A Systematic Review of Dementia focused Assistive Technology

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Abstract. This paper presents a systematic review which explores the nature of assistive technologies currently being designed, developed and evaluated for dementia sufferers and their carers. A search through four large databases, followed by filtering by relevance, led to the identification and subsequent review of papers. Our review revealed that the majority of research in this area focuses on the support of day-to-day living activities, safety monitoring, memory aids and preventing social isolation. We conclude that the majority of AT currently available support day-to-day living activities, safety monitoring and assisting healthcare. However these devices merely address the 'ease of living' rather than focusing on 'quality of life.' Although there are some devices which address social symptoms of Dementia, few address behavioural issues such as aggression and virtually none are available to support recreational activities. After discussing the implications of these findings, we finally reflect on general design issues for assistive technologies in this domain that became apparent during the review.

Keywords: Design: Human Centered Design and User Centered Design, Technology: Adaptive and personalized interfaces, Technology: Interaction design, Technology: New technology and its usefulness, Dementia; Alzheimer's; assistive technology;

1 Introduction

This systematic review explores the types of assistive technologies which are currently being researched in relation to dementia care. By analysing trends in research to date, our aim was is to understand and reflect upon the state of the art in this area, and to highlight domains which appear underexplored, in order to guide future research in this area.

Demographic projections of an aging population in many countries pose a concern for elderly care services [22]. In particular, the increasing number of elderly people with dementia poses serious problems in terms of providing effective infrastructure to support sufferers, such as care homes, nursing and others. In the UK, 5% of over 65 year olds have been diagnosed with dementia and 30% of over 95 year olds suffer with the condition [12]. This causes problems in expenditure of healthcare, quality of care and increases pressure on caregivers due to a lack of resources [9].

Many elderly individuals prefer to stay in their home environment (Davies Et Al., 2008) and others do not have the option to move into residential care due to the cost of being admitted or lack of services. This situation places increasing pressure on family members and informal caregivers. However, there are systems which help to support independence for elder generations to enable them to remain at home [8], known as assisted living. Supporting individuals in their own home can prolong the admittance into care homes which merely transfers the stress and pressure onto the healthcare system and care staff directly [22].

Direct costs to the UK National Health Service and social care are currently estimated as at least £3.3 billion a year [18] and in the World's Alzheimer's report it was stated that by 2050 there will be 115 million people with dementia, emphasising the need for assistive technologies to be developed to ascertain whether they can reduce the prevalence of dementia and reduce the burden on caregivers [12].

The next section of this paper gives an overview of dementia in terms of its definition, typical symptoms and their implications for not only the individual but also their informal caregiver. Assistive technologies are then defined in terms of dementia, highlighting their importance and impact in society. Following this we describe the methods used to perform a systematic review of research papers focusing on the assistive technologies designed for those with dementia. Then we report the findings of this review, identifying which areas are currently under developed. Finally, concerns in the current technologies and critical factors for technology design are discussed.

2 Background

Alzheimer's is the most common form of dementia and accounts for 50 to 80% of dementia cases [2]. It is a chronic progressive disorder that develops and leads to deterioration in the individual over time. It is a disease of the brain that damages and eventually destroys brain cells. This causes a range of symptoms resulting in difficulties throughout everyday life as a result of the loss of brain function [12].

Dementia is a complex condition, so diagnosis can take several months and many hours of medical testing. This is because the main symptoms of Dementia such as memory loss and cognitive impairments are similar to other pathologies and the 'normal' signs of aging. This often results in the symptoms being overlooked, which can lead to misdiagnosis. In addition to this, the early symptoms such as forgetfulness are often so subtle that it is difficult for friends and family to notice them. Finally, individuals showing related symptoms of mild cognitive impairment may or may not go onto to develop Dementia, which also makes early detection unreliable [7].

There is currently no cure for dementia, but some medication and therapies have been shown to reduce the behavioural and psychological symptoms, alleviating pressures and improving quality of life for individuals as well as their caregivers. Living with Dementia can make everyday tasks frustrating for individuals and cause burden and stress for their caregivers, often leading to anxiety[26]. Caregivers and family members often worry about leaving individuals with dementia alone due to their forgetfulness, risk of injury, memory to take medication and also their general safety. This inability to carry out daily tasks causes a reduced quality of life, poor self-esteem, and social isolation. This is a result of impaired executive function, leading to problems in planning, sequencing and attention control. Dementia sufferers also experience difficulties in communication, for example in using telephones to communicate with distant partners. These difficulties can be a further cause of negative social and emotional effects and creates greater isolation [21].

Caregivers reported that one of the main reasons they resorted to nursing homes is due to the sleep disruption to both the individual with dementia and themselves. This is supported by Rowe et al. [24] who found that sleep disturbance occurred in 58% of a large sample of individuals who suffered with dementia and that this was one of the most stressful symptoms to caregivers. Their study on injuries in an emergency department found that 40% of injuries occurred as a result of night time falls and that this resulted in 62% of individuals not being able to return their own home, due to factures or dislocations, resulting in institutionalisation. This is a major concern for an individual's spouse, who is typically elderly as well and so vulnerable due to the physical effects of being a carer. The chronic stressors of caring for a spouse with Dementia can increase health problems due to a decreased immune system in not just elderly individuals but also younger people. This combined with a perceived workload and feelings of isolation reduces the carer's ability to look after their loved one, often leading to an earlier admission into a care home [25].

2.1 Assistive Technologies for Dementia sufferers and carers

The symptoms and effects of dementia presented above can be used to suggest that there is both high potential for assistive technologies to have a positive impact in this area, but also a need for these technologies to be designed with an in-depth understanding of constraints on interaction caused by the disease. Various types of assistive technologies have been developed to help to manage some of the symptoms of Dementia. The term 'assistive technologies (AT)' refers to a device that helps someone do a task that they otherwise would not be able to do, or enables a task to be carried out more easily and in a safer manner [3].

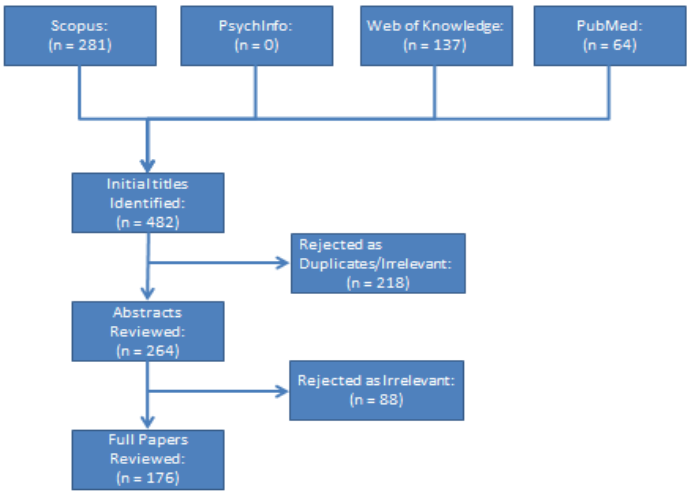
Assisted living can help maintain a healthy and safe environment to enable individuals to live independently and thus reduce stress and burden on informal caregivers [9]. Technological advances can help to slow the onset by keeping individuals cognitively active, improve quality of life and extend independence for longer and therefore prolong institutionalisation [7]. The range of AT are used to not only enhance individual quality of life, but also have the potential to reduce costs for society and public health

systems. It is estimated that by prolonging admission into care homes it could save health care $12 billion annually in America alone [5].

3 Methods

In order to gain a deep understanding of the current state of assistive technology research and development in this domain, and to guide future research, a systematic review was carried out. This focussed on the types of technology reported to have been designed, developed and evaluated across a broad sample of research literature.

Fig. 1. Study Selection Process



3.1 Data Sources and Search Strategy

In December 2014 we searched for English language articles indexed in the Pubmed, PsycINFO, Web of Knowledge and Scopus online repositories. We searched title, abstract and body text for the terms: ("assistive technology" OR "assistive device" OR "adaptive technology" OR "adaptive device") AND (Alzheimer's OR Alzheimers OR Dementia), with query logic modified to reflect the language used by each system. A total of 379 papers were initially identified.

3.2 Study Selection

Two stages of filtering were performed prior to full paper reviews, as illustrated in figure 1. Firstly the paper titles were assessed and 218 papers were rejected as duplicates or obviously irrelevant to the topic at hand. The abstracts of the 264 remaining articles were reviewed and a further 88 rejected as they were found to be irrelevant to this topic. Both stages of filtering were performed independently by two reviewers, and only the

papers rejected by both reviewers were removed from the working corpus. This left 176 papers for the full review.

3.3 Data Extraction and Synthesis

Two researchers independently reviewed the articles in order to identify the general and specific purpose of the technologies described in each case. Articles covering a wide range of technologies and those that did not mention a specific technology were coded as 'Miscellaneous: No Specific Technology'. Where a full paper was not found online, articles were requested directly from authors. If no response was received, they were coded as 'Miscellaneous: Article Not Found'. Where an article discussed multiple discrete technologies, each was considered separately. In the remaining 105 articles, a total of 233 technologies were described. From these technologies 22 specific purposes were identified, falling into 6 general themes, as illustrated in table 1. Finally, in order to explore the significance of the number of technologies identified in each category a Chi Square test was performed on the six general themes.

Table 1. Systematic Review of Technologies for Dementia Suffers

General Theme	Number of Technologies	Specific Purposes
Safety Devices	70	Fall prevention (n=20)
		Cooking Safety (n=12)
		General Sensors (n=2)
		Tracking/Wayfinding (n=34)
		Leak Detection (n=2)
Memory Aids	58	Time orientation calendars (n=8)
		Item locater (n=6)
		General Reminders (n=28)
		Reminiscing Aid (n=8)
		Medication Reminders (n=8)
Preventing Social Isolation	37	Communication Aids (n = 32)
		Artificial Companions (n=5)
Supporting Everyday Tasks	33	Hand/Body Washing Aids (n=8)
		Incontinence/Toilet Assistance (n=4)
		Simple Task Completion (n=19)
		Dressing Undressing (n=2)
Clinical Devices	28	Music Therapy (n=14)
		Symptom Monitoring (n=11)
		Rehabilitation (n=1)
		Doll Therapy (n=2)
Leisure Activities	7	Gaming (n=4)
		Creativity/Arts (n=3)
Miscellaneous	71 Papers	Full paper not found (n=23)
		No specific technology (n=48)

4 Results

A CHI Squared analysis revealed that the distribution of research across these themes was highly significantly different from an expected even split ($CHI^2=62.14$, $p=4.39*10^{-12}$). Post hoc testing was then performed examining the adjusted residuals from each general theme and showed significant differences (at $p<0.05$) for over representation of Memory Aids and Safety Devices and under representation of Leisure Activities and Clinical Devices, as show in table 2.

Table 2. Chi Squared Adjusted Residuals for differences in distribution to expected even split

Theme	Chi^2 Adjusted Residual
Memory Aids	*2.71**
Safety Devices	*4.60**
Preventing Social Isolation	-0.57
Supporting Everyday Tasks	-1.20
Leisure Activities	*-5.279**
Clinical Devices	*-1.986**

*significant at $p<0.05$

4.1 Memory Aids

The review found that memory aids were one of the most common areas of reported AT research and development. For example, TV-based prompting systems can be used to remind people to have their lunch, take medication, or remind them that a family member is visiting. These reminders not only benefit the individual with Dementia, but also reduce the burden to caregivers as they no longer have to constantly remind individuals to carry out certain tasks [7]. This type of technology needs to strike a balance between flexibility and simplicity. It needs to have an appropriate range of prompts that suits the individual such as picture or verbal cues, but these cues needs to be simple to set up and generally usable.

4.2 Safety Devices

The most common theme across the developed technologies was safety devices. These ranged from fall prevention to the tracking of people with Dementia. There are a range of monitoring technologies such as wireless systems and sensors. These can be used to detect any unusual behaviour and provide continual feedback in individuals with dementia to their caregivers [10]. These technologies can be characterised into wandering, fall and navigation devices. Night time wandering is a major issue, but technologies can be used to assist caregivers [24]. However, 'assist' is the key term in this, as such forms of AT merely alert caregivers to the problem, and do not resolve the issue. Therefore while the caregiver's role is still essential, they are being provided with greater potential for awareness and for monitoring from a distance.

4.3 Preventing Social Isolation

Two types of device aimed at reducing/preventing social isolation were identified, aids to communication and artificial companions:

Communication Aids

The inability to recognise people and communicate easily has negative impacts on social interaction for people with dementia [27]. An example of this kind of tool is Social Memory Aid [17], which allows people with dementia to practise name and face recognition. The system allows the user to select photos where questions and clues are given about the friend or family member in order to prompt recall of their name. This helps with social interaction and is a tool which can be applied to aid communication such as the principles used in COGKNOW [14]. This system is a cognitive device combined with current smart home technology to provide a range of services. It was adapted to help combine verbal, written and visual information to aid recall in individuals with dementia to make phone calls independently. Its goal was to achieve patient empowerment and greater autonomy, and to enhance quality of life for mild dementia patients. In additional it aims to provide benefits to caregivers, by relieving them from some daily care tasks. The use of photos and verbal identification helped individuals to recognize partners more easily and confidently, and this improved their communication abilities by enabling them to decide who they wanted to call.

Artificial Companions

Robots are a new and emerging technology, which brings the potential to improve the quality of life for dementia sufferers through social care [4]. Due to the impaired cognitive abilities of people with dementia, they often find new technologies difficult to use. Therefore, robots need to be simple and easy to use whilst being complex enough to cause cognitive and social stimulation in order to reduce psychological distress or social withdrawal. However they still need to be complex enough to cause cognitive and social stimulation in order to reduce any psychological distress or social withdrawal in people with dementia [22].

The potential for robots to be applied in the home environment is supported by their ability to monitor health, remind patients to take their medicine and guide individuals around their home [22]. Companion robots such as Paro, have been developed based on these principles of animal therapy and have been found to help enhance moods, make social interactions possible and generally lead to a higher quality of life in studies conducted in Japan [2]. However cultural differences may impact on the wider uptake of these technologies: A study in a residential facility in New Zealand investigated the suitability of an elderly care robot: Guided, compared with Paro. Whilst Paro had been developed for people with dementia, Guided had only been tested on elderly users and had low acceptance. This highlights the importance of participatory design and gaining insight into sensitive cultural differences.

4.4 Supporting Everyday Tasks

A number of papers explored the use and value of technologies aimed at helping people with Dementia completing everyday tasks that are essential for independent living. The majority of these focus on personal hygiene or food preparation tasks.

Food and Kitchen Tasks

Preparing food, cooking and cleaning is a complex sequence of actions for an individual with cognitive impairments. Many difficulties in kitchen tasks result from sequencing problems, as the reduction in episodic memory causes forgetfulness in steps already taken. This results in repetitiveness and problems in locating items [27]. Computer vision algorithms can be used to detect a person's location and the stage of a task they are currently undertaking. This, combined with RFID tags which label and locate utensils, enables sensors to gather data and infer stages in an activity. This enables a technology to potentially recognise if an individual is not progressing through a task correctly. Dishman [11] looked at RFID tags attached to the utensils needed to make a hot drink and developed a technology which uses audio prompts to give an indication of steps to carry this out [25]. However these verbal commands can be too complex to understand, and so in contrast to this, the Cooks Collage used to visually display the previous six steps completed whilst cooking to help reorient the user to the rest of the process [5].

Personal Hygiene

People with dementia often find it difficult to complete daily tasks such as washing, brushing teeth and using the toilet. As in the kitchen technologies discussed above, video monitoring can be used to track these activities, and a technology COACH has been developed to help individuals carry out these activities [15]. COACH uses a video camera, hand tracking bracelets and machine learning algorithms to guide people through hand washing. It monitors the users' context and has the ability to give verbal aids, detect problems, and prompt the user to complete missing steps. Similarly the 'Friendly Rest Room' project [20] was established with the aimed to design a toilet that allowed greater autonomy and privacy, whilst maintaining dignity.

4.5 Leisure Activities

The clearest finding of this systematic review is a lack of research exploring technologies to support leisure activities. Only seven technologies were identified in this area, four relating to games, and another three that focus on arts and crafts. As the majority of people with Dementia are retired, much of their time could be spend on recreational activities, which could have a range of cognitive and wellbeing benefits. However, the results of the review suggest that technologies to support these activities and subsequently improve quality of life simply do not exist.

4.6 Clinical Devices

A small number of papers explored the use of technology for clinical purposes, be it early detection or therapy to relieve symptoms.

Symptom Monitoring
Diagnosis is usually accomplished via pen and paper tests however computer tests can be used for visio-spatial tests where a subject must match a shape in different orientations to an original shape shown. With a computer test, the images can be shown in 3D which helps to bring out subtleties that are not found in pen and paper tests as patients must mentally rotate the images in their head [13].

Therapy and Rehabilitation.
Caregivers and family members often forget what individuals were like before their cognitive decline. Therefore multimedia biographies can be made which help individuals remember their past and can help reduce their tendency for disruptive behaviour. Interactive video systems are used to monitor the user whilst exercising in the home and give encouraging feedback to carry on completing the task. These systems are shown to help with social development and physical activity has been shown to reduce cognitive decline [1]. However, some systems need further development as they are sensitive to clothing, backlight and home objects.

5 Discussion

In addition to identifying the key technology areas in this domain and highlighting the amount of research currently published in each, a number of specific issues were identified over the course of the review.

5.1 Generalisability and Methodology issues

Whilst there are lots of studies on the aging population in general, few studies worked with participants specifically with dementia. Therefore many studies have low ecological validity as they are not conducted on a representative sample. Although there are obvious ethical and practical difficulties, more research needs to be done in the specified target population in order to develop interventions which offer more appropriate care. Cross cultural studies are also important such as COGKNOW [14] which compared different cultures and this is important so as not to be culturally biased.

Many studies on dementia use interviews to assess individuals and caregivers, which is a valuable technique for gaining rich insights. However an overreliance on any single method can be detrimental to general understanding, and in this case, focusing solely on subjective reporting could result in a distorted view of this how assistive technologies are appropriated. It is also questionable whether their level of cognitive decline enables participants with dementia to know what help they need, in order to reliably help designers in developing technologies.

5.2 Acceptance and Stigma

The use of AT can result in feelings of frustration or embarrassment due to the stigmatism of relying on a device for support. Brooks [6], found that AT which needs users to wear any form of equipment can be perceived as a stigma. Although lots of technologies have the potential to reduce the burden for carers, most current systems are ineffective in real life situations due to their low acceptance rates [5]. Despite this, more empirical studies have found that AT are perceived as beneficial and necessary to individuals. Therefore it needs to be addressed how AT are marketed due to stigmatism which can impede acceptance and adoption. Acceptability is dependent on how a product makes the user feel, what they like about it, whether they think it is useful and its appearance. The use of AT is also influenced by confidence of the user, their fear of performance when using the technology and an awareness or acceptance for personal help and concerns that the technology may inconvenience others around them.

5.3 Awareness

Another issue to be addressed is that individuals may not know what is available or appropriate for their personal circumstances. In a survey analysing at the awareness of the existing supply of AT found that some devices were more well-known than others although living alone or with others made no difference to the awareness of technology available [23]. However those who live alone are more vulnerable and more should be done to increase awareness of the technology available to them. The survey identified gaps in the awareness of specific devices despite the AT usefulness and commercial availability. As well as this problem, it is difficult to access information of the range of AT as current technologies can only be found on charity websites however it is unclear where newer emerging technology can be purchased. This issue of awareness needs to be addressed to improve the accessibility of technologies so that they are more commercially available.

5.4 Importance of User Centered Design and studies to inform AT.

For the future development of AT it is essential that user centred design and user testing is integrated further into the process. There is a range of literature used in order to inform the design of AT for people with dementia. Using interviews with individuals with dementia but also with their caregivers, enables designers to discover what the individuals with Dementia really want and need, as well as what their care givers want and would benefit from so as to increase acceptance [25]. It is not sufficient to simply understand the theoretical causes and implications of cognitive impairment, technologists need to understand what the user and their caregiver really wants from technology.

5.5 Conclusions.

The majority of AT currently available support day-to-day living activities, safety monitoring and can assist in health care. However these devices merely address the ‘ease of

living' rather than focus on 'quality of life.' Although there are some devices which enhance social symptoms of Dementia, few address behavioural issues such as aggression and virtually none are available to support recreational activities. One potential area for development is recreational devices to encourage individuals with dementia to participate in hobbies which they once enjoyed. The range of technologies currently available illustrates a need for more context aware and intelligent software to be developed through extensive user testing and evaluation. This is essential as without design input from both individuals with Dementia and their caregivers, acceptance is often low. This can result in products not being used thus reducing opportunities for increasing independence as well as reducing burden to caregivers. To increase acceptance, AT should be low cost and non-obtrusive so as to reduce stigma. However development is restricted due to ethical considerations and difficulties in accessing appropriate participants.

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