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A Review of Memory Aid Devices for an Ageing Population

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ABSTRACT

The trend for designing memory aids for cognitively impaired elderly individuals is fast growing. In an effort to assist elderly people to carry out tasks of everyday living and to relieve caregivers, several memory aid technologies have recently been introduced. These devices range from everyday technologies such as handheld PDA's to integrated sensory cueing devices. Based on the published literature describing these devices, this review will look at how these memory aids are designed to assist the user and whether they meet the needs and requirements of the older user.

From the evaluations of these devices, it was shown that participant performances with the support of the memory systems were significantly improved compared to performances where the participants used internal strategies for remembering. These results show that electronic memory aids do have the potential to support memory in older individuals.

This review will provide an insight into prospective memory and ageing, and the compensation devices which are designed to support memory decline due to ageing. There are three goals for the present review: (1) to outline the needs of older adults, (2) to review current memory aid devices, and (3) to consider how these devices meet the users needs.

Keywords: *compensatory memory device, older adult, cognitively impaired, dementia*

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1. Introduction

The interest in designing technology for older adults is increasing. This is in part due to the increasing life expectancy of people and the rapid ageing of society that is predicted in the 21st century. Demographic studies have estimated that the percentage of older adults

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in Ireland will have doubled from the year 2000 to the year 2050. The fastest growing subgroup represents those over 80 years of age, increasing by 5.2% in 50 years. According to population projections this ageing trend will be seen across Europe, with older adults almost 35% of the population by 2050 (US Census Bureau, 2005).

These statistics emphasise how important it is that technology developers focus their attention on the older user. Designing for older adults requires developers to take into consideration their capabilities and limitations including psychosocial needs and their acceptance of technological supports. One area of recent interest is the design of prospective memory aids for the older user. Prospective memory (PM) can be defined as the ability to remember to remember (Winograd, 1988). This involves remembering to do things at the right time and PM tasks are pervasive to daily living (Driscoll, McDaniel, and Guynn, 2005). PM tasks could be essential actions such as taking medication to everyday tasks such as remembering to buy milk. PM problems are common with ageing (Maylor, 1996b) and elderly individuals have to develop strategies to cope with this impairment, usually in the form of external aids (Maylor, 1993a). An external memory aid is defined as any device that facilitates memory in some way (Intons-Peterson and Newsome, 1992). This impairment is emphasised in individuals suffering from dementia (Papagno, Allegra, and Cardaci, 2004) and as ageing is the highest risk factor for developing dementias (Keller, 2006), developers are aware that technological supports will be needed to provide relief for carers. Prospective memory aids which have been commercially released include Cellminder, ISAAC, and NeverMiss DigiPad (for review see Horgas and Abowd, 2004; LoPresti, Mihailidis, and Kirsch, 2004).

Although PM aids have been a major focus for designers in recent years retrospective memory (RM) aids, supporting the acquisition of past information, have not been neglected. New developments in this area include conversational tools for individuals with dementia in the form of a touch screen reminiscence device (Alm, Ellis, Astell, Dye, Gowans, and Campbell, 2003) and a retrospective cooking display for absent-minded individuals (Pollack et al, 2003). Pollack (2005) divided cognitive support systems into 3 categories: assurance systems, compensation systems and assessment systems. According to Pollack an assurance system is technology that monitors the individual in an environment such as their home, detecting changes in activity and health for example, and reporting information to family and carers (e.g., the Digital Family Portrait; Mynatt and Rogers, 2002); a compensation system is one that uses strategies to accommodate the user's cognitive impairments (e.g. Autominder, Pollack et al. 2003); and an assessment system is technology which continually assesses the user's cognitive status in a non-clinical setting (e.g., Wired Independence Square; Carter and Rosen, 1999). This paper will specifically address compensation systems for individuals with cognitive impairment. These systems will include electronic memory aids for individuals with memory problems due to brain injury in rehabilitative care and memory support systems for older individuals with declining memory abilities.

There are three goals for the present review: (1) to outline the needs of older adults, (2) to review current memory aid devices, and (3) to consider how these devices meet the users' needs.

2. Memory and Ageing

2.1. The ageing process

From birth our physical and cognitive capabilities grow and age. While some capabilities continue to develop throughout our lifetime (i.e., semantic memory or memory for factual knowledge), others decline with increasing age (i.e., episodic memory or memory for specific recent events in the past). Although elderly people today are fitter and healthier than elderly people in the past, the physical characteristics of ageing have not changed however much delayed. Physical changes that occur in the body with increasing age include the gradual depletion of functional abilities due to the decline of muscle strength, muscle power, flexibility, balance and cardio-respiratory endurance. Sensory capabilities are also affected with ageing; the most common being vision and hearing problems although taste, smell and touch sensations are also dulled with age (Huppert, 2003).

Cognitive capabilities refer generally to our mental abilities by which we pay attention to the world, interpret the information around us, learn and remember, solve problems and make decisions (Huppert, 2003). Age-related differences in cognitive functioning can be seen to stem from the reduction of cognitive resources available impairing older adults' ability to carry out cognitively demanding processes (Craik, 2000; Kester, Benjamin, Castel, and Craik, 2002). Age-related changes in mechanisms of cognitive ageing (i.e., speed of information processing, working memory function, inhibitory function and sensory function) are also believed to mediate the age-related decline observed in a wide range of cognitive tasks that measure cognitive behaviours such as attention, memory, reasoning and problem solving (Craik, 2000). These mechanisms are responsible for the age-related speed decline of performance for mental processes (speed of information processing), the reduction of on-line cognitive resources available at any given time to process, store, retrieve and transform information (working memory), difficulties focusing on target information and inhibiting attention to irrelevant information (inhibitory function) and problems processing information from the senses (sensory function; see Craik, 2000). To briefly portray the complexity of the question concerning whether cognitive functioning declines with age, I refer to Rogers (2000) statement concerning attentional functioning in older adults:

> *Aspects of attention that remain intact for older adults are: selective, focused, divided, and the transition from attention-demanding to automatic processes. Aspects of attention that decline for older adults are: selective, divided, and the transition from attention-demanding to automatic processes.* (p. 69)

As we can see, apart from focused attention, there are the same aspects of attention in both groups. As Rogers notes, age-related differences in performance for cognitive tasks vary significantly depending on the context of the task.

2.2. Ageing and memory

As with attentional functioning there are some aspects of memory that remain intact in older adults while others decline. Tulving and colleagues identified the main areas of memory as procedural memory, perceptual representational system, primary memory, working memory, episodic memory and semantic memory (Craik, 2000).

Procedural memory is a term used to describe the memory system associated with the learning and retention of a wide range of motor, cognitive and academic skills. Procedural memory is relatively unaffected by ageing as the skills required are largely automatic and require minimal cognitive resources to process.

Perceptual representational system (PRS) refers to the memory system responsible for the processing of sensory and perceptual information coming from the different modalities. Their function is to analyse, interpret and briefly hold incoming sense data. There is relatively little research conducted in the area of age-related PRS decline however it is believed that the age decline in sense functioning may affect PRS (see Craik, 2000, for review).

Primary memory, which can be likened to short-term memory, refers to information still in the mind, whereas working memory on the other hand is the term used to describe information held in the mind but that is only retained temporarily. There are minimal age differences for primary memory however the age difference for working memory is significant (Craik, 2000; Kester et al., 2002; Park, 2000). Craik explains this difference by claiming that if a task requires immediate repetition of a small amount of material there is minimal age differences. If the task requires active manipulation of stored information or rapid alteration between storage and processing of incoming information is required then there is a greater age-related difference expected.

Episodic memory refers to the ability to recall specific events that have happened relatively recently (Kester et al., 2002). Laboratory tasks that measure episodic memory include the free-recall of words, sentences and stories. Older adults perform comparatively poorer than younger adults on these tasks. This is thought to be because free-recall demands more attentional resources than does recognition. Older adults show more of an age-related decrement for episodic memory than for other types including primary memory, procedural and some areas of semantic memory (Craik, 2000).

Finally, semantic memory refers to our memory for factual knowledge. There is ample evidence to suggest that older adults show minimal decline in vocabulary, knowledge of historical facts, knowledge of concepts and production of category exemplars (Hedden, Lautenschlager, and Park, 2005; Kester et al., 2002). Charness (2000) claimed that older adults might compensate for their decline in memory and cognition by using this preserved knowledge base. Certain aspects of semantic memory are affected by ageing including word finding and name retrieval failures (Craik, 2000).

Automatic processes that require little cognitive resources are relatively preserved in older adults whereas attention-demanding tasks are greatly impaired with ageing (Park and Hall Gutchess, 2000). Park and Hall Gutchess suggest that older adults are not significantly affected by the decline in memory abilities because many tasks that they carry out, which may have initially been attention-demanding in the past have become automatic and are performed with no conscious awareness, for example the task of driving.

2.3. Retrospective and prospective memory

Memory functions can be divided into two categories by temporal direction: retrospective memory (RM) and prospective memory (PM). RM involves remembering learned information from the past (Guynn, McDaniel, and Einstein, 1998) and has been intensely studied for more than one hundred years starting with researchers such as William James and Hermann Ebbinghaus. Examples of everyday retrospective memory tasks include retrieving a phone number from memory, recognising a familiar place or recalling details of a dinner party. The majority of the literature published on age-related changes in memory is mainly concerned with retrospective abilities of older people. The past few decades have shown a gradual upsurge of interest into people's memory for future intentions, known as prospective memory. There are various definitions of PM. Guynn et al. describe PM as remembering to do an activity in the future whereas, Cohen and O'Reilly (1996) describe it as the activation of representations of a planned action at a planned time, as well as the context of where this action is to take place. Finally, Maylor (1998) describes PM as remembering at some point in the future that something has to be done, without any prompting in the form of explicit instructions to recall.

Because the interest in PM research is gradually growing, specifically in the area of older adults (Einstein and McDaniel, 1990; Einstein, McDaniel, Manzi, Cochran and Baker, 2000; Huppert and Beardsall, 1993; Huppert, Johnson, and Nickson, 2000; Maylor, 1993a,1996a,1998), the main focus of this section will be on PM. This does not mean that RM will not be discussed however as RM plays a significant role in PM processes (McDaniel and Einstein, 1992).

2.4. Prospective memory

Theorists have developed several frameworks to try to explain what processes are involved in PM. Dobbs and Reeves (1996) claimed that there are six components of PM. These are: (1) metaknowledge (the general knowledge about tasks of remembering and the personal knowledge about one's abilities and behaviours), (2) planning (construction and implementation of a future plan), (3) monitoring (remembering at the appropriate time or event that a task is to be done, (4) content recall (remembering *what* is to be done), (5) compliance (one's willingness to execute the task), (6) output monitoring (remembering that the task has been executed). It is suggested that altering the nature of the PM task could consequently alter the components necessary to complete the task (e.g. setting an alarm would eliminate the necessity of monitoring stage). Craik and Kerr (1996) agreed that these components are necessary for successful prospective remembering however they claim that the critical and defining components involved in the processes are the planning and monitoring stages. Ellis (1996) further suggested that prospective remembering consists of five general phases: (1) formation and encoding of intention and action, (2) retention interval, (3) performance interval, (4) initiation and execution of intended action and (5) evaluation of outcome. These frameworks emphasize the multi-dimensional nature of PM tasks.

Prospective memory is a complex memory function as it consists of the ability to remember to do future tasks at the right time and also the ability to remember what tasks need to be done and whether the task has previously been completed. McDaniel and Einstein (1992) proposed that PM consists of the interaction of multiple components, those being a prospective component and a retrospective component. The processes supporting the prospective component provide the ability for the individual to recognise a cue as a stimulus that requires further action, whereas the processes supporting the retrospective component allow the individual to retrieve information associated with the cue from memory, providing the relevant information to complete the task. Estimates of prospective and retrospective components of PM for younger and older adults (West and Craik, 2001) indicate a clear age-related decrease in estimates of the prospective component. It was seen from comparing estimates of studies that age-related differences were greater for the prospective component than the retrospective component regardless of the number of cues and intentions that were included in the task (West, Jakubeck, and Wymbs, 2002). It was suggested that these findings indicate that age-related decline in prospective efficiency can result from failures to detect PM cues and also failures to retrieve the meaning associated with the cue from memory. Furthermore, Maylor, Smith, Della Sala and Logie (2002) demonstrated that not only did young participants outperform older participants in laboratory controlled PM tasks (i.e. responding to cues in a film), Alzheimer's disease patients showed significant deficits in the PM component of PM tasks in comparison to age-matched controls.

To further explain PM, a distinction has been made between event- and time-based PM (Einstein and McDaniel, 1990). Event-based PM involves remembering to perform a particular behaviour when prompted by an external cue, such as remembering to phone a friend when you see a picture of her. Time-based PM involves remembering to perform a particular behaviour at a specific time or after a certain amount of time has passed, for example meeting a friend at 2pm for lunch or taking medication ten minutes after eating. Time-based PM is believed to be more sensitive to age-related decline as compared to event-based PM (Einstein and McDaniel, 1990; Driscoll, McDaniel, and Guynn, 2005; Park, Hertzog, Kidder, Morrell, and Mayhorn, 1997). This is thought to be because time-based PM relies more on internal control mechanisms and self-initiated mental activities, such as time monitoring (Henry, McLeod, Phillips, and Crawford, 2004). Maylor et al. (2002) compared these components to the priming and free-recall components of RM, where event-based PM (like priming) uses a cued response and time-based PM performance (like free-recall) uses a self-initiated response.

2.5. Prospective memory and ageing

Prospective memory is vital for everyday living and failures in PM can result in a range of consequences, from missing appointments to forgetting to take medication (Groot, Wilson, Evans, and Watson, 2002). Initial studies examining age difference in PM found no significant age-related deficit (Einstein and McDaniel, 1990). Further naturalistic studies also found little age-related difference for PM tasks (see Maylor, 1993a for review of studies) however it was believed that this could be due to the use of external strategies rather than superior PM ability in older adults. More recent studies have produced the opposite outcomes with older adults displaying poorer performance compared to younger counterparts (Maylor, 1993b; Maylor et al., 2002; McDaniel, Einstein, Stout, and Morgan, 2003; West and Bowry, 2005). Einstein, McDaniel and colleagues (Einstein, Smith, McDaniel, and Shaw, 1997, McDaniel, et al., 2003) came up with some plausible explanations for the reason why older adults show an age-deficit on PM tasks. One explanation refers again to older adults' limited resource capacity. Einstein et al. (1997) demonstrated in one of their studies that increasing the complexity of the background task while participants are carrying out a task of delayed intentions significantly affects older adult performance. Furthermore, when the background tasks demands were low, age differences were minimal. This finding coincides with Kidder, Park, Hertzog, and Morrell's (1997) earlier study that found significant age-deficits in PM functioning when participants were engaged in a high demand working memory task. The second explanation of PM ageing (McDaniel et al., 2003) demonstrated that older adults do not strategically rehearse the intention of the task over the delay interval, thus maintaining the intention in working memory, whereas younger adults do spontaneously rehearse this intention. They found that when specifically instructed to rehearse the intention over the delay period older adults are more likely to remember to carry out that intention compared to older adults who were not instructed to rehearse. Younger adults showed no performance difference when instructed to rehearse compared to those who were not, indicating that rehearsal was an unconscious automatic process for them.

It is believed that difficulties in PM tasks could be an early indicator for the onset of Alzheimer's disease (Huppert and Beardsall, 1993, Huppert, Johnson, and Nickson, 2000). Huppert and Beardsall proposed that in contrast to RM tasks where participants with mild Alzheimer's perform at a level between normal and more demented participants, individuals with mild Alzheimer's perform just as poorly as demented participants on PM tasks (such as remembering to deliver a message). This finding suggests that remembering to execute intended actions may be particularly disrupted in the early stages of Alzheimer's disease, however the validity of the tasks are under question (Maylor, 1996a; Maylor et al., 2002).

Both prospective and retrospective abilities are required for successful functioning in everyday life (Maylor, 1996a). However, it has been suggested that PM failures have a greater impact on the lives of individuals suffering from Alzheimer's disease and their carers compared to RM failures and therefore are more likely to be reported as an early indicator of the disease (Smith, Della Sala, Logie, and Maylor, 2000). This report was part of a questionnaire study investigating the frequency of prospective and retrospective failures in a sample of participants divided into five groups – patients with Alzheimer's disease (rated by carers), carers of the patients, normal elderly and young participants and married couples. All groups rated PM failures as more frequent than RM failures. Furthermore, carers rated patients' PM failures as significantly more frustrating than retrospective failures. This data highlights the effect that these failures have on patients with Alzheimer's disease and their carers and underlines the potential advantage of a PM aid for elderly individuals with Alzheimer's disease. Furthermore, research has shown that spouses of Alzheimer's disease patients acting as primary caregivers are at an increased risk of chronic stress and consequently advanced cognitive decline compared to non-caregiver counterparts (Vitaliano, Echeverria, Yi, Phillips, Young, and Siegler, 2005). This finding again emphasises the need that Alzheimer's patients and their caregivers have for technical assistance in the home.

2.6. Prospective memory and external aids

Initial studies of prospective memory concluded that older adults outperform younger adults in tasks of delayed intention, such as sending a postcard (e.g., Moscovitch, 1982, see Craik and Kerr, 1996). It was later believed that this superior performance might be due to the use of external strategies by the older participants. Einstein and McDaniel (1990) defined external strategies as some manipulation of the external environment. There are various forms of external aids available and these can be generally categorised as environmental and portable memory aids (Kapur, Glisky, and Wilson, 2002). Of the environmental aids surrounding us, some examples include proximal environmental aids such as wall-charts, alarms and items in conspicuous places, and distal environmental aids such as road traffic signs, name badges and uniforms. Portable aids are aids that are clearly visible and easily accessible and include items such as post-it notes, diaries and electronic organisers. It has been hypothesised that older adults are more likely to use external aids to help them remember because they are more highly motivated and may be more aware of their memory impairments compared to younger adults (Harris, 1984). Many studies have found that younger as well as older adults benefit from the use of external aids, and also that individuals are more likely to use external rather than internal strategies to remember intentions (Einstein and McDaniel, 1990; Kapur et al., 2002).

2.7. Interventions research with older adults

Memory interventions are a means of effectively improving memory functioning in individuals such as older adults, often using memory training strategies (Camp, 1998). According to Camp, some of the training strategies which are used in cognitive ageing research include mental imagery mnemonics training, use of external aids and multi-factorial training (involves the use of multiple training strategies including imagery and method of loci, external aids, attentional skills, and relaxation training). A method that has been found to be effective for improving the memory functioning of dementia patients is a rehabilitative intervention called 'spaced retrieval' (Camp, Bird, and Cherry, 2000). Spaced retrieval involves the learning of new information over increasingly longer time periods and has been shown to improve a person with dementia's ability to remember face-name associations, object names, location of objects and using strategies such as external aids (Camp, 1998; Camp, Bird, and Cherry, 2000).

Another method of intervention, which is the main focus of this paper, is compensatory memory devices for older adults. These devices are used as external aids to support the individual's memory with technology that is designed to meet their specific needs.

2.8. Elderly attitudes towards technology

When considering the design of technology for a target population it is important to initially consider how easily the device will be accepted and adapted into the individual's lifestyle. This is especially important when designing for the elderly user as physical, cognitive and psychosocial factors influencing user attitudes need to be considered. Although it has been established in past studies that elderly people have memory problems when compared to their younger counterparts and benefit from external aids (Maylor, 1993a), the attitude of the individual towards memory aids may influence their usage and ultimately the benefit of the aid. Several studies carried out exploring the effect of attitude on computer use (see Czaja et al., 2006) found that older adults with a more positive attitude towards computers are more likely to use a wider range of technologies.

A questionnaire study was carried out to investigate community dwelling elderly individuals' attitudes towards technology and memory aids (Cohen-Mansfield, Creedon, Malone, Kirkpatrick, Dutra, and Herman, 2005). The results of this study portrayed interesting findings highlighting the preferences and general experience older users have with technological devices. Of the 100 elderly participants questioned, 58% said that they would be interested in using an electronic memory aid, provided it worked as it should and was affordable. The results showed that the type of person most likely to use an electronic memory aid was an individual with a high level of education, a need for external aids (i.e., problems remembering to do future tasks) and with experience using other electronic devices (e.g. calculator, computer, television, microwave etc.). All participants reported to use at least one external aid regularly with the most popular aids being calendars, address books, paper notes and alarm clocks. Participants stated that they would require an electronic memory aid to accommodate visual and fine motor problems. Where some favoured small, portable devices for easy concealment others favoured larger devices that had a large screen, large buttons and was not easy to lose. These finding are consistent with a previous study investigating older adults' use and attitudes toward technology

(Goodman, Syme, and Eisma, 2003). This research showed that there is an age-related decrease in everyday technology use with the exception of telephones, televisions and microwaves. Some of the problems reported by the participants as to why they do not use modern technologies included feelings of frustration and confusion when using electronic devices, a lack of understanding, fear of being too old to learn how to use new devices, the cost of devices and physical difficulties impeding usage. It can be concluded with some degree of confidence from the above studies that these issues are important to the older user and should consequently be considered when designing technology for elderly individuals. Therefore an evaluation of current memory aids for older adults will be based on their cognitive features (usability, learnability), accommodation to physical needs (visual, hearing and fine motor problems) and accommodation to social needs (affordability, size, appearance).

3. Memory Aid Devices

Compensation systems are described as memory aid devices that are designed to support the cognitive impairments of individuals and consequently improve performance (Pollack, 2005). Recent research has shown an increase in the use of memory compensation systems to examine their effectiveness in the rehabilitation of traumatic brain injury patients (Flemming, Schum, Strong, and Lightbody, 2005; Kim, Burke, Dowds, Boone, and Park, 2000; Thöne-Otto and Walther, 2003; Van den Broek, Downes, Johnson, Dayus, and Hilton, 2000; Wilson, Evans, Emslie, and Malinek, 1997). The methodologies used in these studies have included case studies following brain injured patients treatment using the technology (Wilson, Evans, Emslie, and Malinek, 1997) and also clinical trials where patients were trained to use the electronic memory aid and then measured on various PM tasks (Thöne-Otto and Walther, 2003). All of these studies yielded positive effects on memory performance with the help of the aid (e.g., participants were more likely to remember to take medication and meet appointments on time with the help of an electronic aid compared to without an aid). Since this progression researchers are now turning their focus to how these memory aids can be adapted and developed for another target user, the older adult (Thöne-Otto and Schulze, 2003). Compensation systems that have been developed for research with older adults range from simple reminders systems to home robotic support systems (see LoPresti, Mihailidis, and Kirch, 2004; Pollack, 2005). These technologies are more concerned with supporting the users' abilities rather than strengthening them. A summary of the information concerning the electronic memory aids reviewed in this paper can be seen in Table 1 followed by a comparison of the types of memory supported by these devices in Table 2.

Device	NeuroPage	MEMOS	MemoJog	COACH	Autominder	Cooks Collage
Author	Hersh and Treadgold (1994)	Schulze et al. (2003)	Szymokowiak et al. (2004)	Mihailidis et al. (2000)	Pollack et al. (2003)	Mynatt et al. (2005)
Platform	Pager	Handheld Computer, central server	PDA. Remote access from PC with internet	Integrated speaker, camera and sensors. PC to monitor from distance	PDA on mobile robot	Integrated flat screen, cameras
Primary User	Brain injured	Brain injured/Seniors	Memory Impaired young to older adults	Moderate to severe dementia	Normal to memory impaired older adult	Young to older adult with memory impairment
Function	Alert user to perform tasks	Alert user to perform future tasks	Alert users to perform future tasks. Holds personal information	Instructs user to carry out procedural actions when necessary	Adaptive reminder that alters schedule based on users actions	Displays snapshots of users previous actions to refer to while cooking

Table 1: Comparisons of Electronic Memory Aids

Memory Supported	NeuroPage	MEMOS	MemoJog	COACH	Autominder	Cooks Collage
Prospective	✓	✓	✓	✓	✓	
Retrospective			✓	✓		✓
Event-Based				✓	✓	
Time-Based	✓	✓	✓		✓	

Table 2: Comparison of Differential Memory Supports between Memory Aids

3.1. Neuropage [Hersh and Treadgold, 1994]

3.1.1. User group

One of the earliest electronic memory aids introduced for memory impaired individuals was Neuropage, a portable paging system designed by the engineer father of a brain injured patient along with a neuropsychologist (Hersh and Treadgold, 1994). Neuropage was designed as a cueing system to help support PM failures in individuals with cognitive impairment. The aim of the memory aid was to maintain the individuals independence by reminding them to carry out everyday tasks such as making appointments. The popularity of Neuropage for treatment and therapy purposes arose from its simplicity and ease of use for individuals after injury.

3.1.2. Description of memory aid

The device itself is a small pager which can be carried via a belt attachment. Very little learning is involved in the memory aids' use as any schedule information is entered through a paging company. Users are issued reminders at particular times through an adjustable alarm/vibrator alert with an explanatory text message. The user can control the pager with a single large button, which makes it suitable for individuals with motor difficulties. These functions ensure that the electronic memory aid is highly usable, requiring very little input or learning from the user. The simplicity of Neuropage is a key benefit to memory impaired users and non-technology experienced users, however there are areas in which additional functions could improve its potential. For example, schedules are entered and changed through a paging company, which could act as a restriction preventing the user or carer from updating their plans directly into the system. Another issue which has not been considered in the design of Neuropage is the unpredictability of daily life. There are many situations when a user might receive a reminder at an unsuitable time, therefore the device would benefit from a reminder delay or task postponement function so that the user can be reminded at a time when they can successfully carry out the intended task. The system provides a certain level of assurance to a carer of an individual using the system, however there is no way for them to know whether a task has been carried out. For this reason it might improve the memory aid if a task confirmation was included in the design to let the carer know if an important intention was not met. Although it would be ideal to include advantageous functions, designers are also restricted to the technology's integrated abilities. It can be seen from the discussion of subsequent memory aids that more recent devices have taken these issues into consideration.

3.1.3. Evaluation

It cannot be ignored that Neuropage is a remarkably simple solution for reducing memory errors, a complicated area in neuropsychology. Although the device is primarily aimed at younger brain injured patients, an evaluation of Neuropage showed that older adults with brain injury also benefit from its use. Wilson et al. (1997) carried out a study in which fifteen participants' PM performance was evaluated before, during and after using the paging system. Performance was rated depending on the participants' success for executing certain daily tasks (e.g. remembering to take their medication, remembering to pack their lunch). The participants' ages ranged from 19 to 66 years. The results of this study showed that all participants benefited significantly from the device with the mean success rate for performing prospective tasks rising from 37% before treatment, to 85% during treatment and falling slightly to 74% after treatment. These finding predict that despite the systems limits, it has the potential to support an independent lifestyle in memory impaired individuals of varying ages, reducing PM problems and assisting in activities of daily living.

3.2. Mobile Extensible Memory Aid System [MEMOS, Walther, Schulze and Thöne-Otto, 2004]

3.2.1. User group

A computerised PM aid, MEMOS, was designed to facilitate the memory impairments of patients with head injury. MEMOS combines the use of a central server which communicates with a personal memory assistant (PMA) over a wireless cellular phone network.

3.2.2. Description of memory aid

The central server was developed to enable a therapist or caregiver to supervise the actions of brain injured patients outside a clinical environment. The adaptive framework of the system allows therapists to manage the treatment of the patient according to their present state. The system allows the caregiver to encode and input data which transfers to the patients PMA. A web-based architecture was chosen in the design to enable caregivers to access the system over a web-server, which means they can access the information from any computer with an Internet connection and browser.

The PMA was designed specifically for patients with memory impairment. To accommodate for this cognitive deficit the size and usability of the device were taken into consideration making it easy to handle and fault tolerant. The PMA was designed with a few soft, clearly labelled buttons with a large display screen for text information. The device allows patients to leave a voice message relating to future appointments or tasks which they wish to be reminded of, which is then transferred to the central system for the carer to encode and input. The PMA works to support the patient in everyday living tasks sending reminders for appointments, events and other prospective tasks, providing them with feedback and step-by-step guidance.

To maximise MEMOS' relevance for supporting PM tasks Thöne-Otto and Walther applied Ellis' theoretical framework of PM (1996, as cited in Thöne-Otto and Walther, 2003) into the design. As previously mentioned, Ellis claimed that the process of PM takes place over five stages: formation and encoding, retention interval, performance interval, initiation and execution and evaluation of output. This application to the model can be seen through the following:

- Formation and encoding: the patients can speak their appointments into the device which can then be decoded by a carer from the central system.
- Retention interval: system restricted to time-based information
- Performance interval: alarm can be adapted for the individual with a large display for information.
- Initiation and execution: users are guided through intended action through step-by-step instructions. The device is programmed so that completed actions have to be confirmed and steps can be adapted on request.
- Evaluation of outcome: direct contact can be made to carer if confirmation is missed. System searches for future appointments which may conflict if an intended action is postponed.

3.2.3. Evaluation

An evaluation of MEMOS was carried out with six patient participants. For this study Walther, Schulze and Thöne-Otto (2004) compared patients' performance using commercially available electronic memory aids (palm pilot and mobile phone) with performance using the PMA from MEMOS. Participants were required to execute six experimental tasks over different phases of the study, a two week baseline period, followed by two weeks using one of the commercial aids and then two weeks using the other. The next phase took place approximately a year later where participants were again tested during a baseline period followed by a two-week period using MEMOS. Overall the results from these tests showed all the electronic devices improved participant task performance when compared to baseline performance however performance was highest for the PMA.

The design of MEMOS is currently under evaluation to adapt it to accommodate its usability for older users (Thöne-Otto, and Schulze, 2003).

3.3. Memojog [Szymkowiak, Morrison, Shah, Gregor, Evans, Newall et al., 2004]

3.3.1. User group

Another mobile memory aid, Memojog, was introduced by Szymkowiak et al. (2004) to support user's memory for prospective tasks. Memojog contains many features similar to the MEMOS device (Thöne-Otto, and Schulze, 2003). One distinct difference however is that Memojog was specifically designed with features to accommodate the limitations and requirements of the older user.

3.3.2. Description of memory aid

Memojog is composed of three main elements which contribute to its function; a PDA device for the elderly user, a central server and a database that can be accessed through any computer with Internet access. Any information including the input of action prompts or changes to the users schedule can be entered from either the PDA or web based database, both of which communicate with the central server by the user, caregiver or care professional. Alternatively the user can contact an administrator who can then make any necessary changes to the user's schedule. Text based action prompts with an accompanying alarm are issued to the user to remind them of prospective tasks. These reminders can be accepted, postponed or ignored by the user. If the user accepts the reminder it is assumed that they are reminded and are able to execute the action at that time. If the user chooses to postpone the reminder, another reminder is issued after a certain amount of time. Finally, if the user was not alerted to the reminder or fails to either accept or postpone it, the caregiver or care professional is informed by data transmitted back to the server concerning the user's response. A contributing social benefit of Memojog is that it is equipped to store personal information for the user, with applications such as a phone book, address book and a store for birthdays, etc.

3.3.3. Evaluation

Two field evaluation sessions were executed with a group of older adults and their carers. The participants were trained to use the device and were subsequently required to use it for 12 weeks. In the first evaluation four participants (mean age of 60) with memory impairments were asked to perform 10 selected tasks using Memojog and were also asked to rate how difficult they considered each task to be on a 7 point scale. This procedure took place directly after training and again three weeks into the participant's use of the device. On average participants rated the device no more difficult than a rating of neutral (4 on the scale of 7). Participants were happy with the hardware of the device, were impressed with the multi-functional aspect for storing personal information and reported that they appreciated that the device reminded them of tasks accurately. This is particularly important, as any errors would reduce the users trust in the device. Of the negative comments recorded, the most significant was the user's ability to obtain coverage when changing or updating their schedule. This is frustrating to the average user but could cause considerable confusion to a memory impaired elderly user. Some users also found problems with the alert function of the device. The authors acknowledged that a multimodal input/output mode would be more appropriate to the older user, especially for those with hearing and visual impairments; however this technology was not available on the PDA hardware used for the memory aid. Similarly, users found difficulty with the touch screen keyboard but yet again this was an integrated part of the PDA device.

The second evaluation of Memojog yielded similar results. Participants in this trial however also found difficulty using the touch screen on the PDA device, as it was not sensitive enough requiring several interactions to produce a response. These evaluations produced results which imply that elderly individuals can successfully use modern electronic devices without any major difficulties.

3.4. Autominder [Pollack, Brown, Colbry, McCarthy, Orasz, Peintner et al., 2003]

3.4.1. User group

One of the most advanced technological designs in this paper was developed as an adaptive PM aid called Autominder (Pollack et al., 2003). Autominder was designed on a mobile robot platform with an integrated screen display for older adults to help them adapt to cognitive decline and assist them with tasks in their home environment. Pollack and her colleagues predict that Autominder has the potential to prolong an older adult's independence and prevent early institutionalisation for users with memory impairment.

3.4.2. Description of memory aid

Autominder is described as an intelligent cognitive orthotic system (i.e., assistive technology for cognition), which issues prompts about prospective tasks to the user at appropriate times. The difference between Autominder and previous PM aids is that it has the ability to adapt the user's schedule depending on the behaviour detected by sensors installed throughout the home. The device reasons about whether and when to issue reminders to the user based on their observable actions and task execution. For example, if an individual is required to drink five glasses of water a day the device will be programmed to issue a reminder to cue the user to drink their water. If however the device observes that the user has entered the kitchen, opened the glasses cabinet and turned on the water tap, it reasons about whether the user has already had the required drink and decides whether or not it is appropriate to remind the user to drink some water. The benefit of this intelligent memory aid is that it prevents the user from being reminded about tasks that they have already carried out, which may be frustrating or confusing to individuals with memory impairment.

The architecture of Autominder is composed of three main components; the plan manager, the client modeller and the personal cognitive orthotic (Pollack et al., 2003). The plan manager is responsible for the storage of the daily activity schedule of the user and updates this schedule when appropriate, identifying and resolving conflicting activities. The second component, the client modeller, is responsible for monitoring the user's behaviour using information from the board sensors and storing assumptions about the execution status of these activities in the client model. The final component, the personal cognitive orthotic (PCO) is responsible for the reasoning between what the user is supposed to do and what they are doing and whether or not to issue reminders. Most people's daily lifestyles are flexible, and whether or not schedules are planned, activities are likely to be cancelled or modified throughout the day. The authors claim that Autominder contains the intelligent architecture to adapt to a persons unpredictable daily plan, relieving the user from personally altering their new schedule into the system where it is not necessary. The device's adaptive nature deciphers whether to modify or delete planned activities based on the information received from the integrated sensors. The device may ask for verification of the user's actions if it cannot make this decision and to avoid assumption failure. This suggests however that the observable information is not always reliable. Assumption failure if it occurred may lead to various problems, especially for those with severe memory impairment. This failure could cause confusion to the user, disrupting their routine and may produce trust issues towards the device. As noted previously, Autominder is a very advanced and intelligent technology mediated memory aid with impressive abilities for helping older adults in their home. For the older user this quality may appear intimidating however, as elderly individuals who have not grown up with technology, or worked with it may feel apprehensive and wary of a mobile robot to act as a memory aid. As the population grows older more people will have experience using and relying on technology (i.e., PC's, mobile phones etc.), therefore the acceptance of Autominder into people's homes may increase in years to come.

According to Pollack (2005), preliminary field tests have been carried out with older adult and brain injured users however systematic studies investigating the effectiveness of Autominder have not yet been completed.

3.5. Coach [Mihailidis, Fernie, and Cleghorn, 2000]

3.5.1. User group

Dementia is a progressive disease that affects individuals cognitively and consequently limits their abilities for executing everyday tasks, eventually forcing them to become heavily dependent on their carers to assist them in the later stages of the disease. Technological devices have been developed to assist individuals with memory impairments however they are usually limited to users with early dementia (Szymkowiak et al., 2004), as it is believed that these users still have the potential to learn new techniques and are more willing to try new strategies to help them manage symptoms. An alternative to this idea was introduced as a computerized cognitive orthosis called COACH (Mihailidis, Fernie, and Cleghorn, 2000). COACH was designed as an instructional memory aid for users with mild to severe dementia to help them perform everyday tasks in the home with less dependence on their carers. The initial prototype of COACH was designed to assist individuals with a hand-washing task in a bathroom setting. Although procedural memory for tasks such as hand washing is relatively preserved in individuals with dementia, degeneration is displayed in the late stages (Bourgeois, 2002). COACH encompasses both prospective and retrospective memory in that it provides cues to initiate future actions but it is required for procedural tasks. Aside from promoting independence for the user, COACH could provide assistance in place of a carer in a bathroom environment avoiding any possible embarrassment.

3.5.2. Description of memory aid

The architecture involved in the workings of COACH consists of a video camera installed in the washroom which monitors the user's progress, a speaker inside the washroom which issues pre-recorded prompts to the user and a computer outside the area for the carer to track the user's progress. It was observed during baseline testing that dementia sufferers often needed verbal prompts from their carers for different stages of the hand washing task and sometimes needed the carer to help them physically, such as putting the towel in their hands. The aim of the device was to substitute the carer's prompts for computerized prompts. The system works by tracking the user's actions and issuing cues from the speaker only when it is detected that the user had either not initiated a task or had initiated a task out of sequence (e.g. using the soap before wetting their hands). This reduces the possibility of the person becoming over-reliant on the device. A second prompt is issued if the first was ignored. If this is again ignored the carer is alerted to the remote computer, informing them that the person is in need of assistance and for what stage in the sequence of the task.

3.5.3. Evaluation

The main benefit of COACH is that it is not cognitively or physically demanding on either the user or the carer. There is no learning involved in its use and no input required. The output is hearing dependent only, which means that the user does not have to read text from a screen or manipulate small buttons on devices they are not familiar with. Findings from a study examining the effectiveness of COACH found that nine out of ten participants improved task performance and completion for hand washing (Mihailidis and Davis, 2005). A few problems presented themselves during the study however. For example it was observed that some individuals showed signs of agitation from the computerized recording. This problem could possibly be resolved by simply substituting the computerized voice with a human voice. It was also found that on occasions the prompts were issued too quickly or were issued for tasks already executed. This problem may have been resolved after the evaluation as it is claimed that the device adapts to the idiosyncrasies of the users performance. Overall COACH could be a valuable computerized memory aid to assist individuals and their carers in their home environment.

3.6. Cooks Collage [Tran and Mynatt, 2003]

3.6.1. User group

As can be seen from the previously discussed electronic memory aids, designers have focused their attention primarily on prospective aids for memory impaired users reminding them to carry out activities of daily living, generally to make appointments on time, to take medication appropriately and to carry out any other necessary tasks in their day to day lifestyle. Tran and Mynatt (2003) developed a slightly different type of memory aid compared to these in that it focuses on just one activity of daily living; cooking.

3.6.2. Description of memory aid

Cooks Collage was developed as a retrospective memory aid for absent-minded individuals to refer to while cooking, to help cue them for their next cooking action. The technology consists of a flat screen monitor installed in the cooking area at user eye level. Two cameras are also installed in the kitchen to capture countertop images, which are transferred to the screen for the user to view. Displayed on the screen are six action images in time sequence with the most recent image at the bottom right hand corner of the screen, highlighted to make it stand out for the user. The idea behind this device is that the camera captures the cook's actions, taking picture images whenever the cook adds a new ingredient into the mixture. If an ingredient is added a number of times throughout the process the frequency number of the action is displayed on the most recent image, with corresponding slim grey bars preceding the image. The user is required to display the ingredient clearly so that the system recognises it. The authors claim that with the help of this system the user should be able to scan the most recent action images and continue where they left off without any ambiguity or delay.

3.6.3. Evaluation

Although Cooks Collage is ultimately designed for older adults, it was initially tested and evaluated on younger adults (Mynatt and Rogers, 2002). This process may be easier in the short term in terms of gathering participants, however the data collected may not be useful for the particular design. Cooks Collage was evaluated by sixteen undergraduate participants (Tran and Mynatt, 2003). The users were asked to cook something from a given recipe and their reactions to interruptions were observed. The participants' action slips were also recorded along with their perceived performance. From this study it was found that the participants' perceived performance was more accurate than their actual performance. The participants also underestimated the perceived effect of the interruptions. These results show that interruptions do potentially have an effect on a cook's memory for what they are doing or have done during the process.

There are many cognitive benefits to Cooks Collage in that it requires no input from the user and very little learning is involved. Images are presented sequentially in a left to right order which is a familiar display of information to most people. Only visual output is available to the user which might restrict its use for the elderly population, many of whom have visual impairments. However, the designers argue that any audio output would be absorbed into a noisy cooking environment (Tran and Mynatt, 2003). It is also argued that any form of interaction with the screen would only be an inconvenience taking into consideration a cook's "messy hands". On the other hand, the six images displayed may be too small for an elderly user to see any important detail i.e. the ingredient that they added. Therefore it may be useful if the user could temporarily enlarge an image of interest to see the details more clearly.

More recent studies examining the usefulness of Cooks Collage and how users interact with it have focused on older users (Tran, Calcaterra, and Mynatt, 2005). A case study following one older and one younger adult showed that the older user was more dependent on the device after interruptions during cooking, using it to provide real-time feedback while the younger user mainly used it to confirm or verify their actions. It was also observed that both users developed different strategies while cooking with the memory aid. For example, the older user prioritised the cooking tasks over the interruption tasks whereas the younger user prioritised the management of interruptions. A number of limitations were noted regarding how users interacted with the device. For example, several counting errors were made by the device where the ingredient was not displayed clearly to the cameras which resulted in mistakes in the cooking. There was a time delay from when the user added an ingredient to when it was displayed on the screen; therefore the older user delayed her actions waiting for the system to catch up. It was also observed during the study that the younger user was unsure about a previous action but could not verify it with the memory aid as only the six most recent actions are displayed. These limitations could be frustrating to a user however further research and iteration could improve its usability.

4. Discussion

Ageing is one of the highest risk factors of cognitive decline and has been shown to be associated with the accumulation of pathologies contributing to the development of cognitive dementias, the most common being Alzheimer's disease (Keller, 2006). Technology is ubiquitous in today's society yet designers are only beginning to look into how these devices can help an ageing population. Ageing and dementia affects both retrospective and prospective functions of memory however research has shown that prospective errors can have more of an effect on an individual's daily lifestyle compared to retrospective errors (Smith et al., 2000). With this in mind it is understandable why the majority of the memory aids reviewed here focus mainly on PM tasks. The overall purpose of the compensation systems discussed in this paper was to increase the user's independence by assisting them with activities of daily living and consequently relieving their carers somewhat. Research has shown that both normal ageing (Maylor, 1993b) and elderly individuals suffering from dementia (Nolan, Mathews, Truesdell-Todd, and

VanDorp, 2002) display enhanced performance on memory tasks when using external aids. These findings support the design of electronic memory aids for elderly individuals with cognitive decline.

It is important for the successful design of a device for a number of factors to be considered. In the case of a PM aid, the designer should consider whether the device supports both the prospective and retrospective components of PM and whether the reminders issued are useful to the user. For the design of retrospective aids it should be considered whether the information displayed is accurate and of benefit to the user. These design issues can be applied to the devices discussed in this paper. For example, the device Memojog was designed to support both PM (issuing reminders to the user) and RM (storing personal information for the user to look up). The device supports the prospective and retrospective components of PM as it issues a reminder to the user alerting them that they have something to remember and it also gives a brief description of what that task is. The reminder is useful to the user as it is issued at a particular time in advance of when the task is to be executed and the reminder is displayed in a way that is clear and comprehensible.

Above all, it is the user's attitude and preference towards a device that predicts its success. This point was made apparent from findings brought about by Cohen-Mansfield et al.'s (2005) questionnaire study investigating elderly attitudes towards technology and memory aids. This study, supported by previous studies (Goodman et al., 2003), established that cognitive, physical and psychosocial factors are important to elderly individuals concerning the design of technology mediated memory aids. A summary of how the electronic memory aids, Neuropage, MEMOS, Memojog, Autominder, COACH, and Cook's Collage meet the needs of the older user in terms of these factors is displayed in Table 3. Several questions could be considered to determine what features are appropriate and important for the design of an electronic memory aid for an older user in terms of these needs.

4.1. Needs of the older user

4.1.1. Cognitive needs

Older adults are more likely to show memory failures than younger adults and ageing is one of the highest risk factor for the development of cognitive disorders (Keller, 2006).

Therefore it is critical that an electronic memory aid device provides sufficient support to the intended user and is designed with an older user's abilities and limitations in mind. To establish whether the electronic memory aids meet the cognitive needs of the elderly user several questions were put to the design:

- What type of memory does the aid support and does it do this successfully?
- Is the device usable for the intended user and would a cognitively impaired elderly user be able to interact with it?
- Is any input required from either the elderly user or carer?
- Can the user or carer obtain feedback from the device to inform them of their position?
- Is there flexibility allowed by the device to suit the user's current situation?

4.1.2. Physical needs

The issues surrounding the physical needs of the user cover a wide range of usage issues. It is the physical design and the output information which is in question here. This includes how information is displayed (e.g. text, alarm, vibrator, voice etc.), how information is inputted (e.g. touchscreen, buttons etc.), and whether the system is mobile or portable:

- Does the device cater for visual/auditory/motor decline?
- Is the device or information from it easily accessible for the user or carer?

4.1.3. Psychosocial needs

Goodman et al.'s (2003) study highlighted what social factors determine older adults attitude towards technology. They showed that older participants were less likely to use new technologies as they did not want to show an outward lack of understanding towards technology, and that they wanted to avoid feelings of frustration and confusion if they did not understand it. It was also reported that it was important for a device to be easily concealed and affordable. With these issues in mind the following questions should be considered when analysing technology for older users:

- How much interaction is required of the user?
- Is any training needed for its usage?
- Is the size of the device appropriate for its intended use?

- Does the design of the device stand out from other technology devices?
- Is the cost of the device reasonable?

4.2. Evaluation of devices

To evaluate the current memory aids the needs of the target user can be again divided into the three categories, cognitive, physical and psychosocial, and the questions outlined above can be put to their design.

4.2.1. Cognitive issues

From the six memory aids reviewed, five of them support PM tasks. As PM tasks contain both a PM and a RM component (McDaniel and Einstein, 1992) the devices not only remind the user of future tasks but also store the information that is to be remembered. From the literature concerning the design of these systems and based upon the published evaluations, it appears that these technologies support the type of memory that was intended. The usability of each of the systems can again only be determined by these evaluations, which for all devices prove to be more beneficial to users' performance on delayed intentions than internal strategies alone. In relation to whether or not the devices require input from the primary users, it can be seen from Table 3 that only MEMOS, Memojog and Autominder contain this function. This has both positive and negative effects, the former being that the user has control over what information is inputted into the device and the latter being that users may not feel confident entering information or it may be too complex, particularly in the case of cognitively impaired individuals.

In general external memory aids act as a form of prosthesis or compensation for everyday memory function, providing cues to the users to initiate an action (Kapur et al., 2002) rather than improving the user's memory. According to Harris (1984), "An active reminder obviates the need for monitoring because it eliminates the prospective aspect of the memory task leaving just the retrospective one" (p. 89). This is true of the five PM memory aids described here. The users are not required to time monitor during the delay period as the devices are programmed to alarm the user at appropriate times and thus the amount of attentional resources required to carry out the intention is reduced. These devices support time-based PM functioning, which is particularly beneficial to older user as it is age sensitive (Einstein and McDaniel, 1990; Park et al., 1997). Autominder and COACH also have the ability to support event-based PM functioning as they have the ability to adapt their reminders based on observation of the user's actions. A positive attribute of the COACH system which is lacking in the other devices is that it only issues cues to the user when they are needed, reducing the chance of the individual becoming dependent on the system.

As Dobbs and Reeves (1996) outlined in their framework of PM functions, the last phase of the process (output monitoring) requires individuals to remember whether a task has been performed. We already know that older adults have poorer PM compared to younger adults (Maylor, 1996b; Einstein, et al., 2000; West and Bowry, 2005) and that individuals with dementia are further affected (Huppert et al., 2000; Maylor et al., 2002), therefore it can be predicted that a PM aid with a feedback function would considerably benefit older users. From the literature we are told that MEMOS, Memojog, COACH and Cook's Collage contain this function for either the primary user or caregiver to observe.

Overall these memory aids are successful in their aim to support either the PM and RM of the target users and have emphasised the importance of clear and simple designs, particularly with Neuropage. Furthermore, more recent designs such as Memo's and Memojog have taken on board issues that were not met in former designs again like Neuropage. Ideally, it would be more appropriate for older adults to use technical systems that they are familiar and comfortable with to help them perform daily activities, however this issue may be resolved in coming years as the number of technology users coming into late adulthood increases.

4.2.2. Physical issues

As briefly outlined previously in this paper there are physical aspects that show age-related declines in task performance with a decrease in both functional and sensory abilities (Huppert, 2003). Fisk, Rogers, Charness, Czaja, and Sharit, (2000) suggested that in order to enhance the likelihood that older adults will successfully adapt to technical devices, issues of visual and auditory perception should be stressed as these senses are the most affected by ageing. These issues are, to a point, acknowledged in the design of the current memory aids. All of the devices are dependent on at least one functioning sense. For example, Cook's Collage requires functioning vision and COACH requires functioning hearing to make use of the aid. The other memory aids, such as Neuropage, MEMOS, Memojog, and Autominder use both visual and auditory output. All of these devices use sound adjustable alarms to obtain the user's attention with Nuropage having the added function of a vibrator alert. Text is the most common form of reminder output, however it is suggested that Autominder might also make use of speech synthesis for relaying explanatory messages. In most of these cases the potential of the memory aid is limited by the systems hardware (Hersh and Treadgold, 1994; Szymkowiak et al., 2004), a problem which has to be expected when using commercial devices (e.g. pagers, PDA's, mobile phones etc.). Szymkowiak and colleagues note that the use of commercially available PDA's do not offer multi-modal output such as vibrator alert, speech output etc. They also suggest that the design for entering information could be improved as difficulties using the touchscreen keyboard were found, particularly when user's wanted to increase the text size.

In terms of motor functioning, all of the memory aids were integrated on devices suitable for portability in the cases of Neuropage, MEMOS, Memojog, and Autominder, or were easily accessible, such as Cook's Collage and COACH. The portable memory aids used lightweight devices such as pagers and PDAs with the exception of Autominder, which was integrated on a mobile robot. It was also noted that a touch-screen function was the main mode of interaction for all devices apart from COACH. Neuropage used only one large button for user interaction increasing its ease of use. These functions enhance usability for users, such as elderly individuals, who might have fine-motor difficulty (Fisk et al., 2000).

4.2.3. Psychosocial issues

It is predicted that if older adults accept and use technology mediated memory aids to support PM and RM memory functioning, they could sustain their independent lifestyles for longer. The design of the memory aids predicts whether the older adult will accept and use these memory aids. The first issue to be considered is the amount of interaction that is required of the user to use the memory aid and whether its benefit outweighs other external aids, such as calendars. Firstly, COACH and Cook's Collage requires little or no interaction from the user. Neuropage requires only for the user to accept and read their reminder whereas MEMOS, Memojog and Autominder require the user or caregiver to enter the user's schedule and to accept or postpone reminders. Autominder is designed to automatically alter the user's reminders depending on observable behaviours, thus, reducing the user's need to manually change their schedule into the device. Information can also be entered via an external computer by individuals such as care professionals, if either the primary user of caregiver does not feel confident to do so. These functions might decrease the apprehension elderly people feel towards technology (Goodman et al., 2003).

From the literature it seems that all researchers allow training time for participants before the devices were evaluated. Although a device should ideally require little or no learning, training with an instructor, a video or manual would help familiarize the user with the system, increasing their confidence and comfort when using the memory aid alone.

Another issue to be considered is whether the device will cause embarrassment to the user, amplifying their difficulties to the public. The portable memory aids discussed here are all small devices that can be easily concealed, with the exception of Autominder that is meant to be used in the home. They also use commercially available hardware systems which are ubiquitous in today's society making them indiscernible as memory aids and also moderately affordable, important features to older users attitudes according to Cohen-Mansfield et al. (2005) and Goodman et al.'s (2003) findings.

Cohen-Mansfield and colleagues (2005) found that individuals who were most likely to use an electronic memory aid were those with a need for external aids and who had experience using electronic devices. They also found that all participants used at least one external aid. Therefore it follows that an important influencing factor predicting older adult's use of electronic memory aids is their familiarity with technology. This highlight the importance of good training material incorporated before the memory aid devices are used.

Each of the memory aids contained unique features of psychosocial importance that set them apart from the other designs. For example, COACH allowed late stage dementia patients more independence in the restroom, reducing social embarrassment; MEMOS allowed users to contact a caregiver in crisis situation; Memojog provided a function for users to store personal information such as family details; Autominder adapted to the user's behaviour eliminating unnecessary repeated actions; Neuropage provided a simple solution for patients to help them gradually assimilate back into their normal lifestyle; and Cook's Collage acts as an action reference taking some pressure off harassed absent-minded cooks.

5. Conclusion and Future Research

Much work has been accomplished in relation to PM and compensatory memory devices to support this function in both normal older adults and cognitively impaired older adults, as can be seen from this paper. The overall purpose of the systems is to prolong the individuals' independence in their home. However, there is a fine line between the user being independent with the help of a memory aid and being over-dependent on the technology itself. For this reason, it is important that these technologies are designed to act as a support for the user rather than a substitute carer.

Future research might take on board the limitations of the systems discussed to produce a device which has both multi-modal input and output to accommodate for age-related physical and cognitive decline.

Memory Aid	Psychosocial	Physical	Cognitive
NeuroPage	Very small device, therefore easily concealed. Promotes independence for activities of daily living.	Small and portable. Alarm/vibrator alert, with text: multimodal. Large button to control, easy to use even for motor impaired. Small screen.	PM aid. Requires little user input. Input dependent on paging company, may act as limitation but useful for inexperienced tech user. No way for user to confirm action completed or delay reminder.
MEMOS	Small portable ubiquitous device. Promotes independence for user. Assists as contact device in crisis situations (user confused or disorientated).	Portable, lightweight device. Users can leave voice messages if they want to input data which is then decoded from central server. Quite a large screen for visual display with a few clearly labelled soft buttons. Alarm can be adapted for user.	PM aid. Input entered by user via handheld computer or carer/professional carer via central server. Task confirmation function and reminder delay function. Emergency contact function. Little learning involved.
MemoJog	Small portable device. Holds personal information (family details). Carers not reliant on others to input data as device easy to use. Promotes independence for both user and carer.	Small portable device. Quite a large visual display. Adaptable alarm. Keyboard integrated into hardware caused problems when inputting information.	PM aid. Requires schedule input from user or carer. Task confirmation function, carers contacted if task not confirmed. Minimal action steps. Coverage problems reported when modifying diary. May cause confusion to cognitively impaired users.
COACH	Promotes independence for user for procedural tasks which may be affected in late dementia. Reduces embarrassment for individual if help is need in washroom.	Audio output from integrated speakers. Hearing dependent.	Instructive memory aid. Encompasses prospective and procedural memory. Requires no input from user. Carer can observe users progress through computer. Short instructional prompts given only if action is not carried out of completed. Reduces dependence on aid.
Autominder	Adaptive functions allow user to change their routine without updating system. Automatic search for best schedule update. High technology device. Some elderly users may be apprehensive using it	Device set into mobile robot to be used in home environment. Works with visual display and sensors. Robot includes sensitive displays, microphones for speech recognition and speakers for speech synthesis.	PM aid. Flexible reminder system which adapts the users schedule depending on the users actions and makes assumptions about these actions. Schedule inputted by carer with user. Could potentially make assumption failures and result in over reliance of system.
Cooks Collage	Promotes independent cooking. Could be seen an item of prestige. Can be used by people of all ages therefore users not seen as incapable if using.	Screen can be implemented to suit height of user for viewing. No input required. Only visual output, i.e. visually dependent. Images may not be clear to an elderly user.	RM aid for cooking. Interruptions, absent-mindedness and action slips. Requires no input or learning.

Table 3: Evaluation of how electronic memory aids discussed in the literature meet the needs of the older user.

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