

## Autobiographical Memory Training for Older Adults using Wearable Cameras: An Integrative Review

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**Abstract:** Memory decline can be observed even in healthy aging, and memory complaints are common among older adults. While memory training interventions can improve performance in trained tasks, this effect usually does not transfer to everyday activities. Wearable cameras can be useful in developing memory interventions that are more closely related to how memory works in the real world, by collecting pictures that can be used as cues in autobiographical memory tasks. This review aims to investigate the effects of reviewing tasks using wearable camera pictures on autobiographical memory in older adults, a population greatly affected by memory impairments and with specific neuropsychological needs that must be accounted for in interventions. We conducted an integrative review of studies describing interventions in autobiographical memory for older adults using wearable cameras that were found in the PsycINFO, PubMed, ScienceDirect, and Web of Science databases from 2001 to 2021. The results indicate that using wearable cameras to help recall details of specific events could promote well-being for patients in more advanced stages of dementia, but it is unlikely to reverse the symptoms. These interventions are more effective for patients in early stages of dementia or healthy older adults. In addition, studies showed that reviewing the pictures can lead to the recollection of information not visually available, and it can affect global autobiographical memory and other cognitive functions.

**Keywords:** Autobiographical Memory, Wearable Cameras, Aging, Integrative Review.

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### Treinamento de Memória Autobiográfica para Idosos usando Câmeras Vestíveis: Uma Revisão Integrativa

**Resumo:** Declínios de memória podem ser observados mesmo em idosos saudáveis e queixas de memória são comuns entre eles. Embora treinamentos de memória contribuam para melhorar a performance nas tarefas treinadas, esse efeito geralmente não se transfere para tarefas do dia a dia. Câmeras vestíveis podem ser úteis no desenvolvimento de intervenções de memória mais próximas da forma como a memória funciona no mundo real, coletando fotos que podem ser usadas como pistas em tarefas de memória autobiográfica. Esta revisão busca investigar os efeitos de tarefas de revisão usando fotos de câmeras vestíveis na memória autobiográfica de idosos, uma população muito afetada por problemas cognitivos e que tem necessidades neuropsicológicas específicas que precisam ser consideradas em uma intervenção. Foi conduzida uma revisão integrativa de estudos que descrevem intervenções em memória autobiográfica para idosos nas bases PsycINFO, PubMed, ScienceDirect e Web of Science publicados entre 2001 e 2021. Os resultados indicam que o uso de câmeras vestíveis pode ajudar a lembrar detalhes de eventos específicos e contribuir para a promoção de bem-estar em pacientes em estágios avançados de demência, mas não vai reverter os sintomas. Essas intervenções são mais efetivas em pacientes

em estágios iniciais de demência ou em idosos saudáveis. Além disso, estudos mostram que é possível que revisar as fotos resulte em recordação de informações não disponíveis visualmente e afete a memória autobiográfica global e outras funções cognitivas.

**Palavras-chave:** Memória Autobiográfica, Câmeras Vestíveis, Envelhecimento, Revisão Integrativa.

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## Entrenamiento de la Memoria Autobiográfica para Ancianos usando Cámaras Portátiles: Una Revisión Integradora

**Resumen:** Se pueden observar disminuciones de la memoria incluso en ancianos sanos y las quejas de memoria son comunes entre los ancianos. Aunque el entrenamiento de la memoria contribuye a mejorar el rendimiento en las tareas entrenadas, este efecto generalmente no se traslada a las tareas del día a día. Las cámaras portátiles pueden ser útiles para desarrollar intervenciones de memoria más cercanas a cómo funciona la memoria en el mundo real, recopilando fotos que pueden usarse como pistas en tareas de memoria autobiográfica. Esta revisión busca investigar los efectos de las tareas de repaso con fotos de cámaras portátiles en la memoria autobiográfica de los ancianos, una población muy afectada por problemas de memoria y que tiene necesidades neuropsicológicas específicas que deben ser consideradas en una intervención. Se realizó una revisión integradora de estudios que describen intervenciones de memoria autobiográfica para ancianos en PsycINFO, PubMed, ScienceDirect y Web of Science publicados entre 2001 y 2021. Los resultados indican que el uso de cámaras portátiles puede ayudar a recordar detalles de eventos específicos y contribuir a la promoción del bienestar en pacientes en estadios avanzados de demencia, pero no revertirá los síntomas. Estas intervenciones son más efectivas en pacientes con etapas tempranas de demencia o en ancianos sanos. Además, los estudios muestran que revisar fotos puede resultar en el recuerdo de información que no está disponible visualmente y afectar la memoria autobiográfica global y otras funciones cognitivas.

**Palabras-clave:** Memoria Autobiográfica, Cámaras Portátiles, Envejecimiento, Revisión Integradora.

### Introduction

Autobiographical Memory (AM) refers to the memory of personally experienced events, which are integrated into a personal life story and relate to identity construction and relationships with others (Fivush & Graci, 2017). It integrates aspects of both episodic (information about specific events) and semantic (personal and abstract information) memory (Conway, 2005). Specifically, recollection of distinct autobiographical events includes the recall of contextual details, providing information about what, where, and when a specific event happened (Tulving, 2002). Evidence indicates that episodic memory declines can be observed even in healthy aging, while semantic memory is usually preserved (Bahk & Choi, 2018; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). Compared to

younger adults, healthy older adults generally report less contextual and more semantic details when recalling specific events (St. Jacques, Rubin, & Cabeza, 2012). Moreover, older adults often report memory difficulties in their daily lives (Steinberg et al., 2013). Due to these aspects, there is considerable research interest in investigating whether interventions could help improve memory performance in older adults. While memory training interventions can improve performance in the trained tasks, studies show that this result usually does not transfer to everyday tasks (Gross et al., 2012), which raises the question of how to develop interventions that more closely align with how memory works in everyday life.

The effects of using external tools to improve memory performance are well-known and researched.

Memory aids such as calendars, notes, and alarms are some examples (Kapur, Glisky, & Wilson, 2004). These tools can help reduce the cognitive demand of self-initiated processes involved in information retrieval (Woods, 2002) and are commonly used in everyday life. Memory aids such as written notes and smartphone calendars help improve prospective memory (remembering future events such as appointments or medication schedules). Others, such as diaries and old photographs, can help improve retrospective memory (remembering past events). Written diaries are a well-researched method for aiding memory of past events (Bolger, Davis, & Rafaeli, 2003): participants are asked to log information about daily events that can later be reviewed as part of a specific intervention program. However, writing a diary can be time-consuming and discouraging, especially for people with memory impairment (Berry et al., 2007). Another issue is that the amount of information recorded in a diary is limited, which reduces its efficiency in providing memory cues for past events (Allé et al., 2017). Considering these aspects, wearable cameras can be an alternative to this method that is easy to use and less time-consuming.

Wearable cameras (or lifelogging cameras) can be worn around the neck in a lanyard or clipped to clothing, automatically capturing pictures while the person carries out their activities as usual. They are unobtrusive and gather much visual information, making them an interesting alternative to traditional methods of collecting AM data (Allé et al., 2017). The first developed wearable camera was SenseCam, announced in 2003 by Microsoft Research. It was created as a “human black box recorder” to gather information about the user’s daily life without interference. SenseCam was equipped with an internal timer and electronic sensors that capture changes in the environment, allowing it to trigger photographs either according to a predefined time interval or every time the sensors detected significant changes (Hodges, Berry, & Wood, 2011).

Wearable cameras can be a valuable tool in memory research and memory rehabilitation. Pictures from wearable cameras can be used as stimuli in AM tasks, enabling greater ecological validity (Muhlert, Milton, Butler, Kapur, & Zeman, 2010). Passive picture-taking enables the participant to pay attention to their surroundings as they naturally would, reducing interference during encoding. In addition, the pictures’ first-person perspective is closer to how autobiographical

memories are encoded (Allé et al., 2017), making them efficient recall cues. Moreover, the personalized nature of the stimuli makes the task more interesting, relevant, and engaging. Hodges et al. (2011) describe two hypotheses for why they are effective. The first one suggests that the number of pictures collected by a wearable camera in a day is large enough to likely capture a moment when a specific memory was encoded. The second hypothesis is that the pictures’ presentation has characteristics that resemble typical autobiographical memories, such as the field perspective, the time slice each picture represents, the chronological order, and the unintentional aspect. Moreover, wearable cameras are useful for collecting autobiographical memory cues that can be used in different intervention types. These cues allow for more varied autobiographical memory tasks that can stimulate memory in ways not viable via traditional methods. Although these are promising advances, it is still important to investigate the possibilities and limitations of reviewing pictures from wearable cameras for older adults, especially those who already show symptoms of memory deficits due to dementia or other neurological issues.

In 2016, a systematic review of the effects of wearable cameras on memory was published, which included 11 case studies, 11 within-subject experimental studies, and three two-group experimental studies involving participants of all ages (Silva, Pinho, Macedo, & Moulin, 2016). The authors raised important questions about the effectiveness of reviewing wearable camera pictures to improve memory performance, specifically highlighting the relevance of measuring whether these tasks could aid in memory recollection. However, since this review, further studies focusing on the older adult population have been published. These studies investigate the effects of reviewing wearable camera pictures on AM in larger samples and more specific populations. Their results can inform the development of interventions to improve AM performance for the general older adult population, contributing to the efforts in ameliorating the symptoms of memory impairment. Moreover, as with most wearable technology applicable to health care and prevention, life-logging cameras have undergone a period of fast development. This review aims to incorporate data from recent years of scientific and technological developments into the results of Silva et al. (2016) and discuss whether wearable cameras are useful as tools for developing memory interventions

that more closely align with how memory works outside of laboratory settings. We focus on the effects of wearable camera for picture review tasks on autobiographical memories in older adults, as this population is the most affected by memory impairments and has specific neuropsychological needs that should be accounted for in memory interventions, including studies that investigate healthy samples and participants presenting memory impairment due to dementia, neurological issues, or other diseases.

### Methods

A comprehensive search was conducted in the PsycINFO, PubMed, ScienceDirect, and Web of Science databases from 2001 to 2021. A 20-year range was selected to include both recent studies and studies published when wearable camera technology was first being developed. The keywords used in the search were *autobiographical memory* OR *episodic memory* AND *memory training* OR *intervention* AND *wearable camera* OR *lifelogging camera* OR *SenseCam*

AND *older adults* OR *elderly* OR *aging*. In addition, a manual search was conducted in the reference lists of the selected articles for other publications. The studies were selected according to the following eligibility criteria: included an older adult sample (55+ years old), reported a memory performance measure, included wearable camera picture review, and were peer-reviewed. Only studies published in the English language were included. Initially, 46 articles were found in database searches, and 16 additional articles were found through manual searches in reference lists. After excluding 19 duplicates, article titles and abstracts were screened for eligibility, and 31 were excluded. In total, two judges independently screened the articles and applied the selection criteria. Discrepancies were discussed until agreement. The full texts of the selected articles were reviewed, and three more were excluded. The final sample included nine articles (Figure 1). Due to the small number of studies and the variation in their methodologies, an integrative review of the data was conducted (Whittemore & Knaf, 2005).

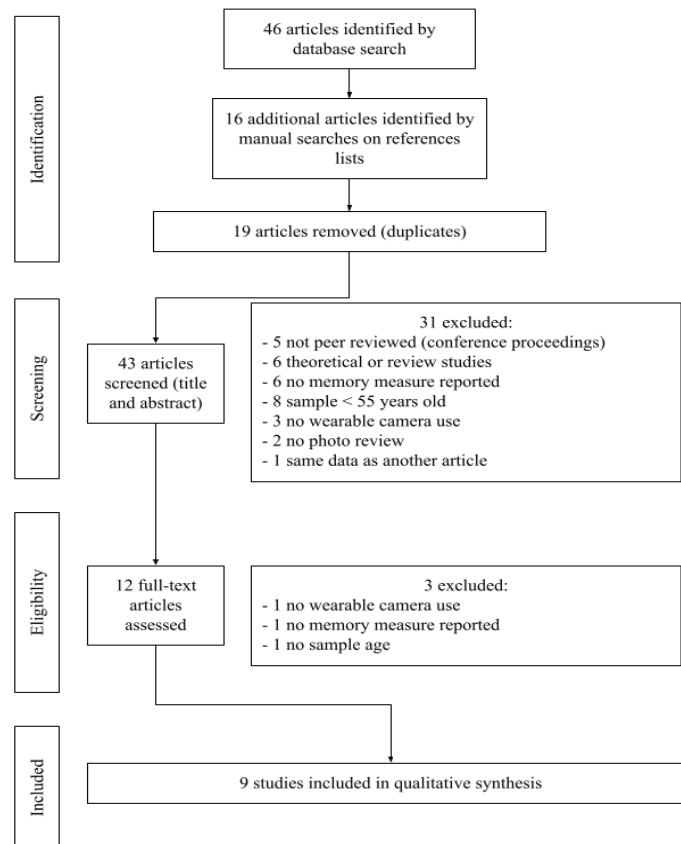


Figure 1  
Flowchart of literature search and selection.

## Results

Growing evidence has shown that tasks involving reviewing pictures from wearable cameras may help improve autobiographical episodic memory performance for both the recorded and non-recorded events, among other effects. This integrative review included nine studies that investigated these effects in older adult samples, which were categorized according to their methodology: case studies, experiments using pictures of real-life events, or experiments using pictures of staged events planned by the researchers (Table 1). The earlier studies investigating the effect of interventions using wearable camera were case studies with memory-impaired patients (Berry et al., 2007; Browne et al., 2011), in which participants wore the camera during selected events and later reviewed the pictures with their partners or a researcher every two days for two weeks. The results showed that, after reviewing the pictures for two weeks, the participants' performance on the recall task improved compared to a written diary condition. Two of the three were single case studies in which the participants felt that the written diary condition was not helpful and had a negative impact on their well-being, ultimately deciding to not complete the procedure for that condition. Woodberry et al. (2015) replicated the same procedure in a sample of six older adults with Alzheimer's disease and counterbalanced the order of the conditions within the sample but did not report any analysis of this variable. One of the participants withdrew before the

follow-up stage of the study, but none of the participants withdrew solely from the written diary condition.

A more recent study compared the effect of reviewing wearable camera pictures (passive capture) with digital camera pictures (active capture) to investigate a more equivalent comparison (Selwood, Bennett, Conway, Loveday, & Kuchelmeister, 2020). In total, 46 healthy older adults used either a digital or a wearable camera during a planned tour to a park and recalled details of the event the following day and 14 days later, both before and after reviewing the pictures. The authors found that participants in the wearable camera conditions recalled more details than those in the digital camera condition. However, it is important to highlight that the wearable camera automatically captured from 126 to 293 pictures, while participants took fewer than 40 pictures each using the digital camera. The authors also compared presenting the wearable camera pictures on a typical desktop computer monitor with an interface that placed the images in an immersive map of the park where the pictures were taken. The results showed no difference between the two modes of presentation; the desktop and immersive interface conditions were more effective than the digital camera condition. The immersive interface condition had some restrictions (e.g., participants prone to dizziness were allocated to one of the other two conditions) and required more equipment and a specific setting for presentation.

Table 1

Summary of research papers included in the review.

| Study               | Category   | Duration                               | Objectives  | Sample (age)   | Intervention  | Study design   | Outcome measures  | Results   |
|---------------------|------------|--|---|--|---|--|---|---|
| Berry et al., 2007  | Case study | 2 weeks + 1, 2 and 3 months follow-up  | To evaluate the use of a wearable camera as an aid to improve recent autobiographical memory in a patient with severe memory impairment following brain injury. | N = 1, a 63 years old patient with limbic encephalitis       | Participants wore the camera during interesting events, reviewed the pictures at different time intervals, and had her memory tested later. | Within-subject longitudinal design: (wearable camera vs. written diary vs. baseline) x time (3 months vs. follow-up) | Free recall of details of the events recorded.  | In the wearable camera condition, the participant was able to remember around 80% of the events. The written diary and baseline conditions were interrupted before the end of the study.  |
| Browne et al., 2011 | Case study | 2 weeks + 1, 3, and 6 months follow-up | To replicate the study by Berry et al (2007) and investigate the effect of reviewing wearable camera pictures in quality of life and well-being measures.       | N = 1, a 55 years old patient with mild cognitive impairment | Participants wore the camera during interesting events, reviewed the pictures at different time intervals, and had her memory tested later. | Within-subject longitudinal design: (wearable camera vs. written diary vs. baseline) x time (2 weeks vs. follow-up)  | Free recall of details of the recorded events. Standardized measures of self-image, anxiety, and depression. Quality of life and general experience measures. | After 2 weeks, the participant remembered 68% of the events details in the wearable camera condition, 30% in the written diary condition, and 38% in the baseline condition. After 6 months, the participant remembered 41% of the events' details in the wearable camera condition and 20% in the written diary condition. |

| Study                | Category                      | Duration | Objectives   | Sample (age)  | Intervention   | Study design   | Outcome measures   | Results   |
|----------------------|-------------------------------|----------|--|---|--|--|--|---|
| Gelonch et al., 2020 | Experiment (real life events) | 12 weeks | To determine whether using an wearable camera would result in improved objective episodic memory performance and increased specificity and richness of recent autobiographical memories. | N = 17 older adults aged 65 to 90 years (M = 76.35, SD = 5.11) with amnesic Mild Cognitive Impairment   | Participants wore the camera for 15 consecutive days and reviewed the images in 8 individualized weekly sessions. In each session, one event was reviewed 4 times, followed by a free recall after the first and last reviews, and questions about the event after the last 3. | Within-subject longitudinal design: pre vs. post training  | Free recall of events at the beginning and end of each session; Logical Memory subtest from the Wechsler Memory Scale  | Significant improvement in both free recall measures and in the Logical Memory measures.  |
| Mair et al., 2017    | Experiment (real life events) | 3 weeks  | To investigate autobiographical memory for everyday events in older and younger adults.  | N = 42 divided into two groups: 21 younger adults aged 18 to 32 years old (M = 24.62, SD = 4.04) and 21 older adults aged 65 to 78 years (M = 69.1, SD = 3.53). | Participants wore the camera for a week during events of their choice. The pictures were later reviewed in correct order, in random order, and just the event title, with no pictures.   | Age group (younger vs. older) x review condition (forward vs. random vs. baseline) x detail type (episodic vs. semantic) | Free recall during the event presentation. The researcher asked questions to clarify the answers and those were later coded into semantic or episodic details. | The forward condition elicited better recall. Older adults recalled more semantic details than younger adults, but there was no difference in the number of episodic details recalled between age groups. |

| Study                               | Category                         | Duration | Objectives  | Sample (age)   | Intervention   | Study design   | Outcome measures   | Results   |
|-------------------------------------|----------------------------------|----------|---|--|--|--|--|---|
| Mair et al., 2018<br>- Experiment 1 | Experiment<br>(staged<br>events) | 14 days  | To measure the effect of reviewing wearable camera images on the number of details older and younger adults could recall and the effect of the temporal order of images on subsequent recall. | N = 43<br>divided into two groups:<br>18 younger adults aged 19 to 32 years old (M = 23.72, SD = 3.91) and 25 older adults aged 64 to 83 years old (M = 72.32, SD = 5.68). | Participants wore the camera during three staged events and after 14 days recalled as many details as they could about the events. | T1 (baseline): recall of the whole event prior to any experimental manipulation.<br>T2: age group (young vs. old) x condition (control vs. random vs. forward) | Free recall (written) of details of the events recorded. | At baseline, younger adults recalled almost twice as many details than older adults. Both younger and older adults performed better after reviewing the wearable camera pictures, with no difference for forward or random order of presentation. Both younger and older adults recalled more specific event details after reviewing wearable camera pictures compared to the control condition. This effect was also observed when visual details were excluded, suggesting that wearable cameras cues recollection details from the original event, and not just recognition of information seen in the pictures. |
| Mair et al., 2018<br>- Experiment 2 | Experiment<br>(staged<br>events) | 15 days  | To test the effect of reviewing wearable camera pictures on older and younger adults' memory focusing on the recall of information not present in the pictures.                               | N = 31<br>divided into two groups:<br>17 younger adults aged 18 to 32 years old (M = 24.29, SD = 4.70) and 19 older adults aged 66 to 85 (M = 71, SD = 4.18).              | Participants wore the camera during two staged events and after 15 days recalled as many details as they could about the events.   | Age group (younger vs. older) x review condition (control vs. wearable camera) x detail type (episodic vs. semantic vs. source error vs. incorrect)            | Free recall of the details of the events recorded.       | At baseline, younger adults recalled almost twice as many details than older adults. Both younger and older adults performed better after reviewing the wearable camera pictures compared to the control condition. This effect was also observed when visual details were excluded, suggesting that wearable cameras cues recollection details from the original event, and not just recognition of information seen in the pictures.  |

| Study                | Category                      | Duration | Objectives   | Sample (age)  | Intervention  | Study design  | Outcome measures   | Results   |
|----------------------|-------------------------------|----------|--|---|---|---|--|---|
| Selwood et al., 2020 | Experiment (staged events)    | 15 days  | To compare traditional computer monitor presentation of wearable camera photographs and actively taken digital photographs with the presentation of wearable camera photographs in a new immersive interface that reinstates the spatiotemporal context. | N = 46 older adults aged 60 to 93 years old (M = 78.06)   | Participants wore the camera or used a digital camera to take pictures during a tour to a national park. The pictures were later reviewed one day after the tour and again 14 days later. | Review stage (one day vs 14 days) x review condition (wearable camera desktop vs. wearable camera immersive interface vs. digital camera desktop) | Free recall before and during picture review.  | The wearable camera pictures were more efficient in supporting recall of details than the digital camera pictures, regardless of how they were presented.                                   |
| Silva et al., 2013   | Experiment (real life events) | 6 days   | To investigate the hypothesis that wearable camera review would enhance cognitive function more generally.   | N = 29 divided into two groups: 15 younger adults (age: M = 19, SD = 1.9) and 14 older adults (age: M = 75, SD = 5.6) | Participants wore the camera for 3 days and returned 3 days later to review the pictures.   | Age group (younger adults vs. older adults) x Condition (wearable camera vs. written diary)   | AMT (autobiographical memory test) and other neuropsychological measures (verbal learning, working memory, executive function, semantic memory, and processing speed). | Both young and older adults showed higher performance in the autobiographical memory test, and in the measures of verbal learning, working memory, semantic memory, and executive function. |

| Study                  | Category                      | Duration                           | Objectives   | Sample (age)   | Intervention  | Study design  | Outcome measures   | Results  |
|------------------------|-------------------------------|------------------------------------|--|--|---|---|--|--|
| Silva et al., 2017     | Experiment (real life events) | 6 weeks + 6 months follow-up       | To examine the efficacy of wearable cameras to stimulate cognition and autobiographical memory in a group of patients with mild Alzheimer's Disease. | N = 51 older adults aged 62 to 80 years old (M = 73,65, SD = 5.49) with mild Alzheimer's Disease | Participants wore the camera and reviewed the pictures two times a week, reporting what they could recall during each review session with the experimenter. | Condition (Wearable camera vs. MEMO+ intervention vs. written diary control) x visit (before intervention vs. after intervention vs. follow-up) | AMT (Autobiographical Memory Test), episodic and semantic memory, attention, and executive function tests. | The wearable camera review group improved more in the autobiographical memory measure after the intervention and at follow-up compared to the other two groups. Both the wearable camera group and the MEMO+ group improved more in the semantic and episodic memory measures compared to the control group  |
| Woodberry et al., 2015 | Case study                    | 2 weeks + 1 and 3 months follow-up | To replicate the findings by Berry et al. (2007) and Browne et al. (2011) in participants with Alzheimer's disease.                                  | N = 6 older adults aged 64 to 84 years old (M = 72) with mild to moderate Alzheimer's disease.   | Participants wore the camera during selected events and reported what they could recall before reviewing the pictures in sessions two times a week.         | Within-subject longitudinal design: conditions (wearable camera vs. written diary vs. baseline) x time (2 weeks vs. 1 month vs. 3 months)       | Free recall of details of the events recorded.   | Five out of the six patients recalled significantly more details of the events over two weeks in the wearable camera condition compared to the written diary condition. At three months follow-up, four out of five participants recalled significantly more details of the events in the wearable camera condition compared to the written diary condition. |

Other studies compared the effect of picture presentation order on recall. In a study by Mair, Poirier, & Conway (2017), 21 younger and 21 older adults wore a camera to collect pictures from their daily lives for a week. After 14 days, they reviewed the pictures and recalled the events in two sessions on different days, with one condition tested per session. The authors found that participants recalled more details when they reviewed the pictures in chronological order than in random order, a small but significant effect. In this study, participants recalled details while reviewing the pictures, which means that they recalled the details in either random or chronological order, a factor that can affect memory performance. In another study (Mair, Poirier, & Conway, 2018 Experiment 1), 18 younger and 25 older adults wore the camera during three staged events in which they performed different group tasks. After 14 days, they recalled details about the staged events before and after reviewing the pictures. To account for the recall order effect, the participants were asked to recall event details after reviewing the pictures in both random and chronological order, and the authors found no difference between these conditions.

These authors also investigated differences between age groups. Mair et al. (2017) compared younger and older adults and found that, while older participants recalled more semantic details, there was no difference in the number of episodic details recalled by the groups after reviewing the pictures. In their first experiment, Mair et al. (2018) found that before reviewing the pictures, younger adults recalled significantly more episodic details than older adults and made significantly fewer errors. After reviewing the pictures, both age groups recalled significantly more details than in the control condition. Silva, Pinho, Macedo, & Moulin (2013) investigated 15 younger and 14 older adults who wore a camera for three days during their normal activities and reviewed the pictures three days later. The authors found that both age groups improved more in the AM measure in the wearable camera condition than in the written diary condition. Moreover, both groups improved in measures of verbal episodic memory, working memory, semantic memory, and executive function. In their second experiment, Mair et al. (2018) asked 17 younger and 19 older adults to wear the camera during staged events, in a procedure similar to the first experiment. This time, the tasks included more non-visual details,

enabling the researchers to evaluate the amount of information participants could recall that was not recorded in the pictures. They found that younger and older adults could recall more specific event details that were not present in the pictures when using the wearable camera compared to the control condition.

Finally, two recent studies using larger samples investigated the effect of longer interventions with multiple wearable camera picture review sessions on AM. Silva, Pinho, Macedo, and Moulin (2017) divided 51 patients with mild Alzheimer's disease into three groups. One group was asked to wear a camera for three days to capture real-life events and review these pictures in a session with the researcher, while another group underwent cognitive training that involved strategies for learning new information. The third control group used a written diary to record events later discussed with the researcher. All groups engaged in two sessions per week for six weeks. Participants in the wearable camera and cognitive training conditions improved in episodic and semantic memory measures compared to the control group. Gelonch et al. (2020) asked 17 patients with amnesic Mild Cognitive Impairment to wear a camera at home for 15 consecutive days and review one event per session in eight individual sessions, one session per week. The participants recalled the events at the beginning of each session before reviewing the pictures and then reviewed them three other times, performing a new recall task at the end. The authors found that the participants' recall and performance in objective episodic memory measures, both before and after the picture review, improved at the end of the training.

## Discussion

The results from the included studies investigating the effect of reviewing pictures from wearable cameras on autobiographical memories (AM) indicate that they can effectively cue the recollection of recorded events. Being able to recollect an event involves remembering what happened, when, and where it happened, in addition to the phenomenological experience of mental time travel described by Tulving (2002), which is typically impaired in older adults (Levine et al., 2002). One possible way to improve recollection in older adults may be via repeated activation of the neural networks involved in this process through interventions using wearable cameras as memory aids. The included studies present

evidence regarding the effectiveness of reviewing pictures collected by wearable cameras in recalling event details, memory for remote, not reviewed events, the order of picture presentation during review, and the method of picture presentation. While these results are relevant to understanding how reviewing wearable camera pictures can benefit AM, some limitations should be considered. There is still a limited number of studies investigating the use of wearable cameras in older adults with larger samples and comparing their effects with other equivalent methods of collecting real-life events.

The first studies to investigate the effect of reviewing pictures automatically collected by wearable cameras on autobiographical memory compared these results with reviewing written diary entries—a traditional method of recording events from participants' personal lives for use in interventions or memory studies (Berry et al., 2007; Browne et al., 2011; Woodberry et al., 2015). However, the authors of all three studies found that the participants felt frustrated by the effort involved in recording their life events in diaries. Specifically, participants in the two case studies (Berry et al., 2007; Browne et al., 2011) were unable to complete the written diary condition, reporting that reviewing the entries was discouraging because they often could not recall the events. By contrast, these same participants reported that wearing the camera was easy, as it required no active effort on their part, that reviewing the pictures was enjoyable, and that, more than once, it helped trigger memories of the events, including details not present in the pictures.

We highlight that these were within-subject studies, with the wearable camera condition taking place first, followed by the diary condition; thus, there might be a comparison effect: maybe the diary condition would not have been perceived as exceedingly frustrating had the participants not first experienced a more engaging intervention. In the study by Woodberry et al. (2015), in which the order of the wearable camera and written diary conditions was counterbalanced, all participants completed both conditions but still indicated that the written diary condition was tiresome and unhelpful. These findings highlight the qualitative difference between automatically collecting personal events, reviewing cues in a practical and efficient format, and having to take notes on their life events and later read them. Nevertheless, a written diary may be

considered an inadequate comparison since it differs from a wearable camera in more than one dimension: the capture mode is intentional, and it provides verbal rather than visual cues.

In their study, Selwood et al. (2020) compared a wearable camera with a more equivalent method of gathering real-life events—actively taking pictures using a digital camera—and found that participants who reviewed passively taken pictures recalled more details from the events. Although this result may indicate that reducing interference during encoding by using a tool that automatically captures pictures from participants' lives enhances subsequent memory test results, it is important to acknowledge the significant difference in the number of pictures collected between the two methods, with fewer pictures taken actively than passively. The authors also reported that the wearable camera's pictures tended to be repetitive, representing the event almost continuously, while the digital camera's pictures were more selective but skipped blocks of time. Future research should continue to investigate the effect of reviewing automatically compared to actively taken pictures to account for the role of interference during encoding in memory interventions using participant's real-life events as stimuli. However, it should also control for the number of pictures collected in each condition to avoid confusion when interpreting the results.

In their review, Silva et al. (2016) stated that for wearable camera pictures to be considered a useful tool in memory training interventions, it is important to investigate whether they can elicit true recollection of the events they represent. One important piece of evidence addressing this question was published after Silva and colleagues' study and it showed that participants who reviewed wearable camera pictures recalled details not present in them, indicating true recollection of the original event instead of only recognizing depicted elements (Mair et al., 2018). Both experiments described by the authors evaluated the number of non-visual details recalled by participants and found that the wearable camera pictures were more efficient in triggering the recall of this type of detail. This supports findings from previous qualitative case studies, which reported that during picture review, participants could recollect the actual events, reporting information not present in the pictures and their thoughts and feelings at that moment (Berry et al., 2007; Browne et al., 2011; Woodberry et al., 2015).

Some studies also found that reviewing wearable camera pictures improved global AM, and not only memory for the rehearsed events. Silva et al. (2013) and Silva et al. (2017) used the Autobiographical Memory Test (AMT – Williams & Broadbent, 1986) to evaluate the effect of their intervention on memory for remote events unrelated to those reviewed and found that participants in the wearable camera condition recalled more details of personal past events in response to word cues. More recently, Gelonch et al. (2020) found that by the last training session, participants could recall more details of events before reviewing the pictures compared to the first session. These results indicate that reviewing wearable camera pictures may have an effect on autobiographical remembering rather than merely a rehearsal effect on the reviewed events. Based on studies showing that reviewing wearable camera pictures can cause activation in the hippocampus and the temporal lobe (Milton et al., 2011; St. Jacques, Conway, & Cabeza, 2011) and that autobiographical memory tasks activate different regions than performing laboratory tasks (McDermott, Szpunar, & Christ, 2009), one hypothesis is that the repeated review of recent events stimulates the brain networks involved in autobiographical remembering, which further improves the recollection of personal events in general.

The question of why wearable camera pictures are efficient cues to event recall has been discussed and investigated in some of these studies, mainly based on the hypotheses raised by Hodges et al. (2011). According to Mair et al. (2017) and Mair et al. (2018), the number of images reviewed is more relevant than the order of picture presentation. The authors found a small effect of order when participants also recalled details during the picture review, with chronological recall yielding better results than random order recall (Mair et al., 2017). However, this effect was not found when the authors separated picture review and event recall, allowing participants to recall, in chronological, order events reviewed in both conditions. It might be that when reviewing a smaller number of images, the order of presentation plays a more important role in event recall, as seen in other studies (St. Jacques, Montgomery, & Schacter, 2015; St. Jacques & Schacter, 2013). Moreover, the involuntary and passive aspect of wearable camera picture collection seems to be an important factor in recall. Selwood et al. (2020) compared the recall of event details after participants

reviewed pictures taken passively by the wearable camera or actively using a digital camera and found that wearable camera pictures were better recall cues. This result is consistent with findings by Sellen et al. (2007) with a younger sample, which showed that passively taken pictures were better cues for recall than actively taken pictures.

Another critical discussion on the use of wearable technology in health interventions and research concerns the privacy aspects of automatically collecting data, where and how to store it, and how to protect participant's sensitive information (Kelly et al., 2013). This problem is even more relevant when considering that older adults are a vulnerable population and targeted victims of scams and fraud (Federal Bureau of Investigation, 2021). Of the seven experiments included in this review, four asked participants to take the camera home and wear it during normal daily activities. Silva et al. (2013) and Silva et al. (2017) instructed their participants to wear the camera for as long as possible and to remove it in situations they did not wish to be included in the review sessions with the researchers. This approach can be problematic, considering participants reported that it is easy to forget they are wearing the camera after only a short time (Gelonch et al., 2019), which can lead to accidentally registering situations the participant would prefer to keep private and not share with the research team. The same can be argued for the methods employed by Gelonch et al. (2020) and Mair et al. (2017). Similarly, participants were instructed to choose when to wear the camera to avoid sharing sensitive content when the research team accessed pictures to filter and organize them into sets for the tasks. In the case studies by Berry et al. (2007) and Browne et al. (2011), participants were instructed to choose specific events they wanted to remember and to wear the camera during those events, accompanied by their partners, with whom they also conducted the picture review sessions. A similar situation is described by Woodberry et al. (2015), in which half of the participants were accompanied by their spouses and the other half by a researcher. In these cases, both people present during the review session were also present during the event, which avoids the privacy issue described, but limits the types of events that can be included in the study. Possible solutions for this issue might involve further automatizing the protocol's filtering and segmentation stage, such as that described by Gelonch et al. (2020).

While the authors mention the use of image processing tools that improved the efficiency of this stage, they still report the need for human supervision during this process.

Finally, there is the question of how older adults adapt to following procedures involving wearable cameras and computers, sometimes more extended periods at home. Two of the studies reviewed (Berry et al., 2007; Woodberry et al., 2015) mention that participants and their partners had an instruction session in which they learned how to use the camera, download the pictures, and review them on a computer. Woodberry et al. (2015) briefly describe how the software used to review images had controls resembling those of a standard VCR player, which helped even participants less familiar with computers to use the software without issues. Berry et al. (2007) do not describe the software used and only report that the participant and her partner had no difficulty using the computer and the camera. Although not the focus of these studies, this part of the procedure must be described so future research can benefit from understanding what adaptations and instructions are necessary for participants to carry out extended interventions at home. In their methodological report, Gelonch et al. (2019) used a focus group and a technology acceptance survey, among other measures, to investigate how older adults adapted to wearable cameras. They found it important for participants to have access to a professional during the study who could help them with technical issues and questions. Their participants reported that they could accept the inconveniences of wearing a camera during their daily activities because the picture review provided them with sufficient benefits. These and other findings informed their intervention and allowed participants to carry out an eight-week-long intervention with the wearable camera (Gelonch et al., 2020). Considering that older adults are one of the populations most likely to benefit from technological memory aids, it is important to investigate which factors can make their adaptation easier and, in turn, more engaging and efficient.

## Conclusion

Overall, these results can shed light on how to utilize wearable cameras in interventions to improve AM in older adults. This population is the most affected by memory impairments as a symptom of dementia or Alzheimer's disease, though some degree of memory

decline also occurs in healthy aging. The studies included in this review, especially those published since 2016, present relevant evidence regarding whether reviewing wearable camera pictures is effective in triggering recollection of the actual event. This is crucial for the intervention's effectiveness in improving autobiographical memory, as discussed by Silva et al. (2016). Moreover, some of the reviewed studies raise relevant questions regarding the acceptability of older adults using wearable cameras at home, highlighting the importance of adapting instructions to better suit this specific population's needs and ensuring that the participants feel supported when dealing with unfamiliar devices (Gelonch et al., 2019).

A growing body of evidence shows that wearable camera pictures are effective retrieval cues for autobiographical memories (Allé et al., 2017; Silva et al., 2016). Researchers found that, after reviewing wearable camera pictures, participants could recall information absent from the images (Berry et al., 2007; Woodberry et al., 2015). Moreover, studies found that reviewing wearable camera pictures was related to activation in brain regions associated with autobiographical remembering (Berry et al., 2009; Loveday & Conway, 2011; St. Jacques, Conway, Lowder, & Cabeza, 2011). Moreover, wearable cameras can easily gather information about common daily events from a participant that would otherwise be less available (Mair et al., 2017). Many memory-impaired participants and their caregivers learned to operate wearable cameras correctly and download pictures to a computer afterward (Berry et al., 2007; Browne et al., 2011; Woodberry et al., 2015), and healthy older participants could operate the cameras by themselves (Mair et al., 2017, 2018; Selwood et al., 2020). This allows for their use in memory intervention and therapeutic contexts with older participants.

It is critical to establish for whom an intervention based on wearable camera pictures could be helpful. Woodberry et al. (2015) found that while older adults with mild to moderate Alzheimer's disease improved in recalling details of the events rehearsed, some of them were unable to remember that the intervention even happened. They would, however, feel a sense of satisfaction from recalling details of events they usually could not, even if they did not know why. This implies that using a wearable camera to help recall details of specific events could be useful in promoting well-being to patients in a more advanced stage of dementia, but

it is unlikely to reverse the symptoms. The results show that this kind of intervention is probably more effective for patients in an early stage of dementia or healthy older adults, aiming to help manage the symptoms of the decline of memory function.

Although recent studies reviewed here have provided new evidence regarding which characteristics of wearable camera pictures are most important for efficient recall cues and how well they promote recollection, a knowledge gap in this area remains. It is important to evaluate whether the effects of reviewing wearable camera pictures transfer to real-life activities, but only two studies have investigated their effects on global AM. Moreover, most studies compare reviewing wearable camera pictures with reviewing written diary entries, while only one study compares wearable camera pictures with those from standard digital cameras. This comparison could help clarify the role of passive image capture (pictures taken automatically) and the first-person perspective (compared with pictures taken by someone else). Another issue is that authors do not usually include enough

information about how they adapted their instructions for older participants, the issues they faced, and how they solved them. Adapting a memory aid to the user's natural lifestyle and considering their perceptions are important factors to increase the chances of its daily use (Baldwin, Powell, & Lorenc, 2011). Authors should also describe more clearly the actions taken to protect participants' privacy when asking them to wear the camera during daily activities. This includes procedures for storing and transferring pictures, selecting useful ones, and grouping them into events.

In conclusion, the evidence gathered indicates that wearable cameras can be useful memory aids and help improve AM in older adults. Recent studies have shown that reviewing the pictures likely leads to recollection of the entire event, as suggested by Silva et al. (2016), and seems to have a positive impact on global AM and other cognitive functions. Further research on the specific mechanisms involved in these results is necessary, as well as an investigation of technology acceptance by older adults, to ensure interventions are efficient and adapted to people's real lives.

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*Received* 07/28/2023

*Approved* 11/11/2024

*Recebido* 28/07/2023

*Aceito* 11/11/2024

*Recibido* 28/07/2023

*Aceptado* 11/11/2024

Disponibilidade de dados: os dados da pesquisa estão disponíveis no corpo do artigo.

<https://doi.org/10.1590/1982-3703003277071>

*How to cite:* Felinto, T. M., & Gauer, G. (2025). Autobiographical Memory Training for Older Adults using Wearable Cameras: An Integrative Review. *Psicologia: Ciência e Profissão*, 45, e277071. <https://doi.org/10.1590/1982-3703003277071>

*Como citar:* Felinto, T. M., & Gauer, G. (2025). Treinamento de Memória Autobiográfica para Idosos usando Câmeras Vestíveis: Uma Revisão Integrativa. *Psicologia: Ciência e Profissão*, 45, e277071. <https://doi.org/10.1590/1982-3703003277071>

*Cómo citar:* Felinto, T. M., & Gauer, G. (2025). Entrenamiento de la Memoria Autobiográfica para Ancianos usando Cámaras Portátiles: Una Revisión Integradora. *Psicologia: Ciência e Profissão*, 45, e277071. <https://doi.org/10.1590/1982-3703003277071>