Supporting older and younger adults' memory for recent everyday events: a prospective sampling study using SenseCam

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1. Introduction

The aim of the present research was to examine AM for *everyday events* in older and younger adults, logged using a wearable camera, SenseCam (SC). While age-related memory changes have been observed across a number of memory tasks, in AM studies events are usually self-selected by participants and are therefore probably well-rehearsed, personally important, and emotionally salient. However, older adults often mention day-to-day difficulties in remembering everyday events (e.g. Jungwirth, Fischer, Weissgram et al., 2004; Mol, van Boxtel, Willems & Jolles, 2006), and since older adults' community independence and quality of life may depend in part on the ability to remember typical everyday activities, this is an important form of memory that, unusually, remains largely unstudied. The present research, then, examines older and younger adults' memory for everyday events and measures the effect of retrieval support, in the form of SC photographs captured during those events.

1.1 Autobiographical memory in ageing

Autobiographical memory is a rich and complex form of memory for events from one's own life, that incorporates both context-bound episodic event details and decontextualised[1] personal semantic details, the latter of which comprises factual knowledge about the self and others and information about routines and repeated events (M. A. Conway & Pleydell-Pearce, 2000; Renoult, Davidson, Palombo, Moscovitch & B. Levine, 2012). Several studies of AM in ageing have reported a deficit in older adults' ability to remember episodic event information (Ford et al., 2014; Habermas, Diel & Welzer, 2013, sample A; B. Levine, Svoboda, Hay, Winocur & Moscovitch, 2002; Piolino, Coste, Martinelli et al.,

[1] *Decontextualised* is used here in the sense that information is removed from the specific context of a single episode, rather than completely without context.

2010; Piolino, Desgranges, Benali & Eustache, 2002; Piolino, Desgranges, Clarys, et al., 2006; Ros, Latorre & Serrano, 2010; St. Jacques, Rubin & Cabeza, 2012) which mirrors the age-related deficit in laboratory tests of episodic memory (Nyberg, Bäckman, Erngrund, Olofsson & Nilsson, 1996). However, a growing body of evidence demonstrates that this is not always the case (Aizpurua & Koutstaal, 2015; Bluck, L. J. Levine & Laulhere, 1999; De Beni, Borella, Caretti, et al., 2013; Habermas et al., 2013, sample B; McDonough & Gallo, 2013; Schryer & Ross, 2014; Schulkind & Woldorf, 2005).

Most studies of AM in ageing have employed a retrospective sampling technique, wherein participants self-select which events to describe, either in response to a cue word (Beaman, Pushkar, Etezadi, Bye & M. Conway, 2007; De Beni et al., 2013; Maylor, Carter & Hallett., 2002; Ros et al., 2010; St. Jacques et al., 2012), a specified time period (Aizpurua & Koutstaal, 2015; B. Levine et al., 2002; Piolino et al., 2002, 2006, 2010), a particular emotion (Fernandes, Ross, Wiegrand & Schryer, 2008; Habermas et al., 2013, sample A; St. Jacques & B. Levine, 2007), or some other cue. During the process of searching for an appropriate event to describe, participants are likely to draw on memories that are well rehearsed and therefore more accessible (Galton, 1879; Harris, O'Connor & Sutton, 2015). Since test sessions necessarily only measure a small number of memories, and without a more specific retrieval cue, typical retrieval sessions are unlikely to probe memory for material that is less readily available. Previous research therefore demonstrates a deficit in older adults' memory for important or significant events.

Nevertheless, everyday interaction and competent goal-directed behaviour requires memory for a host of more mundane, everyday events. We need to remember things such as the last conversation or news from neighbours and friends, the fact that we did buy that needed spice two weeks ago, that our partner told us they will be out on Wednesday evening, and so on. Yet, we know very little about any age-related changes for this type of everyday AM.

Ross and Schryer (2014) note that constancies and repetitions form an integral part of everyday life, which may facilitate remembering, particularly for older people. Studies in which participants are required to generate scripts for routine events show that older and younger adults generate similar numbers of script items (Light & Anderson, 1983), and the script content is similar (Rosen, Caplan, Sheesley, Rodriguez, & Grafman, 2003), which suggests that access to generic event information is maintained in older age. Moreover, while both older and younger adults show a mnemonic benefit for material that is schema-consistent, under some circumstances this effect may be greater for older adults (Badham, Hay, Foxon, Kaur, & Maylor, 2016; Umanath & Marsh, 2014). On the other hand, repeated experiences of similar events can make retrieval of specific instances more difficult (Farrar & Goodman, 1992; Willén, Granhag, & Strömwall, 2016). In this paper we therefore explore whether age affects the retrieval of typical everyday events in the same way as older, well-rehearsed AMs.

1.2 Supporting AM with SenseCam

This study investigates the effect of SenseCam (SC) on everyday event memory. SC is a small camera that is worn around the neck, which automatically captures still images of the wearer's environment from his or her own perspective. Photographs are recorded whenever the device registers a change in external light, motion, acceleration, temperature or magnetic flux; in a stimulating environment SC will take a photograph approximately once every 9-10 seconds. Images can later be uploaded to a computer and presented to the participant as a retrieval cue (Hodges, Berry & Wood, 2011).

While SC has been shown to successfully support AM in amnesic patients (Berry, Kapur, L. Williams, et al., 2007; Loveday & M. A. Conway, 2011) there is little data on whether this effect can be extended to healthy older groups. However, previous research has shown that the use of SC can improve healthy young adults' memory relative to baseline performance. For example, in one study investigating memory consolidation support using an end-of-day review procedure, participants wore SC for a period of 5 days during their normal day-to-day activities. At the end of two of the days, they reviewed a random subset of images collected by their SC. After delays of 1, 3 and 8 weeks, participants were better at recognising their SC pictures, and their picture-cued recall reports contained more words, for those days on which they had reviewed SC images (Finley, Brewer & Benjamin, 2011). Another study used SC as a retrieval support, asking participants to recall basic event details (*who, what, where, when*) before and after viewing images captured 3 days, 10 days or 4 months earlier. At all retention intervals, participants were able to add more details to their memories after viewing SC images, and rated more of their memories as being "remembered" rather than "known" (Sellen, Fogg, Aitken, et al., 2007). In both of the studies described above, SC was worn for the entire day rather than for selected events. In contrast, in a study investigating reconsolidation of a discrete event, St. Jacques and Schacter (2013) found that reviewing SC images 48 hours after a museum tour led to an increase in both hits and false alarms on a subsequent recognition test. Similar findings were observed in older adults in a separate study, although the effect was reduced in the older group, and a modification of the original experimental design meant that participants did not wear SC during the tour and instead were shown standardised SC-like images during reactivation and recognition (St. Jacques, Montgomery & Schacter, 2015).

As the studies described above demonstrate, there are numerous ways SC can be used as a tool to support AM. One of the main challenges in selecting the most appropriate approach is that there is, as yet, no strong consensus on the theoretical basis from which to evaluate SC's effectiveness. That is, it is not empirically clear exactly *why* SC works as a memory aid. Hodges et al. (2011) suggest two possibilities: the first is that the sheer number of images captured by SC makes it likely that at least one of the images reflects the moment that a memory was encoded, and therefore will be effective in cognitively reinstating that moment. The second possibility is that the sequential nature of SC images resembles the way AMs are normally experienced (i.e. time-compressed, temporally ordered, visual, passively captured, field perspective, etc.), and therefore the sequence of images as a whole is important in creating the "SC effect". A small number of previous studies have found some support for the latter hypothesis, including the finding that passively captured images lead to better memory than actively captured images (Sellen et al., 2007), and that recognition memory is better after reviewing images from one's own SC, compared to images taken from an altered perspective (St. Jacques & Schacter, 2013). However, a recent review by Silva, Pinho, Macedo and Moulin (2016) emphasised the need for more research evaluating SC's potential to cue *recollection* (i.e. "something more" than what can be seen in the images), which is largely absent from the SC literature on healthy participants. In keeping with this, in the present study we examine the number and type of memory details produced in an ecologically valid cued recall procedure. If older adults show evidence of a decline in everyday AM performance, SC may be a useful tool to compensate for the deficit. This is especially of interest as lifelogging devices are becoming commonplace and are typically easy to use.

We also included a temporal order manipulation of the SC images, to examine the hypothesis that SC is an effective memory aid because the cue sequence is particularly compatible with human memory (Hodges et al., 2011). If this is the case, viewing SC image sequences in random temporal order should lead to poorer memory performance compared to viewing the images in forward order. In contrast, if the effectiveness of SC as a memory support is due to the high number of images it captures for each event, and therefore the increased likelihood of reinstating something that was originally encoded (Hodges et al., 2011), then the temporal order of the sequence should have no effect. One previous study (St. Jacques & Schacter, 2013) found that reactivating memory with a temporally distorted sequence of SC images led to worse subsequent recognition of related images in young adults. However, in that study only a small number of images were presented (6 per sequence) and the dependent variable was recognition of related images. In the present experiment, we examined whether narrative-style recall is also hurt by randomising the image sequence, which presents the opportunity to investigate whether SC can support recall of “something more” than what is shown in the images, as Silva et al. (2016) suggested. In addition, all images captured by SC were presented to participants, thereby allowing us to compare the two hypotheses put forward by Hodges et al. (2011).

In this study, therefore, we measured older and younger adults’ memory for recently experienced everyday events. Participants used SC to record a selection of events from a typical week, which were recalled after an interval of two weeks. The aim was to establish whether the age-related memory deficit for significant events across the lifespan was also evident in memory for more recent everyday events, and whether reviewing SC images affected the information recalled. The dependent variables of interest were episodic and semantic information, for two reasons: first, to maintain consistency with the previous research in the field of AM in ageing, so that our findings would be directly comparable to the findings concerning age differences in memory for significant events. Second, measuring episodic recall allows us to evaluate the effectiveness of SC for cueing recollective experience (Silva et al., 2016).

2. Method

2.1 Participants. Twenty-one young (age 18-32, *M*=24.62, *SD*=4.04; 18 females) and 21 older adults[2] (age 65-78, *M*=69.10, *SD*=3.53; 11 females) participated for a payment of £8 per hour. Young adults were recruited through advertisements displayed around the university, while older adults were recruited from the University of the Third Age (*n*=8), a local newspaper advertisement (*n*=7) and through word of mouth (*n*=6). All participants had self-reported normal or corrected-to-normal vision. Older adults were screened for cognitive impairment using a cut-off of 27 on the Mini Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975). Older adults were also screened for depression using the Geriatric Depression Scale, with a cut-off of 9 points (GDS; Yesavage, Brink, Rose, et al., 1983). No individuals were excluded on the basis of these screening measures. The full 4-subscale form of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was administered to all participants, and total years of education was recorded for both groups. *Table 1* shows the mean full-scale IQ and years of education for younger and older adults; differences were not significant (p>.05).

Table 1

Group IQ and education scores

	Young adults		Older adults	
Measure	*M*	*SD*	*M*	*SD*
IQ	115.52	11.90	118.67	17.61
Education	17.29	1.95	15.78	5.12

2.2 Design. A 2 (age group: young vs. older) x 3 (review condition: baseline vs. random temporal order (hereafter "random") vs. forward temporal order (hereafter "forward") x 2

[2] The older adult sample described here were predominantly a group of young-old participants (i.e. those aged 65-75; De Beni et al., 2013). However, the participants were not intentionally recruited as a young-old sample, and consequently one participant falls into the old-old category (i.e. those aged over 75). We therefore refer to the sample simply as *older adults*, to avoid misrepresentation.

(segment type: episodic vs. semantic)) mixed factorial design was employed, with review condition and detail type as repeated measures factors. The baseline condition measured participants' recall in the absence of any support from SC, while in the random and forward conditions participants were shown every image captured by SC during a given event in random order and forward order, respectively. The dependent variable was the average number of episodic and semantic segments recalled in each recall condition. Coding of the segments is described in detail below.

2.3 Materials & procedure. Participants visited the laboratory on three separate occasions. During the first session screening tests were administered and each participant was given a SC to take home. Training on the operation of the device was provided, and participants received a comprehensive written guide to assist with operating the camera and troubleshooting technical problems. In addition, participants were provided with short diary forms which they were asked to fill in for each recorded event. The information provided by the participants in the diary forms included an event title, date, start time and duration, and three subjective ratings of event characteristics (event frequency, familiarity of location, event distinctiveness). Event characteristic ratings were made on a scale of 1-10, with a score of 1 representing the lowest possible value (i.e. least frequent/familiar/distinctive).

2.3.1 Event-sampling phase. The day after the first session participants began the event-sampling week, in which they selected and recorded a minimum of 15 typical events distributed as evenly as possible over a period of five days. Participants were free to choose which events to record, although some basic criteria were specified in order to ensure that the resultant images would be of sufficient quality, and to encourage participants to record a range of different events. Specifically, an event was defined as anything lasting between 30 minutes and one hour in duration that could be easily titled and had a definite (though subjective) start and end point. Participants were given suggestions for “good” events (lunch with a friend, trip to the supermarket, visit to a museum, etc.), which typically involved some change of scenery or action so that the SC photographs did not all depict the same scene. They were specifically discouraged from recording events in which there was little movement, such as watching the television or working at a computer. This constraint was included to promote the difference between image sequences in the forward and random conditions, which in more visually static events might be too subtle. Finally participants were asked to record events during the daytime or in a brightly lit indoor space wherever possible since SC is not equipped with a flash, and to be aware that photograph quality would be diminished in low lighting conditions. At the end of the event sampling week, participants returned their SCs and their individualised stimuli were produced for the second phase.

2.3.2 Preparation of stimuli. Twelve of the 15 events for each participant were randomly selected for the recall sessions after excluding any events for which the photographs did not come out well (for example they were underexposed, or the participant’s clothing was covering the lens). In a number of cases, camera malfunctions meant that some of the photographs were not stored, resulting in the loss of one or more of the participant’s events. In such cases, participants proceeded to the recall phase with the maximum number of available events that was divisible by the three recall conditions (baseline, random, forward), such that the number of events recalled in each condition was equated. In total, 36 events were missing or excluded from each age group, therefore 432 events were tested in the recall phase (216 for each group). Selected events were allocated to a retrieval condition on the basis of the event characteristic data (*frequency, familiarity* and *distinctiveness*) provided by the participants during the event sampling phase, such that the distribution of salient events in each retrieval condition was controlled as far as possible. The allocation of events was also constrained by the requirement that retrieval conditions were split evenly over the two recall sessions (i.e. each recall session involved the recall of six events – two in each of the three conditions), and the oldest six events were recalled in the first session in order to equate retention interval.

2.3.4 Event recall. Two weeks (14 ±2 days) after the event sampling phase, participants returned to the lab on two separate dates to complete the event recall in two sessions, each lasting approximately 2 hours. In each recall session, participants recalled six events. The order of presentation of events was randomised within each recall session, so that although the oldest six events were recalled during the first session, they could be recalled in any order within that session. This in turn meant that the order of conditions was also randomised within each recall session. The following instructions were presented on the computer screen before each of the events.

> *Think back to the event in question and say aloud all the details that you can remember for that event – what you did, where you went, who you were with and so on, as well as anything you can remember about what things looked like, any conversations you had, any thoughts you had at the time and anything else at all that you can remember from that specific event.*

The first time these instructions were presented they were also repeated verbally, and emphasis was added to recall all possible details, even if they seemed insignificant. In the baseline condition, participants were given the title that they generated for the event in the sampling phase, as well as the date of the event, but did not see any SC photographs. Unlimited time was permitted in order for participants to talk about the event in as much detail as possible. In the random and forward conditions, additional instructions relating to the viewing of the photographs were presented alongside the above instructions before each event. Participants were instructed that they would see a sequence of images of the event captured by their SC, which may or may not be in the correct order. Participants were asked to verbally recall the details of the event while looking at the SC images.

During the recall session all stimuli were presented by a bespoke computer programme that set the maximum viewing time per SC image at 7s, which was determined in a pilot study to give older adults enough time to view the image carefully. Because the image sequence for each event sometimes contained a large number of similar SC images (e.g. sitting on the bus, talking to a friend in the street, standing in a queue, etc.) participants could press a key to move to the next image more quickly, and no minimum image presentation time was set. In addition, the sequence could be paused if more time was required to inspect a particular image. In practice, therefore, participants largely controlled the timing of their own image sequences, however the 7s automatic presentation time was kept in place to drive progression through the sequence of images.

Participants recalled the event while viewing the photographs, therefore were encouraged to recall information that was “something more” than what was depicted in the images (see Silva et al., 2016). The reasons for concurrent viewing and recall were two-fold. Firstly, if participants first reviewed the images and subsequently recalled the event, it was possible that some of the effect of SC would be missed if, in the intervening period, the reminder provided by SC was forgotten. Moreover, older adults may be more likely to forget the SC cues during such a delay, and thus recalling after review may have favoured the younger adults. Secondly, if participants recall events while looking at the images, it is subsequently easier to code the resultant memories. The reason for this is that the language used to describe what is in the pictures is easily distinguishable from the language used to describe the details of the memory that are not depicted. For example, information recognised within the pictures tends to be reported as a present tense commentary of the event (e.g. *That's me looking to see what we had in the cupboards*), particularly if both the experimenter and the participant view the images together. In contrast, remembered details tend to be reported in the past tense (e.g. *I looked in the cupboards to see if we had any spaghetti*). If the recall attempt took place *after* reviewing the pictures, the information that was seen in the images would be integrated into the recall narrative, and it would be very difficult to determine the source of the information without seeking explicit clarification from the participant on each point. Memories were reported orally, and responses were recorded using a digital hand-held voice recorder. During the recall sessions participants were able to take breaks at any time between recalling events.

2.3.5 Prompts & clarification. Where participants' recollections were overly general (e.g. *It was just my weekly trip to the supermarket*), the experimenter repeated the recall instructions in question form (e.g. "Try to be as specific as you can. Can you remember anyone you saw, any conversations you had, or anything you were thinking?"). In some instances participants were asked for clarification of information they provided, for example if it was not clear whether a location they were describing had been visited previously or just once. Participants who focused on describing what was shown in the photographs (e.g. *That's my husband, that's our kitchen…* etc.) were reminded that they should focus on the event instead and try to remember the details that were not necessarily depicted. If participants recalled something that appeared to be depicted in the images (e.g. *The man that served me had dark hair*) the experimenter asked the participant to clarify whether the image did indeed include the information.

2.3.6 Data processing. Audio files for each participant were transcribed and coded using a novel system. First, information in the transcripts was divided into coarse-grain segments that described a single concept or episode, similar to an idea unit in content/narrative analysis[3] (C. P. Smith, 2000). These were sometimes expressed as a simple sentence or a clause but often were longer if the concept or episode was described in more detail. For example, a participant who reported seeing a dog on their walk might additionally describe several of the dog's features, but the recollected information would be classified as one segment because it related to a single concept or idea. Examples of single segments at this coarse-grain level of coding are presented in *Appendix A.*

Importantly, any details that were deemed to be simply recognised from the images themselves were excluded from the analysis. Recognised details were usually easily identifiable by the language used to describe them (e.g. *that's my local park,* or *I remember that man).* Because the experimenter viewed the images at the same time as the participant, clarification was sought at the time for any ambiguous instances in which a participant appeared to simply describe what was visible in the picture. However, items that were recognised on the photographs and then elaborated were included in the analysis. To clarify, information was included in the analysis if it *explained* what was in the images, but not if it simply *described* the images.

[3] We did not follow previous coding schemes here, such as that of B. Levine et al. (2002), because attempts to do so highlighted some unique challenges presented by the data we collected. Firstly, because participants recalled events while viewing SC images, recall narratives were of a considerable length (number of words per participant: M=9181.02, SD=5228.17; range= 2482—21058), and tended to contain a lot of information, therefore coding entire narratives at a fine grain could take upwards of 10 hours for one participant. Secondly, the detailed nature of recall attempts in the present experiment meant that much of the information could reasonably be construed in various ways, which meant inter-coder reliability was difficult to achieve. For example, if a participant recalled going for a walk around their local neighbourhood, they might mention a number of places they walked to, through, or past. Reiteration of the act of walking could be seen as either repetition (i.e. they have already said they were on a walk) or separate episodic detail (i.e. they recall this particular location from the perspective of walking as opposed to some other form of transport). Such ambiguity is difficult to resolve without knowledge of the participant's recollective experience of each detail at the time of the test. Moreover, participants tended to recall the contents of each event in chronological order, which often involved recall advancing in time beyond the part of the event currently depicted in the SC image sequence. Subsequently, viewing images for a part of the event that had already been described frequently led to the addition of further recalled details which were somewhere between repetitions of what had already been recalled and new details (e.g. changing *I saw a black dog* to *I saw a brown dog*). That is, SC seemed to increase the lability of the event memory. Fine-grained coding required that these ambiguities be resolved within each sentence, whereas the segmentation method allowed for minor amendments to be incorporated into the narrative. In short, the system of Levine et al. is ideally suited to measure episodic detail in memories that are slightly less detailed, and less labile, than those measured in this study.

Individual segments were then coded as either episodic or semantic. In keeping with previous studies, in order to be classed as episodic, a segment had to be specific (i.e. describing a one-off, rather than a general or repeated event; B. Levine et al., 2002; Piolino et al., 2006), context-bound (i.e. inextricably tied to the context of that event, which includes thoughts that the participant remembered having at the time, but excludes reflections on the event that were generated later) and recollective (i.e. something that the participant "remembers" rather than "knows"; Tulving 1983, 1985). Episodic segments that were external to the event in question (those that described a separate event) were not included in the analysis. All other segments were classed as semantic, in the sense that the information they contained was decontextualized (i.e. not tied to one specific context). The semantic category therefore comprised a small, heterogeneous selection of personal and social knowledge, and information about routines (see *Appendix A*). All coding was initially completed by the first author, but four additional raters coded a random subset of the transcripts (n=10; same transcripts for all coders) to give a measure of the reliability of the system. Cohen's κ was calculated for each combination of the five raters and averaged at .80 (range .68-.89), suggesting good agreement between the independent coders.

A second stage of coding measured the level of detail reported for each episodic segment, which was rated on a scale of 1-5. This provided a more fine-grain measure of what was recalled, and here a distinction was made between short, simple details (e.g. *I took the train*) and more complex ideas, concepts or episodes (see *Appendix B*). It is important to note that this second round of coding comprised a scale rating, rather than a count of the total number of details. The reason for avoiding a detail tally is explained in Footnote 4, above, and to avoid confusion this rating will hereafter be referred to as the *specificity score*. Two additional independent coders rated the specificity of a subset participants' transcripts, and a two-way random intraclass correlation was computed to assess the consistency between raters (Shrout & Fleiss, 1979), which was found to be good (r_{ic}=.87; 95% CI = .79, .92).

3. Results

3.1 Preliminary analysis. We first checked whether the sampled events were allocated evenly across the three conditions. Our rationale was that events that are naturally more salient may be remembered in greater detail regardless of the retrieval condition, therefore biased allocation (e.g. more non-salient events in the baseline condition) may confound our experimental manipulation. To check for bias, we examined the three event characteristic ratings (*frequency*, *familiarity*, *distinctiveness*) recorded for each event during the sampling phase. The ratings were significantly correlated (see *Table 2.2.2*), such that less frequent and less familiar events tended to be more distinctive and, as expected, distinctive events were associated with greater episodic recall scores overall (i.e. collapsed across retrieval conditions).

To facilitate the analysis of event distribution, a composite salience score (out of 10) was calculated for each event by summing distinctiveness ratings with inverted frequency and familiarity scores, and averaging the total. This compound salience score (*Table 2*) was correlated more strongly with episodic recall than any of the individual ratings. The mean score for each group in each condition is presented in *Table 3*.

Table 2

Correlations between event characteristics and number of episodic segments recalled

	Frequency	Familiarity	Distinctiveness	Salience
Episodic	-.34**	-.31**	.21**	.38**
Frequency		.53**	-.35**	-.83**
Familiarity			-.20**	-.78**
Distinctiveness				.66**

**p<.001

Event salience was not significantly different across conditions (F(2,80)=.76, p=.47, η_p^2= .02) or age groups (F(1,40)=.66, p=.42, η_p^2= .02), and there was no interaction (F(2,80)=.62, p=.54, η_p^2=.02), suggesting that salient events were evenly distributed.

Table 3

Salience score (out of 10) across groups and conditions

	Baseline		Random		Forward	
Age Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Young adult	4.15	2.24	4.00	2.19	3.96	1.95
Older adult	4.44	2.08	4.43	2.05	4.15	1.99

3.2 Autobiographical recall. The following analyses were carried out on the average number of segments recorded for each participant in each condition, which are presented in *Figure 2A*. While some previous studies have investigated the ratio of episodic-to-total details within AM narratives (e.g. Ford et al., 2014; B. Levine et al., 2002), our primary interest is in whether older adults can remember the details of recent events as well as younger adults, therefore our dependent variables are the *number* of episodic and semantic segments recalled. This distinction is important, since a greater proportion of episodic information within a narrative does not necessarily mean that an event is better remembered. For example, using the proportion of episodic details, a memory containing two episodic segments and no semantic segments would be scored as more episodic than a memory containing 20 episodic segments and 10 semantic segments, despite the latter example clearly containing more specific information about the event. Nevertheless, to facilitate comparison across studies, we calculated the proportion of episodic details in addition to our main analyses, and these are presented in *Table 4*.

Table 4

Mean episodic-to-total ratios across conditions

	Baseline		Random		Forward	
Age Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Young adult	.79	.11	.75	.13	.74	.14
Older adult	.57	.20	.57	.20	.55	.18

Autobiographical recall was analysed in a 2 (age) x 3 (retrieval condition) x 2 (detail type: episodic vs. semantic) ANOVA. There was a main effect of condition ($F(2,80)=29.96$, $p<.0005$, $\eta_p^2=.43$): more segments were recalled in the random ($M=10.35$, $SD=5.36$, $p<.0005$) and forward ($M=11.88$, $SD=6.36$, $p<.0005$) conditions compared to baseline ($M=7.49$, $SD=4.88$), and more segments were recalled in the forward condition compared to the random condition ($p=.03$). There was also a main effect of segment type ($F(1,40)=39.14$, $p<.0005$, $\eta_p^2=.50$), with more episodic ($M=13.36$, $SD=7.75$) than semantic ($M=6.46$, $SD=4.56$) segments recalled overall. There was no main effect of age ($F(1,40)=.03$, $p=.87$, $\eta_p^2<.01$), and no interaction between age and condition ($F(2,80)=1.68$, $p=.19$, $\eta_p^2=.04$), but age did interact with segment type ($F(1,40)=9.22$, $p=.004$, $\eta_p^2 = .19$). The interaction between age and segment type was due to increased semantic recall in the older group ($M_{older}=7.98$, $SD=4.21$; $M_{younger}=4.93$, $SD=4.49$), but no significant group difference in episodic recall ($M_{older}=11.56$ vs. $M_{younger}=15.15$). There was no interaction between condition and segment type ($F(2,80)=.22$, $p=.80$, $\eta_p^2=.01$), thus the pattern of episodic and semantic recall was similar both with and without SC. There was no significant 3-way interaction ($F(2,80)=.41$, $p=.67$, $\eta_p^2=.01$).

[Figure 1 about here]

3.2.1 Specificity analysis. As noted above, specificity is used here to refer to the *average level of detail* within episodic segments. We use the term specificity to avoid confusion with the practice of tallying individual details, although the two approaches should be correlated. One possibility for the lack of age effect reported in the previous section may be that although the number of segments produced by each group was similar, the older adults' segments may be less detailed than the younger adults' segments. *Figure 2B* shows the mean specificity ratings across groups and conditions. The mean specificity rating of episodic segments was 1.74 (SD=.27). Specificity did not differ significantly between age groups ($F(1,40)=.70$, $p=.41$, $\eta_p^2=.02$; $M_{young}=1.78$, $SD=.23$; $M_{older}=1.71$, $SD=.31$) or across conditions ($F(2,80)=1.40$, $p=.25$, $\eta_p^2=.03$; $M_{baseline}=1.75$, $SD=.36$; $M_{random}=1.78$, $SD=.34$; $M_{forward}=1.70$, $SD=.27$), and there was no interaction ($F(2,80)=.56$, $p=.57$, $\eta_p^2=.01$). As such, no impairment was observed in older adults' recall, in either the number of episodic segments or the level of detail present in the segments, and the lack of age effect could not be attributed to coarse-grain coding.

[Figure 2 about here]

4. Discussion

4.1 The "SC effect". Consistent with previous research (Berry et al., 2007; Finley et al., 2011; Loveday & M. A. Conway, 2011; Sellen et al., 2007; St. Jacques & Schacter, 2013), it was found that reviewing SC images was associated with better recall of episodic event information, and this SC effect was evident for both older and younger adults. Two previous studies have also examined SC effects in older adults: St. Jacques et al. (2015) found that reactivating memory with SC-like photos improved recognition performance, while Silva, Pinho, Macedo and Moulin (2013) found that reviewing images of day-to-day activities improved performance on standardised memory measures. The present study extends these findings to include improvement in memory for everyday events as a result of viewing SC images.

Despite general acceptance of the notion that SC is a powerful memory aid (Silva et al., 2016), there has been little agreement in the literature about how to use SC to maximum effect. This is in part because there is as yet no theoretical consensus on why SC should be particularly effective (Silva et al., 2016). Hodges et al. (2011) noted that SC users often report that something trivial or mundane in the images is enough to trigger a “Proustian moment” (Loveday & M. A. Conway, 2011) of recollection, causing past images to flood into consciousness. This is consistent with our experiences of pilot testing the devices, and for that reason we chose not to eliminate any images from the sequences presented to participants in this study. However, even under the present experimental conditions in which participants sampled and recalled a relatively small number of daily events, using SC in this way is time-consuming. It is of practical as well as of theoretical interest, then, to understand what it is about SC images that proves to be effective in triggering AM.

In the present study we included a temporal order manipulation in order to test two competing hypotheses proposed by Hodges et al. (2011). The first hypothesis, was that SC’s effectiveness can be attributed to the sheer amount of information provided by the retrieval cue, such that in a sequence of hundreds of images, at least one or two are likely to depict moments that memories were encoded. The second hypothesis was that SC works because its mode of operation shares properties with AM, for example SC images are taken passively and from the wearer’s own perspective, and cue sequences are temporally compressed and temporally ordered. In the present experiment we addressed these two competing hypotheses using a temporal order manipulation. The former hypothesis predicts that randomising the order of images within the cue sequence should have a detrimental effect on SC's benefit, because the cue sequence is less similar to the way in which AM is experienced naturally. In contrast, if the amount of information in the cue is the important factor, then temporal order should have no effect on SC's benefit because forward order and random order cues sequences contain equal amounts of information. The results of the present study were broadly consistent with the hypothesis that the amount of information provided by SC images supports successful remembering. Although slightly more information segments were recalled when cue sequences were presented in forward order compared to random order, this temporal order effect was small, and both forward-order and random-order conditions were associated with a considerable recall benefit. St. Jacques and Schacter (2013) showed that randomising the order of a small number of SC images during a memory reactivation task hurt later recognition performance in young adults, and it may be that temporal order is of greater importance in shorter image sequences, where less information is available within the cue. Interestingly, in the present study the temporal order effect was observed for both episodic and semantic segments, suggesting that SC cues more than just recall of event-specific information.

4.1.1 Part-set cueing. One possible explanation for the apparent retrieval benefit observed in the SC conditions is that the presentation of images for a subset of events may have rendered the remainder of the events more difficult to recall. Part-set cueing is a form of retrieval-induced forgetting that has been observed in both younger and older adults (Marsh, Dolan, Balota, & Roediger, 2004). In typical part-set cueing procedures, participants study a list of items (e.g. categorised words), and at test are cued with a subset of the studied items (e.g. category labels/exemplars). The presentation of these cues reduces the number of non-cued items participants can recall (Slamecka, 1968). In the present study, it is possible that the presentation of SC images simultaneously cued the corresponding events and interfered with participants' ability to recall baseline events.

However, part-set cueing effects are not always observed for different types of stimuli. Significant inhibitory effects of part-set cueing have been found for shopping lists (Bovee, Fitz, Yehl, & Kelley, 2009) and expository text (Fritz & Morris, 2015) but for other stimuli, such as chess board layouts, uncategorised word lists, serial order, and complex scenes, part-set cues have been found to have either no effect or a facilitative effect on subsequent recall (Cole, Reysen, & Kelley, 2013; Fritz & Morris, 2015; Serra & Nairne, 2000; Slamecka, 1969; Watkins, Schwartz, & Lane, 1984). If the inhibitory effect of part-set cueing is assumed to arise from either the disruption of a preferred retrieval strategy or response competition during retrieval (e.g. Peynircioglu & Moro, 1995), then presumably it should only apply to the retrieval of related material within a single test rather than across multiple unrelated tests. In the present study the recalled events were encoded independently from one another, and were recalled separately; the recall of each event might therefore be argued to constitute a separate test, in the sense that different tasks in an episodic memory experiment might be considered to be unrelated.

Moreover, unlike typical part-set cueing procedures, event memories in the baseline condition of the present experiment were not non-cued, since participants were given the event title. The information required at retrieval was not therefore the event itself, but rather the specific details pertaining to that event. It might be that retrieval-induced forgetting occurs *within* events, such that details recalled early in the narrative inhibit the retrieval of additional details later in the narrative (i.e. output interference; Roediger, 1974); although beyond the scope of the present paper, this could be an interesting avenue for future study.

4.2 Episodic AM. In the present experiment we failed to demonstrate an age-related deficit in episodic AM even at baseline, when memory was not supported by the use of SC. While this is consistent with the findings from a handful of other studies (Aizpurua & Koutstaal, 2015; Bluck et al., 1999; De Beni et al., 2013; Habermas et al., 2013, sample B; McDonough & Gallo, 2013; Schryer & Ross, 2014; Schulkind & Woldorf, 2005), it is inconsistent with the popular conception of memory in old age, as well as with a larger number of studies that have found an impairment in older adults' episodic AM (Ford et al., 2014; Habermas et al., 2013, sample A; B. Levine et al., 2002; Piolino et al., 2002, 2006, 2010; Ros et al., 2010; St. Jacques et al., 2012). To our knowledge this was the first study to examine older adults' AM for prospectively sampled typical everyday events; most previous studies have employed a retrospective sampling approach whereby participants are provided with a generic cue and asked to select any related event from their past experience. Under such conditions, memories that are available for retrieval are likely to be those that are personally significant and/or well-rehearsed (e.g. Galton, 1879; Harris et al., 2015). It is possible that older adults performed as well as younger adults in the present study because their memory for everyday events is not impaired, however there are a number of other important differences between this and previous studies that could explain the lack of age-related deficit observed here, and which cannot be ruled out on the basis of the present findings.

One possibility is that the group of older adults tested in the present study were particularly high-functioning. It is well-understood that the process of cognitive ageing is heterogeneous (Ardila, 2007; Baltes & Carstensen, 1996; Rowe & Kahn, 1997), and that typical samples of older adults can vary widely in terms of cognitive abilities. It is possible, however, that either by chance or due to an unintentional sampling bias, the group of older adults participating in the present study were all high performers. If this were the case, we might reasonably expect that the same individuals would also perform as well as younger adults on other types of memory task. Although the participants in the present experiment did not complete any other tasks, it seems unlikely that cognitive superiority can account for the present findings, since older and younger groups were matched on both full-scale IQ and years of education. Nevertheless, the present findings do not preclude this possibility.

A second possibility is that the comparable performance observed here may have reflected some sort of general benefit of wearing SC during the event sampling phase. That is, the fact of wearing SC during event encoding could have boosted performance even for those events for which SC images were not reviewed. For example, thinking back to the times when SC was worn may have provided a specific retrieval cue that was able to counter any age-related deficit. Indeed, Sellen et al. (2007) found that young participants were better able to recall events for which they had worn SC compared to events for which they had not, even before reviewing the SC images. A related possibility is that the benefit of reviewing SC images at the retrieval stage could have extended to non-reviewed events that took place on the same day, or were same type of event as the reviewed events, by way of increased activation of associated temporal or semantic information. For example, viewing SC images for an event that took place in the morning could increase the availability of information about an event that took place that afternoon. It is possible that a generalised benefit of this sort could have supported older adults' performance enough to eliminate any episodic deficit that might be observed without SC.

4.3 Semantic AM. In the present study we also measured recall of semantic AM in older and younger adults. Following the work of a number of previous studies (e.g. B. Levine et al., 2002) we approached semantic information as a broad category of heterogeneous detail types, including repeated and temporally extended events, as well as autobiographical facts and general knowledge. Consistent with previous work (Addis, Wong & Schacter, 2008; B. Levine et al., 2002; Gaesser, Sacchetti, Addis & Schacter, 2011; Madore, Gaesser & Schacter, 2014), the results of the present study showed that older adults recalled more semantic information than younger adults, thereby extending the previous findings to include recently acquired memories for everyday events.

In the literature to date, relatively little attention has been paid to this seemingly highly reproducible finding. One possible explanation, according to B. Levine et al. (2002), is that the semantic increase is directly related to the difficulty of retrieving episodic details. That is, within the hierarchical structure of AM, specific episodic AMs are considered to be accessed via more general autobiographical information such as lifetime periods (M. A. Conway & Bekerian, 1987; M. A. Conway & Pleydell-Pearce, 2000). Levine et al. suggested that if episodic AMs cannot be retrieved, the retrieval attempt stops at the level of general information instead, thereby giving rise to an increase in semantic recall. The results of the present study are inconsistent with this view, since here the increase in semantic recall in older adults was observed in the absence of any episodic deficit.

B. Levine et al. (2002) proposed two more possible explanations for the increase in semantic recall in older adults. Firstly, they suggested that older adults may be better at applying knowledge and wisdom than younger adults, as proposed in the psychological growth model of cognitive ageing (LaBouvie-Vief & Blanchard-Fields, 1982). A similar conceptualisation was investigated by Habermas et al. (2013), who found an increase in searching for meaning in AM narratives between adolescence and middle age. Secondly, B. Levine et al. (2002) suggested that the increase in semantic recall reflected the need for older adults to contextualise their memories for a young adult experimenter (see James, Burke, Austin & Hulme, 1998). While evaluation of these explanations is beyond the scope of the present study, the robust nature of this finding makes it an interesting avenue for further study.

4.4 The episodic/semantic distinction in everyday memory. Several researchers have questioned the extent to which a strict episodic/semantic distinction applies to naturalistic memory outside the laboratory. Episodic memory by definition refers to specific, unique events, yet everyday experience is characterised by both constancy and repetition (Ross & Schryer, 2014). As both Neisser (1981) and Rubin and Umanath (2015) noted, memories of unique events may be reconstructed from multiple similar experiences, while semantic knowledge may be acquired from a single episode. The properties of an event may therefore be the basis of a somewhat arbitrary distinction in AM. Moreover, in practical terms, semantic AM is a broad category that typically incorporates any kind of explicit memory that is not strictly episodic. Recent advances have suggested that in fact some types of semantic AM (e.g. repeated events, autobiographical facts containing spatiotemporal content) are closer to episodic memory than to semantic memory, in terms of both phenomenological experience at the time of retrieval, and the brain areas that are implicated (Grilli & Verfaellie, 2016; Renoult et al., 2012). Accordingly, one might question the importance of a strict definition of episodic AM, particularly in older age. In the present study we used the episodic/semantic distinction to maintain consistency with previous work; this may have resulted in conservative estimates of how well participants remembered the recalled events since non-unique details (e.g. routines, repeated events) were classed as semantic, even if they accurately described what happened on the specific occasion in question. An alternative approach incorporating both types of detail into a single memory score may have had some benefits, particularly in accounting for the repetitive nature of typical everyday events. However, such a combined score would also be likely to overestimate event memory by not taking account of semantic AM details that were explanatory, off-topic, or highly abstracted (i.e. general knowledge). This issue highlights the need for further work to develop coding and classification systems to better reflect current accounts of semantic AM.

5. Conclusions

Wearable cameras are becoming increasingly accessible for everyday use. The findings of the present experiment, along with numerous previous studies, suggest that devices such as SC are able to provide effective support for everyday memory. This study extends the literature in this area by showing that SC increases healthy older and younger adults' recollection of details not shown in the photographs – that is, SC promotes recall of "something more" (Silva et al., 2016) than the images themselves. This study offers some preliminary support for the idea that the amount of information presented in the image sequence is the main factor in SC's success as a retrieval support. The question of what contributes to the "SC effect" is not only of theoretical interest, but also of practical importance if devices such as this are to be adopted as everyday memory aids. As lifelogging becomes more widespread and event capture becomes more frequent, understanding the mechanisms underlying SC support will be essential to its effective and efficient use.

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Appendix A

Examples of episodic and semantic segments

Episodic	Semantic
I remember she ordered something in black squid ink	The restaurant of the Royal Free Hospital is in the basement
We talked about the kind of difficulties within families and relationships and mothers and children, and how it's difficult to let go of your children	I usually arrive at 10:45 and my class is at half past
I gave him a tenner and he only gave me £3 back and I thought, 'That's a lot for a little bit', so I looked at my receipt and gave it back to him and said, 'Look you've charged me twice', and I asked for the money back and he gave it to me	I'm her only relative in London except for her brother with whom she has an on and off flawed relationship

Appendix B

Criteria for specificity coding

Criteria	Specificity score	Example
Single detail with no elaboration	1	I paid by card
Single detail with a little elaboration, possibly involving two modalities	2	The woman from the counter came over and said that whatever my wife had ordered they didn't have any more and what would she like instead?
More complex detail, usually temporally extended and/or involving two or more modalities	3	I remember triple checking whether I still had the lid because I put it in the right pocket of my blue coat but I thought I'd put it in the other one, so I thought I'd lost it but I hadn't.
Richly detailed recollection describing a distinct episode within the event	4	There was a gentleman down there calling out "Anyone paying by card?", and I asked the chap in front of me if he was paying by card and he said no, so I started to go down to that one but somebody else had already jumped the queue and got there but that was okay, because I arrived at someone who was just leaving and the cashier became free.
As above, but with more detail, giving the impression of exceptionally clear or vivid recollection	5	He was looking at this thing and I asked if he was alright. I think he was looking for an exam room and he said "Where is the Social Sciences room?" So I said, "Do you mean the Social Sciences building?" So I tried to explain that it was the massive glass tower across the road and you can't really miss it. I'd never seen him before but he looked completely lost and that's really clear in my memory. He seemed quite grateful.