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Immediate Benefits of SenseCam Review on Neuropsychological Test Performance

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Background: One of the core applications of SenseCam is memory rehabilitation. Research has shown that it is an effective memory aid which can cue episodic memories. However, the extent to which SenseCam might improve aspects of memory beyond merely re-presenting forgotten events and locations has not been assessed.

Purpose: In line with neuroimaging and anecdotal reports, this study aimed to investigate the hypothesis that SenseCam review would enhance cognitive function more generally.

Methods: Participants were 15 healthy younger adults and 14 healthy older adults who wore a SenseCam for three days, and wrote a diary for another three days (control). In each of these conditions, participants completed a comprehensive neuropsychological battery immediately following review of the pictures or reading of the diary. Data for this study was collected from October to December 2011 and analyzed from January to March 2012.

Results: Both young and older adults showed higher performance on most measures used in this study immediately following SenseCam review. Effects were largest for memory and executive function tasks, whereas speed of processing was not affected.

Conclusions: SenseCam review seems to act as a cognitive stimulant in the short term, with significantly higher neuropsychological assessment scores following SenseCam review compared to re-reading a diary.

Introduction

The beginning of this century was characterized by a change in the field of cognitive enhancement strategies, with growing interest in compensatory techniques – external memory aids. These techniques - personal diaries, agendas, timers, check-lists - described as memory prosthetics,[1] proved to be effective for improving everyday memory function in people with memory deficits.[2] However, these aids required a training period, which was considered an obstacle for those individuals who deny their memory difficulties[3]. SenseCam[4], a wearable camera developed by Microsoft Research Cambridge, is a recent addition to the external aids available for memory rehabilitation. It automatically records pictures of the user's activities which can be reviewed later, with no need for training.

The first clinical studies with SenseCam suggested significant improvement in autobiographical memory (memory for recent episodes captured on the device) in amnesia[4]. In brief, SenseCam generates powerful cues which aid remembering and helps the retrieval of episodic information related to the reviewed images.[5,6,7,8] SenseCam review improves retrieval of autobiographical information even after time intervals of two to six months, suggesting maintenance over long periods.[5,9] Some studies in healthy adults have aimed to understand the processes underlying this effect.[10,11] These initial explanations consider that SenseCam pictures mimic episodic memory[12] because these pictures evoke visual experience, are from an egocentric viewpoint, correspond to reality and make summary records, thus contributing to a stronger memory trace.

SenseCam has therefore been shown to be efficacious in autobiographical memory (mostly visual data), and personal semantic memory,[13] and for events and images contained in the SenseCam images. In this study, the purpose was to examine how SenseCam may stimulate

memory more generally. There are no comprehensive studies conducted with SenseCam as a memory aid that involve a detailed neuropsychological assessment following its use. One impression gained from on anecdotal reports from patients, is that SenseCam might operate to stimulate memory function more generally, for domains and materials beyond those merely captured in the images reviewed. In this study this hypothesis is tested by giving participants a thorough neuropsychological assessment after reviewing SenseCam movies of their daily life, and comparing it – in the same participants – to neuropsychological assessment following re-reading a diary. Groups of younger and older adults were used to examine how this hypothesis may stand up to group differences in memory function. I.e., the focus of this study is whether SenseCam review improves performance on a series of standardised cognitive tests.

Methods

A total of 29 participants completed the study. In the young adults group (*n*=15) the average age was 19 (SD 1.9), where 65% were female; in the older adults group (*n*=14), the average age was 75 (SD 5.6) and there were the same number of males and females. In both groups the mean years' of education was 13 years (SD 2.2). The sample size was dictated by the length of time each participant could have a SenseCam, and the availability of SenseCams in the laboratory; to foreshadow the results, the experiment was suitably powered.

The young adults were recruited through a participant pool scheme running in the Psychology Department at the University of Leeds. In the case of the older adults' recruitment, they were also selected from an Older Adults Voluntary Participant Pool at the University of Leeds. This panel is composed of medically fit volunteers who have previously been screened and excluded if they have cognitive function scores below normal cut offs. Participants were

included only if they were native English speakers. All study procedures were approved by the research ethics board of the department. No participants withdrew from the study. All participants provided informed consent and accepted to use SenseCam and the diary for three days each. Participants were informed from the beginning of the sessions that after the end of the experiment all the images captured with SenseCam would be provided on a CD, and the diary returned.

In this study a mixed design was used, with age as the grouping variable (between subjects factor) and memory aid as a within subjects factor (all participants used the two memory aids tested in this experiment). The SenseCam review condition was compared to a written diary (a common memory aid used as control task). The design was factorial, and the results were yielded to a series of ANOVAs. Data were collected by one of the authors (ARS) in individual test sessions.

Participants wore the SenseCam and were instructed, before starting to use it, how to charge it and how to use the buttons (privacy, on/off button, manual trigger). They were instructed to wear the camera for as long as possible each day, but to remove the camera for any events which they wanted to remain private. All participants produced three days' worth of images to review. After three days, they returned to the Institute of Psychological Sciences at Leeds (IPS) and their pictures were downloaded and imported into SenseCam Image Viewer software[4]. For the diary, participants wrote a page-by-day journal, noting the events that they had experienced over three days. They were instructed to record events in the corresponding day's page as soon as possible after their occurrence but without letting the diary influence the persons' regular behaviour. The diaries were not scored, but each participant complied with the instructions given and produced at least four descriptions of personal events for each

day. After three days with the diary, participants returned to IPS and were asked to read in the session the information they wrote in the diary. Because the emphasis was on the act of review on unrelated neuropsychological tasks we did not analyse or classify the content of people's diaries and SenseCam movies.

Crucially, participants used one of the memory aids (SenseCam or diary) in a counterbalanced fashion for three days and returned for an individual session of neuropsychological assessment. In the assessment session, participants firstly reviewed the contents of their memory aid, and then a comprehensive neuropsychological assessment followed immediately. In terms of review, for the SenseCam condition the participants were shown the pictures captured by the device over the three days. In the diary condition the participants were presented with the pages of the diary that they wrote during the three days.

A battery of neuropsychological tasks (Table 1) was selected on the basis that they had alternate forms; i.e. it was possible to use them meaningfully at two time points. The neuropsychological tests given were: California Verbal Learning test – II (CVLT; [14]); Month ordering (MO[15]); verbal fluency test (VF[16]); Symbol Search and Coding (SSC[17]); Autobiographical Memory Test (AMT[18]); Digit Span task (DST[19]). These tests are routinely used by psychologists in clinical settings for cognitive assessment. Older adults were screened for dementia using the Addenbrooke's Cognitive Examination – Revised[20]. We also asked participants to evaluate their memory and the use of the two memory aids by administering a multiple choice questionnaire. In this questionnaire, participants were asked to rate their memory (on a scale) after using SenseCam or the diary. They rated the impact of watching the memory aids to prompt more memories, and several feelings following review of the diary and SenseCam images: surprise, excitement, alertness, and emotional impact. They also rated

the sense that the memory aid was helpful to remember forgotten information; and the experience of reliving the events. These ratings were all given on a 6-points scale. We yielded the results to a series of ANOVAs for the comparation of the two memory aids.

Results

All analyses were performed in IBM SPSS v19. The critical comparison was whether neuropsychological test performance was higher following SenseCam review compared to re-reading the diary (see Table 2). The two age groups were also compared. The strategy was the same for each of the separate neuropsychological test scores; to compare test performance in a 2 x 2 (age group x memory aid) ANOVA. For conciseness, we focus here on describing the main effects of memory aid (but see full ANOVA terms in Table 2 for completeness). Table 2 presents the F-ratios and partial eta square as effect size (for the main effect of memory aid only). Most measures show a statistically significant higher performance in the SenseCam condition (tasks that tested verbal memory, semantic memory, working memory and executive functions). Only two measures yielded a non-significant main effect of memory aid ($p > 0.05$): the speed of processing measures (Symbol Search/Coding). In most of the tests the younger adults also have significantly superior performance than the older adults, as is usual in the memory literature.[21] There was only one significant interaction found, for the Autobiographic Memory Test task, whereby older adults had more improvement than the younger group with SenseCam ($F(27)= 9.213$, $p<0.001$, $\varepsilon^2 = 0.25$). However, the effects of SenseCam review were parallel in the two groups. This interaction was examined using paired samples t-tests to examine whether each group showed a significant effect of SenseCam review, in line with our key hypothesis. This analysis revealed significant effects in both the young ($t(14)=8.071$, $p<0.01$) and older adult ($t(13)=8.090$, $p<0.01$) groups.

The subjective experience of the memory aids might begin to explain the mechanisms behind these findings (see Table 3 for data). Interestingly, the subjective data are in line with the objective data collected, with SenseCam review rated as prompting more memories than the diary. SenseCam use also led to significantly higher reports of surprise and alertness compared to the diary review. In all, both groups agreed that SenseCam was a more exciting memory aid to work with, more helpful (if they wish to remember something they have forgotten) and that makes them feel more emotional than when they read the personal diary. Finally, participants from the two groups agreed that SenseCam produces a sense of reliving the moments recorded in the pictures, which was not reported with the review of the diary.

Discussion

This study tested whether previously reported improvements in recall of events following the review of SenseCam images generalized to the improvement of cognitive performance. Firstly, the results extend previous findings which show SenseCam improves autobiographical memory by cuing events continued in the images.[5,7,8] It was found that SenseCam also improves performance on a test which measures autobiographical memory for events not captured in the SenseCam images, relative to a diary condition. To reiterate, the Autobiographical Memory Test concerns the whole lifespan, not the limited content of the SenseCam or diary period. Thus, SenseCam review appears to improve the specificity and level of detail of autobiographical memory from across the lifespan.

Second, an effect of SenseCam is present in domains other than autobiographical memory as evidenced by a superior performance in tasks that tested learning a list of words (California Verbal Learning Test), as well as the brief registration of digits and reordering months

(classic tests of working memory and executive function) and also the generation of category exemplars (a measure of semantic memory). This research suggests that SenseCam may operate as a cognitive stimulant in daily life for a healthy population. Further research should attempt to clarify what aspect of SenseCam review leads to this effect. Is it the review of any pictures which is stimulating? Could it be the emotional effect of using a novel gadget? We tentatively suggest that this effect of SenseCam review could stem from the fact that neuroimaging studies have shown it to produce pronounced activation in the hippocampus, an area of the brain critical for memory function.[10] However, the subjective report in the final questionnaire may be useful for the understanding of the basis of the SenseCam effect; these ratings suggest that the improvement in cognitive function may be related to the feelings of alertness, and the pleasure of using the device. Indeed, previous research has shown that using technology to assist cognition is motivating[23] and contributes to a stronger feeling of self-efficacy and an improved mood.[24]

On the other hand, the fact that SenseCam is a passive assistive technology for cognition may explain why the effect worked equally for old and younger adults. Even though older adults had poorer performance overall, they still benefited from review of pictures. This is possibly because review does not require the intentional processes which decline with age.[25] These are, however, provisional suggestions about the processes underlying the effect seen here which we will try to clarify with forthcoming experiments.

To put these results in context, a recent review of memory training in aging[26] stated that that the focus must be put in compensatory strategies more than in internal strategies and that compensatory strategies must be user-friendly, and require as little training as possible so that the compensatory overactivation can occur and promote significant effects improving the

cognitive performance of the ageing person. We consider that this study is in accordance with this perspective. The critical issue would now be evaluating this kind of compensatory memory aids for longer periods of time, so that we can gauge its effectiveness and usability in the long term.

There are some limitations which need noting. Although this study produced some large effect sizes on standardized measures of function, it should be noted that this experiment was run with a convenience-based sample, with participants motivated to use SenseCam. The fact that only a healthy population was tested in this study is also a constraint of this study. Consequently, it is still unknown whether this general benefit of SenseCam is circumscribed to participants without cognitive problems or if this effect is replicated in patients with memory deficits. Most critically, the effect we find here is immediate, and possibly short term. As such, the aim of our larger research programme is to address these limitations by examining the generalization of the effect of SenseCam to other cognitive areas in a clinical sample (patients with Mild Alzheimer's disease). In this larger investigation a more complete cognitive assessment battery will be administered and we will test SenseCam for longer periods of time in patients, with a baseline, a post-intervention and a follow-up assessment.

Conclusion

Hitherto, research with devices like SenseCam has focused on the use of technologies as compensatory aids for memory. This view emphasised 'cognitive prosthetics' because they were considered to act as a substitute for cognitive function following impairment. This idea has dominated the field of the memory aids in general[1] and in new technologies in particular[22]. Our study provides a novel perspective where we find a stimulation of cognition following SenseCam review. This suggests SenseCam has an action which is more than just

supporting or compensating for a lost memory, it may actually act to improve it. Since SenseCam is a passive memory aid, with no need for training, if we could prove its efficacy to delay the appearance of symptoms associated with neurodegenerative diseases it could reduce substantially the resources normally required in these kinds of conditions.

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Table 1. Neurophsychological tasks

California Verbal Learning test – II (CVLT; [14]).	Participants are asked to memorise a 15 item list, which is repeatedly presented and tested across 5 trials. There are measures of recall and recognition. This is a classic measure of verbal episodic memory.
Month ordering (MO[15]).	Participants hear a set of months, and they have to memorise them and organise them into the right order, before repeating them to the experimenter. This is a test of working memory.
Verbal fluency test (VF[16])	Participants are asked to produce as many words as possible beginning with a given letter (F,A,S) or category (animals, occupations) in a minute. This is a test of executive function.
Symbol Search and Coding (SSC[17])	Participants are given a symbol to detect amongst an array of similar symbols. The time taken to detect and cancel each symbol is measured (Symbol search). Participants also re-code a sequence of symbols using a given number code (symbol coding). These are measures of the speed of processing.
Autobiographical Memory Test (AMT[18])	Participants retrieve information from their on life cued by words, such as 'dog', 'happy'. The experimenter rates the specificity of the memories generated according to a standardised scale.
Digit Span task (DST[19])	Participants are presented with a sequence of digits which they must memorise and then repeat immediately

	to the examiner, either in the same order (digits forward) or the reverse order (digits backward)

Table 2. Neuropsychological assessment, by age group and memory aid

Cognitive test[a]	Older Adults		Younger Adults		Main effect of memory aid (F statistic) df =1.27	Main effect of age group (F statistic)	Interaction effect memory aid x group (F statistic)	Memory Aid Effect size, ε^2
	SenseCam Mean (SD)	**Diary** Mean (SD)	**SenseCam** Mean (SD)	**Diary** Mean (SD)				
AMT	19.07 (1.38)	12.57 (3.81)	19.22 (1.15)	15.99 (3.33)	127.05*	6.327*	9.213* ε^2- 0.25	0.82
CVLT (immediate)	13.99 (2.26)	12.43 (2.03)	15.07 (1.34)	13.80 (1.01)	17.22*	5.729*	.020	0.29
CVLT (short delay)	12.64 (3.27)	10.64 (3.20)	14.33 (1.63)	12.33 (2.02)	19.31*	3.906*	.001	0.42
CVLT (long delay)	13.14 (2.79)	11.36 (2.87)	14.80 (1.02)	12.13 (1.64)	37.38*	4.464*	1.363	0.58
CVLT (recognition)	14.86 (1.51)	13.29 (3.02)	15.73 (0.46)	15.01 (1.01)	9.102*	6.433*	2.214	0.25
Month ordering	14.07 (1.14)	12.36 (1.98)	14.53 (0.99)	13.53 (1.06)	22.92*	3.964*	1.587	0.46
Digit Span	21.64 (2.87)	19.64 (4.44)	20.27 (2.91)	17.87 (3.09)	25.99*	3.785*	.215	0.49
Phonemic fluency	59.42 (11.9)	52.00 (14.07)	53.00 (12.2)	44.13 (10.68)	21.04*	3.965*	.202	0.43
Semantic fluency	39.85 (6.53)	34.50 (7.59)	38.13 (3.40)	34.53 (4.42)	32.76*	3.186*	1.261	0.55
Symbol Search	26.71 (6.09)	29.07 (7.22)	43.27 (3.43)	41.93 (3.90)	0.266	73.270*	2.456	.01
Coding	57.29 (9.19)	59.21 (11.3)	91.13 (10.8)	89.20 (8.80)	0.000	91.123*	1.277	.00

[a] For all the standardized measures used to test participants' cognitive function, a higher score corresponds to a better performance in the test.

* significance ≤0.05 – the mean results of the variables analyzed are statistically different.

AMT, Autobiographic Memory Test; CVLT, California Verbal Learning Test

Table 3. Subjective experience ratings, by age group and memory aid[a]

Subjective experience	Older Adults		Younger Adults		Main effect of memory aid (F statistic) df =1,27	Main effect of age group (F statistic)	Memory Aid Effect size, ε^2
	SenseCam Mean (SD)	**Diary** Mean (SD)	**SenseCam** Mean (SD)	**Diary** Mean (SD)			
Prompting memories[b]	0.93 (0.61)	0.50 (0.52)	1.53 (0.64)	0.80 (0.41)	18.38*	8.53*	0.45
Surprise[c]	3.29 (1.32)	1.86 (1.01)	4.40 (0.83)	2.33 (0.98)	43.94*	7.21*	0.62
Excitement[c]	3.71 (1.38)	1.86 (1.23)	4.13 (0.64)	2.04 (1.06)	46.77*	2.23	0.65
Alert[c]	3.79 (1.12)	2.21 (1.46)	4.07 (0.46)	3.33 (0.82)	15.19*	8.40*	0.36
Emotion[c]	2.31 (1.71)	1.86 (1.22)	3.33 (1.23)	2.07 (1.10)	8.07*	2.60	0.23
Helpful[c]	4.50 (0.56)	3.86 (1.16)	4.40 (1.24)	3.87 (1.87)	4.17*	0.03	0.13

Reliving events[c]	3.96 (1.17)	2.29 (1.44)	4.47 (0.74)	2.60 (1.24)	22.85*	3.29	0.46

[a] Example of a question from this questionnaire: "How did it feel to review the diary/SenseCam images? (please indicate how strongly you agree with each statement, where 1(one) indicates strongly agree and 5(five) indicates strongly disagree)…It felt exciting to review those three days." Participants were tested about their subjective experiences with this questionnaire at the end of each condition (diary/SenseCam).

[b] Rating scale: 0 – didn't prompt any more memories; 1- prompted a few more memories; 2 - prompted a lot of more memories

[c] Rating scale from 1 to 6, 1 meaning absence of that subjective experience and 6 meaning totally presence of that subjective experience.