



Government
Office for
Science

 **Foresight**

**Mental Capital and Wellbeing:
Making the most of ourselves in the 21st century**

**State-of-Science Review: SR-E25
Technology Solutions to Prevent Waste of Mental Capital**

Dr Patrick Olivier
School of Computing Science, Newcastle University

Joe Wherton and Professor Andrew Monk
Department of Psychology, University of York

*This review has been commissioned as part of the UK Government's Foresight Project,
Mental Capital and Wellbeing. The views expressed do not represent the policy of
any Government or organisation.*

Summary

This selective review focuses on two possible opportunities to prevent wasted mental capacity. The first describes technologies developed for a general population that can be used to support clinical groups. This is technology to record and then retrieve everyday life events. The second reverses this logic and describes some technology developed for a clinical group, people with dementia, which could be useful for a wider population. This is technology to prompt people through domestic activities. Related work not addressed in this review is clinical research using devices as an aid for cognitive rehabilitation (see Lynch (2002) for a historical review of cognitive retraining).

1. Cognitive prostheses

The history of technology can be seen as an ongoing endeavour to overcome our sensory, physical and cognitive limitations. In this light, information technology is a cognitive prosthesis for perception, memory and reasoning (Engelbart, 1963). Word processors and spreadsheets help us to organise information and reason about complex problems. Search algorithms allow us to find details we cannot remember from personal information repositories. Point-of-sale terminals make skilled mental arithmetic redundant. Despite this widespread use of information and communication technologies, its influence has thus far mainly been on people's working lives.

2. Accessing personal data and experience

Research into memory prostheses, to support access to personal information and personal experience, has proceeded along two main lines of enquiry: the formalisation of the context of information creation and use; and the capture of experience itself. Initial research in this area addressed the problems of office professionals. Desktop and laptop computers could be used as memory prostheses for addressing the limitations of traditional information retrieval by allowing access to documents based on a query that includes terms representative of the context of the task and previous document usage. For example, one could use metrics such as the deployment of a previous document as a measure of salience (Budzik and Hammond, 1999).

Lamming et al. (1994) coined the term 'memory prosthesis' in their presentation of Forget-me-not, a follow-on to the Activity-based Information Retrieval project (Lamming and Newman, 1992). Forget-me-not was an early pervasive computing experiment that utilised the ParcTab, a handheld device that can track its spatial location in an indoor environment by recognising different infrared sensors (generally distributed at the spatial granularity of a room). The ParcTab enhanced standard information retrieval capabilities by allowing the use of contextual information, such as the location of a meeting in which a document was last accessed, as a component of a query term.

Rhodes and Starner's (1996) Remembrance Agent typified attempts to capture and utilise context in wearable computing, and allowed users to write notes during face-to-face conversations on a one-handed keyboard using a head-mounted display. A background process retrieves past notes based on the user's most recent entries. Rhodes collected several years of notes and claimed specific benefits such as the resolution of misattributions. A selection of such just-in-time information retrieval agents (desktop and wearable) are contrasted and empirically evaluated by Rhodes and Maes (2000).

Work-oriented document retrieval utilising spatial, temporal and usage contexts, and continuous information retrieval, have some practical applications. However, a number of recent and ongoing academic

and commercial research projects have been addressing the problem of *lifelogging*: the provision of continuous capture and access to personal experience through the use of wearable and portable computing devices. Microsoft's MyLifeBits project (Gemmell et al., 2002) is an attempt to realise Bush's Memex vision (Bush, 1945) by digitising all the documents a user creates, all web pages visited, photos taken (indexed by time and location) and, in later versions, all video recorded using a wearable camera. Mann's EyeTap devices and experiments in wearable cameras and displays (Mann, 1996; 1997) are related examples of the extended capture and transformation of first-person perspective video imagery.

Lifelogging experiments of this kind raise interesting questions. Firstly, there are the ethical and practical issues concerned with mounting cameras and other sensors on one's person. How do other people feel about interacting with someone who has been 'instrumented' in this way? Secondly, there is the question of what you do with all this information once you have recorded it, that is, to what extent can continuous records or video diaries themselves, support episodic memory (Hoisko, 2003; Eldridge et al., 1992).

Recent studies using SenseCam (Hodges et al., 2006) potentially address this last question. SenseCam, a single-shot camera worn around neck and triggered by changes in light level, is less intrusive than previous offerings in this area. Also, a recent study shows that it has some value in supporting people's memories of past events (Sellen et al., 2007). It has also been used with people with amnesia, where it has been shown effective as a conversational prompt (Hodges et al., 2006).

3. Supporting daily activities

The previous section described some research that started off as an exploration of how anyone could use a continuous record of daily activity to supplement episodic memory and ended up providing potential clinical benefits. The research described in this section was motivated by the clinical problem of reminding older people to take their medication and so on, and also of prompting people in the early stages of dementia through multi-step tasks. We will argue that the resulting systems could be useful to a much wider population of users.

Numerous technologies have been exploited to provide timed reminders and cognitive support at specified intervals, including the use of computer-controlled telephone calls (Friedman, 1998), pagers (Hersh and Treadgold, 1994) and personal digital assistants (Kim et al., 2004). Fixed scheduled prompting has proved valuable for applications such as the provision of medication reminders (Kirsch, 1992), but falls short of supporting deficits in episodic memory, that is memory of personally experienced events – the symptom most commonly associated with conditions such as mild-to-moderate dementia.

In terms of the ability to perform activities of daily living, the parallel deficits observed in executive function are also very important (Nadler et al., 1993; Boyle et al., 2004). Deficits in executive function manifest as problems in planning, sequencing and attentional control. These significantly increase the need for external help in the conduct of everyday tasks such as preparing food, washing, or cleaning.

Feyereisen and colleagues (1999) assessed hospitalised Alzheimer's disease (AD) patients when dressing. Executive function deficits resulted in problems of incorrect choice of clothing, omission errors (missing out an action) and inappropriate orientation and adjustment of clothing (see also, Giovannetti et al., 2002).

Problems due to executive function deficits may be ameliorated in the home setting if the patient can rely on automatic, rather than controlled, processes. According to the Norman and Shallice (1986) model of attention, routine procedures are controlled by activation through a network of action schemas, known as the Contention Scheduling System, and so require little attentional control. Unfamiliar procedures, on the other hand, rely on the Supervisory Attention System to monitor and control actions that constitute the

tasks. When performing regular procedures, a patient is less reliant on attentional resources and can instead rely on associations between actions or stimuli in the environment (Jorm, 1986; Rusted and Sheppard, 2002). The role of a familiar environment and the use of salient cues are widely acknowledged in dementia care practice. Beck and colleagues (1993) refer to the use of 'stimulus control' to support patients through daily tasks (e.g. placing clothing items on the bed to facilitate dressing).

Various technologies have been brought to bear on this problem. Baruch et al. (2004) presented temporal information on computer screens placed in prominent areas of the house. For example, at night, the screen will present a large digital clock along with a pictorial representation (e.g. the moon on a dark background) and a short message such as "It's night time so you need to go to bed").

Kautz et al. (2002) developed a portable orientation aid, the 'Activity Compass', which guides patients both outdoors and indoors. If outdoors, this handheld device can detect when the user is lost through GPS and artificial intelligence algorithms. In such instances, the device provides the patient with a verbal prompt to return home, and directs them by presenting an arrow pointing in the appropriate direction on the display screen. Indoors, the Activity Compass uses sensors to track patients' movements, and directs them when necessary. For example, if a mealtime is overdue, the device prompts the patient when they are in the kitchen to encourage them to make something to eat. The interface uses symbolic representation (e.g. the arrow and a picture of a house to indicate 'going home') and pre-recorded prompts to guide the person with dementia.

Mihailidis and colleagues (2004), extended in Hoey et al. (2007), developed the COACH (Cognitive Orthosis for Assisting Activities in the Home) system, which is designed to guide hospitalised dementia sufferers through the process of washing their hands. COACH uses image processing and probabilistic modelling techniques capable of monitoring a patient's progress through the task and providing assistance when necessary. When an error is detected (e.g. an action out of sequence), or the patient fails to initiate an action after a set period, the system presents appropriate pre-recorded verbal prompts. Similarly, Dishman (2004) presented a prototype system that could guide a patient through making a cup of tea. This system monitors the person's progress using radio frequency identification (RFID) tags attached to the utensils. Audio prompts are then provided to the patient, with video clips of a person carrying out the action to be performed, displayed on a TV screen.

Tran et al. (2005) devised the Cooks Collage to guide a patient through a cooking activity. The system includes a single screen located on the kitchen cupboard, which presents a series of close-up shots of previous actions performed during the activity as a visual summary of the individual's progress. This is presented as a conceptual design and, although effective in supporting graduate students to accomplish a dual task test (cooking whilst learning another language), it has not yet been tested on people with cognitive impairment.

In summary, the literature is not short of ideas about how one might use technology to support people with dementia when carrying out daily tasks, but none have as yet made it as mainstream products. There are hard technological problems to solve before this can happen. An effective prompting system has to infer context: what activity the user is attempting; what they have done so far; and what is the current state of the environment.

For example, COACH has to sense that someone is standing at the sink, oriented in such a way that there is a high probability that they want to wash their hands. It has to track the steps in carrying out this activity and prompt only when necessary. It has to sense whether the tap is on or off and where the soap is. The usefulness of COACH is highly sensitive to errors in this process of sensing and inference. Prompting someone to do something they have already done is confusing. Prompting someone to do something they do not want to do or are about to do anyway can be confusing, or at the very least irritating.

However, if prompting can be done subtly and in a timely way than many people could benefit. We all find ourselves cognitively overloaded on occasions. Systems that keep an eye on us and draw attention to errors of omission or commission could be of value in many contexts, especially where safety is a priority. As is explained in the final section below, recent developments in sensing and machine inference make this a real possibility for the future.

4. The confluence of mental capital and pervasive computing

Since Weiser's (1991) vision for the 'computer of the 21st century', a world in which computers and sensors *disappear* as they are woven into the very fabric of our surroundings, developments in pervasive computing (also referred to as 'ubiquitous computing' or 'ambient intelligence') have seen significant progress. In less than two decades, the technical basis and infrastructure to realise miniaturised computing and sensory devices, seamlessly connected by wireless networks, is already apparent.

Pervasive computing proposes a fundamental shift in the nature of our use of technology. In simple terms, it takes it away from the desktop to our everyday environments. Through the aggregation of sensory inputs and personalised models of human activity, such environments aim to monitor and reason about our behaviours, goals and intentions, thereby facilitating access to information, communication channels and the control of artefacts through speech recognition and tangible interfaces and display technologies (spoken, haptic and visual) ubiquitously embedded in our environments. To realise this vision, significant advances are required in the underlying techniques by which the actions and intentions of users in everyday settings are recognised. These depend not only on future sensing technologies, but also on developments in probabilistic reasoning techniques (Horvitz et al., 1998; Pentland, 1995) and the modelling and use of context (Dey, 2001).

An analogy might be drawn with prostheses for sensory limitations. Contact lenses are almost invisible prostheses for vision that are unconsciously utilised by their wearers as they go about their daily lives. Pervasive computing offers the opportunity for cognitive prostheses that are equally invisible and equally useful. These prostheses will help us remember events in our lives that are of value to us. They will also help us carry out daily activities more safely and effectively.

The cognitive prostheses described above are only just beginning to utilise advances in pervasive computing. The confluence of mental capital and pervasive computing is more than just fortunate. The vision of pervasive computing is of a world in which cognitive prostheses form the very intelligent environment in which impaired and unimpaired people alike reside.

References

- Baruch, J., Downs, M., Baldwin, C. and Bruce, E. 2004. A case study in the use of technology to reassure and support a person with dementia. *Dementia*, 3:371-392.
- Beck, C.K., Heacock, P., Rapp, C.G. and Mercer, S.O. 1993. Assisting cognitively impaired elders with activities of daily living. *The American Journal of Alzheimer's Care and Related Disorders and Research*, 8:11-20.
- Boyle, P.A., Paul, R.H., Moser, D.J. and Cohen, R.A. 2004. Executive Impairments Predict Functional Declines in Vascular Dementia. *The Clinical Neuropsychologist*, 18:75-82.
- Budzik, J. and Hammond, K. 1999. Watson: Anticipating and Contextualizing Information Needs. In *Proceedings of 62nd Annual Meeting of the American Society for Information Science*.

Bush, V. 1945. As We May Think. *Atlantic Monthly*, July, 76:101-108.

Camp, C.J., Foss, J.W., Stevens, A.B. and O'Hannken, A.M. 1996. Improving Prospective Memory Task Performance in Persons with Alzheimer's Disease. In M. Brandimonte, G.O. Einstein and M.A. McDaniel (Eds). *Prospective Memory: Theory and Appliances* (351-367). Mahwah, NJ: Erlbaum.

Dey, A.K., Salber, D. and Abowd, G. 2001. A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications. *Human-Computer Interaction*, 16.

Dishman, E., 2004. Inventing Wellness Systems for Aging in Place. *Computer*, 37:34-41.

Drummond, L., Kirchoff, L. and Scarbrough, D.R. 1978. A practical guide to Reality Orientation: A treatment approach for confusion and disorientation. *Gerontologist*, 18:568-573.

Eldridge, M., Lamming, M. and Flynn, M. 1992. Does a Video Diary Help Recall? In A. Monk, D. Diaper and M.D. Harrison (Eds). *People and Computers VII*, 257-269. Cambridge: Cambridge University Press.

Engelbart, D.C. 1963. A conceptual framework for the augmentation of man's intellect. In P.W. Howerton, (Ed). *Vistas in information handling*, 1-29. Washington, D.C.: Spartan Books.

Feyereisen, P., Gendron, M. and Seron, X. 1999. Disorders of everyday actions in subjects suffering from senile dementia of Alzheimer's type: An analysis of dressing performance. *Neuropsychological Rehabilitation*, 9:169-188.

Friedman, R.H. 1998. Automated telephone conversation to assess health behavior and deliver behavioral interventions. *Journal of Medical Systems*, 22:95-101.

Gemmell, J., Bell, G., Lueder, R., Drucker, S. and Wong, C. 2002. MyLifeBits: Fulfilling the Memex vision. *Proceedings of ACM Multimedia'02*, 235-238. log. SRC Technical Note 1998-014, October 26, 1998.

Giovannetti, T., Libon, D.J., Buxbaum, L.J. and Schwartz, M.F. 2002. Naturalistic action impairments in dementia. *Neuropsychologia*, 40:1220-1232.

Hanley, I.G. 1981. The use of signposts and active training to modify ward disorientation in elderly patients. *Journal of Behavioural Therapy and Experimental Psychiatry*, 12:241-247.

Hanley, I.G. and Lusty, K. 1984. Memory aids in reality orientation: A single-case study. *Behaviour Research and Therapy*, 22:709-712.

Hanley, I. 1986. Reality orientation in the care of the elderly patient with dementia: Three case studies. In I. Hanley and M. Gilhooly (Eds). *Psychological Therapies for the Elderly*, 65-79. Beckenham: Croom Helm.

Hersh, N.A. and Treadgold, L. 1994. Neuropage: The rehabilitation of memory dysfunction by prosthetic memory and cueing. *NeuroRehabilitation*, 4:187-197.

Hodges, S., Williams, L., Berry, E., Izadi, S., Srinivasan, J., Butler, A., Smyth, G., Kapur, N. and Wood, K. 2006. SenseCam: A retrospective memory aid, 177-193 In *Proceedings of Ubicomp 2006*, LNCS 4206.

Hoey, J., von Bertoldi, A., Poupart, P. and Mihailidis, A. 2007. Assisting Persons with Dementia during Handwashing Using a Partially Observable Markov Decision Process. In *Proceedings of the International Conference on Vision Systems (ICVS)*, Bielefeld, Germany.

Hoisko, J. 2003. Early Experiences of Visual Memory Prosthesis for Supporting Episodic Memory. *International Journal of Human-Computer Interaction*, 15:209-230.

Horvitz, E., Breese, J., Heckerman, D., Hovel, D. and Rommelse, K. 1998. The lumiere project: Bayesian user modeling for inferring the goals and needs of software users. In *Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence*.

Jorm, A.F. 1986. Controlled and automatic information processing in senile dementia: A Review. *Psychological Medicine*, 16:77-88.

Josephsson, S., Bäckman, L., Borrell, L., Bernspang, B., Nygard, L. and Rönnerberg, L. 1993. Supporting everyday activities in dementia: An intervention study. *International Journal of Geriatric Psychiatry*, 8:395-400.

Kautz, H., Fox, D., Etzioni, O., Borriella, G. and Arnstein, L. 2000. An Overview of the Assisted Cognition project. *Proceedings of the AAAI Workshop on Automation as Caregiver: The role of intelligent technology in elder care*, 60-65. Edmonton, AB.

Kim, H-J, Burke, D.T., Dowds Jr, M.M., Robinson Boone, K.A. and Park, G.J. 2004. Electronic memory aids for outpatient brain injury: follow-up findings. *Journal Brain Injury*, 14:187-196.

Kirsch, N.L. 1992. Computer-assisted interactive task guidance: Facilitating the performance of a simulated vocational task. *Journal of Head Trauma Rehabilitation*, 7:17-25.

Lamming, M.G. and Newman, W.M. 1992. Activity-based Information Retrieval: Technology in Support of Personal Memory. In F.H. Vogt (Ed). *Information Processing 92, Personal Computers and Intelligent Systems*, 3:68-81.

Lamming, M.G., Brown, P.J., Carter, K., Eldridge, M., Flynn, M. Robinson, P. and Sellen, A. 1994. The design of a human memory prosthesis, *Computer Journal*, 37:153-163.

Lynch, B. 2002. Historical Review of Computer-assisted Cognitive Retraining. *Journal of Head Trauma Rehabilitation*, 17:446-457.

Mann, S. 1996. 'Smart Clothing': Wearable Multimedia Computing and 'Personal Imaging' to Restore the Technological Balance between People and Their Environments. In *Proceedings of ACM Multimedia*, November 1996, 163-174.

Mann, S. 1997. *Smart Clothing: The Wearable Computer and WearCam*, Personal Technologies, 1:1.

Mihaildis, A., Barbenel, J. C. and Fernie, G. 2004. The Efficacy of an intelligent cognitive orthosis to facilitate hand-washing by persons with moderate to severe dementia. *Neuropsychological Rehabilitation*, 14:135-171.

Nadler, J.D. Richardson, E.D. Malloy, P.F. Marran, M.E. and Hostetler Brinson, M.E. 1993. The ability of the dementia rating scale to predict everyday functioning. *Archives of Clinical Neuropsychology*, 8:449-460.

Norman D.A. and Shallice, T. 1986. Attention to action: Willed and automatic control of behaviour. In R.J. Davidson, G.E. Schwartz and D. Shapiro (Eds). *Consciousness and Self Regulation*, 1-18. New York: Plenum Press.

Pentland, A. 1995. Machine understanding of human action. In *Proceedings 7th International Forum on Frontier of Telecom Technology*.

- Rhodes, B.J. and Starner, T. 1996. Remembrance Agent: A continuously running automated information retrieval system. In *Proceedings of The First International Conference on The Practical Application Of Intelligent Agents and Multi Agent Technology (PAAM '96)*, 487-495.
- Rhodes B.J., and Maes, P. 2000. Just-in-time Information Retrieval Agents. *IBM Systems Journal*, 39: 685-704.
- Rusted, J. and Sheppard, L. 2002. Action-based memory in Alzheimer's disease: A longitudinal look at tea making. *Neurocase*, 8:111-126.
- Sellen, A.J., Fogg, A., Aitken, M., Hodges, S., Rother, C. and Wood, K. 2007. Do life-logging technologies support memory for the past?: an experimental study using sensecam. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (San Jose, California, USA, April 28 - May 03, 2007)*, 81-90.
- Tran, Q.T., Calcaterra, G. and Mynatt, E.D. 2005. Cooks collage: Déjà vu display for a home kitchen: *Proceedings of HOIT'05 conference on home-oriented informatics and telematics*, 15-32. York, UK.
- Weiser, M. 1991. The Computer for the 21st Century. *Scientific American*, 265:94-104.

All the reports and papers produced by the
Foresight Mental Capital and Wellbeing Project may be downloaded from the Foresight website
(www.foresight.gov.uk).

Requests for hard copies may also be made through this website.

First published September 2008.

The Government Office for Science.

© Crown copyright