REMEMBER TO REMEMBER: A FEASIBILITY STUDY ADAPTING WEARABLE TECHNOLOGY TO THE NEEDS OF PEOPLE AGED 65 AND OLDER WITH MILD COGNITIVE IMPAIRMENT (MCI) AND ALZHEIMER'S DEMENTIA

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Abstract

Designing for a healthy life includes addressing the needs of an ageing population. The number of people aged 65 and older with mild cognitive impairment and dementia is rising. Whilst there is to-date no pharmacological cure, treatments for symptoms and studies into the effect of non-pharmacological interventions have become more widely available, with the goals of maintaining and supporting cognitive function, helping the person compensate for impairments, and improving the quality of life. Promising yet nascent is the use of wearable technology for cognitive rehabilitation.
We conducted an exploratory feasibility study adapting wearable technologies to support the above-mentioned elderly user group remember to remember their daily activities such as non-routine appointments. Six design concepts with smartwatches, smart bands, smartphones, smart calendar boards, NFC tags, and augmented reality glasses were sketched and two low-fidelity prototypes, Memofy and Komihu, were developed and tested with three patients and their caregivers. Technology acceptance was high both amongst patients and health personnel, encouraging further in-depth and longitudinal tests for health outcomes.

Keywords: Inclusive design, User centred design, Communication, Wearable technologies, Cognitive rehabilitation

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1 INTRODUCTION

How can we as design engineers help designing for a healthy life? Designing for a healthy life includes addressing the needs of an ageing population. The number of people aged 65 and older with mild cognitive impairment (MCI) and dementia is rising world-wide. As a consequence, the costs of health care for Alzheimer's disease and other dementias in addition to associated societal costs from caregiving are substantial. Whilst there is to-date no pharmacological cure, treatments for symptoms and studies into the effect of non-pharmacological interventions have become more widely available, with the goals of maintaining and supporting cognitive function, helping the person compensate for impairments, and improving quality of life (Cochrane Database n.d.).

What kind of non-pharmacological interventions may yield the desired health outcomes? Promising yet nascent is the use of assistive (wearable) technology for cognitive rehabilitation. Industry observers expect 2015 to be a big year for wearable technology in healthcare, i.e. technology devices that can be worn by a user and often include tracking information related to health and fitness. We would like to know: *Can wearable smart technology be adapted to the needs of people with mild cognitive impairment and early onset of Alzheimer's dementia?*

This paper reports a pilot feasibility study called *remember to remember* in which we started to adapt wearable technology to the needs of people aged 65 and over with MCI and early stages of Alzheimer's dementia. The study is part of a wider research project of adapting smart technology for cognitive rehabilitation and is conducted in co-operation with design researchers, neuropsychologists, and medical doctors.

The remainder of the paper is structured as follows: Section 2 provides an overview of research into the use of (assistive) technology for people aged 65 and over with mild cognitive impairment. Section 3 describes the methods used. Section 4 presents the two prototype solutions developed and tested. Section 5 discusses the results in light of implications for research and practice and concludes with avenues for further work.

2 LITERATURE BACKGROUND

2.1 Ambient Assisted Living

Despite the lack of curative treatments for cognitive impairment disorders, early detection and care can delay hospitalisations and improve patients' self-sustainability and perhaps increase their quality of life. The rapid evolution and increasing affordability of mobile computing technologies we have witnessed during the last decade led to many commercial and research initiatives that are concerned with the use of Information and Communications Technology (ICT) for monitoring and non-pharmacological treatment of cognitive disorders. In addition to the existing difficulties in monitoring and assistance, the ageing populations of the Western world will bring many further social and economic challenges. The Ambient Assisted Living (AAL) joint research programme is one of the first initiatives to tackle the issues of the aging society with ICT tools. It started in 2008 with the participation of 22 countries. Between 2008-2013, the AAL and FP7 programs supported a number of projects that aim to provide ICT-based assistance to patients with cognitive disorders, such as: The MATCH project (Turner 2012) aimed to develop integrated home care technologies, the CARE project (Belbachir et al., 2011) focused on visual sensor technologies to provide intelligent monitoring and alarming systems for the elderly, and the SOPRANO (Wolf et al., 2008) and OpenAAL projects (OpenAAL n.d.) targeted a software platform for developing, testing, running and maintaining assisted living environments.

In addition to more generic assistive platforms, AAL has also supported projects that target to assist patients with non-generative cognitive diseases. The ROSETTA project (Rosetta n.d.) aimed to provide sensor-based activity guidance to patients with dementia, the ALFA project aimed (Alfa n.d.) to develop a visual tool to stimulate walking and chewing for dementia patients, and the BEDMOND project (Hochgatterer et al. 2011) aimed to develop an ICT-based system for early detection of Alzheimer's disease for elderly while living at home.

The last decade witnessed many research projects that have suggested ICT-based platforms and conceptual and technical frameworks. Despite the significant research interest in AAL solutions, most of these projects have not reached maturity or become operational beyond experimental prototypes.

Our hypothesis is that one of the main reasons for the lack of widespread use of the results of these projects is that the solutions are not sufficiently adapted to the highly complex, dynamically changing and individualised needs of people with dementia. Rather than adapting existing technologies, many of these projects aimed to design special products for the elderly: custom sensors for fall detection, localisation (GPS), activity monitoring (motion); custom mobile computing devices, tablets, watches, and custom software platforms for 'app-stores', sensor communication gateways and development of firmware for a plethora of devices. While these research projects created an important body of knowledge in ambient assisted living technologies, and perhaps more importantly, validated that the end users – patients, care takers and healthcare professionals – demand these technologies; economic and practical viability, acceptance, and use of the proposed solutions are yet to be proven.

2.2 A wearable future

Wearable technologies have been on the rise in the last few years. We believe that the wider uptake of smart and connected devices for general use will also have a significant impact on the design and implementation of assistive technologies. In this project we aim to use the existing and upcoming technologies that already have a significant market adoption, multiple software distribution platforms (existing app stores) and well documented development tool chains for new apps and accessories. This strategy also warrants the feasibility of the solutions as wearable devices are marketed for mass markets with affordable prices, and the software platforms – which have been the bottleneck in many of the AAL projects – often come open-source or free of charge.

With only a few years of history, the wearables market is young, and especially in the last year has witnessed a number of new initiatives from the major players. Most recently Apple has introduced the Apple Watch that is expected to be on the market in early 2015 (Apple n.d.). In addition to a number of commonly found sensor technologies, Apple also introduced a heart-beat sensor to their watch, in alignment with the HealthKit, which will be an embedded part of the future iOS operating systems. Similarly, Sony's SmartWear (Xperia n.d.), Samsung's Gear (Samsung Wearable Tech, n.d.), LG's G watch (LG n.d.), Motorola's Moto 360 (Motorola n.d.) have entered the market in the last few years with comparable sensor and communications technologies. These companies consider wearables as a natural extension of the smartphone market and it is expected that they will develop and release newer and better products on a yearly basis and keep the platforms alive and active. In addition to device manufacturers, Google – as a content provider – has shown a significant interest in wearables. In alignment with new hardware from several companies, Google has developed the Android Wear platform (Android Wear n.d.) which aims to provide seamless integration between wearables, smartphones, smart homes and other smart devices that are expected to be ubiquitous in the following years. Another platform from Google that received significant interest is the Glass (Google Glass n.d.) – a wearable computer in the form of glasses.

Perhaps one of the important features of the new generation wearables is the vast amount of options for configuration. A watch is considered a personal accessory and it is deemed to be important that the users have the chance to find the most workable option for them. We believe that this opportunity for customisation can have a significant effect on the adoption of smart watches and wearables as assistive devices by patients with mild cognitive disorders. Patients will have the chance to find the most pleasing configuration for their needs. In other words, we believe that adaptation of existing devices such as consumer products (e.g. smartphones, smart watches, wearables) instead of specifically designed devices will enhance acceptance and use.

2.3 Research into using technology for cognitive rehabilitation

ICT-based solutions have been developed for patients with cognitive impairments (Pollack 2005). Such technologies appear to have been well received by the targeted users and users have shown to be capable of using such technologies correctly (Lauriks et al. 2007). However, developing for our user-group of people age 65 and over with mild cognitive impairment and mild Alzheimer's dementia, the literature-base is rather thin (Philipose et al. 2004). As demented people often have multiple cognitive (amnesia, agnosia, aphasia) and perceptual impairments (visual, sensory, auditory), the needs for patients with dementia are rather special and existing technology may not be able to accommodate for such needs (Gerritsen et al., 2010). Lauriks et al. (2007) point out that there is demand for studies exploring the potential of smart technologies as cognitive support tools. To name a selection of recent efforts, Armstrong et al. (2013) have developed a simple smartphone for patients with Alzheimer's

dementia. TalkMeHome is another project that uses smartphones and GPS systems to guide patients over the phone and Shin et al. (2014) have also developed a smartphone solution targeted for patients with Alzheimer's (Olazaran et al., 2010), and there is also recently launched *Doro* phone (Doro, n.d.). In summary, whilst there are a number of studies looking into the potential of technology for cognitive support of elderly, studies specifically investigating our targeted user group are, however, rare. When adding the criterion of adapting and using *wearables*, we are definitely arriving at an under-researched space. This project is starting to fill the niche with a pilot feasibility study on adapting wearables to the needs of the specified user group.

3 METHODS

As part of the *remember to remember* research project, ten design and innovation students were tasked with adapting wearable technology to the needs of people suffering from Mild Cognitive Impairment (MCI) and early Alzheimer's dementia. In collaboration with design researchers, neuropsychologists, doctors and patients, the students elicited user requirements and designed, prototyped and evaluated assistive solutions for MCI patients. Using wearable technologies, the overarching aim of the *remember to remember* project is to improve the quality of life of the patients, by providing them with the necessary technological solutions for an independent and socially-included life.

The methodological steps taken to arrive at two low-fidelity prototypes are described here. The development journey involves understanding the patients' experience of using (wearable) technology in their daily life and covers the overall system development process from eliciting user needs, to developing requirement specifications, concepts, detailed designs and user-tests of the final solutions (see Figure 1 for an overview of the user-centred development process).
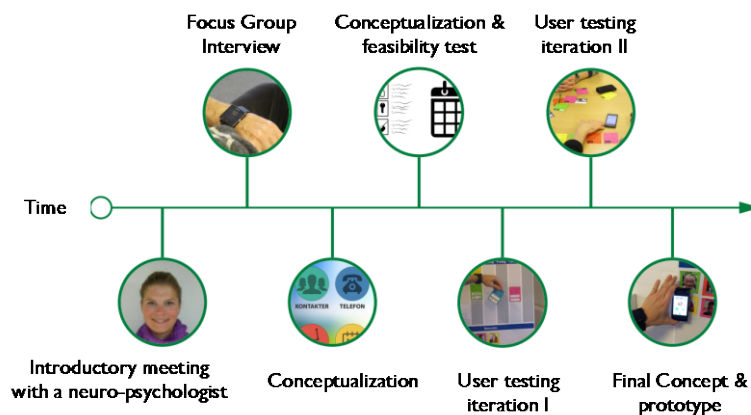

Figure 1. User-centred development process

3.1 Eliciting user needs towards requirements specifications

3.1.1 Interview with a neuropsychologist to get a first glimpse into the condition

By interviewing a neuropsychologist, we were made aware of that MCI is not a uniform condition (Petersen 2004). However, in general, MCI patients are in their early stage of forgetting day to day information. While remembering routines such as making breakfast, putting on clothes, or collecting the mail are not problematic, occasional events such as birthdays, grocery shopping, or newly agreed coffee appointments may easily be forgotten. Patients are not proud when they remember something as they see this as something normal that everyone should be capable of. Instead, they may feel sad or angry, they may feel that they have let themselves and others down and they may feel disappointed when they don't remember that they should have remembered.

3.1.2 Focus group for eliciting user needs and understanding technology savviness

The first focus group session at the hospital consisted of three MCI patients (primary user group), their caregivers (secondary user group), and a neuropsychologist. Outpatients from the Glostrup Memory Clinic who were diagnosed with MCI or mild Alzheimer's disease and their relatives were asked if they were interested in participating in the project. The aim of this focus group session was to obtain

an understanding of everyday challenges for the primary user group and to observe how elderly patients interact with touch user interfaces of wearables such as smartwatches.

Figure 2. Selection of wearable technology tested with the elderly over 65 with MCI

Each of the participants was encouraged to 'play' with the three different smartwatches that were available in this session. The MCI patients showed a lot of interest in the smartwatches and thought they were clever and good looking. Contrary to our expectations, focus group participants were not intimidated by the technology, but rather curious about the touch user interface and wanted to find out how it worked.

3.1.2.1   User needs and values

Based on our discussions with the focus group, we divided user needs and values into four categories:
- **Independence:** *"I can handle a day-to-day schedule on my own, so I don't have to bother my relatives for help"*.
- **Remembering:** *"I can keep track of future and previous events, so I can add structure to my life"* and *"I am reminded about events when I need to know about them"*.
- **Interaction:** *"As a user with reduced eyesight and motor skills, I need large and unambiguous input interfaces in order to be able to interact with the system"*.
- **Context:** *"As a user, I need to be reminded about what to remember at certain locations when I am out, as I do not always remember on my own what I have set out to do"*.

3.1.2.2   Requirements

All focus group participants had a mobile phone, but none of them were using *smartphones*. So far, they would use handwritten notes to remember, but tended to misplace and forget them. Judging by the feedback from the focus group when introducing the smartwatches and asking for the possibilities they see in using such devices, we can sketch the main technology features desired:
- Large and unambiguous input interfaces for easy interaction with the system,
- reminders on the watch, e.g., including shopping lists, so whenever entering supermarket, the device could show the list of groceries to buy,
- a day-to-day schedule with a good overview of past and future events,
- a notification-system which can remind of scheduled events, and
- location-based notifications.

3.2 Iterative concept development of low-fidelity prototypes and user-testing

After eliciting what the design must achieve and researching existing solutions, we conducted brainstorm sessions to create ideas for six different concepts from which two were selected for detail development. Co-creating the user-centric technology solution with the end-user meant in our case to test the solutions in three iterations with the user group (see figure 1). The third iteration represents the final designs.

4   DEVELOPING AND TESTING TWO LOW-FIDELITY PROTOTYPES

Adapting and re-combining already existing wearable technology and applications on the market, two low-fidelity prototypes were developed and evaluated with the target user group. Prototype one, *Komihu*, focuses on paths tracking, alerting if the direction was changed and on remembering to bring the device. Prototype two, *Memofy*, focuses on integrating a wall-calendar into a smartphone and smartwatch based solution. Short video illustrations can be found here (designportfolio.dk).

4.1 Prototype 1: *Komihu*

This prototype solution consists of a smartphone with a simple touch interface. The touch interface is a display with large text and symbols only for essential functions displayed on the start screen such as calling, texting, calendar, alarm clock and GPS. The solution focuses primarily on aiding patients to attend their planned events and on interactions when making appointments with other people both at home and outside the house.

4.1.1 Personas

Patients will have different needs according to the severity of their condition. The *Komihu* prototype is designed to fit the needs of the individual patient as functions can be added and removed when needed. Two personas served as orientation:

- Matilde is 73 years of age and wears glasses. She is retired and lives with her husband. Matilde can take care of herself inside the home but she is suffering from MCI. In her case it means that she cannot leave the house without forgetting where she was heading to. Matilde also forgets appointments and her husband currently communicates appointments through sticky notes on the fridge. Her former occupation was inside a telecommunications company. Matilde is physically very mobile but struggles mentally due to MCI. She gets very upset and angry with herself when she forgets.
- Per is 76 years old and Matilde's husband. Per is also retired and formerly worked as a mason. Per uses a lot of time writing remembering-notes for his wife. Per is not afraid of technology and would love more gadgets in his everyday life to help him help his wife. He thinks that a device helping Matilde to remember her appointments would help a lot. Per often experiences that Matilde is not at a certain place at a certain time and sometimes, this causes lots of concerns, especially when Matilde does not pick up her phone. Both Matilde and Per would love if he could find Matilde without her having to answer her phone.

4.1.2 Features

Icon-based touch screen phone operation system (Figure 3 below and see also Figure 4 for overview):

- Call function: Photos of who to call
- Messaging system with large icons and sufficient spacing between the icons (Figure 3, left)
- Calendar: Inspired by existing Google calendar for others also to make appointments
- Shopping *Komihu*
- Going from A to B *Komihu*, using geofence and tracking system
- Timeline *Komihu*, inspired by existing App *Moves* (Figure 3, right)
- Walking *Komihu*
- Docking station for remembering to bring the device

Figure 3. Messaging system (left) and timeline inspired by Moves

4.1.3 Testing and evaluating

Two user-tests were conducted with three patients and their caregivers. This solution is using smart technology (smartphone), yet, not wearable technology. The elderly user group highly appreciated the manageable and uncluttered touch interface with its simple, intuitive, and easy to use design. The design included big icons, pictograms instead of text, faces and names for making a phone call, the overall black and white theme for clear contrasts, easy answering options for text messages (yes, no, call me), simple colour codes for confirming appointments, having read a message, or embarking on a journey to the supermarket (red = no and green = yes).

The solution creates value for the patient and also for their relatives and caretakers. The patient is reminded of their daily plans through the phone and not via multiple sticky notes, other notes or phone calls made by the caretaker(s). During the focus group session it was uncovered that several caretakers are often worried about their relative (the patient) when they are not at a certain place at a certain time. Through the incorporated GPS system, the caretaker can easily locate the patient if, of course, the patient and caretaker have agreed this to be acceptable in terms of privacy.
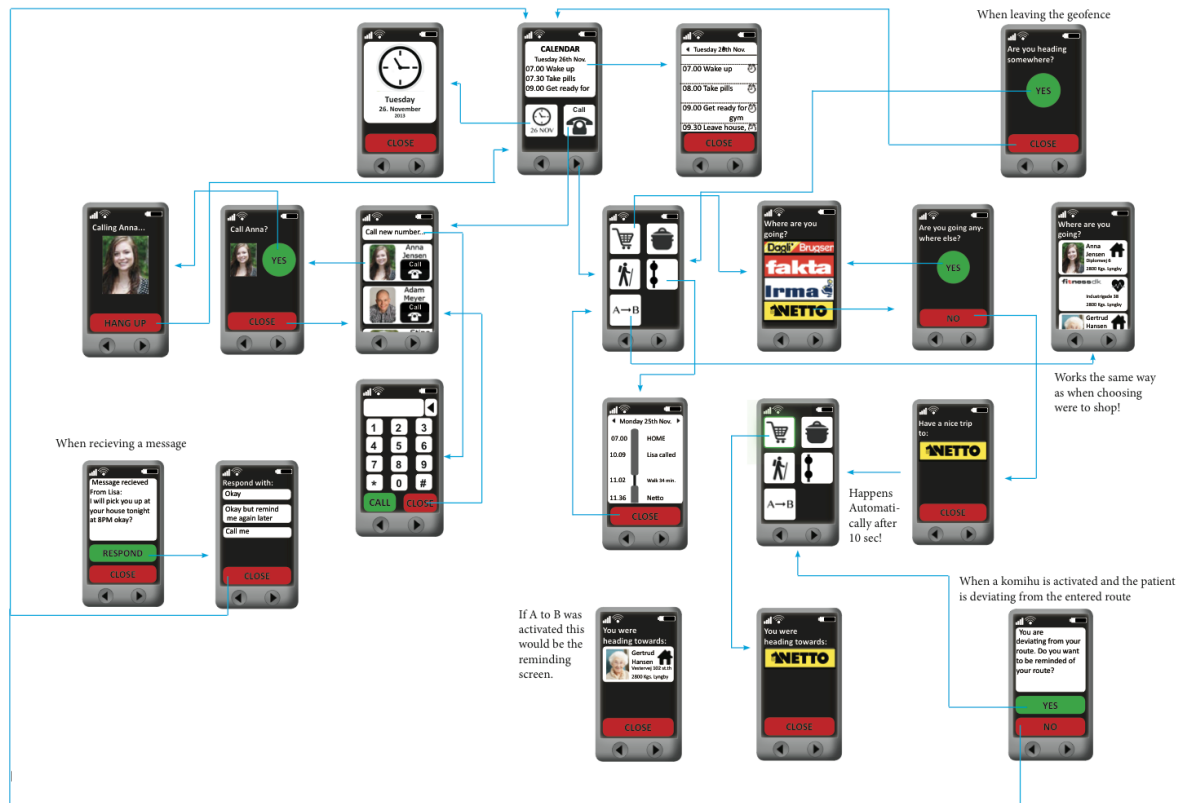

Figure 4. Screenshots of the connection between the different features of the Komihu

4.2 Prototype 2: *Memofy*

This prototype solution integrates a smartphone, a smartwatch and a physical wall calendar. It mainly addresses problems concerning planning, scheduling and remembering day-to-day activities (see Figure 5).

4.2.1 Personas

Two personas were used for this design task:
- Karen, 65, has been diagnosed with MCI which causes her to forget new things. This is often apparent when shopping alone or talking to her children on the phone. After a few hours, she forgets who she has spoken to. A today-view will help her remember who she has talked to earlier.
- Liam, 80, has been diagnosed with Alzheimer's dementia. He tends to forget newly scheduled events and his family is troubled as they have to remind him all the time about the appointment. A calendar will help him to get an overview of future appointments and to remind him when to leave so he arrives at the intended destination on time.

4.2.2 Features

- A large calendar/smart board on the wall, including appointment cards (a camera detects input).
- Mobile application which takes care of the basic planning of presenting contacts and other relevant features in a simple manner. The mobile application should be extended by the smartwatch.
- A smartwatch that vibrates on the wrist to draw attention to notifications (no input possibilities).
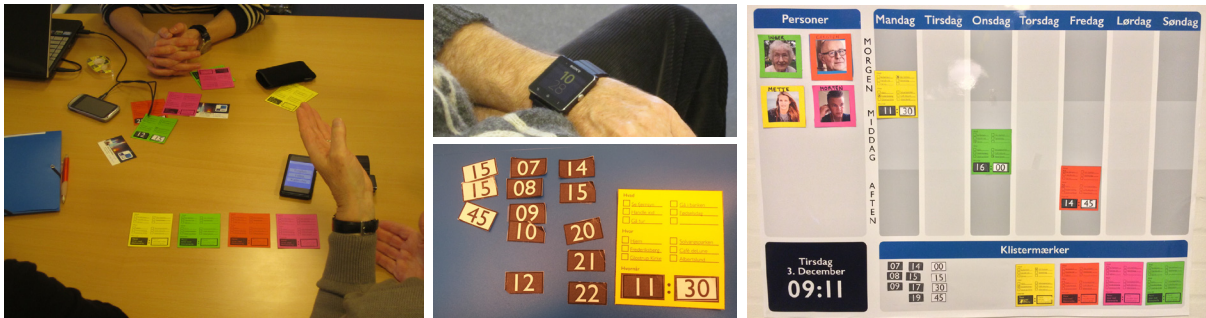- Geo-positioning and NFC as intelligent input for the system to assist the user.

Figure 5. User-testing of Memofy, consisting of a mobile application (smartphone interface), a smartwatch, and a wall calendar (smartboard)

4.2.2.1 Mobile application and smartwatch

The set of smartphone and smartwatch applications devised for the use of MCI patients are:

- Contacts: Personalised pictures of each contact person including their names with capital letters. Navigation buttons.
- Telephone: With a full keypad with rounded icons in black and white. The buttons that are used more often are highlighted in bright colours.
- Today-view: Includes the timeline of past events and each of them have their own unique icon to represent the activity/event. An up and down button is situated in the bottom, so you can move up and down in the timeline to assist memory.
- Phone calendar synchronised with the wall calendar: Includes daily and future events. At the top of each day we have mentioned the current date and highlighted the day. Each event is made in similar sections showing their start time and title. A back and forth button is included in the bottom to view upcoming events.

4.2.2.2 The smart wall calendar with customised appointment cards

The concept of the physical wall calendar was chosen in order to combine a real world object they can relate to in order to facilitate technology acceptance with a digital interface from a smartphone and a smartwatch. Furthermore, we believe it will have a positive effect on the memory of the patients, as the more a person can learn through a combination visual, auditory and kinaesthetic modalities, the more embedded the learning will be.

The final calendar design (Figure 5, right) is a one-week calendar combined with pre made appointment-cards that had a time-and date area It has two interaction areas: the weekly calendar and an area with pictures of close family/friends/others (mainly for making appointments). The main area is the calendar itself. It includes all days from Monday to Sunday. To make a grid, but without being too specific, we have included three states of the day: morning, afternoon and evening. The user will be putting appointment-cards directly onto this calendar. The cards have different colours according to which person they are going to meet. The cards include a what-section where the user can fill in the appointment, and then either write where they will meet or tick-off a pre-selected, often used place.

The family and friends-area consists of pictures of the closest family and friends with coloured frames, one colour for each person. The colours correlate with the colours of the cards, so that all the pink cards correspond to the persona named 'Morten', as Morten has a pink frame (see Figure 5). Each picture is linked to a Near Field Communication (NFC) tag, so when you hold the phone up to the picture, the interface directly turns into the contacts-list; like a shortcut to call or text this person.

4.2.3 Scenario: System interaction between the mobile application and wall calendar

In order to exemplify how the system works, we have the following scenario: Karen has MCI, and has just gotten the new *Memofy* system. She has talked to her friend Lisa, and they have made an agreement for meeting at 16:00 hours on Friday afternoon. Karen therefore takes an appointment-card corresponding with Lisa's colour, and fills in the location, time, date, what they are going to do, and sticks it on the calendar. The camera detects the horizontal position of the card (which day) and the time and date (in the white area of the card itself). This is transcribed into a web based calendar that is accessible by Karen's caregivers. This calendar is also synchronised with the calendar in the mobile

phone application. When Friday arrives, Karen gets an early reminder on the smartwatch that says she is going to meet Lisa at 16:00 hours at the specified location. More reminders, depending on the personal settings, will make sure Karen does not miss her appointment.

4.2.4 Testing and evaluation

Two user-tests were conducted with three patients and their caregivers. This solution is using a mobile application with a smartphone and a smartwatch and a physical smart board on the wall. Participants in the user-tests appreciated the appointment cards and the simplicity of the wall calendar. Patients with more severe impairments preferred simple and limited interfaces, especially for the smartphone interface. In general, patients appreciated that relatives and other people of their choice could add new appointments to the wall calendar and thereby activate push notifications on the phone and watch. Further tests, especially in the patients' home environments have to be conducted for ecological validity, e.g. to see whether the whole system can eventually be used without a facilitator present.

4.3 Technology acceptance by patients and health personnel

Technology acceptance among the user group was high. People wanted to continue using and wanted to buy the solutions. Our observations of patients interacting with the prototypes we developed lead us to believe that with the incorporation of new smart technology into the user-groups lives, we can activate learning capabilities of MCI patients. To quote: *"I never thought that with this disease I would ever be able to learn something new again."* However, the severity of the condition and also the relationship between the caregiver and the patient play an important role. If the technology is going to be used on a regular basis, which will be a pre-condition for success, interactions with the wider healthcare system including caregivers/relatives and health care personnel need to be designed into the solution. When presenting the results of the pilot feasibility study to health care personnel including doctors, nurses, and neuropsychologists, their feedback was strongly encouraging. The doctors and neuropsychologists in particular were highly interested in the opportunities with data logged on the devices for more tailored diagnosis and report on, for example, sleeping patterns.

5 CONCLUSIONS AND FURTHER WORK

The results of our pilot study into the feasibility of adapting wearable technology to the needs of people aged 65 and over with mild cognitive impairment and mild Alzheimer's dementia showed that yes it is possible, as in, technology acceptance appears to be high. Two low-fidelity prototype solutions were designed, developed, and tested with patients and their caretakers. Prototype one, the *Komihu*, consists of a smartphone with a simple touch interface. Prototype two, the *Memofy*, integrates a smartphone, a smartwatch and a physical wall calendar. The prototypes are based on existing functionality of commonplace smart technologies rather than being specifically designed devices.

There are a great many avenues for further work, including in-depth and longitudinal tests for health outcomes incorporating quality of life parameters such as subjective wellbeing and level of social interaction. As the low-fidelity prototypes were only tested in the hospital setting and as such a laboratory-like situation, tests in the natural environment of the users' homes need to follow. The biggest challenge in practice with this study population will most likely be to secure continuous use of the devices. The devices need to be designed to overcome the fact that the patients will forget to use them.

The great potential smart technologies bring, last but not least, with respect to logging data on activity patterns can only be harnessed when implemented and integrated into the wider health care system. Even though when designing, we may treat the elderly as a distinct group, age and decline of cognitive function is something we will all experience during our life course and as such what we design for the elderly will benefit us all (Clarkson et al., 2003). Helping the elderly will have a positive ripple effect, as we may at the same time also design an increasingly healthy life for the many caretakers and for our future selves. In sum, we believe that teams of design engineers in collaboration with interdisciplinary professionals and users have an important role to play in designing for healthy lives in general, and in developing solutions for cognitive rehabilitation in particular.

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