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REVIEW

Wearable Cameras Are Useful Tools to Investigate and Remediate Autobiographical Memory Impairment: A Systematic PRISMA Review

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Abstract Autobiographical memory, central in human cognition and every day functioning, enables past experienced events to be remembered. A variety of disorders affecting autobiographical memory are characterized by the difficulty of retrieving specific detailed memories of past personal events. Owing to the impact of autobiographical memory impairment on patients' daily life, it is necessary to better understand these deficits and develop relevant methods to improve autobiographical memory. The primary objective of the present systematic PRISMA review was to give an overview of the first empirical evidence of the potential of wearable cameras in autobiographical memory investigation in remediating autobiographical memory impairments. The peer-reviewed literature published since 2004 on the usefulness of wearable cameras in research protocols was explored in 3 databases (PUBMED, PsycINFO, and Google Scholar). Twenty-eight published studies that used a protocol involving wearable camera, either to explore wearable camera functioning and impact on daily life, or to investigate autobiographical memory processing or remediate autobiographical memory impairment, were included. This review analyzed the potential of wearable cameras for 1) investigating autobiographical memory processes in healthy volunteers without memory impairment and in clinical populations, and 2) remediating autobiographical memory in patients with various kinds of memory disorder. Mechanisms to account for the efficacy of wearable cameras are also discussed. The review concludes by discussing certain limitations inherent to using cameras, and new research perspectives. Finally, ethical issues raised by this new technology are considered.

Keywords Wearable cameras · Autobiographical memory · SenseCam® · Cognitive remediation

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The aim of the present study was to provide an overview of the new therapeutic and research possibilities offered by wearable cameras. The article begins by a review of the literature on the topic in relation to autobiographical memory research. Although it has progressed considerably in the past three decades, autobiographical memory research still has inherent limitations, in both investigation and remediation.

After a brief description of existing methods of autobiographical memory remediation and their limitations, questions of how wearable cameras work and what possibilities they offer in the autobiographical memory field are addressed, focusing on how wearable cameras are used to investigate autobiographical memory functioning in healthy volunteers and autobiographical memory dysfunction in clinical populations. Some successful results for the use of wearable cameras in autobiographical memory deficit remediation are then described and considered. Finally, methodological limitations, data management, ethical issues and perspectives regarding the use of wearable cameras are discussed.

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Introduction

Thinking about the past and remembering events in one's life is a crucial aspect of human cognition known as autobiographical memory (Suddendorf et al. 2009; Suddendorf and Corballis 2007). This particular memory system encompasses the set of personal information one has on oneself and the various memories of past personal events that one has experienced throughout life (Conway 2005). Conceptually, autobiographical memory comprises several types of information, from the most general to the most specific (Conway and Pleydell-Pearce 2000; Conway 2005). The first set of information represents abstract autobiographical knowledge, the retention intervals of which may be days, weeks or decades (for instance, the university period, last summer holidays, names of friends). The second corresponds to highly specific information represented by unique perceptual-sensory episodes experienced by the individual. The retention interval for these episodes is rather seconds, minutes or hours, unless they are striking, highly emotional or of significant importance (Conway 2009; Tulving 2002). Such episodic information comprises the phenomenological details (perceptual-sensory, contextual, emotional details, thoughts, feelings) that constitute the autobiographical memory and provide the individual with the subjective experience of remembering past personal events. Hence, specific autobiographical memories are mental constructs of single personal events, composed of both general and episodic information, which lasted less than 24 h and was located in space and time (for instance, my car accident in 2002).

Furthermore, according to Conway's Self-Memory System model (Conway 2005), the construction and conscious recollection of autobiographical memory is under the control of the "self", a set of complex, dynamic executive processes. The self, through executive processes, is deeply involved in encoding and storing information at the occurrence of an event, and in retrieval processes during recall. It also influences the way in which autobiographical memories are recalled, for instance, the subjective experience of the remembering subject. These executive processes, fundamental to autobiographical memory functioning, include, at the encoding level, visual-spatial abilities, attention, and the self-initiation and development of strategies to bind the great variety of information and details present at an event's occurrence (Boyer et al. 2007; Schacter 2001), so that a unified mental representation of the event can be stored in long-term memory. Likewise, when a personal memory is recalled, executive processes are involved in the strategic retrieval of the several details, and the organization and mental processing of other types of information that are extracted to construct a coherent mental representation of the memory.

Through these mechanisms, autobiographical memory tells the story of a person's life and enables them to consciously re-experience their past, forging a strong sense of identity and continuity through time (Conway 2005). Autobiographical memory also serves a social function, enabling past events to be shared with friends and relatives (Bluck 2003; Pillemer 2003). These functions allow the individual to adapt efficiently and be actively involved in different domains of daily life: personal relationships, and occupational, social or leisure activities. Autobiographical memory deficits have been extensively observed and studied in the last decades in a variety of populations: the healthy elderly (Martinelli et al. 2013; Piolino et al. 2010), patients suffering from neurodegenerative diseases such as Alzheimer's disease (Irish et al. 2011; Piolino et al. 2003), multiple sclerosis (Ernst et al. 2014, 2015), brain lesions (Berryhill et al. 2007; Piolino et al. 2007), or psychiatric disorders such as depression (Dalgleish and Werner-Seidler 2014; Williams et al. 2007), post-traumatic stress disorder (Sutherland and Bryant 2008), schizophrenia (Berna et al. 2016; Danion et al. 2005; Elvevåg et al. 2003; Potheegadoo et al. 2013, 2014, 2012) or autism spectrum disorder (Crane and Goddard 2008). Depending on their primary cause, these autobiographical memory impairments can take different forms and show different levels of severity. In some cases, such as brain injury, autobiographical memory impairment can be so severe as to amount to amnesia, either anterograde (inability to encode new information about personal life) or retrograde (inability to access past personal information). Retrograde amnesia shows a gradient, whereby patients forget remote past events but still remember recent ones. Apart from complete amnesia, various patterns of autobiographical memory impairment are associated with neurological and psychiatric pathologies, with substantial impact on daily life. Thus, Kenealy et al. (2000) showed that autobiographical memory impairment affected subjective quality of life in multiple sclerosis patients. Additionally, Mehl et al. (2010) showed that autobiographical memory impairment was the strongest predictor of social dysfunction in schizophrenia, even more than schizophrenic symptoms as such. It therefore seems important to develop methods and tools in remediation programs to provide patients with strategies to lessen autobiographical memory deficits and their impact on daily life.

What Methods to Remediate Autobiographical Memory?

Various methods to improve autobiographical memory have been developed in recent decades (for a review, see Dalgleish and Werner-Seidler 2014). They focus on different aspects of autobiographical memory, and aim at improving retrieval of more detailed and vivid memories of past personal events. Most focus on memory of remote past events to enhance autobiographical recall by means of cues (for instance, memory detail enrichment methods). The methods have been shown effective, using music with Alzheimer's disease patients (Palisson et al. 2015) or smells with healthy volunteers (Chu and Downes 2002; Herz 2004). Life review therapy (Latorre

et al. 2014; Serrano et al. 2004; Serrano Selva et al. 2012) is another effective method to help patients to retrieve specific positive memories of remote past events. There is some preliminary evidence of a decrease in narrative disempowerment themes after treatment (McDougall et al. 1997), and preliminary qualitative evidence in patients with psychosis (Lesser and Friedmann 1981). Life review therapy has also been shown to be very efficient in elderly patients suffering from depression (Serrano et al. 2004; Serrano Selva et al. 2012). Some of these methods, such as memory specificity training (Raes et al. 2009), are implemented in group settings, and others, such as autobiographical reminiscence therapy (Piolino 2006) or mental visual imagery-based facilitation (Ernst et al. 2013, 2015), in a one-to-one setting with the therapist.

The diary method is probably one of the oldest strategies known to improve autobiographical memory. Contrary to methods based on learning new memory strategies (autobiographical reminiscence therapy, memory details enrichment, mental visual imagery-based facilitation, memory specificity training, etc.), the diary method is an external memory aid. Acting as a form of "prosthesis" for everyday memory functioning (Kapur et al. 2004), it aims at supporting and improving autobiographical memory skills. For example, autobiographical memory training based on the diary method demonstrated substantial effect with patients suffering from schizophrenia (Blairy et al. 2008; Ricarte et al. 2012). However, the method has also some limitations. It is time-consuming, particularly for some patients who find it bothersome to write into their diary every day and tend to get discouraged with keeping up their daily entries (Emma Berry et al. 2007; Brindley et al. 2011). A further point reported in these studies is that the details of the events entered in the diary are limited, suggesting that the number of memory cues enabling retrieval of vivid past memories may not always be sufficient using the diary method, due to the weakness of the written description of the memory, which is too remote from the original experience.

In view of these limitations, wearable cameras (such as SenseCam®), which record visual information experienced by the individual on-line, are an interesting alternative to the written diary. As the camera works automatically, it is effortless to use, even for severely cognitively impaired patients. Moreover, the recorded information is not in the form of words or a written description, but rather a continuous flow of pictures taken from the first-person point of view, circumventing the risk of a lack of information reported in a diary.

Wearable Cameras

SenseCam®

The history of wearable cameras began in 2003 with the launch of SenseCam®. Initially created to be a "human black box recorder" (Wood et al. 2004), the first SenseCam® prototype recorded information continually, like devices in airplanes or cars. During a visit to Microsoft Research, Cambridge (UK), a SenseCam® prototype was shown to Narinder Kapur, a clinical neuropsychologist, who was working at Addenbrooke's Hospital in Cambridge. He understood the potential of SenseCam® for working on severe memory impairment (Hodges et al. 2011). Subsequently, Microsoft Research and Addenbrooke's Hospital started to work together to develop the first device devoted to memory research.

Various prototype versions of SenseCam® were developed before the final version was marketed by Microsoft in 2009. This small wearable camera, about 5 cm by 6 cm, is usually worn around the neck with a lanyard. Pictures are automatically taken every 30 s and the device does not require user intervention. Moreover, various sensors trigger image capture according to light, temperature and movement, generating a photographic record of the most relevant moments depending on environmental changes. The device has a long battery life, up to 8 h, and contains a standard Secure Digital card of up to 2 GB (gigabytes).

Other Devices

Since 2014, SenseCam® has no longer been the sole device available, as new wearable cameras have been developed. For instance, the Narrative Clip® is a new device from Narrative Company. It is simply hung on the clothes, and is smaller than the SenseCam® (3.6 cm by 3.6 cm) with longer battery life (2 days' autonomy), bigger memory capacity (up to 8 GB), and is used in the same way as SenseCam®. Other devices are also available (GoPro®, MeCam®, PnJCam®) with options for photographs or movies, extending the possibilities.

Method

Protocol and Registration

The protocol for this review was not registered. The systematic review was executed according to the PRISMA guidelines (Moher et al. 2015, 2009).

Eligibility Criteria

Studies were included in the present review if (a) wearable cameras were used in the research protocol and (b) wearable cameras were used either in memory investigation or remediation protocols or were the central question of the article. Studies reporting ethical issues regarding wearable cameras use were also taken into consideration and summarized in the review.

Studies involving wearable cameras but unrelated to autobiographical memory, therapeutic intervention or ethical issues were excluded.

Information Sources

Studies concerning wearable cameras published between January 1st, 2004 and December 31st, 2015 were searched for by two investigators (MCA and FB) in the PsycINFO, PUBMED and Google Scholar data-bases. The starting date was chosen because the first international conference on SenseCam® took place in 2004.

The data-base search used the following search terms, which had to be part of the title or keywords: [SenseCam OR wearable camera] AND [autobiographical memor*] AND [remediat* OR training OR intervention]. Studies in any language were considered, although all studies included in this systematic review were published in English. Additionally, the reference lists of all identified studies were searched for further studies, enabling us to include one more study in this review

Study Selection

The data-base search retrieved 171 articles, and another was found by checking the reference lists. After removing duplicates, 127 studies were screened for title or abstract fulfilling the inclusion criteria. Sixty-four studies were then screened on a full-text basis, and 35 were excluded as not matching the study topics of interest. Finally, 28 studies were included in the review; three assessed the impact of the various camera parameters on autobiographical memory recall; five investigated autobiographical memory functioning; eight were case reports (including one study with a small group of patients) assessing wearable cameras for the remediation of autobiographical memory disorder; two were group studies of other therapeutic benefits ensuing from wearable cameras use; five focused on data management challenges; and five dealt with ethical issues raised by wearable cameras use (see Fig. 1 for a flow-chart of the selection process). These studies are presented and summarized in Table 1.

Results

Impact of Camera Parameters on Memory in Young and Memory-Unimpaired Volunteers

As SenseCam® offers many different possibilities with which to work, several studies compared the impact of different configurations on memory support in healthy volunteers to determine optimal parameters for memory enhancement. The particularity of SenseCam® is that the individual is aware of wearing a device, which already modifies cognitive processes (Sellen et al. 2007). Moreover, the device enables pictures to be taken either automatically or intentionally, raising the question of a possible difference between active versus passive event recording when participants review the pictures. Pictures taken automatically can be either time-triggered every 30 s or sensor-triggered in reaction to environmental change. Finally, images can be reviewed at the end of the day or later, reinforcing event encoding and also to test memory of the events.

Automatic versus Intentional Capture Triggering

Sellen et al. (2007) asked participants to wear the device for 2 days. Three variables were tested: whether participants wore the device, whether pictures were taken automatically or intentionally, and the time interval for the memory test. The

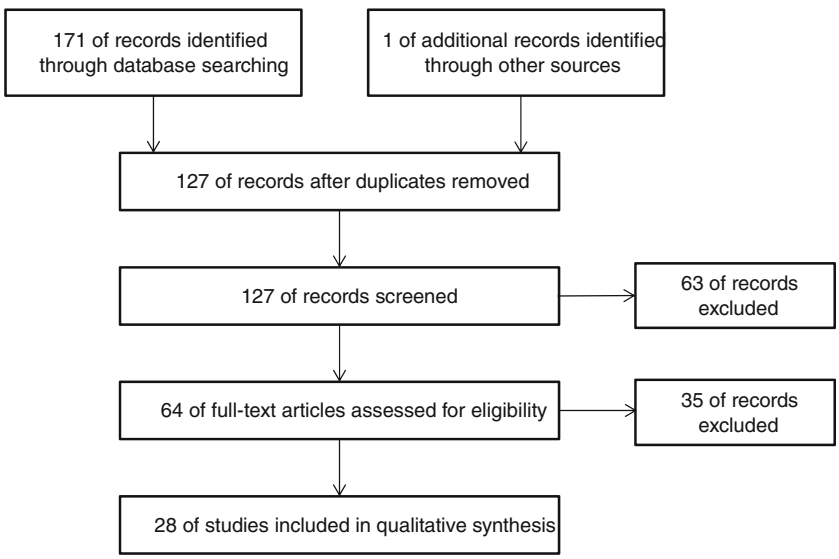

Fig. 1 The flow chart of the selection of the articles

results showed, firstly, that the simple fact of wearing the device enriched the recall of events. This effect may be explained by motivation and attention enhancement related to wearing the camera, but may also be due to novelty and might thus be attenuated with longer or more regular wearing of the camera in a treatment context. Secondly, pictures taken automatically were found to be better cues for recall than those taken intentionally. This finding is counter-intuitive, one might have assumed that pictures taken intentionally would require more attention, thus enhancing the encoding of memory for the particular time. One explanation for this surprising result may be that the act of taking a picture interferes with memory construction, as the subject concentrates more on the action rather than on the experience, preventing efficient encoding. Another explanation could be that pictures taken passively trigger stronger surprise effects on reviewing the pictures, leading to a more intense sense of recollection.

Sensor-Based versus Time-Based Automatic Triggering

Finley et al. (2011), testing 12 young adults, showed that memory performance did not differ between for sensor-triggered and time-triggered pictures (taken automatically every 30 s). This result is also unexpected, as sensor-triggered pictures correspond to changes in the environment, which have often been shown to be relevant to short-term personal goals (Zacks and Swallow 2007). It may have been due to using inappropriate algorithms to filter and extract sensor-triggered images that did not actually represent relevant environmental change and as a consequence not really capture relevant event transitions.

Pictures Reviewing

The device also works through reminiscence training, based on reviewing images. Seamon et al. (2014) investigated this issue. Participants who reviewed SenseCam® images accompanied by an experimenter who monitored the participant's recall (providing corrective feedback for missing actions, incorrect actions or action sequencing errors) had better recall than those who reviewed SenseCam® images by themselves. Thus, what they have called "social reminiscence" enables better structuring of memory.

To sum up, studies in memory-unimpaired participants (mostly undergraduate students) showed SenseCam® to be effective for autobiographical memory enhancement (Seamon et al. 2014; Sellen et al. 2007). However, the intensity of the observed effect was modulated by the task itself. It seems that what works best is to use pictures taken passively (automatically) for memory tests after participants have reviewed the pictures at the end of the same day. The optimal interval between camera use and memory tests showing strongest effects is between 10 days and 4 months.

The Use of Wearable Cameras to Investigate Autobiographical Memory Processes

The next step is to understand how memory works in healthy people, in order to determine what is impaired and what is conserved in amnesic patients, and to try to remediate impairment with a more specific approach. Wearable cameras are proving to be remarkable tools for studying the memory of everyday events. Autobiographical memory research is hampered by factors inherent to the nature of autobiographical memory, inasmuch as the laboratory tasks used in previous studies were not actually related to real-life events. Some studies therefore also used more "ecological" material to investigate the neural substrates of everyday life recognition memory (Levine et al. 2004), using self-recorded audio cassettes to trigger memories (Botzung et al. 2010; Cabeza et al. 2004). Furthermore, wearable cameras provide a degree of control that memory researchers have never had before, concerning both the collection of autobiographical images and their subsequent presentation as memory cues, as they enable naturalistic materials to be collected without the subject's active involvement.

Investigation of Autobiographical Memory Processes in Healthy and Memory-Unimpaired Volunteers

Besides the possibility of improving autobiographical memory, SenseCam® can also be used to create a recognition memory test for real-life events. Thus, some studies investigated autobiographical memory processes close to daily life functioning. The influence of gender differences on autobiographical recall was highlighted in a study with neuroimagery (St Jacques et al. 2011a) that demonstrated a gender effect on functional activity associated with memory vividness, with males showing greater activity in medial temporal lobe regions associated with visual-spatial processing and females showing greater activity in prefrontal cortex regions linked to control processes, such as temporal context. Differences in brain activation between self-projection into the personal past and self-projection into the life of another person were also highlighted in an fMRI (functional Magnetic Resonance Imaging) paradigm using SenseCam® images (St Jacques et al. 2011b). Milton et al. (2011a) also investigated the neural correlates of everyday recognition memory. SenseCam® images were used in an fMRI paradigm adapted from the "Remember/Know" procedure (Rajaram 1996). During a scan session, participants were asked to classify SenseCam® images as strongly or weakly remembered, familiar or novel (Milton et al. 2011b). After a 5-month interval, participants were retested using precisely the same cues (Milton et al. 2011b). Milton's results were very close to those highlighted by the meta-analysis of Svoboda and colleagues (Svoboda et al. 2006), suggesting a close relationship between

real-life recognition memory and autobiographical memory. Moreover, Milton's two studies identified the neurophysiological correlates of recognition memory for everyday life events, showing different brain activation patterns associated with the retrieval of consciously recollected memories and memories associated with a feeling of familiarity. Thus, despite common features, these two processes may have distinct neural activation patterns for autobiographical memory material. Some of the main analyses showed mediotemporal lobe disengagement over time combined with stable continued engagement of extra-mediotemporal lobe regions in both recollection and familiarity memory. In conclusion, the use of first-person point-of-view images appears to be a promising approach to investigate the neural processes that underlie everyday recognition memory, and is also valuable for exploring long-term everyday life memory.

Investigation of the Mechanisms of Autobiographical Memory Dysfunction

Wearable cameras have been also used in order to shed light on memory dysfunction in various pathologies and to understand how pathophysiological processes affect memory. Muhlert et al. (2010) investigated whether accelerated long-term forgetting, as described in epileptic patients using a word list task or procedural memory task, was also observed in autobiographical memory. Eleven patients with transient epileptic amnesia matched to 11 controls were asked to wear SenseCam® while visiting a local museum. Memory for images of events, word lists and procedural tasks was assessed at intervals of 1 day, 1 week and 3 weeks. The results demonstrated that accelerated long-term forgetting in transient epileptic amnesia patients concerns memory for real-life events as well as laboratory materials, and is specific to the declarative memory system, since implicit memory for procedural tasks did not differ during accelerated long-term forgetting episodes. Finally, the results showed that accelerated long-term forgetting is maximal over the first day.

To sum up, wearable cameras can (a) extend previous results on memory functioning using laboratory stimuli to memory for real-life events, (b) assess more precisely what happens during the event, whether that be emotional state, personal importance of the event, thoughts related to the event, or other features of the event, and (c) provide powerful visual cues for memory recall tasks.

Remediation Protocols in Patients with Autobiographical Memory Impairment

The first study using SenseCam® in autobiographical memory remediation protocols was published in 2007 (Berry et al. 2007). Since this inspiring seminal work, eight studies focused on SenseCam®'s potential: seven case reports, and one group study. Six of the eight protocols compared different remediation methods: SenseCam® versus diary versus no remediation, using a cross-over design.

Case Reports

The first case report was that of a patient with severe memory impairment following limbic encephalitis (Berry et al. 2007). The experimental design assessed the possible superiority of SenseCam® over the diary method, with three conditions: SenseCam®, written diary and baseline. The SenseCam® condition was applied first and lasted 11 months. The patient and her husband were given a SenseCam® and a laptop computer. She wore the camera, autonomously, during interesting or non-routine events and worked on SenseCam® images with her husband. She reviewed images and tested her memory for a particular event every 3 days for 2 weeks. Long-term retention was tested at 1, 2 and 3 months for every event recorded by the SenseCam®. The written diary condition replicated the SenseCam® condition as closely as possible, it started 2 months after the SenseCam® condition and lasted 2 months. The patient wrote up any interesting or non-routine events in her diary, then her husband asked her to recall the written events, every 2 days for 2 weeks, encouraging her to read over the diary several times. Finally, the baseline condition started after the diary phase, and lasted 1 month. The patient was asked to recall any interesting or non-routine events every 2 days for 2 weeks. In the SenseCam® condition, the patient was able to recall approximately 80% of recent personally experienced events. Moreover, retention was maintained over the long term: 11 months, and without having viewed SenseCam® images for 3 months. In contrast, in the written diary condition, the patient was able to remember on average only 49% of events, and had no recall of the event after 1 month without reading the diary. In the baseline condition, the patient was not able to remember an event 8 days after having experienced it. Thus, this initial study demonstrated the main benefits of using a wearable automatic camera to support autobiographical memory in a patient with severe memory impairment. Importantly, these findings were supported by the patient's fMRI data (Berry et al. 2009), which showed significantly greater activation of frontal and posterior cortical regions, but not of the hippocampus, when the patient reviewed SenseCam® images compared with written dairy extracts. Several case-studies subsequently replicated these remarkable findings, in patients with autobiographical memory impairments due to brain injury, herpes simplex encephalitis, mild cognitive impairment or metastatic intracranial tumor (Brindley et al. 2011; Browne et al. 2011; Loveday and Conway 2011; Pauly-Takacs et al. 2011; Svanberg and Evans 2014). These studies also compared the efficacy of SenseCam® versus other autobiographical memory remediation methods, and all reported better memory recall with the

Table 1 Overview of studies about wearable cameras and their use as tools for memory remediation and investigation

Exploring the impact of SenseCam® parameters on autobiographical memory recall

Authors	Date	Population	Number of subjects	Age (years)	Aim	Study design (+ recording time)	Testing method	Main results
Sellen et al.	2007	Students	19	18 to 22	Exploring SenseCam® possibilities to enhance memory in memory unimpaired subjects	2*2*2* within-subject factorial design - SenseCam® condition vs. control condition - Images taken passively vs. images taken intentionally - 3 days vs. 10 days vs. 4 month interval before testing *Recording time: 2 days*	- First free recall (Remember/ Know/Guess procedure) - Ordering images - Second free recall - Recognition	Results showed a clear effect of simply wearing and using the camera. On average, the number of events recalled before viewing any images was higher on SenseCam® days than on Control days. SenseCam® images enabled more events to be remembered, but the power of these cues to spark remembering deteriorated over time. However, the ability to know that something occurred after viewing SenseCam® images showed greater stability and greater advantage over time.
Finley et al.	2011	Students	12	18 to 21	Comparing the impact of picture capture procedure on autobiographical recall	3*2*2* within-subject factorial design - 1 vs. 3 vs. 8 weeks retention intervals - Sensor-triggered vs. time-triggered pictures - Picture review at the end of the day vs. no review *Recording time: 5 consecutive days*	- Recollection yes/no judgment - Recognition rating (1 to 7 scale) - Picture-cued recall - Time-cued recall - Recall of time - Temporal order judgment	The most fruitful of the 6 measures were recognition rating and picture-cued recall length. On these tests, end-of-day review enhanced performance compared to no review, while pictures triggered by SenseCam's sensors showed little difference in performance compared to those taken at fixed time intervals.
Seamon et al.	2014	Students	144	17 to 23	Exploring whether SenseCam® image review consolidated memory in unimpaired subjects	3*2* within-subject factorial design - SenseCam® vs. diary vs. no aid - Social vs. self reminiscence *Recording time: a 1 h walk on campus*	One week after - Free recall - Order recall	For SenseCam® images and diary entries, prior social reminiscence produced greater recall than self-reminiscence, but there were no differences between memory aid conditions for action free recall or action order recall. Controlling for methodological variables, there was no recall advantage for SenseCam® reminiscence in memory-unimpaired participants.

Table 1 (continued)

Autobiographical memory investigation protocols - In healthy volunteers

Authors	Date	Population	Number of subjects	Age (years)	Aim	Study design (+ recording time)	Testing method	Main results
St Jacques et al.	2011a	Healthy Volunteers	23	23.7±-3.6	Exploring gender differences in autobiographical memory elicited by SenseCam® images vs. verbal cues	2*2 between-subjects design - male vs. female - SenseCam® images vs. verbal cues Procedure coupled with fMRI *Recording time: 3 days long*	One week after encoding phase Cued recall associated with Remember/Know/ Guess paradigm	The behavioral results indicated that there were no gender differences in subjective ratings of reliving, importance, vividness, emotion or uniqueness, suggesting that gender differences in brain activity were not due to differences in these measures of phenomenological experience. The fMRI results revealed that males showed greater difference than females in functional activity associated with the rich experience of SenseCam® vs. Verbal Cues.
St Jacques et al.	2011b	Healthy Volunteers	23	23.7± 3.6	Exploring neural correlates of self-projections using SenseCam® images	Between-subjects design - self-projection of self vs. others Procedure coupled with fMRI *Recording time: 3 days long*	One week after encoding phase Picture-cued recall	Self-projection to the personal past recruited greater ventral mPFC, whereas observing another person's perspective recruited dorsal mPFC. This article suggests that ventral-dorsal subregions of the anterior midline are functionally dissociable and may differentially contribute to self-projection of self vs. other
Milton et al.	2011a	Students	15	18 to 25	Exploring neural correlates of everyday recognition memory using SenseCam® images	Between-subjects design - Remembered vs. known events Procedure coupled with fMRI *Recording time: 2 days long*	36 h after encoding Picture-cued recall associated with Remember/Know procedure	Within the medial temporal lobes, 'Remember' responses specifically elicited greater activity in the right anterior and posterior parahippocampal gyrus than 'Know' responses. Strong recollection elicited greater activity in the left posterior hippocampus/ posterior parahippocampal gyrus than weak recollection, indicating that this region is specifically modulated by the degree of recollection
Milton et al.	2011b	Students	10	18 to 25	Exploring neural correlates of long-term everyday memory using SenseCam® images	Between-subjects design - Remembered vs. known events - short vs. long interval before recall Procedure coupled with fMRI *Recording time: 2 days long*	36 h and 5 months after encoding Picture-cued recall associated with Remember/Know procedure	The study showed decreased activation in anterior hippocampus/anterior parahippocampal gyrus at 5 months compared to a 36-h retention interval. Familiarity was associated with greater activation in anterior parahippocampal gyrus and posterior parahippocampal gyrus than recollection and new responses. Familiarity activation decreased over time in anterior hippocampus/ anterior parahippocampal gyrus and posterior hippocampus/ posterior parahippocampal gyrus. An engagement of neocortical regions, such as medial prefrontal cortex at a 5-month interval, with

Table 1 (continued)

									reduced medio-temporal lobe activation at 5 months relative to at 36 h were shown.
Autobiographical memory investigation protocols - In patients									
Authors	Date	Population	Number of subjects	Age (years)	Aim	Study design (+ recording time)		Testing method	Main results
Mulhert et al.	2010	Patients with transient epileptic amnesia	11	68.6±-9.9	Investigating accelerated forgetting of real-life in transient epileptic amnesia	Between-subjects design - 4 different intervals before recall phase (3 h vs. 1 day vs. 1 week vs. 3 weeks) *Recording time: 3 h while visiting a local attraction*		Picture-cued recall	The results indicated that accelerated forgetting in transient epileptic amnesia: (a) affects memory for real-life events as well as laboratory stimuli, (b) is maximal over the first day, and (c) is specific to declarative memories.
		Controls	11	66.0±-8.3					
Autobiographical memory remediation protocols									
Authors	Date	Population	Number of subjects	Age (years)	Aim	Remediation method	Duration of remediation (interval before testing)	Testing method	Main results
Berry et al.	2007	Post-encephalitic patient with amnesia	1	63	Assessing SenseCam® efficacy in remediating severe memory disorder	SenseCam® vs. diary vs. no intervention	2 weeks (1, 2 and 3 months)	Free recall regarding events experienced under SenseCam® and diary conditions Within-subject comparison	After three months, recall of about 80% of experienced events in SenseCam® condition vs. 0% in 'written diary' or' no intervention' conditions.
Berry et al.	2009	Post-encephalitic patient with amnesia	1	63	Investigating brain activity induced by the use of SenseCam® in memory remediation	SenseCam® vs. diary vs. no intervention	2 weeks (1, 2 and 3 months)	Free recall regarding events experienced under SenseCam® and diary conditions. fMRI was conducted only with SenseCam® pictures Within-subject comparison	Relative to the written condition, successful recognition of SenseCam® images was associated with activation of frontal and posterior cortical regions associated with normal episodic memory in fMRI.
Brindley et al.	2011	Brain-injured patient with anxiety disorder	1	21	Assessing SenseCam® efficacy in remediating severe memory disorder associated with anxiety disorder	SenseCam® vs. conventional psychotherapy aid vs. no intervention	Three different anxiety-related events	Free recall regarding the three events Within-subject comparison	The findings indicated that SenseCam® supported retrieval of events triggering high levels of anxiety better than conventional psychotherapy or no strategy, in terms of both details and internal state information of the memory.
Browne et al.	2011	Patient with mild cognitive impairment	1	55	Assessing SenseCam® efficacy in remediating severe memory disorder	SenseCam® vs. diary vs. no intervention	2 weeks (1, 3 and 6 months)	Open questions about the experienced events Within-subject comparison	Self-report measures suggested that autobiographical recollection was triggered by SenseCam® condition but not by reviewing the written diary. Recollection was associated with emotional and social well-being.
Loveday and Conway	2011	Patient with amnesia caused	1	44	Understanding how and why SenseCam® may promote	SenseCam® vs. diary vs. no intervention	4 weeks (recall each week-end)	Free recall, cued recall and self-assessment of vividness for each events	SenseCam® enabled the patient to recall significantly more detailed episodic memories than reading the diary. The

Table 1 (continued)

		by viral encephalitis			remembering compared to written diary			Within-subject comparison	nature of recalled details was different according to the method used initially, with more episodic details in SenseCam condition and more general knowledge with the diary.
Pauly-Takacs et al.	2011	Patient with brain tumor	1	13	Using SenseCam® as a rehabilitation tool in a child with severe episodic memory impairment due to brain tumor and subsequent treatment	Reviewed pictures vs. non-reviewed pictures	One event (2, 12 and 15 weeks)	Cued recall contrasting reviewed pictures vs. non-reviewed pictures	Results indicated that repeated viewings of SenseCam® images supported the formation of personal semantic memories.
Svanberg and Evans	2014	Patient with Korsakoff's syndrome	1	51	Investigation of the impact of SenseCam® on subjective mood and identity through the enhancement of autobiographical recall	ABA experimental design	5 activities in 8 weeks (daily remembering)	Self-rating of mood and self identity	The patient experienced improved recall for events recorded using SenseCam®, and showed improvement in subjective ratings of identity. However, a corresponding improvement in mood was not seen.
Woodberry et al.	2015	Patients with Alzheimer's disease	6	72	Assessing SenseCam® efficacy in remediating severe memory disorder	SenseCam® vs. diary vs. no intervention	2 weeks (1 and 3 months)	Cueing questions for each event of each condition Within-subject comparison	Across 40 events, the SenseCam® review method resulted in significantly more details of an event being recalled over 2 weeks than the written diary method, in 5 out of the 6 patients.

Other therapeutic benefits

Authors	Date	Population	Number of subjects	Age (years)	Aim	Study design (+ recording time)	Test method	Main results
Murphy et al.	2011	Students	20 (7 men)	19.8	Assessing the link between mental imagery and emotional bias in memory using SenseCam® images	Within-subject factor - Images paired with positive captions vs. images paired with negative captions *Recording time: 12 tasks (3,5 min each)*	SenseCam® images with captions were shown to participants, who were asked to produce mental image of them. Rating scales to assess mood, memory vividness and field imagery	The results indicated that SenseCam® review with captions does have significant potential to bias participants' mood and enjoyment of a set of ambiguous laboratory based tasks immediately afterward and 24 h later. The results were also asymmetric with respect to valence. Whereas negative captions gave rise to the larger component of mood effects immediately following SenseCam® review, the valence effect on enjoyment at 24-h was due to a shift to a generally positive assessment of experience of carrying out the 12 tasks.
Silva et al.	2013	Healthy young adults vs. healthy older adults	15 14	19±1.-9 75±5.-6	Investigating the hypothesis that SenseCam® review enhances cognitive function more generally	Mixed design Between-subjects factor - young vs. old Within-subject factor - SenseCam® vs. diary *Recording time: 3 days for each condition*	Neuropsychological battery tasks after 3 days using SenseCam® or the diary as a memory remediation tool	Both young and older adults showed better performance on most measures immediately following SenseCam® review. Effects were largest for memory and executive function tasks, whereas speed of processing was not affected.

Table 1 (continued)

Data management

Authors	Date	Main findings
Conaire et al.	2009	The aim of this study was to compare two methods of SenseCam® picture analysis (SURF and SIFT), in order to automatically determine the wearer's location using an annotated image database. They showed that SURF out-performed SIFT in matching SenseCam® images.
Doherty and Smeaton	2008	This study aimed at reporting how it is possible to automatically segment SenseCam® images into relevant events. The authors described the different steps required to automatically segment a day of images into distinct events: 1) comparing adjacent images (or blocks of images) against each other to determine how similar they are; 2) determining a threshold value whereby higher dissimilarities values indicate areas that are likely to be event boundaries; and 3) removing successive event boundaries that occur too close to each other.
Doherty et al.	2008	The aim of this study was to explore the possibility of gathering similar events together by merging MPEG-7, SHIFT and SURF content-based retrieval techniques. The authors showed that the fusion improved retrieval. Events could be discriminated through the amount of pictures and similar events experienced at different times could be identified.
Doherty et al.	2011	Based on previous work (Doherty and Smeaton 2008; Doherty et al. 2008), this study presented a software browser constructed with the aim of using the characteristics of memory to organize SenseCam® images into a form that makes the wealth of information stored on the camera more accessible. The aim was to minimize effort when browsing and searching.
Lee et al.	2008	This study identified 3 stages in the process of capturing and structuring SenseCam® images, and presented how they are compiled into a canonical media process. The 3 stages are: image capture and upload, processing (event segmentation, landmark photo selection and calculation of novelty values for events), and accessing (organization, publication and distribution of pictures).

Theoretical and ethical considerations

Authors	Date	Main findings
Barnard et al.	2011	This paper reflects on the mechanisms involved in memory recollection and their links with SenseCam®-facilitated recollection. The authors based their reflections on a comparison of autobiographical memory impairment mechanisms involved in normal aging, depressed patients and patients suffering from dementia. They presented various hypotheses to explain how SenseCam® facilitates recollection, offering a very direct and rapid means to activate the retrieval of a specific event.
Hodges et al.	2011	This paper discusses the history of SenseCam®, its design and associated viewing software. The authors reflected also on some of the ongoing research questions being addressed with the help of SenseCam®. For instance, they suggested the interest of using SenseCam® as a tool to assist in the assessment of physical and mental health problems such as autism, learning disability and neurological conditions. In another field, SenseCam® could be used to monitor travel behavior and exercise in programs designed to improve fitness and/or reduce patients' weight.
Kelly et al.	2013	This study attempted to establish the critical points of using wearable cameras in a public health context. Wearable cameras can be intrusive for users and for third parties. Some may feel uncomfortable being photographed so often, without being prepared. This paper tries to develop an ethical framework in which wearable cameras should be used, to prevent annoyance and formalize protection for users and third parties. They emphasize respect of ethical guidelines for the use of automated wearable cameras in health behavior research. These guidelines focus on precise informed written consent, privacy and confidentiality, non-maleficence and third-party autonomy.
Lindley et al.	2009	This study reflected on personal feeling of SenseCam® users or a third parties. Reflections were based on images taken by the device but also on the act of wearing it or seeing others wear the camera. Participants' main discussions were about 1) what the SenseCam® is recording, 2) what kind of self-images the device gives as feed-back, 3) the fear of being misrepresented thought the pictures lacking context, and 4) some practical limitations regarding, for instance, the review of SenseCam® pictures.
Nguyen et al.	2009	This study raised the question of others' perception of SenseCam® use. Results indicated that people would tolerate potential incursions from SenseCam® in their private life, but only for particular purposes. Furthermore, they would typically prefer to be informed about and to consent to recording, and grant permission before any data are shared. These preferences, however, are unlikely to instigate a request for deletion or other action on their part. These results inform future design of recording technologies like SenseCam® and provide a broader understanding of how ubiquitous computing technologies might be taken up across different cultural and political regions.

SenseCam® compared to a diary: patients were able to recall more memories, with more episodic details, and over longer retention periods. In more detail, Browne et al. (2011) showed that a patient with mild cognitive impairments was able to recall twice as many details for SenseCam® reviewed events (41%) than diary-reviewed events (20%). Brindley et al. (2011) showed the efficacy of SenseCam® at 3 weeks compared to the automatic though record strategy, with a correct recall rate around 100% in the first condition against 40% in the second. Loveday and Conway (2011) showed that the ability of an amnesic patient to retrieve episodic details (new information not present in the cue) was much greater in the SenseCam® condition (419 details) compared to the diary condition (76 details). Pauly-Takacs et al. (2011) reported the efficacy of SenseCam® pictures reviewing on memory formation. Finally, Svanberg and Evans (2014) found a relationship between improved recall and enhanced feeling of identity, although not between improved recall and mood. Besides these results, patients also reported better self-confidence and lower stress when using SenseCam® compared to a diary (Berry et al. 2007). For those who have lost the ability to consciously recollect past events, SenseCam® seems to be the only device able to trigger this particular experience of conscious recollection (Berry et al. 2007).

Group Studies

Woodberry et al. (2015) conducted the first multiple case study, with six Alzheimer's disease patients, comparing SenseCam® versus the dairy method. They used the procedure developed by Berry et al. (2007). Participants were asked to wear SenseCam® during a significant event they would like to remember, then recalled and reviewed the SenseCam® images of this event every 2 days for 2 weeks, the same procedure was applied with the diary. Two long-term retention tests were conducted at 1- and 3-month follow–up sessions. SenseCam® outperformed the diary method for 5 of the 6 patients: the greater the number of viewings of the SenseCam® images during the 2 weeks, the higher the level of recall, whereas in the diary condition recall was and stayed lower during the 2 weeks. On average, the amount of information recalled in the SenseCam® condition at 3 months' follow-up was more than triple that recalled in the diary condition. Despite the severity of Alzheimer's disease and the associated severe episodic memory impairment, the study demonstrated that this cognitive impairment could be remediated by SenseCam®, additionally improving patients' well-being.

To conclude, it is worth mentioning again that patients report feeling more confident, less stressed and more able to cope with their impairment when using SenseCam® compared to keeping and rereading a written diary (Berry et al. 2007). In line with this result, studies using SenseCam® demonstrated the impact of improved recollection on well-being and quality of life (Berry et al. 2007; Browne et al. 2011; Loveday and Conway 2011). Moreover, in a social perspective, participants reported enriching and enjoyable moments with close relatives, remembering, sharing and reconstructing private memories thanks to SenseCam® images.

How Does It Work?

With increasing reports of the positive impact of wearable cameras on autobiographical memory, light needs to be shed on the cognitive mechanisms at work when both healthy controls and particularly patients presenting with autobiographical memory deficits visualize the images taken by SenseCam®. As previously mentioned, most patients had poor autobiographical memory recollection before using SenseCam®. The improvement in recall suggests that SenseCam® images trigger several cognitive mechanisms during memory retrieval. The images, taken from a first-person point of view, can be considered as critical cues that activate a series of cognitive and emotional reactions to facilitate direct retrieval of an event (Barnard et al. 2011; Loveday and Conway 2011). Several reports have described "Proustian moments", during which both healthy and memory-impaired users experience intense and vivid recollection of an event and access sensori-perceptual details, emotions or thoughts that are not directly entailed by the images presented to the participants. This supports the idea that some SenseCam® pictures are able to trigger conscious recollection of past events, where the whole experience of the initial event comes "flooding back" (Hodges et al. 2011). This could be explained by certain characteristics of SenseCam® pictures (the first-person point of view, level of visual details, frequency of image capture, and dynamic visualization), which are very close to the reality initially experienced. One interpretation of these reports is that SenseCam® images immediately activate involuntary retrieval from autobiographical memory, triggering the pool of information, and particularly the appropriate and necessary memory details needed to construct a coherent mental representation in the form of a vivid memory. Berntsen (1998) argued that involuntary memories are almost always triggered by external visual or auditory cues that relate directly to the central features of the retrieved memory. This line of argument suggests that WeC pictures, with their first-person point of view, are very effective cues to trigger involuntary memory. Contrary to voluntary (or indirect) retrieval, involuntary (or direct) retrieval of information such as perceptual or sensory, contextual, emotional details or thoughts linked to a particular personal event, requires little cognitive effort or executive control (Berntsen 2012; Hall et al. 2008). This may explain how patients, while presenting with executive

dysfunction, nevertheless benefit from SenseCam® pictures to retrieve specific and detailed memories.

Nevertheless, it could be argued that SenseCam® images are simply a first step that facilitates voluntary retrieval of memories, where the images act as primary external cues and enhance subsequent controlled access to autobiographical information. In that case, the strength of SenseCam® images may simply alleviate patients' executive dysfunctions, while also preventing them from initiating and carrying out suitable retrieval strategies on their own. This hypothesis advocates for complementary procedures to help memory-impaired patients to learn appropriate retrieval strategies to access vivid memories of their past, independently of using a wearable camera. The role of mental imagery in the retrieval process is well known (Williams et al. 1999) and some authors suggest that externally viewed and internally generated images are processed by the same cognitive system (Teasdale and Barnard 1995). Considering these arguments, pictorial cues could compensate for mental imagery impairment, using the same cognitive network. Moreover, Williams et al. (1999) suggested that visual images provide a rich source of information about events and thus provide an efficient summary of information that can be used for searching in the memory system. The very recent study by Ridout et al. (2016) supports this claim, showing that, in memory-unimpaired participants, image cues led to more specific memories than word cues. Thus, wearable camera pictures may trigger a cascade of activation, described by Greenberg and Rubin (2003) as a key process of remembering. Step by step, retrieval activates different cortical regions and finally produces a similar pattern of firing to that present during the original encoding (Rubin and Greenberg 1998). Wearable camera pictures could be the first step in this cascade of activation, which would account for the efficacy of image reviewing.

In parallel to the effect of wearable cameras on memory retrieval, and based on evidence showing the importance of visual imagery in autobiographical memories formation (Conway 2005; Greenberg et al. 2005), it could also be hypothesized that visualizing wearable camera images strengthens the re-encoding of details of personal events, and consequently helps to construct more unified and coherent mental representations of events (Woodberry et al. 2015).

Other Therapeutic Benefits

We have described the potential of wearable cameras for autobiographical memory remediation. However, wearable cameras, in remediation protocols or other uses, can also provide wider therapeutic benefits. Silva et al. (2013) showed that, over and above autobiographical memory improvement, SenseCam® review, compared to reviewing a diary, enhanced cognitive functions in a more comprehensive way. In their study, participants wore the SenseCam® for 3 days and kept a diary for 3 other days, in random order. Participants returned to the lab to review pictures taken by the SenseCam® or read their diary, and then underwent neuropsychological assessment. Results showed that the SenseCam® condition provided significantly better performances than the diary condition in verbal learning, working memory, semantic memory and executive function tasks (Silva et al. 2013). As well as improving cognitive function, autobiographical memory remediation by SenseCam® seems to have a positive impact on self-identity (Svanberg and Evans 2014). A patient with Korsakoff's syndrome underwent SenseCam® remediation for 45 days. Throughout the study period, the self-identity ratings (for instance, "I feel like myself") increased, as did sense of usefulness. Improvement in subjective memory may allow memories of specific experiences to reinforce information about identity. For instance, the sense of "usefulness" was considered important to the patient herself and may have contributed to a more coherent sense of self (Conway 2005). Moreover, in healthy volunteers, SenseCam® may operate as a cognitive stimulant in daily life. This effect could be explained by the experience of participants viewing SenseCam® images, who reported enhanced feelings of alertness and pleasure using the device. Using technology to assist cognition has already been shown to be motivating, inducing a stronger feeling of self-efficacy and improving mood (Gillespie et al. 2012; Scherer 2005). Despite the absence of a SenseCam® review effect on mood in the patient with Korsakoff's syndrome (Svanberg and Evans 2014), Murphy et al. (2011) showed that SenseCam® review did have a significant influence on the mood of healthy volunteers, depending on the emotional valence of the images shown. The effect was still observed 24 h later.

Data Management

New technologies are progressing very fast and various models of wearable cameras are now available to conduct such studies. Likewise, movie cameras have been developed for first-person point-of-view video recording without active user intervention. This possibility of obtaining recorded audio data and continuous flow may represent an even stronger tool to investigate memory processing or remediate memory impairment instead of pictures. Time resolution is greater, but on the other hand autonomy is shorter, and recording a complete day is not yet possible. Moreover, this flood of innovation raises some questions about the management of the vast quantity of recorded data and ensuing ethical issues. Wearable cameras take pictures automatically, at high frequency, generating between 2000 and 5000 pictures per day. This poses a major challenge for image utilization. To facilitate use of the device as a rehabilitation tool by researchers, caregivers and patients, new algorithms and software have been developed

for image processing (Conaire et al. 2009; Lee et al. 2006). Doherty et al. (2010) developed a SenseCam® browser which enables efficient retrieval, based on neuropsychological principles, following three steps: event segmentation, event association and event importance. Firstly, according to Zacks and Tversky (2001) "segmenting ongoing activity into distinct events is important for later memory for those activities", thus the SenseCam® browser enables image segmentation, creating 20–30 coherent units per day to represent different daily events (Doherty and Smeaton 2008). Secondly, as human memory works by associating related events and locations in a conceptual network, the SenseCam® browser is able to do the same and groups similar events together (Doherty et al. 2008). Thirdly, considering that memory is organized by self-relevant structures and goals (Conway 2005), the determination of self-issues and event importance is made possible by combining automated facial recognition (representing social engagement) with detection of the degree of visual novelty of each event.

Critical View of Previous Studies and Limitations of Wearable Cameras

The studies presented in this review showed certain methodological limitations. They provided evidence of the efficacy of wearable cameras, but mainly based on single case reports, insufficient to support extended use as a therapeutic device in routine clinical settings. At this stage, clinical trials are needed that test the efficacy of such devices in larger samples, comparing experimental and control groups. Moreover, in the single case reports, a close relative of the patient (or sometimes the actual therapist) participated in the protocol and took part in the testing (Berry et al. 2007; Browne et al. 2011; Loveday and Conway 2011). This strategy was justified by the difficulty for patients to comply with the protocol, but it is also an obvious source of bias that was not discussed as such in the reports. More precisely, relatives might be more convinced of the efficacy of wearable cameras and therefore influence patients' attitudes toward the diary and wearable cameras. Further clinical trials should take these limitations into account.

In general, studies showed impressive efficacy of wearable cameras for remediating autobiographical memory deficits, especially in comparison with the diary method. However, it cannot be ruled out that the results correspond to the effort of diary writing compared to passive viewing of wearable camera pictures, in particular for neurological or psychiatric populations characterized by apathy and cognitive impairment. Further studies could try to bypass this limitation by comparing passive viewing of wearable camera pictures to passive listening to short verbal records (previously recorded by the participants at the end of their day). Yet, it is important to highlight that the ease of use of wearable cameras is also one of its strong points. Cameras are able to offer an alternative to previously used cognitive supports, which required too much cognitive ability and motivation, and in that sense were not suitable for all patients.

Otherwise, it can be argued that wearable cameras provide much more information on past events than a diary written by the patient. This could explain why retrieval is enhanced by wearable camera reviewing compared to diary reading. Interestingly, however, Loveday and Conway (2011) showed that the amount of detail not present in the cues but retrieved by the amnesic patient was much greater in the wearable camera reviewing condition, confirming that wearable cameras are able to trigger recall of much more information than that contained in the pictures.

Regarding these limitations, the relevance of using such device instead of old personal pictures in autobiographical memory remediation protocols may not be obvious. In fact, the advantage of using a wearable camera over past photographs (including pictures in a 3rd person point of view) has not been assessed, but various authors have described a very powerful effect of wearable camera picture reviewing, which provides a strong feeling of remembering the event (Barnard et al. 2011; Hodges et al. 2011). They consider that the flow of wearable camera pictures provides a dynamic chronological sequence of event (close to a movie) and the first person point of view enhances the feeling of belonging for the viewer. Because of these two very important properties, wearable camera pictures offer a unique means of triggering specific memory of past events along with other phenomenological modalities, in a very different way from framed, often contrived, momentary snapshots in a photograph album (Barnard et al. 2011). Interestingly, a recent study provided some evidence for the effectiveness of the first-person versus third-person point of view in a behavioral task (Watanabe and Higuchi 2016). Behavioral performance improved when participants mimicked action from first-person compared to third-person point-of-view movies. These behavioral differences were associated with stronger activation following the first-person point-of-view presentation in brain regions considered to be part of the neural substrate of imitation (Watanabe et al. 2013). Finally, a study in memory-unimpaired participants showed that pictures taken passively by the wearable cameras were more powerful cues for triggering memories of the events than pictures taken actively by the participant (using the same device). Taken together, these arguments encourage the use of wearable cameras pictures rather than old third-person point-of-view personal pictures to help amnesic patients to improve their memory functioning. Having said this, movies of very important events recorded from the first-person point of view might be even more effective than wearable cameras pictures in reviving and re-encoding personal events. This is worth considering in remediation protocols, although data manageability and ethical questions might be more difficult.

However, as with the diary method, it is important to stress that wearable cameras are only useful in case of anterograde amnesia, and only when the amnesia is not too severe. In other words, patients need still to be able to create long-term episodic memories, memories with at least minimal information, to benefit from wearable cameras remediation. Wearable cameras can remediate autobiographical memory for recent personal events, which is needed to help patients with certain pathologies such as Alzheimer's disease, which initially affects recent memories and new memory formation. Patients with depression may not benefit as much from this type of remediation, as their autobiographical memory is not "damaged", but simply less accessible. Moreover issues relating to the content, meaning and lessons associated with past events are sometimes meet patients' demands more directly, being the target of particular forms of psychotherapy focusing on autobiographical memory (Singer et al. 2012). For patients with schizophrenia, who suffer from difficulty in recollecting not only remote but also recent life events, wearable cameras may be useful for cognitive remediation of autobiographical memory. Whatever the clinical condition, it should be stressed that wearable cameras can assist only anterograde and not retrograde autobiographical memory impairment. That is to say, memory for events that are particularly important and relevant for the self cannot be reached in some clinical populations. For patients who need a support for remote personal memory, wearable camera protocols should be paired with more standard remediation methods using, for instance in that case, old third-person point-of-view personal pictures.

More generally, regarding the device itself, wearable cameras may present some disadvantages for certain people. In particular, patients who are supposed to use these kinds of device already suffer from social stigma (see for instance, for Alzheimer's disease, Jolley and Benbow 2000; or for schizophrenia, Lysaker et al. 2007; West et al. 2011). Using wearable cameras to improve their memory might make them recognizable as suffering from a disorder, and this could increase social stigma and possibly lead to an uncomfortable feeling when wearing the device all day long. Although not referred to in previous reports, this possibility should be taken into account when working with patients and should be explicitly mentioned when presenting the device to them. Recent developments in wearable cameras (for instance, Narrative Clip®) have led to very small and discrete devices, which may reduce this problem.

Finally, as follow-up lasted 6 months, the long-term efficacy of wearable cameras remains unknown and further studies with longer follow-up are required. Such studies may also gain further information by adding assessment of daily life functioning, well-being and sense of self, which are critical to consider in addition to efficacy on memory.

Ethical Considerations

In addition to the issues raised by the use of recorded images, the increasing use of wearable cameras raises ethical issues about privacy and data control. In particular, movie cameras could be used to record conversations or people without their knowledge. In this context, the Google Glass story is interesting. This new technology enables pictures to be taken or movies to be recorded from simple glasses, without people around realizing it. Not surprisingly, this technology sparked serious debate about privacy rights, and finally the project was abandoned in 2014 (New York Times, 5th of February 2015).

The question of privacy has to be considered from two directions, namely, the privacy of the patient and the privacy of third parties not directly involved in the protocol. Thus, Kelly et al. (2013) attempted to identify and discuss the ethical issues of research using wearable cameras. They highlighted some contentious issues, such as the type of pictures taken passively by the device, and the privacy and confidentiality of the pictures, regarding both the patient and third parties (family, colleagues or strangers). Some solutions were suggested. With regard to pictures taken by the device, participants should be informed of the possibility of stopping the device at any time during the experiment. Moreover, participants should be made aware that unwanted images could be taken and that they will be given the opportunity to review and delete them (in private if requested) before the researcher views them. This would ensure participants' privacy. Interestingly, in this perspective, the Narrative Clip® offers an additional security guarantee, only the person in charge of the study has access to the pictures recorded by the device, it is impossible for participants or third parties to access the images. Finally, Kelly and colleagues' work highlighted the importance of the information given to participants, enabling them 1) to be aware of the above concerns, and 2) to answer questions from third parties in order to reassure them.

In line with these ethical considerations, Nguyen et al. (2009) conducted a study of how those liable to be recorded perceive and react to SenseCam®. Results showed that people would tolerate potential incursions from SenseCam® for particular purposes but would prefer to be informed and to consent to recording and to be asked permission before any data is shared. Positively, and in spite of these observations, people did not demand that the data collected should be deleted. Finally, some researchers tried to understand how people recorded by wearable cameras react and feel about this experience. Lindley et al. (2009) conducted a study to explore how people react to wearing and seeing others wearing SenseCam® in daily life. They asked all members of a family to wear the SenseCam® and collected their reflections about their own life and also each other's lives while they were wearing the device and after reviewing the pictures. At the end of this study, participants expressed an interest in learning

about each other's days, and seemed to make new discoveries, particularly when reviewing picture streams taken by their children. Adults seemed more concerned about how their lives might be depicted through a SenseCam® lens.

Perspectives

This review highlights the great potential of these new tools for future clinical and research investigations, as they open up new perspectives and new challenges. First of all, in the short term, it appears of prime importance to consider the technical difficulties that people using the device may encounter. Considering that elderly persons with severe memory deficits could greatly benefit from life-log browsing techniques, Caprani et al. (2010) designed specific interfacing or browsers that can easily be learned and used by this population. Enabling easy access to this technology for elderly people or patients with neurological or mental illnesses, who are those primarily concerned, will be an important challenge for future research. To go further in autobiographical memory investigation, it would be interesting to combine wearable cameras with physiological sensors, with the aim of better understanding what happens during memory encoding, for instance. Brindley et al. (2011) used this combination in a single case study to examine the impact of emotions experienced during the event (in particular, anxiety) on further autobiographical memory remediation using SenseCam®. This approach, including healthy volunteers or patients, could enable investigation of encoding processes and how emotional, cognitive and subjective states can influence both the encoding and retrieval of events in everyday life. Finally, using wearable cameras could be a specific step included in a more global therapy to remediate autobiographical memory. Participants might start using a wearable camera in their daily life to learn how to use the device and generate memory improvement, and then learn to become more autonomous, using the device whenever they particularly want to remember something.

Conclusion

In conclusion, this PRISMA review aimed at providing an overview of the first empirical evidence of wearable cameras' potential in autobiographical memory investigation and autobiographical memory remediation. Research using wearable cameras in the field of autobiographical memory is just starting and will expand in coming years. However, the 28 articles included in this review already show that wearable cameras have been used successfully with healthy volunteers to explore the neural correlates of everyday memory. In patients with epilepsy and transient amnesia, wearable cameras enabled accelerated long-term forgetting to be examined in ecological conditions, with better discrimination of the memory impairments caused by this condition. Finally, autobiographical memory remediation protocols demonstrated that wearable cameras are a useful resource to help patients to alleviate their memory deficits of diverse origins, including limbic encephalitis, brain injury, herpes simplex encephalitis, mild cognitive impairment, metastatic intracranial tumor, or Alzheimer's disease.

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References

Barnard, P. J., Murphy, F. C., Carthery-Goulart, M. T., Ramponi, C., & Clare, L. (2011). Exploring the basis and boundary conditions of SenseCam-facilitated recollection. *Memory, 19*(7), 758–767.

Berna, F., Potheegadoo, J., Aouadi, I., Ricarte, J. J., Allé, M. C., Coutelle, R., et al. (2016). A meta-analysis of autobiographical memory studies in schizophrenia Spectrum disorder. *Schizophrenia Bulletin, 42*(1), 56–66.

Berntsen, D. (1998) Voluntary and Involuntary Access to Autobiographical Memory. *Memory, 6*(2), 113–141

Berntsen, D. (2012). Spontaneous recollections: involuntary autobiographical memories are a basic mode of remembering. In: D. Berntsen and D. Rubin (Eds.), *In Understanding Autobiographical Memory* (p290–310). Cambridge: University Press.

Berry, E., Kapur, N., Williams, L., Hodges, S., Watson, P., Smyth, G., et al. (2007). The use of a wearable camera, SenseCam, as a pictorial diary to improve autobiographical memory in a patient with limbic encephalitis: a preliminary report. *Neuropsychological Rehabilitation, 17*(4–5), 582–601.

Berry, E., Hampshire, A., Rowe, J., Hodges, S., Kapur, N., Watson, P., et al. (2009). The neural basis of effective memory therapy in a patient with limbic encephalitis. *Journal of Neurology, Neurosurgery, and Psychiatry, 80*(11), 1202–1205.

Berryhill, M. E., Phuong, L., Picasso, L., Cabeza, R., & Olson, I. R. (2007). Parietal lobe and episodic memory: bilateral damage causes impaired free recall of autobiographical memory. *The Journal of Neuroscience, 27*(52), 14415–14423.

Blairy, S., Neumann, A., Nutthals, F., Pierret, L., Collet, D., & Philippot, P. (2008). Improvements in autobiographical memory in schizophrenia patients after a cognitive intervention: a preliminary study. *Psychopathology, 41*(6), 388–396.

Bluck, S. (2003). Autobiographical memory: exploring its functions in everyday life. *Memory, 11*(2), 113–123.

Botzung, A., Rubin, D. C., Miles, A., Cabeza, R., & Labar, K. S. (2010). Mental hoop diaries: emotional memories of a college basketball game in rival fans. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 30*(6), 2130–2137.

Boyer, P., Phillips, J. L., Rousseau, F. L., & Ilivitsky, S. (2007). Hippocampal abnormalities and memory deficits: new evidence of a strong pathophysiological link in schizophrenia. *Brain Research Reviews, 54*(1), 92–112.

Brindley, R., Bateman, A., & Gracey, F. (2011). Exploration of use of SenseCam to support autobiographical memory retrieval within a cognitive-behavioural therapeutic intervention following acquired brain injury. *Memory, 19*(7), 745–757.

Browne, G., Berry, E., Kapur, N., Hodges, S., Smyth, G., Watson, P., & Wood, K. (2011). SenseCam improves memory for recent events

and quality of life in a patient with memory retrieval difficulties. *Memory, 19*(7), 713–722.

Cabeza, R., Prince, S. E., Daselaar, S. M., Greenberg, D. L., Budde, M., Dolcos, F., et al. (2004). Brain activity during episodic retrieval of autobiographical and laboratory events: an fMRI study using a novel photo paradigm. *Journal of Cognitive Neuroscience, 16*(9), 1583–1594.

Caprani, N., Doherty, A. R., Lee, H., Smeaton, A. F., O'Connor, N. E., & Gurrin, C. (2010). Designing a touch-screen SenseCam browser to support an aging population. SIGCHI (Ed). In *CHI '10 Extended Abstracts on Human Factors in Computing Systems* (p. 4291–4296). New York: ACM.

Chu, S., & Downes, J. J. (2002). Proust nose best: odors are better cues of autobiographical memory. *Memory & Cognition, 30*(4), 511–518.

Conaire, C. Ó., Blighe, M., & O'Connor, N. E. (2009). SenseCam image localisation using hierarchical SURF trees. In B. Huet, A. Smeaton, K. Mayer-Patel, & Y. Avrithis (Eds.), *Advances in multimedia modeling* (pp. 15–26). Berlin Heidelberg: Springer.

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language, 53*(4), 594–628.

Conway, M. A. (2009). Episodic memories. *Neuropsychologia, 47*(11), 2305–2313.

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review, 107*(2), 261–288.

Crane, L., & Goddard, L. (2008). Episodic and semantic autobiographical memory in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 38*(3), 498–506.

Dalgleish, T., & Werner-Seidler, A. (2014). Disruptions in autobiographical memory processing in depression and the emergence of memory therapeutics. *Trends in Cognitive Sciences, 18*(11), 596–604.

Danion, J.-M., Cuervo, C., Piolino, P., Huron, C., Riutort, M., Peretti, C. S., & Eustache, F. (2005). Conscious recollection in autobiographical memory: an investigation in schizophrenia. *Consciousness and Cognition, 14*(3), 535–547.

Doherty, A. R., & Smeaton, A. F. (2008). Automatically segmenting lifelog data into events. In: *WIAMIS 2008 - 9th International Workshop on Image Analysis for Multimedia Interactive Services*, 7-9 May 2008, Klagenfurt, Austria.

Doherty, A. R., Ó Conaire, C., Blighe, M., Smeaton, A. F., & O'Connor, N. E. (2008). Combining image descriptors to effectively retrieve events from visual lifelogs. In: *MIR 2008 - ACM International Conference on Multimedia Information Retrieval*, 30-31 October, Vancouver, Canada.

Doherty, A. R., Moulin, C. J. A., & Smeaton, A. F. (2010). Automatically assisting human memory: a SenseCam browser. *Memory, 19*(7), 785–795.

Doherty, A. R., Moulin, C. J., & Smeaton, A. F. (2011). Automatically assisting human memory: A SenseCam browser. *Memory, 19*(7), 785–795.

Elvevåg, B., Kerbs, K. M., Malley, J. D., Seeley, E., & Goldberg, T. E. (2003). Autobiographical memory in schizophrenia: an examination of the distribution of memories. *Neuropsychology, 17*(3), 402–409.

Ernst, A., Blanc, F., Voltzenlogel, V., de Seze, J., Chauvin, B., & Manning, L. (2013). Autobiographical memory in multiple sclerosis patients: assessment and cognitive facilitation. *Neuropsychological Rehabilitation, 23*(2), 161–181.

Ernst, A., Blanc, F., de Seze, J., Sellal, F., Chauvin, B., & Manning, L. (2014). Impaired mental simulation of specific past and future personal events in non-depressed multiple sclerosis patients. *Journal of the Neurological Sciences, 345*(1–2), 68–74.

Ernst, A., Noblet, V., Denkova, E., Blanc, F., de Seze, J., Gounot, D., & Manning, L. (2015). Functional cerebral changes in multiple sclerosis patients during an autobiographical memory test. *Memory, 23*(8), 1123–1139.

Finley, J. R., Brewer, W. F., & Benjamin, A. S. (2011). The effects of end-of-day picture review and a sensor-based picture capture procedure on autobiographical memory using SenseCam. *Memory, 19*(7), 796–807.

Gillespie, A., Best, C., & O'Neill, B. (2012). Cognitive function and assistive technology for cognition: a systematic review. *Journal of the International Neuropsychological Society: JINS, 18*(1), 1–19.

Greenberg, D. L., & Rubin, D. C. (2003). The neuropsychology of autobiographical memory. *Corstex; a Journal Devoted to the Study of the Nervous System and Behavior, 39*(4–5), 687–728.

Greenberg, D. L., Eacott, M. J., Brechin, D., & Rubin, D. C. (2005). Visual memory loss and autobiographical amnesia: a case study. *Neuropsychologia, 43*(10), 1493–1502.

Hall, N. M., Gjedde, A., & Kupers, R. (2008). Neural mechanisms of voluntary and involuntary recall: a PET study. *Behavioural Brain Research, 186*(2), 261–272.

Herz, R. S. (2004). A naturalistic analysis of autobiographical memories triggered by olfactory visual and auditory stimuli. *Chemical Senses, 29*(3), 217–224.

Hodges, S., Berry, E., & Wood, K. (2011). SenseCam: a wearable camera that stimulates and rehabilitates autobiographical memory. *Memory, 19*(7), 685–696.

Irish, M., Lawlor, B. A., O'Mara, S. M., & Coen, R. F. (2011). Impaired capacity for autonoetic reliving during autobiographical event recall in mild Alzheimer's disease. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 47*(2), 236–249.

Jolley, D. J., & Benbow, S. M. (2000). Stigma and Alzheimer's disease: causes, consequences and a constructive approach. *International Journal of Clinical Practice, 54*(2), 117–119.

Kapur, P. N., Glisky, E. L., & Wilson, B. A. (2004). Technological memory aids for people with memory deficits. *Neuropsychological Rehabilitation, 14*(1–2), 41–60.

Kelly, P., Marshall, S. J., Badland, H., Kerr, J., Oliver, M., Doherty, A. R., & Foster, C. (2013). An ethical framework for automated, wearable cameras in health behavior research. *American Journal of Preventive Medicine, 44*(3), 314–319.

Kenealy, P. M., Beaumont, G. J., Lintern, T., & Murrell, R. (2000). Autobiographical memory, depression and quality of life in multiple sclerosis. *Journal of Clinical and Experimental Neuropsychology, 22*(1), 125–131.

Latorre, J. M., Serrano, J. P., Ricarte, J., Bonete, B., Ros, L., & Sitges, E. (2014). Life review based on remembering specific positive events in active aging. *Journal of Aging and Health, 27*(1), 140–157.

Lee, H., Smeaton, A. F., O'Connor, N. E., & Jones, G. J. (2006). Adaptive visual summary of lifeLog photos for personal information management. In: *the First International Workshop on Adaptive Information Retrieval* , October 2006., Glasgow, Scotland, U.K.

Lee, H., Smeaton, A. F., O'Connor, N. E., Jones, G., Blighe, M., Byrne, D., ... & Gurrin, C. (2008). Constructing a SenseCam visual diary as a media process. *Multimedia Systems, 14*(6), 341–349.

Lesser, I. M., & Friedmann, C. T. (1981). Attitudes toward medication change among chronically impaired psychiatric patients. *The American Journal of Psychiatry, 138*(6), 801–803.

Levine, B., Turner, G. R., Tisserand, D., Hevenor, S. J., Graham, S. J., & McIntosh, A. R. (2004). The functional neuroanatomy of episodic and semantic autobiographical remembering: a prospective functional MRI study. *Journal of Cognitive Neuroscience, 16*(9), 1633–1646.

Lindley, S. E., Randall, D., Glancy, M., Smyth, N. & Harper, R. (2009). Reflecting on oneself and on others: Multiple perspectives via SenseCam. Presented at the CHI 2009 workshop on Designing for Reflection on Experience.

Loveday, C., & Conway, M. A. (2011). Using SenseCam with an amnesic patient: accessing inaccessible everyday memories. *Memory, 19*(7), 697–704.

Lysaker, P. H., Davis, L. W., Warman, D. M., Strasburger, A., & Beattie, N. (2007). Stigma, social function and symptoms in schizophrenia and schizoaffective disorder: associations across 6 months. *Psychiatry Research, 149*(1–3), 89–95.

Martinelli, P., Anssens, A., Sperduti, M., & Piolino, P. (2013). The influence of normal aging and Alzheimer's disease in autobiographical memory highly related to the self. *Neuropsychology, 27*(1), 69–78.

McDougall, G. J., Buxen, C. E., & Suen, L. J. (1997). The process and outcome of life review psychotherapy with depressed homebound older adults. *Nursing Research, 46*(5), 277–283.

Mehl, S., Rief, W., Mink, K., Lüllmann, E., & Lincoln, T. M. (2010). Social performance is more closely associated with theory of mind and autobiographical memory than with psychopathological symptoms in clinically stable patients with schizophrenia-spectrum disorders. *Psychiatry Research, 178*(2), 276–283.

Milton, F., Muhlert, N., Butler, C. R., Benattayallah, A., & Zeman, A. Z. (2011a). The neural correlates of everyday recognition memory. *Brain and Cognition, 76*(3), 369–381.

Milton, F., Muhlert, N., Butler, C. R., Smith, A., Benattayallah, A., & Zeman, A. Z. (2011b). An fMRI study of long-term everyday memory using SenseCam. *Memory, 19*(7), 733–744.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Journal of Clinical Epidemiology, 62*(10), 1006–1012.

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews, 4*, 1.

Muhlert, N., Milton, F., Butler, C. R., Kapur, N., & Zeman, A. Z. (2010). Accelerated forgetting of real-life events in transient epileptic amnesia. *Neuropsychologia, 48*(11), 3235–3244.

Murphy, F. C., Barnard, P. J., Terry, K. A. M., Carthery-Goulart, M. T., & Holmes, E. A. (2011). SenseCam, imagery and bias in memory for wellbeing. *Memory, 19*(7), 768–777.

Nguyen, D. H., Marcu, G., Hayes, G. R., Truong, K. N., Scott, J., Langheinrich, M., & Roduner, C. (2009). Encountering SenseCam: personal recording technologies in everyday life. In *Proceedings of the 11th International Conference on Ubiquitous Computin. September, 2009. Orlando, Florida, USA.*

Palisson, J., Roussel-Baclet, C., Maillet, D., Belin, C., Ankri, J., & Narme, P. (2015). Music enhances verbal episodic memory in Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 37*(5), 503–517.

Pauly-Takacs, K., Moulin, C. J. A., & Estlin, E. J. (2011). SenseCam as a rehabilitation tool in a child with anterograde amnesia. *Memory, 19*(7), 705–712.

Pillemer, D. B. (2003). Directive functions of autobiographical memory: the guiding power of the specific episode. *Memory, 11*(2), 193–202.

Piolino, P. (2006). La mémoire autobiographique : Théorie et pratique en neuropsychologie. *Revue québécoise de psychologie, 27*(3), 65–85.

Piolino, P., Desgranges, B., Belliard, S., Matuszewski, V., Lalevée, C., De la Sayette, V., & Eustache, F. (2003). Autobiographical memory and autonoetic consciousness: triple dissociation in neurodegenerative diseases. *Brain: A Journal of Neurology, 126*(10), 2203–2219.

Piolino, P., Desgranges, B., Manning, L., North, P., Jokic, C., & Eustache, F. (2007). Autobiographical memory, the sense of recollection and executive functions after severe traumatic brain injury. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 43*(2), 176–195.

Piolino, P., Coste, C., Martinelli, P., Macé, A.-L., Quinette, P., Guillery-Girard, B., & Belleville, S. (2010). Reduced specificity of autobiographical memory and aging: do the executive and feature binding functions of working memory have a role? *Neuropsychologia, 48*(2), 429–440.

Potheegadoo, J., Cuervo-Lombard, C., Berna, F., & Danion, J.-M. (2012). Distorted perception of the subjective temporal distance of autobiographical events in patients with schizophrenia. *Consciousness and Cognition, 21*(1), 90–99.

Potheegadoo, J., Berna, F., Cuervo-Lombard, C., & Danion, J.-M. (2013). Field visual perspective during autobiographical memory recall is less frequent among patients with schizophrenia. *Schizophrenia Research, 150*(1), 88–92.

Potheegadoo, J., Cordier, A., Berna, F., & Danion, J.-M. (2014). Effectiveness of a specific cueing method for improving autobiographical memory recall in patients with schizophrenia. *Schizophrenia Research, 152*(1), 229–234.

Raes, F., Williams, J. M. G., & Hermans, D. (2009). Reducing cognitive vulnerability to depression: a preliminary investigation of MEmory specificity training (MEST) in inpatients with depressive symptomatology. *Journal of Behavior Therapy and Experimental Psychiatry, 40*(1), 24–38.

Rajaram, S. (1996). Perceptual effects on remembering: recollective processes in picture recognition memory. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 22*(2), 365–377.

Ricarte, J. J., Hernández-Viadel, J. V., Latorre, J. M., & Ros, L. (2012). Effects of event-specific memory training on autobiographical memory retrieval and depressive symptoms in schizophrenic patients. *Journal of Behavior Therapy and Experimental Psychiatry, 43*(Suppl 1), S12–S20.

Ridout, N., Dritschel, B., Matthews, K., & O'Carroll, R. (2016). Autobiographical memory specificity in response to verbal and pictorial cues in clinical depression. *Journal of Behavior Therapy and Experimental Psychiatry, 51*, 109–115.

Rubin, D. C., & Greenberg, D. L. (1998). Visual memory-deficit amnesia: a distinct amnesic presentation and etiology. *Proceedings of the National Academy of Sciences of the United States of America, 95*(9), 5413–5416.

Schacter, D. L. (2001). *Memory, brain, and belief*. Cambridge: Harvard University Press.

Scherer, M. J. (2005). Assessing the benefits of using assistive technologies and other supports for thinking, remembering and learning. *Disability and Rehabilitation, 27*(13), 731–739.

Seamon, J. G., Moskowitz, T. N., Swan, A. E., Zhong, B., Golembeski, A., Liong, C., et al. (2014). SenseCam reminiscence and action recall in memory-unimpaired people. *Memory, 22*(7), 861–866.

Sellen, A. J., Fogg, A., Aitken, M., Hodges, S., Rother, C., & 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. April, 2007. San Jose, California, USA.*

Serrano Selva, J. P., Latorre Postigo, J. M., Ros Segura, L., Navarro Bravo, B., Aguilar Córcoles, M. J., Nieto López, M., et al. (2012). Life review therapy using autobiographical retrieval practice for older adults with clinical depression. *Psicothema, 24*(2), 224–229.

Serrano, J. P., Latorre, J. M., Gatz, M., & Montanes, J. (2004). Life review therapy using autobiographical retrieval practice for older adults with depressive symptomatology. *Psychology and Aging, 19*(2), 270–277.

Silva, A. R., Pinho, S., Macedo, L. M., & Moulin, C. J. (2013). Benefits of SenseCam review on neuropsychological test performance. *American Journal of Preventive Medicine, 44*(3), 302–307.

Singer, J. A., Blagov, P., Berry, M., & Oost, K. M. (2012). Self-defining memories, scripts, and the life story: narrative identity in personality and psychotherapy. *Journal of Personality, 81*(6), 569–582.

St Jacques, P. L., Conway, M. A., & Cabeza, R. (2011a). Gender differences in autobiographical memory for everyday events: retrieval elicited by SenseCam images vs. *Verbal Cues. Memory, 19*(7), 723–732.

St Jacques, P. L., Conway, M. A., Lowder, M. W., & Cabeza, R. (2011b). Watching my mind unfold versus yours: an fMRI study using a novel camera technology to examine neural differences in self-

projection of self versus other perspectives. *Journal of Cognitive Neuroscience, 23*(6), 1275–1284.

Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: what is mental time travel, and is it unique to humans? *The Behavioral and Brain Sciences, 30*(3), 299–313 351.

Suddendorf, T., Addis, D. R., & Corballis, M. C. (2009). Mental time travel and the shaping of the human mind. *Philosophical Transactions of the Royal Society, B: Biological Sciences, 364*(1521), 1317–1324.

Sutherland, K., & Bryant, R. A. (2008). Autobiographical memory and the self-memory system in posttraumatic stress disorder. *Journal of Anxiety Disorders, 22*(3), 555–560.

Svanberg, J., & Evans, J. J. (2014). Impact of SenseCam on memory, identity and mood in Korsakoff's syndrome: a single case experimental design study. *Neuropsychological Rehabilitation, 24*(3–4), 400–418.

Svoboda, E., McKinnon, M. C., & Levine, B. (2006). The functional neuroanatomy of autobiographical memory: a meta-analysis. *Neuropsychologia, 44*(12), 2189–2208.

Teasdale, J. D., & Barnard, P. J. (1995). *Affect, cognition, and change: Re-modelling depressive thought*. Hove: Psychology Press.

Tulving, E. (2002). Episodic memory: from mind to brain. *Annual Review of Psychology, 53*, 1–25.

Watanabe, R., & Higuchi, T. (2016). Behavioral advantages of the first-person perspective model for imitation. *Frontiers in Psychology, 7*, 701.

Watanabe, R., Higuchi, T., & Kikuchi, Y. (2013). Imitation behavior is sensitive to visual perspective of the model: an fMRI study. *Experimental Brain Research, 228*(2), 161–171.

West, M. L., Yanos, P. T., Smith, S. M., Roe, D., & Lysaker, P. H. (2011). Prevalence of internalized stigma among persons with severe mental illness. *Stigma Research and Action, 1*(1), 3–10.

Williams, J. M., Healy, H. G., & Ellis, N. C. (1999). The effect of imageability and predicability of cues in autobiographical memory. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology, 52*(3), 555–579.

Williams, J. M. G., Barnhofer, T., Crane, C., Herman, D., Raes, F., Watkins, E., & Dalgleish, T. (2007). Autobiographical memory specificity and emotional disorder. *Psychological Bulletin, 133*(1), 122–148.

Wood, K., Fleck, R., & Williams, L. (2004). Playing with SenseCam. In Proceedings of Playing with Sensors: Exploring the boundaries of sensing for playful ubiquitous computing, Workshop at Ubicomp 2004, the 6th International Conference on Ubiquitous Computing. Retrieved from http://www.sussex.ac.uk/Users/rmmf20/SenseCamPlay.pdf.

Woodberry, E., Browne, G., Hodges, S., Watson, P., Kapur, N., & Woodberry, K. (2015). The use of a wearable camera improves autobiographical memory in patients with Alzheimer's disease. *Memory, 23*(3), 340–349.

Zacks, J. M., & Swallow, K. M. (2007). EVENT SEGMENTATION. *Current Directions in Psychological Science, 16*(2), 80–84.

Zacks, J. M., & Tversky, B. (2001). Event structure in perception and conception. *Psychological Bulletin, 127*(1), 3–21.