and his ability to share them were important, he provided us with a drawing to include with his story. For David's abstract expression pages we included an interactive drawing experience enhanced by the sounds and sensations of a person drawing (Fig. 4 [Left]). Overall, we tried to give participants more control of the books content through their self and abstract forms of expression.

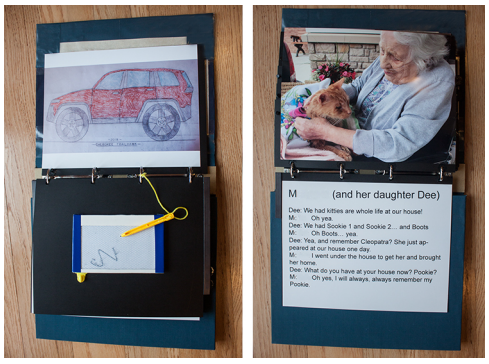

Fig. 4. [Left] David's abstract experience page, with visual of one of his drawings. [Right] Margaret's story page, with an image of her with her cat and the transcript of the story told with her daughter Dee.

2) Demonstrating and Feedback: On the day we shared the completed book, we were only able to meet with two of our five participants. One participant had been only in short-term rehabilitation care and had returned home, and two were incapacitated due to health issues. Despite these limitations, we were pleased to find that book elicited our desired reactions from our users and care staff. We first showed the book to David. While he found the haptic content amusing,

Fig. 5. When showing David the other pages, he shared his own stories. When he saw a story about chickens, he told us about the ones his father raised.

he reacted more towards the story content (Fig. 5). When the story about Margaret's pet cat played, he mentioned the cat he once had, and when he came to the story about chickens, he told us about how his dad had also raised chickens. By talking about these stories, he began to open up and tell us even more stories about his past and current daily life. Next,

Fig. 6. [Left] Before seeing the book, Margaret was falling asleep. [Right] As viewing began, she became talkative and animated.

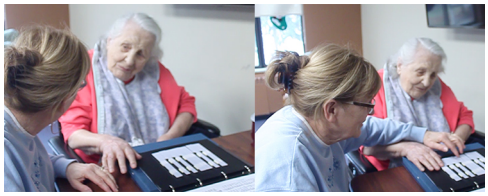

Fig. 7. [Left] Notices her daughter not paying attention and gets her attention by touching her hand [Right] The daughter happily obliges and plays with her mother.

we shared the book with Margaret and her daughter. When we approached her with the book, she was falling asleep. However, upon hearing the stories and interacting with the haptic content, she became talkative and animated (Fig. 6). As Margaret interacted with one page (Fig. 7), she noticed her daughter not paying attention; so she paused to grab her daughters hand in order to involve her in the activity. Although she could not share stories like David, Margaret was able to use the book as a means of socially engaging with her daughter and us.

VII. DISCUSSION

Haptic technologies have been used to supplement and even substitute verbal communication. This research, along with research conducted regarding social engagement of dementia patients, indicates the potential haptic technologies have in facilitating the social welfare of dementia patients. However, research into practical applications of haptics for

dementia patients is limited as accessibility is an issue. To address this we suggest for designers and researchers to use a multi-modal system which engages a variety of senses and is incorporated into a familiar form. As discovered during our demonstrations, we found that the novelty of the haptic technology led to initial engagement with the device. By including stories along with the haptic experiences, we were able to develop a device that was also interesting for adults without dementia. Our solution allowed users to use the book as a catalyst to start verbal or non-verbal conversations. Content relatability helped to sustain user's interests for longer spans of time and for some users the sustained interest led to sharing of personal anecdotes to deepen the interactions.

VIII. Limitations and Future Work

Our work is limited by the sample size; thus far, we have only tested the book with one individual who had dementia and we were unable to see the effects of the book on her interactions with others over time. Therefore, positive results could be due to the book's initial novelty. In the future, we plan to work with more dementia patients and observe the effects the book has on social engagement over an extended period. Furthermore, regarding content creation for future books and dementia patients, we would like to work with a patient who develops the content while in the early stages of dementia and observe how they continue to interact with the book as their dementia progresses. For the book design, we plan to streamline the base and hardware design to improve the ease of customization.

IX. Conclusion

In this paper, we analyzed the social issues that arise among members of the dementia patient's social network: the peers, family members, and care staff. Based on these observations and interviews, we concluded that relying on only verbal means of communication can limit the level of social engagement. Through our literature review, we discovered that multi-sensory stimulation such as haptics are an effective form of non-verbal communication for dementia patients. However, the application of haptic technology needs to be accessible for dementia patients. We proposed developing a multi-modal system which incorporated both passive and active elements into a book as a means of bridging social connections between verbal and non-verbal communicators. The multi-modal system, by simulating multiple senses in relation to positive, personal stories made the content accessible to not only dementia patients but all stakeholders within the nursing home community.

X. ACKNOWLEDGMENT

We would like to thank Doctor Chiaki Mishima and CEO Kanoko Oishi and all the staff at Mediva Inc.; the staff at the Hyldemoer assisted living community; our interviewees from the US; David and Omega Barks; everyone at the Lourdes Senior Community; Yurike Chandra, Tania Ananta Hidayat, and Nancy, Paul, and Chris Czech for their assistance. This work is done in collaboration with Mediva Inc. and partly supported by the HAYAO NAKAYAMA Foundation for Science Technology and Culture.

References

[1] K. M. Alam, A. S. M. M. Rahman, and A. E. Saddik, HE-book: A prototype haptic interface for immersive e-book reading experience, 2011 IEEE World Haptics Conference, Jun. 2011.

[2] F. Arab, S. Paneels, M. Anastassova, S. Coeugnet, F. L. Morellec, A. Dommes, and A. Chevalier, Haptic patterns and older adults: To repeat or not to repeat?, 2015 IEEE World Haptics Conference (WHC), Jun. 2015.

[3] V. Braun and V. Clarke, Using thematic analysis in psychology, Qualitative Research in Psychology, vol. 3, no. 2, pp. 77-101, 2006.

[4] S. Brave and A. Dahley, inTouch, CHI 97 extended abstracts on Human factors in computing systems looking to the future - CHI 97, Apr. 1997.

[5] M. Brereton, A. Soro, K. Vaisutis, and P. Roe, The Messaging Kettle, Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI 15, Apr. 2015.

[6] J. Cha, M. Eid, L. Rahal, and A. E. Saddik, HugMe: An interpersonal haptic communication system, 2008 IEEE International Workshop on Haptic Audio visual Environments and Games, Oct. 2008.

[7] "Dementia," World Health Organization, 17-Dec-2017. [Online]. Available: https://www.who.int/en/news-room/fact-sheets/detail/dementia. [Accessed: 25-Jan-2019].

[8] M. Ellis and A. Astell, Correction: Communicating with people living with dementia who are nonverbal: The creation of Adaptive Interaction, Plos One, vol. 13, no. 4, 2018.

[9] D. R. George, H. L. Stuckey, and M. M. Whitehead, How a creative storytelling intervention can improve medical student attitude towards persons with dementia: A mixed methods study, Dementia, vol. 13, no. 3, pp. 318-329, 2012.

[10] D. Kim, B. J. Johnson, R. B. Gillespie, and R. D. Seidler, Role of haptic cues in motor learning, 2013 World Haptics Conference (WHC), Apr. 2013.

[11] P. C. Kontos, Embodied selfhood in Alzheimers disease, Dementia, vol. 4, no. 4, pp. 553-570, 2005.

[12] B. M. Luchesi, N. A. D. Oliveira, D. D. Morais, R. M. D. P. Pessoa, S. C. I. Pavarini, and M. H. N. Chagas, Factors associated with happiness in the elderly persons living in the community, Archives of Gerontology and Geriatrics, vol. 74, pp. 83-87, 2018.

[13] E. Lykkeslet, E. Gjengedal, T. Skrondal, and M.-B. Storjord, Sensory stimulationA way of creating mutual relations in dementia care, International Journal of Qualitative Studies on Health and Well-being, vol. 9, no. 1, p. 238-288, 2014.

[14] A. Mazzoni and N. Bryan-Kinns, How Does It Feel Like? An Exploratory Study of a Prototype System to Convey Emotion through Haptic Wearable Devices, Proceedings of the 7th International Conference on Intelligent Technologies for Interactive Entertainment, 2015.

[15] A. Meroni, Strategic design: where are we now? Reflection around the foundations of a recent discipline, Strategic Design Research Journal, vol. 1, no. 1, pp. 31-38, 2008.

[16] S. Nassir, T. W. Leong, and T. Robertson, "Positive Ageing," Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction on - OzCHI 15, Dec. 2015.

[17] M. Obrist, S. Subramanian, E. Gatti, B. Long, and T. Carter, Emotions Mediated Through Mid-Air Haptics, Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI 15, Apr. 2015.

[18] S. Paz, J. Mayas, and S. Ballesteros, Haptic and Visual Working Memory in Young Adults, Healthy Older Adults, and Mild Cognitive Impairment Adults, Second Joint EuroHaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems (WHC07), 2007.

[19] P. M. Thompson, K. M. Hayashi, G. D. Zubicaray, A. L. Janke, S. E. Rose, J. Semple, D. Herman, M. S. Hong, S. S. Dittmer, D. M. Doddrell, and A. W. Toga, Dynamics of Gray Matter Loss in Alzheimers Disease, The Journal of Neuroscience, vol. 23, no. 3, pp. 994-1005, Feb. 2003.

[20] C. Treadaway, D. Prytherch, G. Kenning, and J. Fennell, In the Moment: Designing for Late Stage Dementia, roceedings of DRS2016: Design Research Society Future-Focused Thinking, pp. 1442-1457, 2016.