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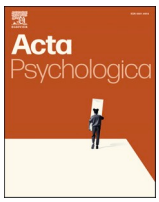

First-person and third-person lifelogging improves episodic memory

Erik Oudman [a,b,*], Isabelle F. Klukas [a], Tijmen van Teijlingen [a], Albert Postma [a,b]

[a] Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[b] Slingedael Center of Expertise for Korsakoff Syndrome, Slinge 901, 3086 EZ Rotterdam, the Netherlands

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ABSTRACT

Lifelogging, the practice of recording daily activities through photographs or videos, enhances memory in healthy individuals and those with memory disorders by aiding both memory consolidation and retrieval processes. This study, involving 32 adults in controlled settings, investigated its effectiveness on episodic memory from first and third-person perspectives. Contrary to expectations, perspective did not influence memory performance. Results indicated that lifelogging significantly improves subjective memory and the recall of visual, but not non-visual, information compared to non-lifelogging conditions. These findings suggest that lifelogging, regardless of perspective, holds promise for supporting episodic memory, especially for visual content, advocating for its wider application.

1. Introduction

Visual lifelogging is the act of wearing an automated camera that continuously and automatically takes photographs or movies from the wearer's first-person point of view (Hodges et al., 2006). A great number of case and group studies suggest that the review of lifelogging photographs can improve episodic memory in both healthy and memory-impaired individuals (Hong et al., 2024; Martin et al., 2022; Chow & Rissman, 2017; Dubourg et al., 2016; Silva et al., 2016; see van Teijlingen et al., 2021 for a review). These promising results raise hope that lifelogging can be efficient in easing the burden of episodic memory loss, such as dependency on care, decreased everyday functioning, impaired social relationships, and an impaired sense of the self (Hodges et al., 2006; Silva et al., 2016).

Lifelogging cameras are worn on a band around the neck or mounted to the upper body and possess a fisheye lens. Consequently, their photographs capture a wide field of view from the user's first-person perspective (i.e., egocentric perspective). Furthermore, lifelogging photographs are taken automatically, without user intervention. This happens either by default after a certain time interval (e.g., 30 s) or through special sensors on the camera which can detect changes in sound, light, temperature, or movement. Because most lifelogging devices have no display, the images usually need to be uploaded to a computer to review recordings (Hodges et al., 2006). Since 2009 several lifelogging cameras have been launched, such as the Sensecam, which was developed specifically for memory research by Microsoft Research Cambridge (Hodges et al., 2011, 2006). Other examples are the Vicon Revue (St. Jacques & Schacter, 2013), OMG Autographer (Selwood et al., 2020), Narrative Clip (Dassing et al., 2020), and the commercially available GoPro series. While all of the above-mentioned devices are similar in their functions, the newer cameras usually possess greater storage capacities and deliver better image quality. Furthermore, some lifelogging cameras now enable users to view the photographs directly on the device (Chow & Rissman, 2017). However, many of the devices have been discontinued by the developers due to a lack of substantial interest.

The evidence concerning the effectiveness of lifelogging in supporting episodic memory is predominantly positive. In several literature reviews, lifelogging has been evaluated as a promising, non-invasive memory aid which could be applied to support memory for a wide range of events from everyday experiences to special memorable occasions (Chow & Rissman, 2017; Dubourg et al., 2016; Silva et al., 2016; van Teijlingen et al., 2021). Two competing theories explain their effectiveness of lifelogging: the compatibility theory and the information theory (Conway, 2005; Hodges et al., 2011). The compatibility theory suggests that first-person (egocentric) photos enhance recall by aligning with natural memory encoding. In contrast, the information theory posits that memory benefits stem from the volume of details available, regardless of perspective (Conway, 2005; Hodges et al., 2011). Recent findings showing no significant difference between egocentric and allocentric images support the information theory, suggesting that the amount of information, rather than perspective, drives

* Corresponding author at: Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands.
E-mail address: e.oudman@leliezorggroep.nl (E. Oudman).

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memory enhancement. Additionally, participants naturally retrieving memories from an egocentric viewpoint may explain the absence of a perspective advantage (Rice & Rubin, 2009, 2011). Future research should examine whether similar effects occur in elderly individuals and those with memory impairments.

Broadly, lifelogging-mediated memory support can take place during two memory stages: First, lifelogging photographs have been used to support the consolidation of event memories in an attempt to increase their overall availability. More specifically, lifelogging photographs are reviewed one or more times to increase the chance that the depicted events can be successfully recalled at a later point in time. For the purpose of this article, this method is termed *lifelogging-supported consolidation*. Second, lifelogging photographs have been utilized to cue memory at the time of retrieval. Thereby, the images are reviewed during or just before attempting to remember the events they depict, in order to render the corresponding memories more accessible. For the remainder of this paper, this method of lifelogging is referred to as *lifelogging-supported retrieval*.

Lifelogging-supported consolidation has been applied in several case studies involving patients with memory impairments due to limbic encephalitis (Berry et al., 2007), acquired brain injury to the medial temporal lobe (Brindley et al., 2011), Korsakoff's syndrome (Svanberg & Evans, 2013), and mild cognitive impairment (Browne et al., 2011), as well as in a small-scale clinical study including patients with Alzheimer's disease (Woodberry et al., 2015). All of these studies indicate that with an increased amount of lifelogging photograph reviews, there is a corresponding increase in the number of details patients can remember from the events depicted in the images. Furthermore, two single-group experimental studies investigated whether a one-time review of lifelogging photographs could also be effective in improving episodic recall at a later point in time. Seamon et al. (2014) conducted a guided walking tour with 144 university students. Immediately after the tour, the students had 25 min to reminiscence about the event while reviewing either lifelogging photographs, verbal descriptions, or no records of the walking tour. However, no statistically significant difference between conditions were found in a free recall test one week later. In contrast, Finley et al. (2011) found that an end-of-the-day review of lifelogging photographs, as compared to no review, significantly improved cued recall one, three, and eight weeks later.

Lifelogging-supported retrieval has been investigated in two single case studies including patients with herpes simplex viral encephalitis (Loveday & Conway, 2011) and brain damage after a tonic-clonic seizure (Mair & Shackleton, 2021). Both cases showed improved recall with regard to the amount and quality of details they remembered of events that were cued by a lifelogging image review compared to the review of a written diary or no cues. Interestingly, in the study of Mair and Shackleton (2021), lifelogging-supported retrieval could even stimulate the recall of events for which there had been no memory at baseline but were connected in time or place. Further evidence comes from single-group experimental studies with healthy participants. For example, Sellen et al. (2007) let 19 undergraduate students use lifelogging devices to record their daily activities. When being asked to remember the lifelogged events a few days later, participants recalled significantly more details when their memory retrieval was supported by their own lifelogging photographs, as compared to another person's images. In a similar study, Mair et al. (2017) demonstrated that both younger adults ($n = 21$) and older adults (n = 21) showed significantly improved recall shortly after a lifelogging photograph review compared to no support. In 2019, Mair and colleagues repeated the study with 17 younger and 19 older adults in a more controlled setting. Two weeks after taking part in complex laboratory-encoded events, both groups performed significantly better on a standardized episodic recall questionnaire if they had been cued with lifelogging images compared to no cues.

As far as we know all of the studies discussed in the foregoing employed a first-person perspective in the images that were collected for the review. It is currently unknown whether a first-person (egocentric) perspective lifelogging is better in assisting consolidation and retrieval than a third-person (allocentric) perspective. According to the compatibility theory, lifelogging-mediated memory support is facilitated by the typical egocentric perspective of the photographs that is supposed to match the perspective in which episodic memories are naturally stored and retrieved (Conway, 2005; Hodges et al., 2011). Moreover, this perspective greatly overlaps with the perspective of the memory holder at the time of originally experiencing (encoding) the event (Hodges et al., 2006). In line with the principle of encoding specificity, the greater the match between a memory cue and the conditions during which the associated memory was formed, the higher are the chances for successful retrieval of the memory (Tulving & Thomson, 1973).

Rice and Rubin (2009) performed three consecutive studies showing that individuals often experience more than one perspective during memory retrieval, supporting the notion of an independent framework rather than mutually exclusive or complementary models. Perspectives are not fixed and can shift during recall, with implications for understanding how people mentally reconstruct personal events. A later study showed that people can flexibly shift between different vantage points when recalling events (Rice & Rubin, 2011). This flexibility suggests that third-person perspectives are not limited to specific spatial locations, which has implications for understanding how we mentally reconstruct past experiences. Recall from an allocentric perspective (i.e., third-person perspective) might facilitate better memory for the more abstract and external aspects of events, such as actions, and spatial relations among objects (Mcisaac & Eich, 2002; Rice & Rubin, 2009, 2011).

As far as we know, only one study thus far has adopted multiple perspectives in lifelogging. St. Jacques & Schacter, 2013asked 41 healthy participants to go on a self-guided museum walking tour while wearing a lifelogging device. 48 h later, participants reviewed lifelogging images of stops of the museum tour in two different conditions. In the reactivation-match condition, participants viewed their images from an unchanged egocentric perspective. In the reactivation-mismatch condition, participants reviewed images of the same stops but the perspective of the images was altered in angle, height, or both. In a recognition test another 48 h later, participants were significantly more confident in their ability to recognize which stops they had taken during the museum tour when these stops had been reviewed in the reactivation-match condition as compared to the reactivation-mismatch condition. Furthermore, their recognition memory for stops in the reactivation-match condition was significantly higher. These findings support the earlier mentioned compatibility theory (Conway, 2005; Hodges et al., 2011). A key difference between the present study and St. Jacques and Schacter (2013) lies in how perspective was manipulated and its impact on memory retrieval. St. Jacques & Schacter altered the visual perspective of lifelogging images during a reactivation phase, modifying their angle, height, or rotation before a recognition memory test. Their findings supported the compatibility hypothesis, which suggests that memory retrieval benefits from a consistent egocentric perspective between encoding and recall. In contrast, our study directly compares first-person (egocentric) and third-person (allocentric) perspectives without modifying images post-encoding. Unlike their within-subjects manipulation, we employ a between-groups design to assess whether retrieval benefits stem from alignment with natural memory processes (compatibility hypothesis) or the amount of contextual information available (information hypothesis;Conway, 2005; Hodges et al., 2011). The allocentric perspective, which includes the participant within the scene, may provide unique retrieval advantages absent in egocentric lifelogging (Rice & Rubin, 2009, 2011).

Based on the present overview, it is evident that visual lifelogging has yielded positive outcomes for both memory-impaired individuals and healthy subjects. The research has extensively covered the benefits of lifelogging with an emphasis on a first-person (egocentric) perspective. Nevertheless, a research gap emerges when comparing the

effectiveness of first-person (egocentric) and third-person (allocentric) perspectives in lifelogging. Though the current literature and the compatibility theory suggest more effectiveness when using an egocentric perspective, because of the congruence with the original viewpoint at encoding (Conway, 2005; Hodges et al., 2011), the allocentric perspective could have other benefits (Mcisaac & Eich, 2002; Rice & Rubin, 2009, 2011). This has not been investigated thoroughly. Closer examination is vital because it addresses the foundations of the mechanisms for episodic memory recall with respect to lifelogging. Furthermore, more evidence can support the effectiveness of lifelogging as a successful tool for memory rehabilitations.

In light of the foregoing the present study aimed to further verify the effectiveness of lifelogging-mediated episodic memory aids, by examining the impact of review perspective in both lifelogging supported consolidation and lifelogging supported retrieval, whilst comparing the effects of an egocentric and allocentric perspective. For our study, one group of healthy young participants reviewed controlled events in the lab with help of egocentric images and the other group with help of allocentric perspective lifelogging images. We next tested the effects of lifelogging supported retrieval by assessing recall immediately after a lifelogging review. Moreover, lifelogging-supported consolidation was compared across groups by assessing participants' subjective and objective episodic recall 24 h after the lifelogging reviews.

2. Methods

2.1. Participants

We enrolled 32 healthy adults in our study. Participants were randomly allocated to either the egocentric (first-person) perspective group ($n = 16$) or the allocentric (third-person) perspective group (n = 16). The participants' age ranged between 20 and 27 years in the egocentric (M = 23.25, SD = 2.46) and 21 to 37 years in the allocentric perspective group (M = 25.81, SD = 4.69) ($t(30) = 1.93$, $p > .05$). The majority of participants in both groups were female (egocentric perspective group: 13 females, 3 males; allocentric perspective group: 10 females, 6 males) (X^2 (2, $N = 32$) = 1.39, $p > .05$). Level of education was as follows: 25 % in the egocentric perspective group had a High School degree, 50 % had a Bachelor's degree, and 25 % had a Master's degree. In the allocentric perspective group, 12.5 % had a High School degree, 37.5 % had a Bachelor's degree, and 50 % had a Master's degree. All participants were 18 years or older, had normal or corrected to normal vision, and good English proficiency. Additionally, participants had internet access to participate in the research project. Exclusion criteria were colour blindness, a diagnosed perceptual, memory, or attention disorder, or a (history of a) diagnosed mental health disorders or brain injury. Six participants had to be omitted from the original sample which consisted of 38 participants. Three of these participants dropped out before the end of the experiment. Furthermore, one participant met an exclusion criterion, another participant had technical difficulties, and a final participant was an outlier concerning the time intervals at which she completed the second and third part of the experiment. Participation in the study was voluntary but it was rewarded with either 16 Euro or two research participation hour credits (PPU). Those PPU are needed by the social science students of Utrecht University to complete their bachelor's. The study was approved by the Faculty Ethics Review Committee (FETC) of the Faculty of Social Sciences, Utrecht University (file number: 21–1956).

2.2. Design

Four similar mixed-factorial designs were employed to assess the two dependent variables 'subjective episodic memory strength' and 'objective episodic memory strength' in both the lifelogging-supported consolidation and lifelogging-supported retrieval manipulation. In each case, the independent variables were 'Perspective' (egocentric perspective vs. allocentric perspective) and 'support type' (review vs. control/baseline). Additionally, the quasi-independent variable 'type of information' (visual vs. non-visual) was created by splitting the variable 'objective episodic memory strength' into scores for visual and non-visual recalled information. 'Perspective' was a between-subjects factor and 'support type' and 'type of information' were within-subjects factors. However, 'type of information' could only be considered for 'objective episodic memory strength'.

3. Materials and procedure

Participants were recruited through the online research participation platform of Utrecht University (Sona Systems). Moreover, an advertisement for the study was posted on social media platforms (Facebook and WhatsApp). Finally, flyers and posters that advertised the study were distributed at Utrecht University. The study took place on three consecutive days (see Fig. 1 for an overview of the study).

3.1. Procedure

3.1.1. Day 1

The first part of the experiment took place in the laboratory of the Faculty of Social Sciences at Utrecht University. Participants provided written informed consent and demographic information, including gender, age, and highest level of education. They then attended two separate 5-min events in different research rooms (referred to as Event A and Event B in Fig. 1). Each room contained six unrelated objects (e.g., a towel, a book, a tennis ball) and had audio recordings of nature sounds playing in the background to create an immersive environment.

In each room, participants performed three tasks: a 1-min conversational exercise, a verbal rating of their experience in the room (e.g., "On a scale from 1 (not pleasant at all) to 7 (very pleasant), how would you rate your experience in this room?"), and had to complete three simple tangram puzzles (see Fig. 2 for an example). (See Figs. 3 and 4.)

A tangram puzzle is a traditional Chinese dissection puzzle consisting of seven flat pieces called "tans." These pieces include five triangles of various sizes, one square, and one parallelogram. The objective of a tangram puzzle is to rearrange the seven pieces to form a specific shape, such as an animal, object, or geometric figure, without overlapping them. The pieces must be used in their entirety and can be rotated or flipped. This setup aimed to simulate complex real-life events and provide content for subsequent memory tests. The tangram pieces were cleaned after the test event. Due to Covid-19 restrictions, participants attended the sessions alone and communicated with the researcher via walkie-talkies. The tangram pieces were cleaned after the test event.

The two rooms were designed to be distinct yet comparable in terms of memorability. For instance, they featured different objects, background sounds, and tasks, and each room was colour-coded as either 'The Blue Room' or 'The Green Room' to help participants differentiate between them. Between sessions, participants had a 5-min break in a separate room to ensure they viewed each event as a distinct experience. During the break, participants were asked not to use their phones and could play a simple online game instead.

To collect lifelogging data, each participant wore a GoPro Hero 4 camera mounted on a harness to capture egocentric (first-person) images, while another GoPro Hero 9 camera mounted in the room captured allocentric (third-person) images. Both cameras took photos every 10 s.

3.1.2. Day 2

On the second day, participants reviewed lifelogging photographs as part of the memory consolidation phase. They received a link via email and had a 4-h window to complete the review online, which took approximately 15 min. Participants first viewed six neutral images that were unrelated to either Event A and B(control condition) and, after a 1-min break, six lifelogging photographs for Event A (review condition). They were instructed to study each image for 10 s and try to recall as

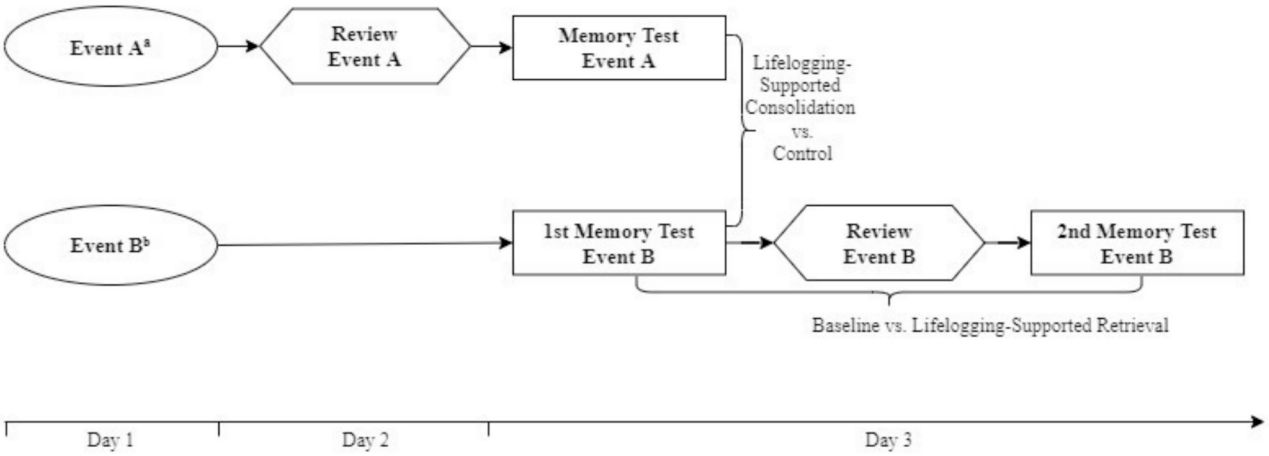

Fig. 1. Experimental Procedure
Note. Fig. 1 shows the experimental procedure and conditions which were compared with each other to investigate the effects of both lifelogging-supported consolidation and lifelogging-supported retrieval. a
We counterbalanced across participants whether the blue room or the green room provided Event A. b
We counterbalanced across participants whether the blue room or the green room provided Event B. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Example of a tangram puzzle of a tree.

much detail as possible. Lifelogging photographs were carefully selected based on image quality and distinctiveness, to ensure the most relevant content of the events was captured, rather than adhering to an equal time distribution. Whether egocentric or allocentric images were used depended on to which group the participant had been assigned (first person perspective review versus third person perspective review).

3.1.3. Day 3

On the third day, participants completed a memory test for both events. This session took place 46–50 h after the initial events and lasted about 60 min. First, participants were tested on their memory of Event A (review condition), followed by Event B (control condition). To measure the effects of lifelogging-supported retrieval, participants then reviewed lifelogging photographs of Event B and immediately completed a second session of the memory tests for this event.

The memory tests included two parts: subjective and objective episodic recall. Subjective recall was assessed through 10 items across four subscales (overall memory, target memory, spatial context memory, and temporal order context memory) using a 7-point Likert scale. Objective recall was measured by eight items across four subscales, consisting of both open-ended and multiple-choice questions. Participants were instructed to re-evaluate their memories instead of simply repeating previous answers.

All test items were chosen and constructed on basis of the relevant literature on episodic recall and were piloted with five participants to ensure clarity and accuracy. For detailed information on the questionnaires, please refer to Appendices A and B (Tables 3 and 4).

3.2. Counterbalance procedure

A complex counterbalancing procedure was employed. The variations in the experimental conditions included: (1) the order in which participants visited the two rooms on Day 1, (2) which room was assigned to each perspective condition (consolidation vs. retrieval), and (3) the order in which the rooms were reviewed on Day 3. These three factors were fully counterbalanced across participants, resulting in four orders in which the participant could do the full experiment. The different event assignments within a room (e.g tangram puzzles) were always performed in a fixed order within the rooms were not counterbalanced. On Day 3 all participants first recalled the consolidation event followed by the retrieval event.

3.3. Data analysis

Data were analyzed using the statistical program IBM SPSS Statistics [Version 23]. A simple descriptive analysis of the variables age, gender, and level of education was conducted to provide a demographic overview of the participants. Independent t- and chisquared tests were

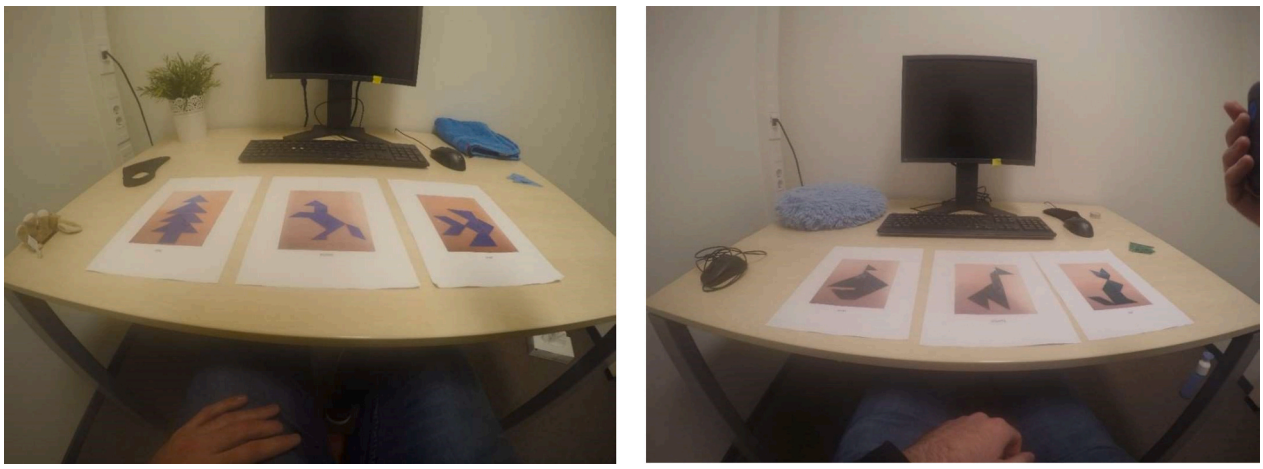

Fig. 3. Example of an Egocentric Perspective lifelogging photograph from the Blue Room (left) and Green room (right)
Note. The images on the table are the templates for the three tangram puzzles which the participants had to complete during the event. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

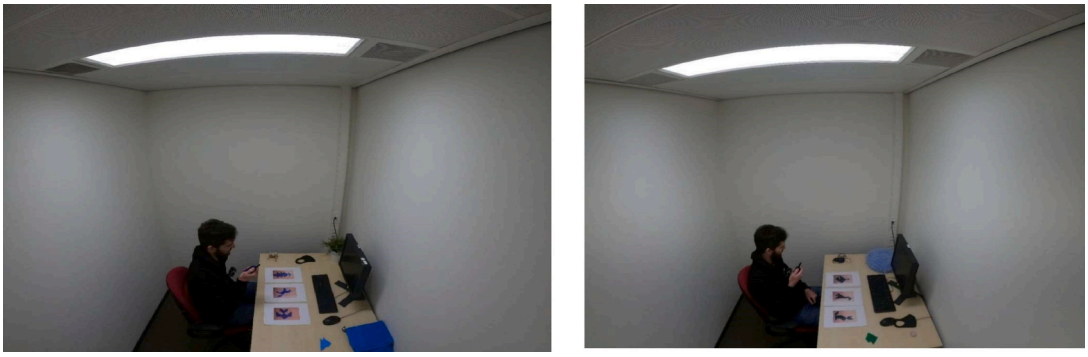

Fig. 4. Example of an Allocentric Perspective lifelogging photograph from the Blue Room (left) and Green Room (right)
Note. The images on the table are the templates for the three tangram puzzles which the participants had to complete during the event. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

conducted to check for potential significant demographic differences between the egocentric perspective group and allocentric perspective group. Besides, a descriptive analysis of participants answers concerning the perspective from which they retrieved the memories of the events at each test was carried out. Moreover, for each variable, Shapiro-Wilk (Shapiro & Wilk, 1965) tests were conducted to analyze the data for normality and boxplots were created to check for potential outliers.

To investigate whether lifelogging-supported consolidation could improve participants' episodic memory performance, it was tested whether the participants' subjective and objective memory scores for the event in the review condition were significantly higher than for the event in the control condition. Additionally, it was tested whether such a potential effect was influenced by the perspective of the lifelogging photographs used. For objective memory scores, it was also assessed whether the possible effects of support type and perspective were significantly different for visual compared to non-visual information. Therefore, a 2 × 2 mixed factorial ANOVA with the factors 'perspective' and 'support type' was conducted with the subjective memory scores, and a 2 × 2 × 2 mixed factorial ANOVA with the factors 'perspective', 'support type', and 'type of information' was conducted with the objective memory scores. A similar 2 × 2 ANOVA was performed to investigate whether lifelogging-supported retrieval could benefit participants' subjective episodic memory performance and whether the perspective of the lifelogging images played a role in that. Furthermore, a similar 2x2x2 ANOVA was conducted to investigate the effect of lifelogging-supported retrieval on objective episodic memory performance for visual and non-visual information across both perspective groups.

4. Results

Table 1
Means (M) and standard deviations (SD) for the allocentric perspective group (n = 16) and the egocentric perspective group (n = 16).

	Consolidation M (SD)	Retrieval M (SD)	Control M (SD)
Subjective Episodic Memory Strength (score: 7–70)	1st: 52.31 (5.20) 3rd: 55.81 (5.90)	1st: 49.75 (6.47) 3rd: 52.25 (8.14)	1st: 47.06 (5.97) 3rd: 49.94 (8.40)
Objective Episodic Memory Strength (score: 0–10)	1st: 11.88 (3.02) 3rd: 11.06 (2.57)	1st: 12.56 (2.40) 3rd: 12.88 (1.92)	1st: 10.03 (2.62) 3rd: 9.94 (1.97)
Objective Episodic Memory Strength for visual information Score (0−10)	1st: 6.00 (2.39) 3rd: 5.56 (2.13)	1st: 7.44 (1.93) 3rd: 7.31 (1.66)	1st: 4.75 (2.44) 3rd: 4.25 (2.02)
Objective Episodic Memory Strength for non-visual information Score (0–10)	1st: 5.88 (1.35) 3rd: 5.50 (1.32)	1st: 5.13 (1.49) 3rd: 5.56 (1.58)	1st::5.28 (1.63) 3rd: 5.69 (1.75)

Note. 1st: egocentric (first-person) perspective, 3rd: allocentric (third-person) perspective.

Table 2
Frequencies of self-reported memory retrieval perspectives per support type for the egocentric (n = 16) and allocentric (*n* = 16) perspective group.

Self-reported perspective/ Condition	Egocentric Consolidation	Allocentric Consolidation	Egocentric Retrieval	Allocentric Retrieval	Egocentric Control	Allocentric Control
Egocentric perspective	8	7	10	6	10	8
Allocentric perspective	1	0	2	2	1	1
Both perspectives	7	9	4	8	5	7

Note. The frequencies show how many participants reported retrieving the memory of the event in each condition from an egocentric perspective, allocentric perspective or both perspectives.

5. Subjective episodic memory

First, we analyzed the effect of lifelogging-supported consolidation on the participants' subjective perception of their episodic memory performance across both the egocentric and allocentric perspective group. There was a strong significant main effect of 'review support type' ($F(1,30) = 18.53$, $p < .001$, partial $\eta^2 = 0.38$). Independent of the perspective groups, participants' scores in the review support type were significantly better ($M = 54.06$, $SD = 5.75$) than in the control condition ($M = 48.50$, $SD = 7.32$), suggesting beneficial effects of lifelogging on subjective memory. There was no statistically significant main effect of 'perspective' ($F(1, 30) = 2.84$, $p = .103$, partial $\eta^2 = 0.09$), as well as no statistically significant 'perspective' by 'review support type' interaction effect ($F(1, 30) = 0.06$, $p = .811$, partial $\eta^2 < 0.01$), suggesting that first-person lifelogging was as effective as third-person lifelogging in enhancing memory.

Moreover, we tested the effects of lifelogging-supported retrieval on participants' subjective memory performance across both perspective groups. For that reason, a 2 (perspective: egocentric perspective vs. allocentric perspective) x 2 (review support type: review vs. baseline) mixed factorial ANOVA was conducted. The analysis yielded a strong effect-size significant main effect of 'review support type', ($F(1, 30) = 5.44$, $p = .027$), partial $\eta^2 = 0.15$. Irrespective of the perspective from which lifelogging photographs had been reviewed, participants scored significantly better in the review support type ($M = 51.00$, $SD = 7.34$) than in the baseline condition ($M = 48.50$, $SD = 7.32$). There was no statistically significant main effect of 'perspective', ($F(1, 30) = 1.30$, $p = .263$, partial $\eta^2 = 0.04$. Furthermore, there was no statistically significant 'perspective' by 'review support type' interaction effect, ($F(1, 30) = 0.03$, $p = .862$, partial $\eta^2 < 0.01$), suggesting that both lifelogging conditions were equally effective.

6. Objective episodic memory

We assessed whether lifelogging-supported consolidation with lifelogging images from one or both perspectives had an effect on the number of visual and non-visual details participants objectively recalled of the events. A medium effect-size significant main effect of 'review support type' was found ($F(1, 30) = 7.17$, $p = .012$, partial $\eta^2 = 0.19$), suggesting beneficial effects of lifelogging on objective memory. This main effect was qualified by a significant medium effect-size 'review support type' by 'type of information' interaction effect, ($F(1, 30) = 4.41$, $p = .044$, partial $\eta^2 = 0.13$), suggesting a beneficial effect of lifelogging for visual but not non-visual information. No statistically significant main effect of 'perspective', ($F(1, 30) = 0.39$, $p = .535$, partial $\eta^2 = 0.01$), or 'type of information' alone, ($F(1, 30) = 1.05$, $p = .313$, partial $\eta^2 = 0.03$), was found, suggesting that both forms of lifelogging are equally effective. Furthermore, no statistically significant 'review support type' by 'perspective', ($F(1, 30) = 0.42$, $p = .522$, partial $\eta^2 = 0.01$); 'type of information' by 'perspective', ($F(1, 30) = 0.31$, $p = .581$, partial $\eta^2 = 0.01$); or 'review support type' by 'perspective' by 'type of information', ($F(1, 30) = 0.68$, $p = .418$, partial $\eta^2 = 0.02$), interaction effects were found, suggesting that the beneficial effect for objective visual information of lifelogging was comparable between conditions.

Finally, we measured whether lifelogging-supported retrieval with lifelogging photographs from an egocentric or allocentric perspective had an effect on participants' objective recall of visual and non-visual details of the events. Therefore, a 2 (perspective:

egocentric perspective vs. allocentric perspective) x 2 (review support type: review vs. baseline) x 2 (type of information: visual. vs. nonvisual) mixed factorial ANOVA was conducted. The results demonstrated a strong significant main effect of 'review support type', ($F(1, 30) = 44.95$, $p < .001$, partial $\eta^2 = 0.60$). Again, this effect was qualified by a strong significant 'review support type' by type of information' interaction effect, ($F(1, 30) = 103.57$, $p < .001$, partial $\eta^2 = 0.78$). Recall scores in the review support type differed significantly from recall scores in the baseline condition (2.88, $p < .001$) only when objective episodic memory strength for visual information was considered. No statistically significant main effect of 'perspective', ($F(1, 30) = 0.03$, $p = .874$, partial $\eta^2 < 0.01$), or 'type of information' alone, ($F(1, 30) = 1.11$, $p = .300$, partial $\eta^2 = 0.04$), appeared. Similarly, no statistically significant interactions effects were found: 'review support type' by 'perspective', ($F(1, 30) = 0.25$, $p = .622$, partial $\eta^2 < 0.01$); 'type of information' by 'perspective', ($F(1, 30) = 0.55$, $p = .465$, partial $\eta^2 = 0.02$); or 'review support type' by 'perspective' by 'type of information', ($F(1, 30) = 0.34$, $p = .566$, partial $\eta^2 = 0.01$).

7. Discussion

The current study aimed to further investigate the effectiveness of lifelogging-supported consolidation and retrieval, as well as to explore whether the perspective of lifelogging photographs plays a role in their memory-enhancing effects. Our results demonstrated significant improvements in participants' subjective assessment of their episodic recall when either memory consolidation or retrieval was supported by lifelogging reviews compared to no support. Although both lifelogging-supported consolidation and retrieval were found to improve memory, no significant differences were observed between the two in their effectiveness, with both primarily benefiting the recall of visual information over non-visual details. Moreover, positive effects of both lifelogging methods on objective measures of episodic recall were found for the recall of earlier displayed visual information. No benefit of lifelogging for the objective recall of non-visual details was found. Furthermore, no influence of the perspective of lifelogging photographs on the effectiveness of either lifelogging-supported consolidation or retrieval could be detected.

Visual lifelogging has been shown to have a great potential in helping people who are suffering from memory loss by increasing both objective and subjective memory for events. It can offer an excellent alternative to currently popular memory rehabilitation techniques such as the use of a diary and errorless learning and it can very well be applied in clinical settings (van Teijlingen et al., 2021). The results of the present study offer further support for the beneficial effects of lifelogging irrespective of the memory stage (consolidation vs retrieval) and are most striking

for subjective non-visual and visual memory and objective visual memory. Several studies have demonstrated that the use of these memory aids can substantially enhance the amount and quality of details participants report to remember from autobiographical events (Chow & Rissman, 2017; Dubourg et al., 2016;Silva et al., 2016; van Teijlingen et al., 2021). By additionally employing an objective and verifiable measure of episodic memory, the current study further extends these findings. Unlike Mair et al. (2019), the present study did not demonstrate that lifelogging-supported retrieval also significantly improves participants' episodic recall for non-visual information. Similarly, no effect of lifelogging-supported consolidation on non-visual episodic memory was found.

In contrast to earlier suggestions (Silva et al., 2016), objective memory enhancement following lifelogging was restricted to visual information. Based on the earlier available evidence (Silva et al., 2016; van Teijlingen et al., 2021) one might expect that lifelogging might incite a carry-over effect of visual to non-visual information. However, we did not corroborate this possibility. Recent evidence suggests that visual details are generally recalled more easily and accurately than auditory or non-perceptual information because of our ability for visual imagery (i.e., the ability to perceive previously encountered or imagined visual experiences in the mind) (Pearson, 2019; Scheurich et al., 2021). Since visual memory aids, such as lifelogging photographs, may primarily stimulate visual imagery, it should be investigated if they can support episodic recall not only of visual information depicted in lifelogging photographs but also for visual information that is not depicted. An alternative explanation for the observed difference between visual and non-visual recall could be the relative sensitivity of the respective tasks. The maximum possible score for visual details was higher than for non-visual information, and while participants recalled approximately 30 % of the available visual details, they recalled 80 % of the non-visual details. This discrepancy suggests a possible ceiling effect for non-visual memory, which may have limited the potential for observable improvement in that domain. Furthermore, a limitation of our study concerns non-visual probes, particularly the question requiring recall of the exact minute an event began. Such a high level of temporal precision is unlikely to have been encoded unless participants were explicitly instructed to pay attention to the time. If this information was not reliably encoded, it cannot serve as a valid measure of lifelogging's impact on non-visual memory. More broadly, future research should ensure that a sufficient range of non-visual details is probed, using measures that are more clearly comparable to those assessing visual recall.

In contrast to prior findings (St. Jacques & Schacter, 2013), we found no effect of photo perspective (egocentric vs. allocentric) on memory enhancement. The current findings suggest that both egocentric and allocentric perspectives provide sufficient information to support memory, which is consistent with prior research showing that either perspective can benefit episodic recall (McIsaac & Eich, 2002; Rice & Rubin, 2009, 2011). Nevertheless, interpreting the null effect of perspective as indirect evidence for the information theory is complex. The lack of a perspective effect might be better understood by considering participants' retrieval perspectives during the memory task. Most participants, regardless of the photo perspective they reviewed, reported retrieving memories from an egocentric or mixed perspective. This suggests that the perspective of the reviewed photographs may not necessarily dictate how participants recall the event. It is possible that participants naturally revert to an egocentric perspective when recalling personal events, thus reducing the potential advantage of reviewing egocentric photos. However, our findings contrast with those of St. Jacques and Schacter (2013), who reported superior memory outcomes when participants retrieved memories from an egocentric perspective. A key difference between the studies is that St. Jacques and Schacter manipulated the visual perspective during retrieval, whereas our study maintained consistent perspectives throughout. The discrepancy between our findings and those of St. Jacques and Schacter (2013), who found superior memory outcomes with egocentric perspectives, may stem from differences in task design and the type of memory assessed. St. Jacques and Schacter altered the visual perspective during retrieval, whereas our study maintained consistent perspectives throughout. Future studies should investigate whether increasing the number of lifelogging photographs further enhances memory effects, as greater exposure to relevant event details may contribute to stronger retrieval support.

Although the current null findings should be viewed with caution, they could indirectly support the information theory, which contrasts with the compatibility theory (Conway, 2005; Hodges et al., 2011). The compatibility theory suggests that lifelogging aids are particularly effective because the first-person perspective of the photos closely matches how we naturally store and recall episodic memories. In contrast, the information theory argues that the effectiveness of these aids is due to the sheer volume of information provided by the images, rather than the perspective itself (Conway, 2005; Hodges et al., 2011). In line with the information theory, it would be reasonable to expect no significant differences between lifelogging methods using egocentric and allocentric perspective photographs since an allocentric perspective can provide as much information as an egocentric one. Further research, including lifelogging reviews with varying amounts of information depicted in the images, is needed to investigate if the information theory can explain the observed positive effects of lifelogging memory aids. A further reason why the egocentric perspective group did not perform significantly better on the memory tests than the allocentric perspective group may be that the majority of participants in both groups reported retrieving the memories of the events from an egocentric or mixed perspective. It has been suggested that the memory advantage of the egocentric perspective stems specifically from retrieving memories from this perspective (Rice & Rubin, 2009, 2011). Future research should test whether there is also no perspective advantage in elderly participants and patients with memory disorders.

8. Strengths and limitations

A strength of the current study was its high level of experimental control. Unlike most previous studies, the lifelogged events were specifically designed laboratory-encoded events. In this way, it could be ensured that all participants made experiences that were comparable in terms of content and memorability. Furthermore, social interactions had to be excluded from the design (based on Covid-19 restrictions). Therefore, the overall ecological validity of the present study was lower than originally intended. A limitation of this study was that the described method of visual lifelogging, while developed for memory-impaired patients, was only examined in healthy participants for the purpose of this study. Although the positive effects are likely to extend to the former group of patients, as also described by the discussed literature, it is important to also perform similar tests in the specific targeted patient group. Conducting a similar experiment in memory-impaired patients can provide further insights into how different perspectives of lifelogging can impact these individuals. A possible second limitation was that those tests were self-developed and could therefore not be compared to earlier objective memory indices in earlier projects. An important reason to self-develop these tests was to keep a direct link between the test setting and the lifelogging setting. A possible third limitation is that the baseline memory test for Event B may not have been entirely independent from the earlier event. Reviewing Event A could have influenced Event B due to content overlap, and since Event B was always recalled after Event A, the recall of A might have facilitated B. Moreover, testing of events could have enhanced memory recall of the event. A fourth limitation is the relatively small sample of university students involved in this study. As a result, it is uncertain whether the findings would generalize to older adults who may experience age-related memory challenges. To address this, future research should include a more diverse sample to ensure broader applicability of the

results. Finally, the time-span of 48-h could have been enlarged to test for potential effects of longer retention.

9. Conclusion

The present study was able to show that lifelogging methods can not only improve how people subjectively relive past events but are also effective in increasing the number of more objective details people can successfully recall. Surprisingly, the lifelogging photograph perspective did not influence this effectiveness. Consequently, several new possibilities on how to apply lifelogging may open up. Indeed, many people might find it easier and less intriguing to install a lifelogging device at a fixed place rather than wearing it on the body. However, further research should also keep investigating the determinants underlying lifelogging memory aids to ensure that they can be used most efficiently. Nevertheless, the results of the current study have shown once again how positively lifelogging can affect people's appraisal of their ability to recall autobiographical events. In light of the negative psychological consequences of episodic memory impairment, this might be among the strongest assets of this relatively recent episodic memory aid.

CRediT authorship contribution statement

Erik Oudman: Writing – review & editing, Writing – original draft, Validation, Investigation, Data curation. **Isabelle F. Klukas:** Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tijmen van Teijlingen:** Writing – review & editing, Writing – original draft, Visualization. **Albert Postma:** Writing – review & editing, Writing – original draft, Supervision, Software, Formal analysis, Data curation.

Declaration of competing interest

The authors have no declaration of interest.

Appendix A. Test of subjective episodic memory strength

Table 3
Questions to measure participants' Subjective Episodic Memory Strength and Retrieval Perspective.

	Subscale	Question	Answer
Q1	Overall Memory	"I have a vivid memory of the event"; "When recalling the memory of the event, I have the feeling of going back in time and reliving that event"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q2		"When recalling the memory of the event, I have the feeling of going back in time and reliving that event"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q3		"I can consciously remember visual details (i.e., details of what I have seen during the event)"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q4		"I can consciously remember auditory details (i.e., details of what I have heard during the event)"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q5	Target Memory	"I can consciously remember the tasks (experience rating, puzzles, conversational exercise) that I have performed during the event"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q6		"I can consciously remember the content of the conversational exercise that happened during the event"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q7	Spatial Context Memory	"I can consciously remember the location of the Blue Room (First Room)/Green Room (Second Room) in the Langeveld building"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q8		"I can consciously remember where objects were in the Blue Room (First Room)/Green Room (Second Room) during the event"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q9	Temporal Order Context Memory	"I can consciously remember the time of when the event happened"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q10		"I can consciously remember the order in which the different tasks of the event (experience rating, puzzles, conversational exercise) took place"	7-point Likert Scale ranging from Strongly disagree to Strongly agree
Q11	Perspective	"From which perspective do you perceive the memories of the event?".	Multiple-choice question (I perceive these memories from a first-person perspective (from my own eyes)/I perceive these memories from a thirdperson perspective (like I am perceiving it from another viewpoint)/I can perceive these memories from both perspectives (first-person perspective AND third-person perspective)/I do not perceive these memories from a certain perspective/I don't understand the question)

Appendix B. Test of objective episodic memory strength

Table 4
Questions and Scoring form to measure participants' Objective Episodic Memory Strength.

	Subscale	Question	Answer	Scoring
Q1[a]	Target Memory	"Which figures were depicted on the puzzles that you completed in the Blue Room (First Room)/Green Room (Second Room)?"	Blue Room (First Room): Fish, Horse, Tree	Give 1 point per right fig. (0–3 points)

(*continued on next page*)

Table 4 (*continued*)

	Subscale	Question	Answer	Scoring
			Green Room (Second Room): Cat, Giraffe, Boat	
Q2[b]		"What was the topic of the conversational exercise in the Blue Room (First Room)/Green Room (Second Room)?"	Blue Room (First Room): Favourite animal Green Room (Second Room): Favourite TV show	Give 1 point for right topic (0–1 points)
Q3[a]	Overall Context Memory	"Which objects were present in the Blue Room (First Room)/Green Room (Second Room)? Please name as many as you can. (excluding the table and chair, the puzzles, the templates, the GoPros, and the computer set up)"	Blue Room (First Room): Book, Stuffed animal, Towel, Plastic plant, Remote control, Tissues Green Room (Second Room): Candle, Additional computer mouse, Hairbrush, Dopper, Pillow, Tennis ball	Give 1 point for every right object (0–6 points)
Q4[b]		"Which sound was played in the background in the Blue Room (First Room)/Green Room (Second Room)?"	Blue Room (First Room): Ocean waves Green Room (Second Room): Birds singing	Give 1 point for right sound (0–1 points)
Q5[b]	Spatial Context Memory	"Where was the Blue Room (First Room)/Green Room (Second Room) in the Langeveld building? (Please select the right room by writing down the corresponding letter from the floor plan below)"	Blue Room (First Room): Answer E Green Room (Second Room): Answer C	Answers indicated on a floorplan sketch with 16 different answer options Give 1 point for the right multiplechoice answer (0–1 points)
Q6[a]		"Please try to mentally travel back to the event and perceive it in your mind. In which corner of the Blue Room (First Room)/Green Room (Second Room) was the remote control/ the candle located? (See sketch below for an illustration of the answer options)"	Blue Room (First Room): Answer C Green Room (Second Room): Answer D	Answers indicated on a sketch of the room with 4 different answer options Give 1 point for the right multiplechoice answer (0–1 points)
Q7[b]	Temporal Order Context Memory	"When did the event in the Blue Room (First Room)/Green Room (Second Room) start and end? (If you do not remember the exact time, please try to guess the most accurate time)"	Dependent on individual participant	Give 1 point for the right hour, the right sextile of the started hour, and the right minute, and 1 point for the right amount of time (0–4 points)
Q8[b]		"What was the order of tasks (experience rating, puzzles, conversational exercise) in the Blue Room (First Room)/Green Room (Second Room)?"	Blue Room (First Room): Conversational exercise, Rating question, Puzzles Green Room (Second Room): Puzzles, Conversational exercise, Rating question	Give 1 point per correctly placed task (0–3 points)

[a] Questions concerning visual information.
[b] Questions concerning non-visual information.

Appendix C. Debriefing questionnaire

Table 5
Debriefing Questionnaire.

	Question	Answer Options
Q1	"How much did you like participating in this study?"	7-point Likert Scale ranging from Not at all to Very much
Q2	"Did you have any difficulties completing this study? If yes, please specify…"	Multiple-choice (No/Yes, please specify)
Q3	"What do you think was the purpose of this study?"	Open question
Q4	"Do you have any feedback, questions or complaints for the researcher? If yes, please specify…"	Multiple-choice (No/Yes, please specify)

Data availability

Data will be made available on request.

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