Reminders that Make Sense:

Designing Multimodal Notifications for the Home

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***Abstract*—This paper argues that reminders or notifications delivered in the home (such as appointments or when to take medication) should be available in multiple modalities (visual, auditory, tactile and olfactory) in order to increase the usability and acceptability of electronic home reminder systems. Briefly reviewing the context of the home as an interaction space this paper introduces some of the issues that can be addressed by exploiting multimodality. The paper goes on to present an overview of the different modalities available for electronic reminder delivery and finally gives an overview of the guidelines for multimodal reminder design emerging from the first year of the MultiMemoHome Project.**

Keywords - homecare, assitive technology, multimodal, notifications, reminders.

I. TECHNOLOGY FOR CARE AT HOME

Due to an increasing ageing population and continued pressure on health care budgets throughout Europe, many of us will be expected to self manage our care from our own homes for longer [10, 12]. A positive side effect of this is that more of us will be supported to age in place in the comfort of our own homes and remain independent for longer [12]. Technology can play a key role in facilitating this shift in the balance of care and in enhancing our population's health and wellbeing at home [8, 10, 12].

Technology designed specficially to support health or wellbeing at home is often referred to as Telecare, Telehealthcare, or Assidted Living Technology (ALT). Despite these types of technologies becoming increasingly available and affordable, take-up by local authorities, care professionals and end users is still relatively poor. Clark and McGee-Lennon [8] discuss some of the barriers at the root of this problem and suggest some ways to address these and increase the uptake of ALTs in the UK.

Studies of attitudes towards, and expectations of technologies for care at home such as [8] and [21] have shown that the home is a complex interaction design space. Although it is often considered very private and intimate, it is also often shared with other people [e.g. 8, 16, 20, 21]. This means that there are many potential users of ALTs including spouse, children, and health and social care professionals. These users may interact directly with the technology itself or might simply want to view or manipulate the health or wellbeing data the system produces (in the home, or remotely from a clinic). Any of these stakeholders might also want to influence how the system should be configured or behave in practice. This makes designing ALTs that are considered usable and acceptable to all potential users a significant challenge.

Another significant barrier to the widespread uptake of ALTs is the fact that many commercially available telecare devices are point solutions, and not configurable either in terms of their design and appearance (which can lead to stigmatisation) or in their behaviour (which can lead to it being unusable by certain populations of user). This means that the currently prescribed telecare packages are not always suited to people's individual needs, capabilities or preferences [8]. This can result in unusable and/or unacceptable solutions which are often switched off or ignored, or simply not prescribed in the first instance.

In this paper we argue that assisted living technologies should have rich multimodal and multisensory user interfaces (text, speech, gesture, audio etc.) to enable use and personalisation by those with a wide range of capabilities. Furthermore, the solutions should be easily configurable by the many potential users of the technology and this should be based on individual user needs, preferences and abilities, and also on the social and physical context of the home.

The MultiMemoHome Project [24] is investigating the design and evaluation of multimodal reminders systems for the home. The focus of the project is to understand more fully the different multimodal solutions available and to understand how effective and appropriate the various reminder delivery methods are with real users in the home context. This paper presents an overview of some of the findings from the first year of the MultiMemoHome project. Section 2 discusses the user requirements for reminder system in the home while Section 3 provides an overview of the various modalities currently available for multimodal reminder design and how they have been evaluated so far. In section 4 we present a synthesized overview of the guidelines emerging from our body of work on the design of usable and acceptable multimodal reminders for the home.

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II. REMINDER SYSTEMS FOR THE HOME

We all use reminder strategies on a daily basis such as calendars, diaries, sticky notes, and visual reminders around the home or office. In the ageing population it is even more likely that these strategies are an important part of structuring our day or making our lives easier to manage. Reminders can range from things we need to take with us (such as a bus pass), to meetings and appointment details, and specific tasks or chores for the day. For older people, or younger people managing their care at home, being able to remember certain tasks (such as medication intake or turning off an oven) can be the difference between having to be cared for in hospital or a care home and being able to age in place, in the comfort of your own home. Assisted Living Technology that allows the setting and delivery of electronic notifications or reminders in the home (often referred to as Home Care Reminder Systems) can support this.

Work on reminder systems has often focused on when to deliver reminders [1, 17, 26], while some has investigated how reminders should be delivered [1, 34]. Much of the current literature on reminders however does not adequately address the issues of delivering reminders in the home care context. The aim of the MultiMemoHome Project (MMH) is to design, prototype and evaluate multimodal reminders that take into account these issues including: making reminder systems accessible to older people and people with sensory impairment; creating systems that cater for choice of delivery method based on both their needs and preferences; and offering reminders that are usable and acceptable in a variety of different physical and social contexts.

The MMH project been exploring these issues by (1) qualitatively exploring the needs and requirements of older users and people with sensory impairments [e.g. 21, 34] and (2) empirically designing and evaluating various multimodal delivery methods both in the lab [22, 23, 34] and in the home [20]. The remainder of this section briefly summarizes the findings from our qualitative work on understanding reminders in the home. Section 4 will provide an overview of the empirical work on the different modalities available for reminder design and delivery.

McGee-Lennon et al. [21] present a comprehensive mixed-methods study into the underlying requirements for reminders in the home. The study consisted of a questionnaire (N=379), 6 focus groups, and 7 home tour interviews. The work explored the things people forget and need reminding about in and around the home, as well as exploring the devices and modalities people would prefer to receive reminders to in the home. They categorise the things that people generally forget or want reminded about at home as Appointments, Medication, Home Safety (e.g. lock the door) and Chores (such as take the bins out). They also describe the existing reminder strategies that people use varying from Low tech solutions such as pill boxes to visual and physical reminders (such as a bag hanging over a door handle) to Interaction Surfaces (such as fridge doors and pin boards) – see Figure 1. Their results highlighted the need for highly flexible and contextualized multimodal and multi-device reminder solutions that build on existing successful strategies for remembering in and around the home [21].

Figure 1: Physical/visual reminders from [21]

The users of ALTs are far more likely to have one or more sensory impairments, such as sight or hearing loss [2, 12, 27]. Due to a lack of appropriate commercially available reminder solutions for this user group, many people currently rely on friends, family or technologies such as automatic pill dispensers and cooking timers [20, 21, 34]. Making reminders accessible via different modalities is crucial to ensure that users will be able to receive the reminder despite their impairments. For example, if a user has impaired vision, auditory notifications could deliver the message. Likewise, for a user with sight and hearing loss tactile alarms could be considered (see Section 3). It is also important to offer a variety of modalities (even in the impaired sense) so that the users can choose those modalities which are best suited to them. Wolters et al. [34] and McGee-Lennon et al. [21] discuss how users with sensory impairments often want the choice to pick delivery methods in their impaired modality as long as it is adapted to their needs [20, 21, 34].

The changing physical and social context of the home is also reason to provide multiple modalities. If there is lot of background noise in the home (such as a TV or radio) then an audio notification could be swapped for a visual notification if the system can sense this background noise. If the user is in the hall then a visual reminder to the TV can be diverted to speech in the hallway. If a user has visitors in the home, notifications could be delivered more discretely via tactile reminders to a mobile or wearable device (see Section 3).

A home care reminder system will be ineffective if the user switches it off because the reminders are ineffective, annoying or disruptive. Allowing users to adapt the reminders to their needs, preferences and social context using an alternative modality should make the reminders more likely to be attended to in the first instance and be deemed both usable and acceptable to the user in the context of the home.

Section 3 presents a brief overview of some of the work being carried out in investigating the properties of, and potential of a variety of multimodal delivery methods.

III. INVESTIGATING MULTIMODAL REMINDERS

In a home environment, auditory, tactile, and olfactory reminders offer some advantages over traditional visual notifications: (1) they can be attended to while the user is doing something else; (2) they do not rely on a user being near a visual display and (3) they can be accessed by people with sensory impairments. We have also argued in Section 2 that reminder systems should offer multimodal delivery methods for reminders in order to increase their usability and acceptability. The following section briefly reviews some of the empirical work conducted so far in the MultiMemoHome project in order to understand more fully the strengths and weaknesses each of the lesser explored modalities offers for the design of reminders.

A. Auditory Reminders

Even though hearing acuity declines with age [2], auditory reminders are still a key interface modality, because they do not require the user to attend to a screen and can be especially effective if eyesight is poor [6]. Furthermore our work with older users and users with hearing impairment [20, 21] revealed that people with a sensory impairment still want the option to receive reminders in that modality if they are appropriately designed.

Simple auditory notifications are already common in the home, from mobile phone alarms to cooker timers which remind us we need to do something to more lengthy speech instructions that can provide details on the task to be remembered, and details of when, where, and how the task has to be carried out [17, 26]. Researchers have also been exploring the use of Auditory Icons and Earcons as alternatives to simple bleeps and more lengthy speech [e.g. 22, 29, 34].

Auditory Icons are a mapping of computer events and attributes to the events and attributes that normally make sounds. An example in the home context might be the sound of a rubbish bin being emptied for a reminder to take the bins out. Earcons are a nonverbal audio message used to provide information to the user about some computer object, operation, or interaction and can be considered the aural counterpart of an icon [6]. They use a musical tone or sequence of tones as a basis for building messages. An example in the home context would be an increasing sequence of piano notes for a notification to turn the oven up [22].

When creating reminder systems for the home, designers need to balance the ease of comprehension of the reminder and the privacy and/or disruptiveness of the message. Privacy issues might arise when there are others in the home who can overhear reminders that are easy for anyone to understand. While Earcons might ensure privacy, some users may find them more difficult to learn than Auditory Icons for example [5]. And while speech might require the least learning, it may be the most disruptive. Earcons may not be as immediately intuitive as speech or auditory icons, but research shows they can be easily learned and users have found them appropriate for general applications [6, 22]. It has also been argued that Earcon reminders may also be less annoying than more explicit speech in prolonged use [29].

McGee-Lennon et al. [22] compared the performance of, and preference for speech and non speech (Earcon) home notifications (e.g. 'turn the oven down'). To compare how each delivery method performed the user had to attend to a series of reminders (in Speech or Earcon) while engaged in a cognitively demanding (digit recall) primary task. A key finding was that different people preferred different delivery methods, and perhaps more importantly people's preferences for a modality did not necessarily correlate with their performance using that modality as a delivery method. For example, people performing well with speech commented that they would not always prefer speech as they often have people in the house that they would not want to share the message with. On the other hand, some people performing well with earcons preferred speech as it would mean that they would not have to explain their private notifications in a social setting. This study highlighted an important issue in the design of reminders – how do we design reminders that are both effective (attention grabbing) and acceptable (not rated as annoying or unacceptable for the home). These complex relationships must be investigated further.

More recently work has been carried out investigating a potentially more private musical alternative to auditory icons and earcons. 'Musicons' are shorts clips of instrumental music used for information presentation [23]. McGee-Lennon et al. [23] investigated the use of Musicons as a delivery method for home based reminders such as 'Take your medication'. In the study the accuracy and learnability of Musicons for reminding was compared to synthetic speech. The results revealed that people could recognise extremely short (0.5 seconds) clips of popular songs and can semantically link (and remember this link) these clips to reminders such as 'take your medication'.

The key property of Musicons is that they are long enough to allow listeners to identify the original piece of music but too short to sound like a clip from the piece when played on their own without any previous context. They are more abstract than earcons and speech so might offer a more private and ambient way to deliver notifications if this form of reminder can be learned and recalled in context. We are currently investigating user defined Musicons and the properties of music that make good or bad Musicons. In addition, we plan to test Musicon reminders with older users.

B. Tactile Reminders

22% of all adults over 60 suffer from both visual and auditory impairment [2, 30] and this is set to increase partly as a consequence of the ageing population [6, 30]. Alerts that are based on touch and smell are particularly interesting to investigate for these users yet little work has been done on using these alternative modalities in reminder systems in the home.

Vibrotactile displays are increasingly common in everyday devices such as mobile phones, pagers and games controllers which featuring vibration feedback. Tactile feedback has also been used in sensory substitution systems for many years, for example to present audio signals to users with hearing impairments [11, 15]. The vibrations being exploited in current devices are usually basic and do not fully exploit the

potential of vibration as a means of communication of the message itself. In order to create more effective messages, it is necessary to systematically investigate how best to use vibration in computer interfaces.

Brewster and Brown developed the concept of Tactons (tactile icons) [7] which have been used successfully in mobile devices. Tactons [7] are structured vibrotactile messages which can be used to communicate information non-visually. They are the tactile equivalent of audio Earcons and visual icons, and could be used for communication in situations where vision is overloaded, restricted, or unavailable, such as navigation systems for blind people, or in mobile/wearable computers [7]. An example of the hardware being used is the Engineering Acoustics C2 Tactor which can be seen in Figure 2.

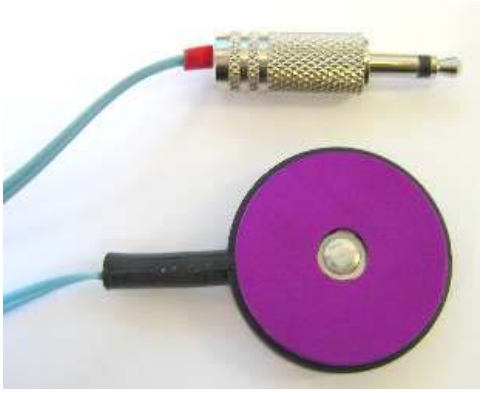

Figure 2: Engineering Acoustics C2 Tactor (www.eaiinfo.com)

The C2 Tactor can be placed on a device or directly on to the skin to produce vibrations in the form of structured messages similar to the way in which earcons are composed in the auditory modality. Brewster and Brown showed that multidimensional information can be encoded in Tactons using parameters of vibration such as waveform, rhythm and spatial location. They also showed that users can learn mappings between Tactons and their meanings, and retrieve information or alerts from Tactons when used in mobile or desktop computer interfaces.

Thermal stimulation is an even less explored medium in human computer interaction yet it could offer an emotive and salient feedback channel for the delivery of messages to the skin. Thermal reminders might be particularly suited to environments that are too loud for audio (a noisy household) or too bumpy for vibrotactile feedback (while on the bus to the shops).

Using the Peltier based hardware illustrated in Figure 3 Wilson et al. [32] conducted two studies into how well users could detect hot and cold stimuli presented to the fingertips, the palm, the dorsal surface of the forearm and the dorsal surface of the upper arm. Their results showed that the palm is most sensitive, cold is more perceivable and more comfortable than warm and that stronger and faster-changing stimuli are more detectable but less comfortable.

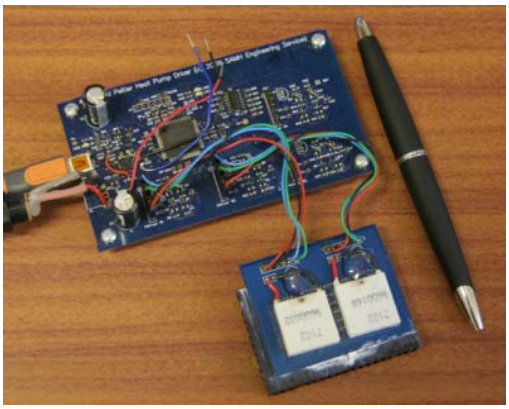

Figure 3: Microcontroller and Peltier stimulators used in [Wilson]

There is potential for Tactons and Thermal cues in human computer interaction and especially for reminder delivery since these types of cues can be more private and no one but the recipient would know a reminder had occurred. If the tactile modality is to be exploited in the home reminder domain more work is needed – particularly to investigate the perceptual and subjective factors that tactile feedback might offer. The MultiMemoHome project is currently exploring the usability of tactile reminders (such as Tactons and Thermal feedback) in the context of the home [21, 32, 34].

C. Olfactory Reminders

The potential of smell as a notification medium has been somewhat overlooked. In everyday life our sense of smell (olfaction) is often used to grab our attention when we cannot necessarily see something (the smell of freshly brewed coffee for example). Smell also has strong links to memory and emotion [e.g. 4, 5]. These properties of smell could be exploited in the home context for message delivery where users may have multiple sensory impairments and/or memory decline. Smell-based technology (such as that shown in Figure 4) is however often dismissed as impractical (despite plug in and controllable air fresheners becoming more commonplace in houses and cars). These technologies can allow software to trigger a fan to dissipate an aroma (or several aromas) into the environment.

Figure 4: Dale Air Vortex Olfactory Display (www.daleair.com)

Although olfactory alerts have been compared to other modalities [4, 5], these studies have been limited in size and scope and have not looked at potential for smell in the home,

where simple cues such as the smell of food might make good reminders for when it is time to eat.

More recently Warnock et al. [32] included olfactory reminders in their evaluation of the disruptiveness of home care notifications while playing a memory intensive card matching game. Olfactory reminders were slower to deliver than many of the other types of notification. With the current devices they also have limited range and are harder to contain and dissipate once the reminder has been attended to [5, 32]. Despite these possible practical issues, they showed that their primary task (a card matching game) was disrupted by olfactory reminders no more than any other modality tested [32]. Further work is needed on the olfactory modality to explore the people and contexts for which smell based messages might be an appropriate option for reminder delivery.

IV. Design Issues for Multimodal Reminders

The following section summarizes what we believe to be the main themes emerging from our work on how to design usable and acceptable multimodal reminders for the home. For more details on the work involved in extrapolating these and other themes see [18-24, 32, 34].

A. Understanding different delivery methods

We strongly believe that more fundamental human computer interaction (HCI) research is needed (both in the lab and in the home) in order to more fully understand the modalities available to us for presenting information to the user at the interface. Many years of research has been required to understand our visual sense and how this can best be exploited in interaction design and information presentation. More recently auditory interfaces have been explored (Speech, Auditory Icons and Earcons are all now reasonable options in interface design) and becoming more understood in the area of HCI. Novel methods of presentation in HCI such as Musicons [23], tactons [6], thermal feedback [33], and olfactory notifications [4, 5, 32] need to be explored further.

Once more is understood about how attention grabbing, how easy to comprehend, and how distracting the various modalities are in a variety of contexts, designers (and those that set up and deploy the systems) can provide users with options and configurations that results in effective, usable and acceptable reminders.

B. Supporting User Preferences

It is clear from our empirical work that the effectiveness of a reminder (how well people correctly attend to reminders) does not always correlate with people's preferences [22]. Our qualitative work reveals that users want a system that can be adapted to their own preferences and capabilities [20, 21, 34]. Speech output in particular should be configurable based on subjective preferences. Individual reactions to gender, politeness, accent and length of message were strong and varied. People commented that they might prefer urgent messages (such as the oven needs to be turned off) in a shorter message and more authoritative voice, while less frequent, and less urgent messages (such as 'remember the re-cycling tomorrow') should be in a longer, more polite message [21].

Overall, modality preferences depended not just on the modality itself, but also on the amount of information to be conveyed. Beeps and vibrations are often favoured for grabbing attention while reminders containing more information (such as details of the time and location of an appointment) might require speech or tactons or earcons with some learned structure. Tactons, Musicons, and thermal and olfactory reminders offer the possibility of more peripheral or ambient reminders which need to be explored further in the home context.

C. Catering for Sensory Impairment

Many of the older users we have consulted have raised basic concerns about usability issues such as the font size of visual reminders and intelligibility of existing audio reminders [34]. It is crucial that alternative modalities are available in a home care system to increase the accessibility of the information and make reminder systems appropriate for the widest possible range of users. It is also clear from our qualitative work [21] that people with a visual or auditory impairment might actually want a display in their impaired modality – as long as the presentation was configured to their needs (larger font, louder speech).

It is important therefore that configuration choices at design time, and run time should include as many of the available delivery methods as possible to increase the overall accessibility of reminder systems for the populations that will benefit from them most.

D. Exploiting Available Devices

The home tours we conducted in [20] revealed clear generational effects in the preferred devices for message delivery. A middle-aged mother discussed solutions that could exploit her mobile phone, younger children were very positive towards wearable devices and the grandmother was keen to exploit mainstream technologies such as her Television. There also appear to be strong synergies between location and device. For example, people favored reminder screens at the hub of the home, which is often the kitchen or the living room [16, 20]. These could be used to remind inhabitants of general tasks and schedules, while a screen by the front door could be used to alert people to security precautions when leaving the house, for example.

Our work has highlighted that reminders are most effective when delivered at the right location, at the right time and through the right device. The ideal home reminder system would be able to automatically switch from delivering a reminder to your mobile phone when you are out to the television when you are at home. This level of context awareness or service discovery by the system could certainly lead to more acceptable reminders based on where we are and what we are doing at the time. This should also be allowed to change as more devices become available in the home or more acceptable or appropriate to the user over time.

E. Understanding Social Context

The complex social context of the home as an interaction space significantly impacts the design and presentation of reminders. Users want a reminder system to be easily integrated into their daily life and their physical surroundings. Visual displays and screens should be placed where users are most likely to see them, such as in the living room or kitchen or as a control panel in the hallway so that it can be seen entering or leaving the house. More personalised displays should also be considered – such as mobile displays or wearable devices, which are particularly useful if you want to deliver more private messages.

Reminders are often presented with no real awareness of the social setting, often resulting in reminders being switched off to avoid annoyance or embarrassment. Successful reminder systems need to strike a balance between being attention grabbing yet subtle enough not to be perceived as intrusive or distracting [1, 3, 32]. For example, when visitors are present, toileting reminders could be given using tactons or an Earcon or Musicon that only the intended recipient can decode. Reminders such as these that cannot be easily interpreted by visitors provide privacy, especially if users do not want to be seen as needing care. Finally if novel reminder systems are to be usable and acceptable they will need to exploit existing metaphors and strategies of reminding. Knowledge of the home and the structure of daily life is required to ensure that reminder systems can be integrated into users' daily lives.

F. Supporting Personalisation

Personalisation relates to an overarching approach that addresses the themes we have already discussed. Reminders need to be highly personalizable, because one size does not fit all. Technology that does not allow for personalization in this context is not likely to be accepted in the first instance or used for prolonged periods. We have already seen the impact that personalized phone covers and ring tones have had in the mobile phone domain. Personalisation is crucial to encourage people to want these devices in their homes and to allow them to be successfully integrated into daily life.

We would caution against creating reminder technology packages that are mainly differentiated by the intended age group. Age might influence the interaction techniques that users are familiar and comfortable with and therefore find most acceptable but it is not the defining factor. Since our older user group consisted of people over the age of 60, their preferences provide a good estimate of the design space for accommodating the oldest old of the next decade. Solutions for the next generation of older users on the other hand are likely to be best deployed on mobile devices including smart phones and tablet PCs.

Home care reminder systems should be configurable at deployment so that it can be set up in conjunction with the use to suit their particular needs at the time. The system can then be adapted or personalised over time as the users' needs and preferences change, as new devices and services are introduced in to the home, and as they learn to use the system in new ways.

V. Conclusions and Future Work

We have argued that reminder systems for assistive living need to support a variety of interaction modalities and that they should be configurable and personalisable both at design time – based on what is known about the users capabilities and the relative effectiveness of the different delivery methods, and at run time, based on what the user (and their carers) choose to be appropriate reminders over time in their home. We argue that this will increase the usability and accessibility of reminder systems while future proofing them and making them accessible to the widest variety of users.

The MultiMemoHome Project is tackling these issues by qualitatively exploring the context of the home as an interaction design space and empirically investigating a variety of reminder modalities in the lab and in the homes of real users. This paper summarized some of the findings from the first year of this project. For further information please visit www.multimemhome.com.

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