

The use of a wearable camera improves autobiographical memory in patients with Alzheimer's Disease

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ABSTRACT

Despite the marked impairment of recent episodic memories in Alzheimer's Disease, there have been few attempts to rehabilitate these deficits. We used a novel external memory aid to promote recall of episodic memories in patients with mild to moderate Alzheimer's Disease. SenseCam, a small wearable camera, recorded significant events in the lives of six Alzheimer's Disease patients. Every two days for two weeks, each patient's memory for an event was assessed, followed by a structured review of the SenseCam images. Longer-term recall was tested one and three months later. A written diary control condition followed the same procedure. Across 40 events the SenseCam review method resulted in significantly more details of an event being recalled over two weeks than the written diary method in five out of the six patients. At three months post event, four out of five patients (one had dropped out) recalled significantly more details of events in the SenseCam condition while the other patient showed no significant difference. Viewing SenseCam images of personally experienced events may significantly improve autobiographical memory in patients with even moderate Alzheimer's Disease.

Key Words

Alzheimer's disease

Autobiographical Memory

SenseCam

Rehabilitation

Wearable camera

Introduction

An impairment in episodic memory is a well documented feature of Alzheimer's Disease (Morris and Becker, 2006). Episodic memory is the ability to recollect information that is associated with a particular time and place, a form of mental time travel that is considered to be unique in humans (Tulving, 1983, 2002). 'It enables people to travel back in time as it were, into their personal past, and to be consciously aware of having witnessed or participated in an event and happenings at earlier times' (Tulving, 1989, page 362). Autobiographical event memory has many similar features to episodic memory. It occurs when autobiographical knowledge of the self is associated with episodic memories (Conway, 2005). Both episodic and autobiographical event memories are believed to require a recollection of the event (the difference between remembering that an event took place, rather than simply knowing it took place) and this recollection often takes the form of visual imagery, alongside other sensory-perceptual features (Conway and Pleydell-Pearce, 2000; Brewer, 1986). When people recollect a recent trip or what they had for supper last night, they are drawing upon their episodic or autobiographical memory systems.

In Alzheimer's Disease, not only is poor episodic memory considered to be one of the key symptoms at diagnosis, but it is also the most prominent symptom pre-clinically, and may well occur many years before the disease becomes clinically apparent (Small, Herlitz and Backman, 2006). The impairment in episodic memory is found in the verbal and non-verbal domain, and in recall as well as recognition, although in the early stages recall is considered to more impaired (Backman, Small and Fratiglioni, 2001a). The obvious deficit in recall of episodic events in Alzheimer's Disease is likely to be, at least in part, directly linked to the neuropathological changes in the disease which lead to senile plaques and neurofibrillary tangles forming in the medial temporal lobes very early on in the course of the disease (Ouchi et al. 1998). The autobiographical memory impairment often includes more remote periods, with evidence of a temporal gradient for such memory loss that is characterised by relative sparing of earliest memories (see Bright and Kopelman, 2006, for a review).

The cognitive neuropsychology of Alzheimer's Disease is complex and not entirely well understood. However it is likely that deficits in encoding, storage and retrieval affect the ability to form new episodic memories. This is further complicated by a loss of semantic knowledge in Alzheimer's Disease which may make it difficult for patients to establish connections to their semantic knowledge base during encoding (Garrard, Patterson and Hodges, 2006). Executive deficits are apparent early on in the disease, which may affect a patient's ability to retrieve stored memories (Collette et al., 1999).

The literature on rehabilitation of cognitive deficits in Alzheimer's Disease suggests that patients can be helped in a number of ways to optimise their functioning, minimise disability and enhance their self-efficacy and coping skills (Clare and Woods, 2001), thereby extending independence and reducing caregiver burden (see Rusted and Clare, 2006, for a review). Rehabilitation has been attempted using techniques applied to populations with acquired brain injury such as external aids and errorless learning techniques (Hoerster, Hickey and Bourgeois, 2001; Clare et al., 1999). Researchers have significantly improved episodic memory functioning by interventions at both the encoding and retrieval stage (Backman, 1992). Other methods to rehabilitate cognitive functioning in dementia involve the use of psychological therapies such as Reminiscence Therapy (Woods et al., 2005), Reality Orientation (Spector et al., 2001) and Validation Therapy (Feil, 1993, Neal and Briggs, 1999). Reminiscence Therapy is the most widely used approach with patients with dementia. It employs music, photographs, videos and items from the past to stimulate personal memories, both recent and remote. It considers a person in the context of their life history, and by respecting this and bringing to mind enjoyable or comforting memories, aims to promote enhanced levels of well-being (Brooker and Duce, 2000) although its direct effects on memory and cognitive functioning are less clear (Rusted and Clare, 2006). More recently Spector et al. (2009) introduced Cognitive Stimulation Therapy (CST) which aims to combine Reminiscence therapy and cognitive training approaches. This method has been shown to have as beneficial effects as efficacious as drug therapy, and is now recommended by National Institute of Health and Clinical Excellence (2006). To

sum up therefore, while rehabilitation of more remote autobiographical memories have often been included in therapeutic interventions in patients with Alzheimer's Disease, more recent autobiographical memories are not so often targeted, possibly because technologies developed to support memory of this type have not been available.

Recent research suggests that episodic memory functioning can be successfully rehabilitated in clinically impaired populations using a device called SenseCam (Berry et al., 2007; Berry et al., 2009; Browne et al., 2011; Loveday and Conway, 2011). SenseCam is a small wearable camera which takes pictures automatically every thirty seconds or so, without the user having to take a picture manually. Worn around the neck, the camera takes hundreds of images every day, and these images can be readily uploaded onto a computer and viewed in relatively quick succession in a sequence which plays automatically. In previously published studies (Berry et al., 2006; Browne et al., 2011; Conway and Loveday, 2011), review of SenseCam images of personal events by memory impaired patients led to significantly improved recollection for the events in question. This in turn led to improved confidence and well-being. In this study we aimed to replicate these findings by using the same technology and method to improve the ability of patients with Alzheimer's Disease to remember recently experienced personal events.

Method

Participants

There were 6 participants, aged 64 to 84, with a mean age of 72. There were four women and two men. All had received a diagnosis of Alzheimer's Disease from the Memory Clinic at Addenbrooke's Hospital in Cambridge. The participants were in the mild to moderate stages of the disease. Four of the participants had spouses, and two did not. On the Addenbrooke's Cognitive Examination-Revised, they had a mean score of 70.8 (see Table 1).

Table 1: Demographic Details of Participants

| Patient Name | AGE | Addenbrooke's Cognitive Examination Score- Revised |
|---------------------|------------|---|
| HY (CLG) | 66 | 81 |
| OO (JS) | 64 | 79 |
| OA (BD) | 76 | 79 |
| DU (EB) | 80 | 56 |
| RA (FH) | 84 | 65 |
| EU (WB) | 64 | 65 |

Materials

SenseCam is a small wearable camera, approximately 5cm by 6cm, which has been developed by researchers at Microsoft Research Cambridge (Figure 1). It has been designed to be used independently, without user intervention. It is usually worn around the neck on a lanyard, and it automatically takes photographs in response to various sensors. Sensors that trigger the capture of an image include a temperature sensor, a light sensor, and a passive infrared sensor. Therefore if the wearer leaves a building and the temperature changes, the camera will take a photograph.

Similarly, if the light level changes, the camera will take a photograph. If nothing significant happens in the environment, the camera will take a photograph at regular intervals. In the current study, the interval was set at every thirty seconds. Consequently, over the course of a single day, the camera takes hundreds of images which can then be uploaded to a computer and viewed at speed (see below). The effect is rather like watching a movie of one's day, taken from the perspective of the wearer. For a detailed overview of the camera and its uses, see Hodges et al., 2006 and Hodges, Berry and Wood, 2011.

Figure 1: SenseCam



A purpose-built user interface was used for viewing SenseCam images on a standard PC (see Figure 2). The interface was designed to allow forward (or backward) playback through the images. Controls on the interface appear similar to those of a standard VCR player, allowing users with little knowledge of computers to operate the software. Images can be viewed as a rapid slide show (10 frames per second), a slower slide show (6 frames per second) and a slow slide show (1.5 frames per second), or one by one. In the rapid playback mode, several hundred images may be viewed in a matter of minutes.

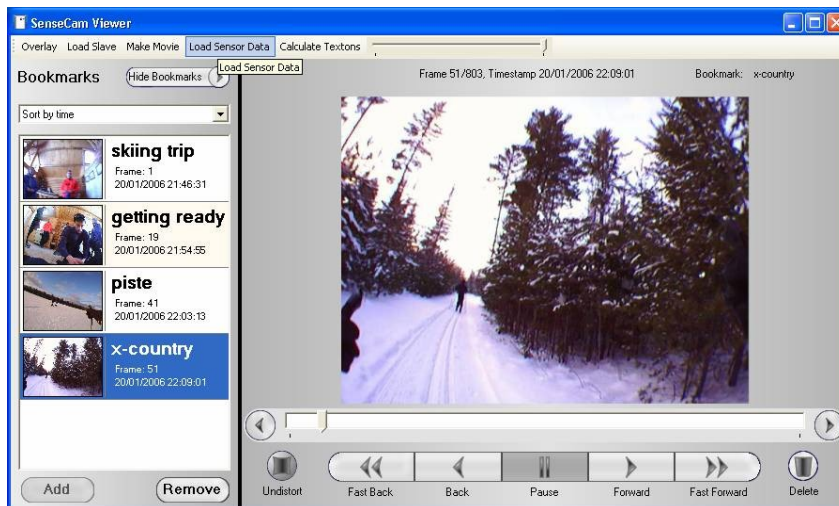


Figure 2: The SenseCam Viewer

Procedure

The experimental period lasted 3.5 months. The patients were given a SenseCam and a laptop computer, with detailed instructions on how to use both. They were taken through the instructions by one of the research team. Although some were not familiar with computers before this experiment, all of the spouses demonstrated that they were able to use SenseCam, upload the images to a PC and to view them with no difficulty. The patients were asked to wear SenseCam or to use a written diary to record interesting or non-routine events in their lives – when deciding whether the event was worth recording or not, the patient was asked to consider the following question ‘is [the event] the type of event you would very much like to remember if you didn’t have any memory difficulties?’.

The study followed a within-subject longitudinal design, comparing the effects of using SenseCam versus a written diary to aid retrospective recall of significant personal events. There were two conditions: 1 – SenseCam facilitated recall, and 2 – Written Diary facilitated recall. In three of the six cases (HY, OA, DU), the experiment was conducted by one of the authors (EW) who accompanied the patient during the event and monitored memory for the event over the following three and a half months. In the other three cases (OO, DU and EU), the experiment was conducted, under strict supervision, by the spouses of the patients, as was the procedure in our original study (Berry et al., 2007).

Condition 1 – SenseCam facilitated recall

Phase 1: two week retention. Each patient wore the camera when s/he was doing something personally significant that s/he wanted to remember. Following the event, either the experimenter (EW) or the spouse made notes of the important details that occurred during the event. Depending on the event, notes were made of 7 to 14 details, not all of which were captured by SenseCam. For example, details of a striking conversation or something that happened ‘off camera’, such as the quality of the food in the restaurant, were occasionally recorded. The experimenter/spouse was also responsible for uploading the images from the SenseCam to the laptop.

Table 2 contains the number of SenseCam and Written Diary events recorded for each patient in each condition.

Table 2: Number of SenseCam and Written Diary events recorded for each patient

| Patient Name | SenseCam Condition (number of trials) | Written Diary Condition (number of trials) |
|---------------------|--|---|
| HY (CLG) | 3 | 3 |
| OO (JS) | 5 | 2 |
| OA (BD) | 4 | 4 |
| DU (EB) | 4 | 3 |
| RA (FH) | 3 | 3 |
| EU | 2 | 2 |

The notes were used as a quasi-objective record of the event, against which the patient’s recall could be tested. The day following the event, the experimenter/spouse asked the patient what s/he remembered of the event. One cueing question was allowed, which was ‘What do you remember of our trip to x?’. The patient’s responses to this cue were scored against the notes. For example, if the patient freely recalled 6 of the 10 points he had made, s/he gained a score of 60%. Recall was then tested in this same way every two days for two weeks, generating 7 data points. Immediately following each recall test, the experimenter/spouse and the patient reviewed the images together. This was done in the first instance by looking at each of the images one by one, approximately one per second, although certain images would facilitate discussion and be paused on for longer. After this had taken place, the experimenter/spouse and the patient would look through the images on playback mode, at a rate of 6 images per second. The entire procedure typically took approximately twenty to thirty minutes.

Phase 2 – longer-term retention. The patients' memory for the events was tested at one month and three month follow-up sessions. SenseCam images of the events were not reviewed during this time. The experimenter/spouse tested the patient's memory for the event in the same way as has been described above. This generated one and three month follow-up data points.

Condition 2 – Written Diary facilitated recall

The procedure for Condition 2 followed that of Condition 1, substituting the experimenter/spouse's notes in place of the SenseCam images as the means by which to prompt better recall and consolidation of the events.

Phase 1: two week retention. The patient and the spouse/experimenter experienced a significant event and the spouse/experimenter made notes of the important details. SenseCam was not worn during these events. Again, the notes were used as a record of the event against which to test the patient's recall. Following each recall test, the spouse/experimenter and the patient immediately reviewed the notes and as they did so, they discussed the event. On average, this took approximately twenty to thirty minutes. The spouses/experimenter were instructed to spend the same amount of time reviewing the notes of the event as the SenseCam images of the events in the SenseCam condition.

Phase 2 – longer-term retention. One and three month follow-up sessions were conducted as per Condition 1, testing the patient's longer-term retention of the events recorded using the written diary.

Baseline data

Baseline data were also collected for each of the subjects. The patients and their spouses/experimenter experienced a significant event together and the spouse or experimenter

made notes in the way described above. Over the next two weeks no stimuli related to the event were looked at. At the end of the two week period the spouse/experimenter tested the patient's memory for the event, and again at one month and three months. Two events were recorded in this way for each patient.

Order of Trials

The order that the trials took place varied but the baseline condition took place first for each patient. Four of the six patients undertook the written diary trials before the SenseCam trials, and two of them undertook the SenseCam trials first. Baseline data were collected first to ensure that any superior SenseCam memory performance could not be attributed to better cognition earlier on in the course of the study, and thus the course of the disease.

Feedback

The patients were interviewed informally after the trial and asked about their experiences of using SenseCam. Questions included whether the camera was easy to use, whether the laptop and the software was easy to use, whether it was uncomfortable or embarrassing, whether the quality of the images was good, if the diary was easy to use, if the camera and the diary were beneficial as memory aids, if they would use either the camera or the diary again and any other comments or suggestions. We collected further qualitative data to gauge people's emotional reaction and any improvement to psycho-social well-being as a result of using the memory aids. For example, at the end of each experimental condition we asked questions such as 'did you enjoy using the SenseCam/ written diary', do you think it had any impact on your levels of stress associated with your memory difficulties? Would you continue to use SenseCam / written diary as a memory aid?

Measures

Statistical analysis

A chi-squared analysis of linear trend was used to measure whether there was a learning effect across the initial two week period of review, in both conditions.

A chi-squared analysis was used to compare the proportion of details remembered at one and three month follow-up in the SenseCam and Written Diary conditions.

Results

Assessment of autobiographical memory

The results of the study can be seen in Table 3 and Figure 3.

Table 3: Chi-Squared analysis

| Patient | Chi-Squared linear trend analysis | | Chi-squared analysis of proportion remembered at one month follow-up (SenseCam v. Written Diary) | | Chi-squared analysis of proportion remembered at three month follow-up (SenseCam v. Written Diary) | |
|----------|-----------------------------------|---------------|--|--------------------|--|--------------------|
| | SenseCam | Written Diary | Chi-Square | Significance value | Chi-Square | Significance value |
| HY (CLG) | p<0.001* | p=0.28 | 24.44 | p<.001 * | 16.13 | p<.001* |
| OO (JS) | p<0.001* | P=0.43 | 2.66 | p=.10 | 0.25 | p=0.62 |
| OA (BD) | p<0.001** | p<0.001** | 49.02 | p<.001 * | 36.99 | p<.001* |
| DU (ED) | p=0.51 | p=0.93 | 0.00 | p=.96 | 7.84 | p<.005* |
| RA(FH) | p<0.001* | P=.066 | 22.90 | p<.001* | 15.85 | p<.001* |
| EU | p<0.001* | P=0.18 | discontinued | discontinued | discontinued | discontinued |

Over the initial two week learning period, in terms of recall of autobiographical events, SenseCam outperformed the diary method for 5 of the 6 people in the study; that is to say that for 5 of the 6 patients, the greater the number of viewings of the SenseCam images, the higher the level of recall. For 4 of these patients, SenseCam showed improvement over time and the diary method did not show such an improvement. For one other patient (OA), both the SenseCam method and the Written Diary method showed improvement, but the improvement was more pronounced using SenseCam (CHI-SQUARE(1) = 4.58,p=.032). OA also has a higher overall proportion remembered

with SenseCam (CHI-SQUARE(1)=55.67, $p < .001$) than the written diary. For the remaining person (DU) there was no improvement with either method.

In order to evaluate the effects of the two conditions on longer-term memory, a chi-squared analysis was carried out between conditions to compare between proportions of retained recall. At one month follow up, three out of the five patients remaining had a higher proportion of retained recall (i.e. they remembered more about the event) in the SenseCam condition than the Written Diary condition, and two of the patients showed no difference in the proportion of correct responses between conditions. At three months follow-up, four out of five patients showed a higher proportion of correct responses in the SenseCam condition than in the written diary condition, with one patient showing no difference in the proportion remembered between conditions.

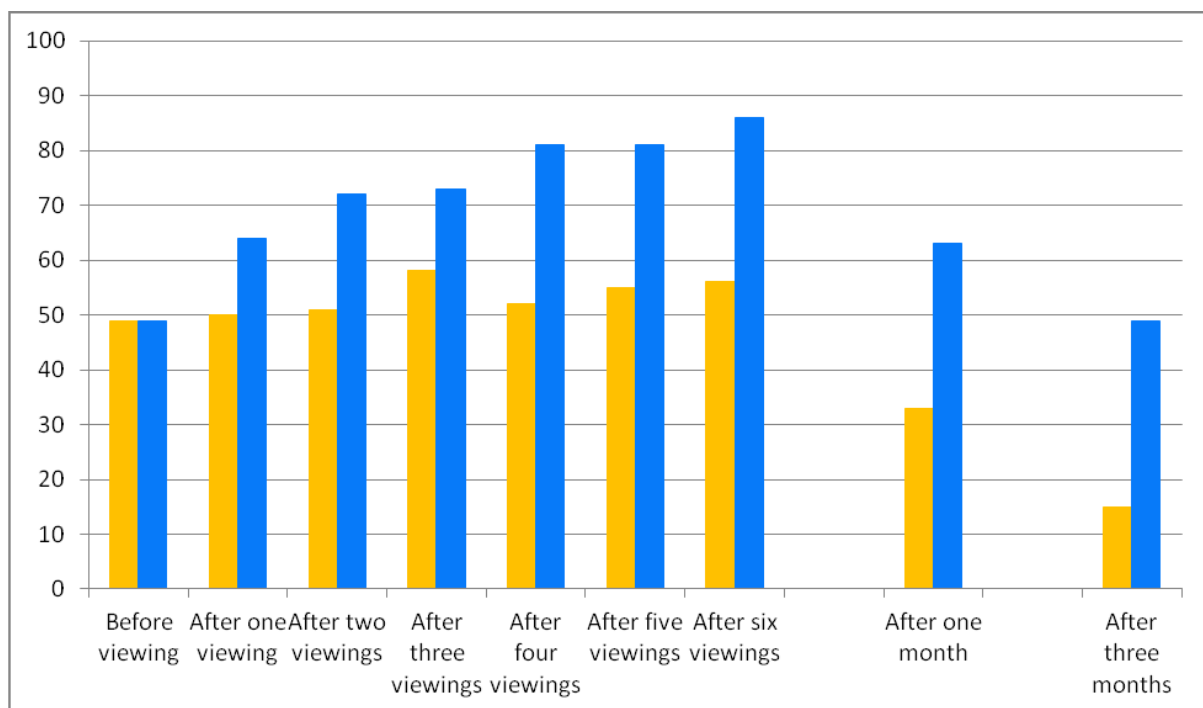


Figure 3: The mean percentage recall of autobiographical events, over two weeks, and subsequent longer-term testing at one and three months, for the Written Diary and SenseCam conditions

Feedback from Patients

Five of the six patients enjoyed using SenseCam. All of the five said that they enjoyed looking through the images and recalling past events. One patient (DU) said 'It is definitely helpful...normally I would just forget these things'. Another (OO) commented specifically that SenseCam improved his confidence since he was more assured that he would have something to talk about in social situations. Whilst using SenseCam seemed to have a positive impact on the well-being of patients whilst they were undertaking the study, in the long-term, some patients could not recall that they had been involved in the research and were surprised that their memory should have improved. One (OA) did not enjoy wearing SenseCam, even though it significantly helped his memory, because he believed it drew attention to him and he felt embarrassed by it. Without exception, each of the patients said that they did not like using the written diary. They described it as difficult to use and 'boring' and 'unhelpful'. One patient said 'I don't like being reminded of things I cannot remember' (FH).

Discussion

Our results indicate that a wearable camera, SenseCam, was better at helping five out of six of the Alzheimer's Disease patients in this study to remember events over a three month period than reviewing a written diary. Specifically, over the initial two week consolidation period, for five of the six patients, the greater the number of viewings of the SenseCam images, the higher the level of recall. At one month follow up, three out of the five remaining patients remembered more about the events they had experienced in the SenseCam condition than in the Written Diary condition, and two of the patients showed no difference in the proportion of correct responses between conditions. At three months follow-up, four out of five patients showed a higher proportion of correct responses in the SenseCam condition than in the written diary condition, with one patient showing no difference in the proportion remembered between conditions. On average, the amount of information recalled in the SenseCam Condition at three months follow-up was more than triple that recalled in the written diary condition.

Our findings add to the growing body of literature which has demonstrated the effectiveness of SenseCam as a memory aid for healthy subjects and memory impaired populations (Berry et al., 2007; St Jacques, Conway and Cabeza, 2011; Loveday and Conway, 2011; Browne et al., 2011; Pauly-Katacs, Moulin and Estlin, 2011). Why is it that viewing SenseCam images appears to significantly improve recollection of autobiographical memories, even in patients with neurodegenerative disease? Observation of the patients while they view SenseCam images suggests that some SenseCam images offer a powerful cue that leads to a rich recollection of the event itself. An example of this phenomenon was when one of the authors (EW) had been to the cinema with a patient with moderate Alzheimer's Disease (CLG) the previous day. The following morning EB went to CLG's house to look through the SenseCam images. CLG had no recollection of the author or of the previous day. She nevertheless allowed the author to enter her home and to look through the images together, one by one. They looked through nearly two hundred images at a rate of approximately one per second, but CLG had no recall of the previous day. Image 198 was an image

of the author bending over the boot of her car, and in the background, some buildings. Suddenly CLG exclaimed 'That's it! I remember thinking 'why is that building (built to the same design but) a different colour to that building?' And then CLG said 'Didn't we go to the Grafton Centre? We watched a film...'. The event came back to her and she was able to describe accurately what happened. Similar occurrences happened with each of the patients involved in the study; certain images or groups of images prompted vivid recall. The images promote recall of information that is not depicted in the images – a recollection or re-living of the event itself. The reason SenseCam images appeared to be such a powerful aid for recall may be because the images contain many of the same qualities of autobiographical memory (Conway, 2005), in that they are 'snapshots' or summary records, which represent short time slices, and are predominantly visual. Viewing the images, which are taken from a first person perspective, may therefore activate many of the contextual cues needed for accurate and vivid recollection, overcoming any executive or retrieval deficit that has arisen from the hippocampal pathology associated with Alzheimer's disease. Moreover there is evidence that visual imagery is important in the formation of autobiographical memories (Conway, 2005; Greenberg, 2005; Brewer, 1988). These potentially potent cues therefore, combined with the sheer number of images, means that even in severely memory impaired patients some images are likely to correspond with the memory and as such are almost bound to cue recall.

This initial aid to recall was further encouraged in our study by using spaced rehearsal. Spaced rehearsal is a technique that promotes learning by requiring the subject to retrieve information repeatedly at intervals. It is thought that the very act of retrieving information is a powerful way to promote learning (Landauer and Björk, 1978). Our patients reviewed their images and recalled the event every two days for two weeks, which may have been sufficient to reinforce consolidation of the episode into a long-term memory store. They were then able to recall the event one and three months later, without the need for further prompting. By contrast, a written diary does not provide powerful enough cues to overcome the hippocampal deficit.

The data indicate that the information recalled in the SenseCam condition represents a vivid autobiographical memory as opposed to a learning of correct responses, since firstly, patients recall information not contained in the images, and secondly, recall increases over the initial two-week period without additional prompting or alerting to correct responses. The notion that the memories described by our patients are episodic and not semantic is bolstered by fMRI findings in healthy and impaired subject which demonstrate that when people view their own SenseCam images they activate parts of the brain involved in autobiographical memory (St Jacques, Conway and Cabeza, 2011; Berry et al., 2009, Milton et al., 2011). Thus SenseCam could prove to be a useful memory prosthesis and may have general positive effects on people with age-related cognitive decline and those with diagnosed memory impairments, although more research needs to be undertaken to investigate this tentative hypothesis.

In our study, three of the five patients said that they enjoyed using SenseCam because viewing the images and recalling the event was pleasurable. They described enjoying looking through the images together with their spouses or the experimenter, and re-experiencing the event that took place, since without the images, they were unable to recall the event in any detail. However one patient said he did not enjoy wearing the camera because he did not want to draw attention to himself. He declined to use the SenseCam again after the study was over (the current development of smaller, less conspicuous wearable cameras should help to alleviate this potential problem). None of the patients enjoyed using the written diary, which they considered to be time-consuming and laborious. In our previous studies, we have found that patients do not like using a written diary because it does not promote episodic recall and patients do not like to be reminded of the severity of their memory deficit by being told the details of events that they have forgotten (Berry et al., 2007; Browne et al., 2011). Previous studies using SenseCam have demonstrated the impact of improving recollection on well-being and quality of life (Berry et al., 2007; Loveday and Conway, 2011; Browne et al., 2011). However in the current study, although the patients and their spouses

described enjoying viewing the images together in the moment, SenseCam facilitated retrieval did not appear to have such a profound effect on well-being in the longer-term, possibly because the patients did not recognise the effects that the device was having on their memory. One of the patients (HY) was intrigued that her memory for certain events had improved to the extent that she could now recollect them, but she was never able to recall why this was. This contrasts with Mrs B (Berry et al., 2007) and 'CR' (Loveday and Conway, 2011), both of whose confidence improved markedly as a result of using the camera. It may be that the more global cognitive deficits associated with Alzheimer's Disease prevented the patients in this study from understanding the impact of their memory deficits on their lives and on those around them. But while this group of patients did not demonstrate the same level of insight into the impact of the device on their memories, the act of remembering itself appeared to bring enjoyment and comfort. Remembering, sharing and reconstructing private memories with loved ones is thought to be not only communicative, but also intrinsically pleasurable, rewarding and enriching (Stephenson, Kniveton and Wagner, 1991; Fivush, Haden and Reese, 1995; Hirst and Manier, 1995; Nelson, 2000). Thus, the act of viewing the images and the inherent enjoyment it brought some of our patients in the moment contributed to their wellbeing.

Despite the degenerative nature of Alzheimer's Disease and the prominent nature of the episodic memory deficit characteristic of the condition, our findings suggest that rehabilitation of episodic memories can be achieved, which may enhance well-being. Whether or not this effect can somehow slow down the rate of progression or have other longer-term effects is yet to be seen, but nevertheless, even short-term outcomes may be helpful in this patient group (Clare and Woods, 2001).

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