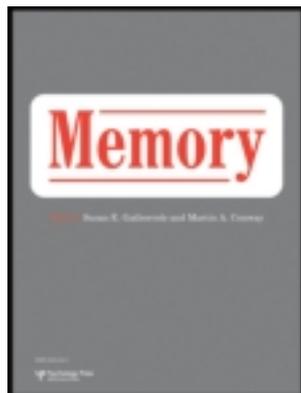


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### SenseCam improves memory for recent events and quality of life in a patient with memory retrieval difficulties

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# SenseCam improves memory for recent events and quality of life in a patient with memory retrieval difficulties

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A wearable camera that takes pictures automatically, SenseCam, was used to generate images for rehearsal, promoting consolidation and retrieval of memories for significant events in a patient with memory retrieval deficits. SenseCam images of recent events were systematically reviewed over a 2-week period. Memory for these events was assessed throughout and longer-term recall was tested up to 6 months later. A written diary control condition followed the same procedure. The SenseCam review procedure resulted in significantly more details of an event being recalled, with twice as many details recalled at 6 months follow up compared to the written diary method. Self-report measures suggested autobiographical recollection was triggered by the SenseCam condition but not by reviewing the written diary. Emotional and social wellbeing questionnaires indicated improved confidence and decreased anxiety as a result of memory rehearsal using SenseCam images. We propose that SenseCam images provide a powerful boost to autobiographical recall, with secondary benefits for quality of life.

**Keywords:** SenseCam; Autobiographical memory; Rehabilitation.

The cognitive profile of Alzheimer's disease (AD) is well documented and emphasises marked deficits in episodic memory related to rapid forgetting of new information (Morris & Becker, 2004). A related diagnosis, mild cognitive impairment (MCI), is reached when patients display similar memory decline (i.e., greater than would be

expected for their age), but do not display either reduced functioning in other cognitive domains or impaired activities of daily living, both of which are required for a diagnosis of AD (Grundman et al., 2004; Petersen et al., 1999).

A common presenting problem in both these populations is loss of autobiographical memory

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(Dorrego et al., 1999; Hodges, 2006; Leyhe, Muller, Milian, Eschweiler, & Saur, 2009; Murphy, Troyer, Levine, & Moscovitch, 2008; Rubin, 1999), perhaps one of the most devastating effects of episodic memory decline. Autobiographical memory is regarded as a specific component of episodic memory and “refers to a person’s recollection of past incidents and events, which occurred at a specific time and place” (Kopelman, 2002, p. 192). The term has received increasing attention over the last two decades, and accordingly there have been increasing attempts to define it. Tulving (2002) elaborated on his notion of re-experiencing to state that autobiographical remembering, or auto-noetic awareness, is special in that one effectively undertakes mental time travel to recollect the original event as it occurred in the past. Notably, Brewer (e.g., 1988, 1996) has undertaken many extensive and thorough reviews of the literature and similarly concluded that autobiographical memory is a kind of “reliving of the individual’s phenomenal experience during that earlier moment” (Brewer, 1996, p. 60). He contends that this particular kind of personal recollection is largely experienced as a visual mental image, representing salient information about the original event: the place, actions, people, objects, which may also engender associated thoughts and emotions.

It is unsurprising, then, that autobiographical memory is thought to play an intrinsic role in the development and maintenance of a stable sense of self. Conway (2005) has described the reciprocal nature of the relationship between memory and the self, suggesting that the coherence of the working self is maintained by the encoding and consolidation of episodic memories, and subsequent access to and construction (and reconstruction) of these memories. In turn, a coherent and stable self promotes higher self-esteem, a positive sense of wellbeing and associated physical health benefits. Indeed, there is evidence to suggest that reduced sense of self-identity in AD is related to poor autobiographical memory functioning (Addis & Tippett, 2004).

Moreover, memories are intrinsically pleasurable. They are not only cherished by the individual but they also have a social function—when memories are shared they facilitate intimacy and bonding within relationships and shared experiences lead to socially constructed memories (Nelson, 2000; Singer, 2006). There is evidence to suggest that when people are feeling depressed they draw on positive memories to lift their mood (Josephson, Singer, & Salovey, 1996). It is not

surprising, then, that memory impairment can lead to a disruption of close relationships (Robinson & Swanson, 1990, cited in Baddeley, Eysenck, & Anderson, 2009), and reduction in self-confidence, social withdrawal, anxiety, and depression (Ballard, Boyle, Bowler, & Lindesey, 1996). Clare (2003) suggests that loss to social and psychological function is commonplace following cognitive deterioration.

There are therefore an increasing number of interventions focussing on cognitive rehabilitation. While the effectiveness of pharmacological interventions has yet to be conclusively demonstrated in AD and MCI populations (Raschetti, Albanese, Vanacore, & Maggini, 2007), there are an increasing number of non-medical interventions that may provide a suitable alternative.

Cognitive interventions, for example, are typically aimed at helping people to re-learn skills and information, or teaching compensatory strategies according to aims and goals set by the individual (Wilson, 2002). Following a recent meeting in Canada, a set of evidence-based guidelines were drawn up in response to the systematic review of 314 studies looking at the diagnosis and treatment of MCI (Chertkow et al., 2008). The team found four studies indicating improved cognition (working memory and verbal episodic memory) following cognitive training in the MCI population. However, these studies were either not randomised controlled trials (RCTs), the gold standard for measuring treatment success, or had small sample sizes, and thus the guidelines drawn up by Chertkow et al. (2008) concluded that while cognitive stimulation should be promoted in this population as part of a healthy lifestyle, there was as yet insufficient evidence to advocate the implementation of cognitive therapy as a treatment for MCI. One large-scale study undertaken with healthy older adults in America found that cognitive training delayed both cognitive and functional decline over a 5-year period (Willis et al., 2006). This study is supported by a number of RCTs similarly reporting positive effects of cognitive training in healthy older adults (Belleville, 2008). In conjunction with the association between intellectually stimulating activity and reduced risk of developing Alzheimer’s disease (cf. Chertkow et al., 2008), such results may well generalise to the memory impaired populations. One methodological issue with studies investigating cognitive outcome is that they predominantly measure success in terms of performance on standardised

cognitive assessments, which may have poor ecological validity and therefore tell us little about the impact on the individual's everyday activities and quality of life.

Cognitive and psychosocial rehabilitation has recently been the focus of an RCT investigating the use of a new evidence-based program in the memory-impaired population (Stuss et al., 2007). Stuss and his colleagues targeted memory, goal management, and psychosocial functioning as areas for improvement within the intervention. Their long-term follow-up results indicated maintenance of improved cognitive (Winocur, Craik, et al., 2007) and psychosocial functioning (Winocur, Palmer, et al., 2007), and highlighted the important and reciprocal relationship between these domains.

As yet, however, none of the treatments available focuses on improving autobiographical memory specifically. Current advances in assistive technologies have led to new interventions in the clinical setting; however it remains the case that most memory aids focus on systems for improving prospective memory (cf. Wilson, 2002), such as remembering appointments and shopping lists. Given the link between intact autobiographical memory and psychological and social wellbeing, rehabilitating recent autobiographical memory may lead to improvements in quality of life for people with memory loss and their carers. Berry et al. (2007) report the use of a wearable camera, SenseCam, which led to improved autobiographical memory for recent events in a patient with amnesia. We sought to replicate these findings and gain an index of impact on quality of life. The current study thus describes the use of SenseCam in a patient with memory retrieval difficulties, who was initially diagnosed with MCI and has not progressed to AD.

## METHOD

### Participant

*Demographic details.* Mrs W, a retired social worker, was diagnosed with mild cognitive impairment at the age of 55 and commenced taking a cholinesterase inhibitor (Aricept). She began participation in this study 10 months after her initial diagnosis and completed the study a further 10 months later. She lives at home with her

husband, Mr W, and continues to lead a very active and full life.

*Clinical details.* Table 1 shows Mrs W's cognitive test profile at her initial diagnostic memory clinic assessment, and highlights memory impairment greater than expected for her age, with acceptable performance across other cognitive domains. At the time of diagnosis she was managing activities of daily living without difficulty.

At the time of writing—that is, 12 months post-study—Mrs W's condition had not progressed. Her scores on cognitive assessment had in fact improved following the SenseCam intervention such that her subsequent memory test performance was considered normal for her age: she scored 85/100 on Addenbrooke's Cognitive Exam Revised (ACE-R) and 27/30 on the Mini Mental State Exam (MMSE). Magnetic resonance imaging (MRI) and Pittsburgh Compound-B (PIB) scanning were inconsistent with Alzheimer's disease as a probable diagnosis, and she continues to be reviewed in our memory clinic.

### Procedure

This single-case study followed a within-participant longitudinal design, comparing the effects of using SenseCam versus a written diary to aid retrospective recall of significant personal events.

There were two conditions: SenseCam facilitated recall and written diary facilitated recall. Each of the two conditions comprised two phases: in phase 1 recall of an event was tested over a 2-week period and in phase 2 longer-term recall of the event was tested a number of months later.

For the collection of SenseCam stimuli, Mrs W wore a small (6 cm × 8 cm × 2 cm) wide-angled lens camera, SenseCam, around her neck to collect images of significant personal events. Image capture was triggered automatically by the camera in response to changes in light, temperature, and motion, and by default every 30 seconds. Mrs W was not required to actively participate in the collection of the images: she did not need to remember to take the pictures herself and her full engagement in the activity was not disrupted by taking the pictures. Following an event Mr W uploaded the images onto a standard PC, ready for review the following day.

During phase 1 Mrs W wore the camera when she and her husband were doing something that

**TABLE 1**  
Cognitive assessment details for Mrs W at point of diagnosis

<i>Test</i>	<i>Raw score</i>	<i>Statistic score</i>
<i>General batteries</i>		
ACE*	72/100*	> 5 SDs below mean*
MMSE*	25/30*	> 3 SDs below mean*
<i>Verbal memory</i>		
WMS-III Logical Memory		
Immediate Recall*	4*	%ile < 1 <sup>st</sup> *
Delayed Recall*	4*	%ile < 1 <sup>st</sup> *
<i>Non-verbal memory</i>		
Rey Figure Delayed Recall	3/36*	%ile < 10 <sup>th</sup> *
PAL		
3 Pattern Tries	3	> 1 SD below mean
3 Pattern Errors*	3*	> 3 SDs below mean*
6 Pattern Errors*	42*	> 5 SDs below mean*
<i>Verbal skills</i>		
Graded Naming Test	23/30	%ile = 75 <sup>th</sup>
Category Fluency		
Animals	14	%ile = 16 <sup>th</sup> –19 <sup>th</sup>
Fruit	19	%ile = 79 <sup>th</sup> –82 <sup>nd</sup>
Dogs	10	%ile = 31 <sup>st</sup> –38 <sup>th</sup>
TEA Elevator Counting with Distraction	7	%ile = 12 <sup>th</sup> –21 <sup>st</sup>
<i>Executive functioning</i>		
Trails B		
Time	92	Within normal limits
Errors	0	Within normal limits
Stroop errors	23*	Impaired*

SD = standard deviation; %ile = percentile, \*indicates impairment relative to age-matched control group.

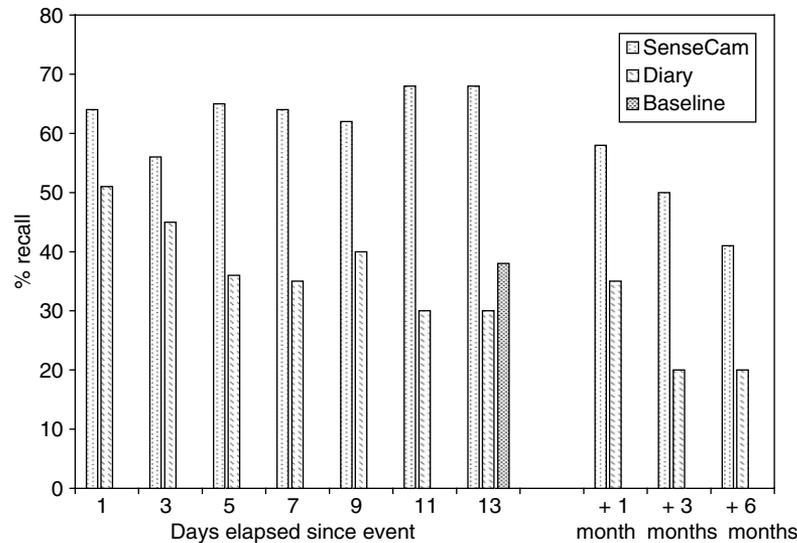
she particularly wanted to remember, such as a meal out with their granddaughter, or a trip to the seaside. Mr W made notes of the main event details, against which Mrs W's recall was subsequently tested. Mr W was asked to record facts, such as "we took the train to London" as well as any significant thoughts or emotions associated with the event. The day following the event Mr W asked his wife one cueing question, for example, "What do you remember of our trip to x?". He allowed his wife to free recall as much of the event as possible and scored her responses against his notes. If, for example, she recalled 9 of 12 items that he had written down, she scored 75%. Recall was tested in this same way every 2 days for 2 weeks.

Immediately following each recall test Mr and Mrs W reviewed the images together, which were played on a standard PC as a rapid slide show, talking through the event as they went along. Note, then, that the first recall test on day 1 occurred before any review of the event had taken place, and all subsequent memory tests reflect recall of the event in relation to her score

on day 1. A total of six events were recorded in this way and results were averaged across trials.

After intervals of 1 month, 3 months, and 6 months without reviewing the images, Mrs W's longer-term recall of the events was reassessed (phase 2). A written diary control condition followed the same protocol, substituting Mr W's notes for the SenseCam images as the means by which to review the events. Mrs W reviewed just two events using this method, since she found it impacted negatively on her emotional wellbeing and did not want to continue with this part of the study.

Phase 1 baseline data were also collected for Mrs W's normal rate of forgetting over a 2-week period using no memory aids or other means of rehearsal. Mr and Mrs W experienced a significant event together, for which Mr W made notes as described above. No stimuli prompting recall or rehearsal of the event were looked at or discussed over the next 2 weeks. At the end of the 2-week period, Mr W tested Mrs W's memory for the event. Two events were recorded in this way.



**Figure 1.** Average recall for SenseCam-reviewed versus diary-reviewed events.

Treatment order (and thus data collection) ran from baseline to SenseCam to written diary conditions. That is, baseline data were actually collected at the start of the study. This was followed by all data collection for phase 1 of the SenseCam condition, which was followed by all phase 1 data collection for the written diary condition. Phase 2 data collection followed accordingly. This order of data collection was intended to control for the possibility of cognitive recovery (spontaneous or otherwise) to Mrs W's cognition as a variable in explaining any superior SenseCam results, should we find them.

## Measures

Three standardised measures were used to record Mrs W's psychological and social functioning: the Self-Image Profile for Adults (Butler & Gasson, 2004), the State-Trait Anxiety Inventory for adults (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and Beck's Depression Inventory – Second Edition (Beck, Steer, & Brown, 1996). These measures were undertaken at the beginning of the study and at the end of phases 1 (2 week retention) and 2 (longer-term retention) of the SenseCam condition. Two in-house qualitative measures were developed to assess Mrs W's experience of using SenseCam and the written diary as memory aids and were administered at the end of phase 1 in both conditions. The first in-house measure comprised a semi-structured interview using open-ended questions to generate

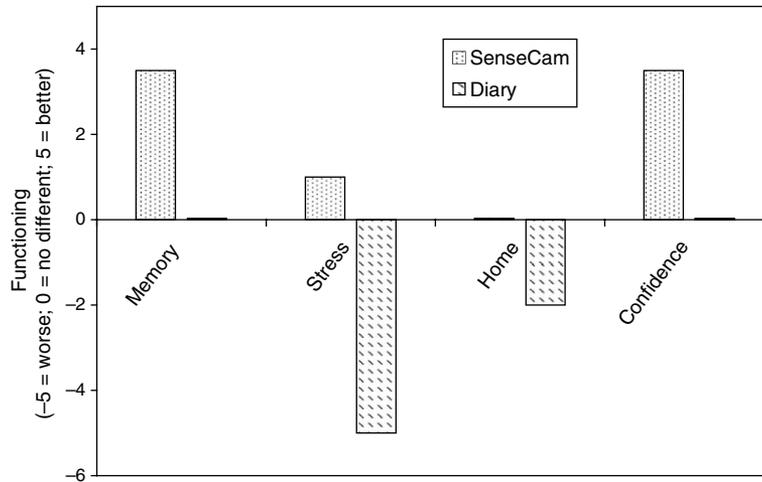
qualitative feedback about the experience of using SenseCam and the written diary. For example, Mrs W was asked, "How do you feel about using SenseCam/a written diary to help your memory?" The second measure was a quality of life assessment that used Likert scales to rate the impact of using the aids in terms of subjective levels of stress, confidence, ability to cope at home, and memory function. For example, Mrs W was asked, "As a result of using SenseCam/a written diary, do you think there is any difference in how 'stressed out' you are?" and asked to grade her response on a scale where  $-5$  indicated worse and  $+5$  indicated better.

## Statistical analysis

For each condition, chi-squared analyses were used to compare the mean recall scores across the two conditions. For remaining measures of psychosocial functioning, these scores were plotted and reviewed non-statistically.

## RESULTS

Overall, the proportion of events recalled was significantly greater for the SenseCam condition than the diary condition,  $\chi^2(1) = 29.25, p < .001$ . Figure 1 details Mrs W's average recall of an event over time for the two conditions. Using SenseCam, her recall over the 2-week reviewing period ranged from 64% on day 1 to 68% on



**Figure 2.** Impact of using SenseCam and a written diary as memory aids on Mrs W's day-to-day wellbeing.

day 13, which compared to a drop from 51% to 30% using the diary review method. Her baseline rate of forgetting over the 2-week period indicated an average of 38% recall on day 13, suggesting that the written diary made no difference to her normal rate of forgetting.

Longer-term follow-up data also indicated superior performance for SenseCam over written diary-facilitated recollection. Over the course of 6 months without reviewing images or diary, while there was decline in Mrs W's memory for all events, at 6 months' follow-up she recalled twice as many details for SenseCam-reviewed events (41%) than diary-reviewed events (20%).

Figure 2 shows Mrs W's subjective response to using SenseCam and the written diary as memory aids. She thought using SenseCam made no difference to her ability to cope at home, but led to improvements in her memory, level of stress, and self-confidence. Using the written diary made no difference to her memory or level of self-confidence, but had a negative impact on her level of stress and ability to cope at home.

Qualitatively, Mrs W reported much enjoyment from using SenseCam, and stated that it had had a positive impact on her memory: "it was like having another pair of eyes or another person with you helping you remember" since the SenseCam images were "actually what my eyes were seeing" or "re-experiencing". She said that looking back over the images "jogged my memory of things that I didn't remember that were in the back of my mind ... things that normally I would just forget ... [it was] as if I was back on the trip again". Mrs W reported

that these memories were "all there" and "just came rolling out" and on occasion she was able to recall information not recorded in the SenseCam images, such as conversations that had taken place and her feelings about particular events.

Mr and Mrs W both thought using SenseCam had been beneficial for their relationship as they spent more time together talking about recent events: Mrs W stated "we can sit and talk together about where we've been". Mrs W further noted that "if you have memory problems, you have low confidence" but since using SenseCam improved her memory, she had "more confidence talking about things" and thus noted an improvement in her day-to-day self-assurance.

This contrasted with Mrs W's experience of using the diary, which her husband reported did not stimulate "actual recall" of the event. Mrs W said, "If I just talk about [an event], I drift off and don't remember it". She even felt unsure that the events depicted by the diary were ones that had actually happened: "[Mr W] tells me [about the trip] but I don't know whether I really did it ... I had to take [Mr W's] word for it", and this led to bickering and tension between Mrs W and her husband. She stated that she "hated" the written diary condition, which was therefore discontinued after collecting data for two events. There was no change to scores on the standardised measures of anxiety, depression, or self-image, which were all within the normal range both pre and post SenseCam intervention.

## DISCUSSION

Regular review of SenseCam images resulted in superior recall of recent events compared to reviewing a written diary, and this effect was maintained in the long term. These results are consistent with a number of other recent studies showing improved memory following SenseCam use (e.g., Berry, Browne, Kapur, Watson, & Hodges, 2011; Berry et al., 2007; Lee & Dey, 2008; St. Jacques, Lowder, Conway, & Cabeza, 2011).

A preliminary study investigating the neural activation associated with SenseCam facilitated recollection in healthy adults found that stimulation of hippocampal networks resulted in moderate improvement on tests of general cognitive functioning, and concluded that it may have been the use of SenseCam that ultimately facilitated this effect (St. Jacques et al., 2011). Thus it could also be argued, albeit very speculatively at this stage, that SenseCam use could, in part, account for the improvement seen in clinic from moderate memory impairment at the time of initial MCI diagnosis to normal memory functioning (on standardised tests) nearly 3 years later.

An alternative account for the cognitive recovery could be that Mrs W's memory difficulties had no neurological basis in the first instance, and subsequently resolved spontaneously. Indeed, a fifth of people initially diagnosed with MCI may spontaneously recover normal cognitive functioning (Solfrizzi et al., 2004). If Mrs W belongs to this group, one would expect to see increasingly better results as data collection for the study progresses. Indeed this may in part account for the superior performance of the SenseCam data over the baseline data. However, by this argument, the written diary should outperform both baseline and SenseCam, since the timeline for data collection ran from baseline to SenseCam to written diary conditions. It does not: SenseCam results are superior despite the possible improvement over time to general cognition, and baseline and written diary results are equivalent in effect. This would seem to lend weight to concluding that SenseCam is a better tool for facilitating autobiographical recollection than a written diary. That is, Mrs W's cognition may have recovered spontaneously over the course of the study, irrespective of SenseCam use, which nevertheless outperforms the written diary as a memory aid.

A third possibility that may account for Mrs W's improved cognition is that she is one of the 10–20% who respond to cholinesterase inhibitors (cf. Lemstra, Richard, & van Gool, 2007), with which she was treated following her initial diagnosis. However, it would be extremely rare to see such a striking effect in terms of improved cognitive function (cf. Hogan et al., 2008). Furthermore, this argument is subject to the same criticism of treatment order effect noted previously, and thus the conclusion that SenseCam outperforms the written diary as a tool for facilitating autobiographical recollection still holds.

This study also highlights the positive impact SenseCam had on quality of life, secondary to improved autobiographical memory. Our findings are consistent with a recent study that also reports improved psychosocial functioning following the use of SenseCam (Crete-Nishihata et al., 2011). Mrs W noted improved memory and thus self-esteem and confidence as a result of using SenseCam. She and her husband both commented on the increased time they spent discussing activities they had done together and that this had had a positive influence on their relationship. This contrasted with their experience of using a written diary as a memory aid, which Mrs W indicated impacted negatively on her stress levels and on her ability to cope at home. She disliked using the diary as she found it did not promote memory of events. Undertaking the recall tests in this condition led to squabbling with her husband, as she could not recall the events when they reviewed the notes together and they argued about what had really happened.

It is possible that this reported benefit to quality of life following the use of SenseCam may have been facilitated simply by taking part in the research: receiving innovative technology and regular input from a member of the research team may have positively biased Mr and Mrs W's perceived impact of using SenseCam. Nevertheless, Mrs W appeared to genuinely enjoy reviewing activities using the SenseCam images, as observed by one of the authors (GB). On one occasion she was asked to look through a set of images taken 8 months previously and that she had never seen before. She did not recall the event until about half way through the set when one particular image “jumped out” at her. The image was of her dog jumping up at a visitor. At this point Mrs W clapped her hands, laughed and remarked, “now I remember”, and recalled the entire event.

Mrs W described such recollections as if she were “re-experiencing” the event, which may provide insight into the mechanisms facilitating recall when using SenseCam. Firstly, there may be individual or single images that act as “trigger” images cueing recall for the entire event (see also our observations in Berry et al., 2011), perhaps akin to what Croucher, Calder, and Barnard (2006) call “impact images”. Secondly, Mrs W’s description mirrors that used by Tulving (2002) when he referred to autobiographical recollection as a “conscious re-experiencing of past experiences”. Indeed, the properties of SenseCam imagery correspond well with the properties of autobiographical memory: they are largely visual (Brewer, 1988), and represent a time-compressed, summary record from the first person perspective (Conway, 2005). As such, they may provide a powerful cue to the recollection of personal events, enabling effective retrieval and consolidation of the memory in long-term storage.

Our findings have important implications for cognitive therapy in both the MCI population and, more broadly, the ageing population. It is clear that memory decline can lead to poor psychosocial functioning (Ballard et al., 1996; Clare, 2003). This study complements this evidence: Mrs W’s poor recall for events led to reduced psychosocial functioning. Moreover, as her memory for events improved, so too did her psychological wellbeing and her relationship with her husband. While there remains a need for large-scale RCTs investigating the effects of cognitive rehabilitation in both dementia and normal ageing, there are nevertheless increasing numbers of small-scale research and single-case studies that suggest benefits to both cognitive function and psychosocial wellbeing in MCI and AD (e.g., Berry et al., 2011; Brooker & Duce, 2000; Clare et al., 2009; Kurz, Pohl, Ramsenthaler, & Sorg, 2009; Massimi et al., 2008. For reviews see also Chertkow et al., 2008; Clare & Woods, 2004; Hogan et al., 2008; Woods & Roth, 2005) and a small number of promising large-scale studies and RCTs in the normal ageing population (e.g., Ball et al., 2002; Stuss et al., 2007; Willis et al., 2006. For reviews see Belleville, 2008; Chertkow et al., 2008).

It remains the case, however, that cognitive rehabilitation programmes typically focus on activities such as memory training, problem solving, reality orientation, and reminiscence therapy, and not on activities for improving autobiographical memory. There currently exists

a small but compelling literature that SenseCam is effective at improving memory for recent significant events (e.g., Berry et al., 2007, 2009; Berry et al., 2011; Lee & Dey, 2008; St. Jacques et al., 2011). In conjunction with both the evidence for improved psychosocial functioning following cognitive rehabilitation, and the literature linking intact autobiographical memory with self-identity and thus self-esteem, there is good evidence to suggest that memory rehabilitation programmes should aim to include methods for improving recent autobiographical memory, and more specifically, that devices such as SenseCam may be effective tools for this purpose.

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