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ORIGINAL ARTICLE

# The eyes of the past: larger pupil size for autobiographical memories retrieved from field perspective

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## Abstract

**Background** Visual perspective during memory retrieval has mainly been evaluated with methodologies based on introspection and subjective reports. The current study investigates whether visual perspective can be evaluated with a physiological measurement: pupil dilation.

**Methods** While their pupil diameter was measured with an eye-tracker, forty-five participants retrieved one memory from a field perspective (i.e., as viewed through our own eyes) and one memory from an observer perspective (i.e., as viewed from a spectator's standpoint). After retrieval, participants rated the emotional intensity of the memories.

**Results** Analysis demonstrated larger pupils during the retrieval of memories from a field perspective and higher emotional intensity for memories retrieved from a field perspective.

**Discussion** The larger pupils for memories recalled from a field perspective could, however, not be attributed to their higher emotional intensity. These findings suggest that pupil dilation could be used as a physiological assessment of visual perspective during memory retrieval.

**Keywords** Autobiographical memory · Pupil dilation · Mental imagery · Visual perspective · Vantage point

## Introduction

Autobiographical memory refers to the ability to retrieve personal memories, which allows us to construct our sense of self and our feeling of identity and continuity. Autobiographical retrieval triggers several subjective features such as mental time travel, emotion, and mental imagery. During autobiographical memory retrieval, a distinction can be made between imagery retrieved from a field perspective and imagery retrieved from an observer perspective [1]. Field perspective involves remembering through our own eyes, as we are looking outward, perceiving the retrieved event now much as we did before. Alternatively, observer perspective involves a spectator's standpoint, which allows us to see ourselves as an actor in the retrieved mental scene [2, 3]. Field perspective is associated mostly with strong feelings of re-experiencing of the original event, accompanied by a high degree of vividness and recollective experience; in contrast, observer perspective involves less vividness and recollective experience [1, 4–6].

The experimental study of the visual perspective, or vantage point, during autobiographical remembering was initiated by Nigro and Neisser [1] who proposed that the field perspective is mainly triggered by experiences that were so important or so emotional that they have resisted reconstruction. This proposition has been supported by research demonstrating that emotional memories, in non-pathological populations, are typically retrieved from field perspective [7–9]. Research has also demonstrated that imagining memories from field

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perspective triggers strong affective reactions and physical sensations, whereas imagining memories from observer perspective triggers more information concerning physical actions or spatial relations [5]. Visual perspective during remembering may depend on emotion [10]. For instance, we may retrieve emotional memories from an observer perspective to decrease the intensity of the emotional experiences and, conversely, we may retrieve emotional memories from a field perspective to increase their emotional intensity [11]. Adopting an observer perspective during remembering may therefore serve an emotional-regulation function by which we alleviate the emotional charge of some memories [11].

Although mental imagery during autobiographical retrieval is still the subject of empirical research and heated theoretical debates, one concern with this research is the subjective methodology based on introspection (e.g., participants are required to indicate whether they feel their memories reflect a field or observer standpoint after retrieval). This subjective assessment can be complemented by objective, and physiological, measures of visual perspective. The present study therefore aims to examine whether visual perspective during autobiographical memory retrieval can be evaluated with pupil dilation.

Until recently, little was known about pupil dilation during autobiographical memory retrieval. This issue was addressed by El Haj, Janssen [12] who instructed participants to remember autobiographical memories freely (i.e., first memory that comes to mind) as well as positive and negative autobiographical memories (i.e., memories associated, respectively, with the words "happy" and "sad"). In a control condition, participants were instructed to count aloud. During the autobiographical memory and control conditions, pupil dilation was recorded with eye-tracking glasses. Although there were no differences between the retrieval of the three types of memories, results demonstrated larger pupil diameters during the retrieval of the autobiographical memories than during the control condition. El Haj, Janssen [12] attributed the pupil dilation during the autobiographical memory retrieval to the general cognitive load required to reconstruct the context in which the retrieved events were previously encoded. Although the study of El Haj, Janssen [12] offers the first investigation of how autobiographical memory retrieval can activate pupil dilation, it did not investigate whether this dilation varies with the field/observer perspective from which the memories were recalled. The same thing can be said for subsequent studies on pupil dilation during autobiographical retrieval [13–15].

To summarize, visual perspective can be considered one core subjective characteristic (besides other subjective characteristics such as mental time travel and emotion) of autobiographical memory. However, visual perspective during autobiographical retrieval has been extensively assessed with introspective tools. The aim of the current study was to evaluate visual perspective with a physiological tool (i.e., pupil dilation). More precisely, it aimed to examine whether there are differences in pupil diameter between memories retrieved from a field perspective and memories retrieved from an observer perspective. As mentioned earlier, the field perspective involves more emotional load than the observer perspective [7–9]. Also, pupil diameter typically increases with emotional load [16, 17]. Larger pupil size was expected during the retrieval of memories from a field perspective than during the retrieval of memories from an observer perspective, probably because field memories involve more emotional load than observer memories. To investigate this hypothesis, participants retrieved autobiographical memories from a field or an observer perspective while their pupil diameter was measured with an eye-tracker. To assess the emotional account, participants also rated the emotional intensity of the retrieved memories.

## Method

### Participants

The sample size was determined using G*Power [18]. As our experimental design involved one independent variable with two levels measured within subjects (i.e., field vs. observer perspective), sample size calculation was conducted for paired-samples *t*-tests (two-tailed). This calculation was based on 95% power, an estimated probability of making type I error of .05, and a medium effect size of 0.50 [19] and suggested that 54 participants would be necessary to obtain sufficient statistical power.

The original sample consisted of 59 participants. We excluded five participants as they declared previous psychiatric or neurological disorders, two participants as they were not native French speakers (the procedures, as described below, involved verbal production of memories), and two participants owing to signal loss during recording. As recommended by Kret and Sjak-Shie [20], five additional participants were excluded as their pupil data exceeded typical ranges (i.e., beyond the interval of 1.5 to 9.0 mm).

The final sample therefore consisted of 45 undergraduate and graduate students from the University of Nantes (26 females; *M* age = 22.82 years, *SD* age = 4.64; *M* education = 13.32 years, *SD* education = 4.62); no significant difference was observed regarding the number of male and female participants [$X^2(1, N = 45) = 1.12$, $p = .29$]. Participation was entirely voluntary, and participants received no course credit or financial compensation.

### Procedures and materials

Participants were tested individually in a quiet room at the Psychology department of the University of Nantes. Informed consent was obtained in accordance with the principles laid down by the Helsinki Declaration. To ensure that

differences in pupil dilation were not caused by differences in retinal illumination, the window blinds were closed and the brightness of the room (60-watt fluorescent lamp) was the same in the two conditions. Prior to the start of the experiment, participants were informed that the study was concerned with eye-tracking research and memory in general. To not influence their performance, details about pupil dilation were not provided.

Participants were instructed to recall two personal experiences verbally. Prior to each memory, we explained: "When we remember an event, we see the memory from either a field or an observer perspective. For the field perspective, we see the event from the same visual perspective that we originally did, in other words, as if we are looking out at the event through our own eyes. If not, we are probably seeing the event from an observer's visual perspective; in other words, we may actually see ourselves, as well as our surroundings, in the event. You are invited to remember a personal event from a field (or observer) perspective." These instructions replicated those by Libby and colleagues [21, 22] and were repeated to cue one memory from a field perspective and another memory from an observer perspective. The order of the two visual perspectives was counter-balanced; half the participants first retrieved a memory from the field perspective, followed by the retrieval of a memory from the observer perspective, and vice versa for the other half.

In line with typical autobiographical memory assessments [23, 24], participants were also instructed that the description had to be precise and specific (i.e., include when and where the event occurred, what they were doing during the event, who was present, and what their feelings were). Participants were allocated 2 min to describe each memory, and this duration was clarified before retrieval, so that participants could structure their memory retrieval accordingly. At the end of the description of each of the two memories, participants indicated whether retrieval had occurred from a field or an observed perspective. All participants declared retrieving the memories from the assigned perspective.

Participants wore eye-tracking glasses (Pupil Lab), consisting of a remote pupil-tracking system that uses infrared illumination with 200 Hz sampling rate and a gaze-position accuracy of < 0.1°. Participants were seated in front of a white wall and the distance between the participants and wall was approximately 30 to 50 cm. The wall contained no visual stimuli (e.g., drawings, windows). Prior to providing participants with the retrieval instructions, calibration was made by inviting participants to fixate on a black cross (a 5 × 5-cm cross, printed on an A4 white paper fixated at the wall center) that was used as a calibration reference. This cross was removed after calibration. Participants were instructed not to look outside the wall, but they were free to explore all parts of it. Pupil dilation was recorded while participants recalled the autobiographical memories, and these recordings were processed with the Pupil Capture software. The mean pupil diameter during each of the memory retrievals was used as the dependent variable. Note that, during data processing, we eliminated blinks and data exceeding typical ranges.

In the two conditions, and immediately after memory retrieval, the participants rated the emotional intensity of the memories on a 5-point scale. More specifically, they were asked to rate whether retrieval triggered emotion on the following scale: 1 = "not at all," 2 = "a little," 3 = "moderately," 4 = "quite a bit," and 5 = "very much." At the end of the experiment, the participants were thanked for the contribution and briefly explained what the study entailed.

## Results

We compared pupil size and emotional intensity, as provided by participants immediately after memory retrieval, between memories retrieved from a field perspective and memories retrieved from an observer perspective. These comparisons were conducted with paired-samples *t*-tests. We provide 95% confidence intervals and effect sizes, using Cohen's *d* [19]: 0.20 = small, 0.50 = medium, and 0.80 = large. Level of significance was set at $p < .05$. We also calculated correlation coefficients and conducted an analysis of covariance (ANCOVA) to examine whether differences in pupil size can be attributed to differences in emotional intensity.

### Larger pupil size for field than for observer perspective

Individual data related to pupil diameter is provided in Fig. 1. The analysis showed a medium-sized effect for pupil dilation. Pupil size during the retrieval of memories from a field perspective ($M = 3.20$, $SD = 0.83$) was significantly larger than pupil size during the retrieval of memories from an observer perspective ($M = 2.70$, $SD = 0.73$) ($t(44) = 3.73$, $p = .001$, Cohen's $d = 0.65$ (95%CI = 0.23–0.78)).

### Higher emotional intensity for field than for observer perspective

Emotional intensity, as reported by the participants immediately after memory retrieval, is provided in Fig. 2. The analysis showed a large effect for emotional intensity. Memories retrieved from a field perspective ($M = 3.98$, $SD = 0.87$) were rated as significantly more emotionally

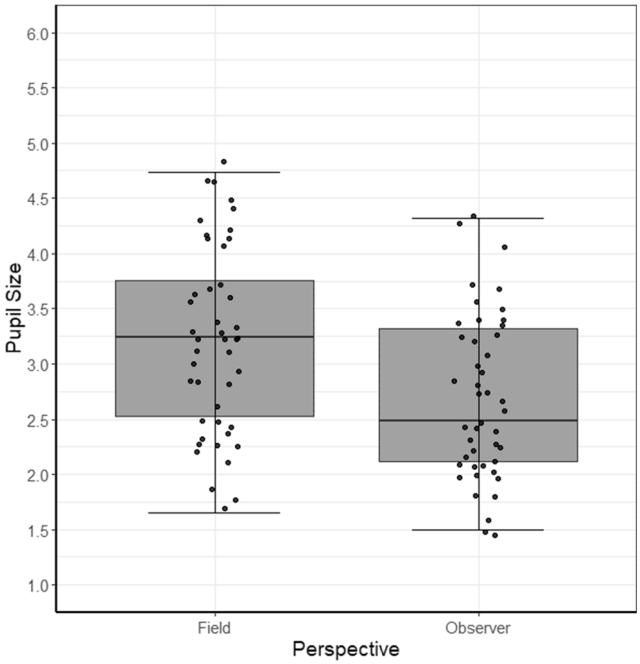


**Fig. 1** Pupil size (in mm) of memories retrieved from field and observer perspectives. Thick lines represent medians, gray bars represent interquartile range, and whiskers represent range. Dots represent individual observations, but their positions are jittered to reflect their spread better

intense than memories retrieved from an observer perspective ($M$ = 3.13, $SD$ = 0.89) ($t(44) = 4.63$, $p < .001$, Cohen's $d$ = 0.80 (95%CI = 0.18–1.21)).

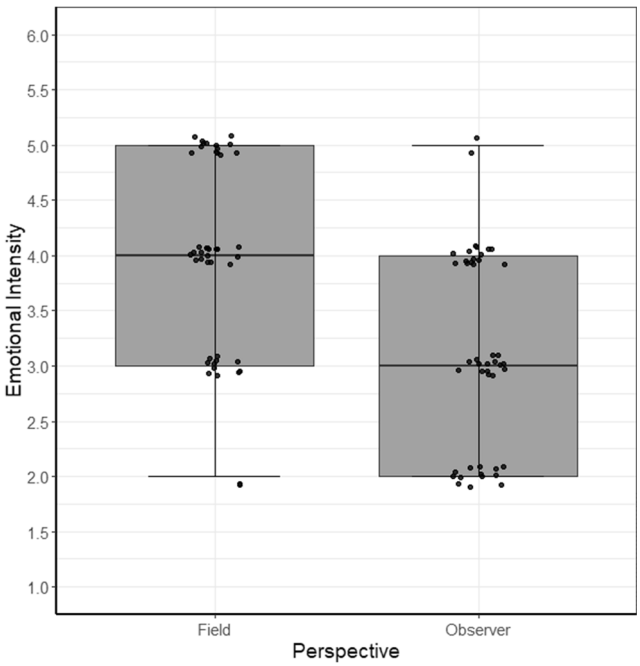


**Fig. 2** Emotional intensity of memories retrieved from field and observer perspectives. Thick lines represent medians, gray bars represent interquartile range, and whiskers represent range. Dots represent individual observations, but their positions are jittered to reflect their spread better

## No significant correlations between pupil dilation and emotional intensity

We also explored the relation between pupil dilation and emotional intensity. Pupil size during field memories correlated significantly with pupil size during observer memories ($r$ = .318, $p$ = .033 (95%CI = .02–.56)), highlighting individual differences. However, and as illustrated in the Appendix, the correlation between emotional intensity and pupil dilation was not significant neither for memories recalled from a field perspective ($r$ = −.230, $p$ = .128 (95%CI = −.49 to .07)) nor for memories recalled from an observer perspective ($r$ = −.130, $p$ = .393 (95%CI = −.41 to .18)), suggesting that the difference in pupil dilation between field and observer perspectives was unlikely to be caused by the difference in emotional intensity between field and observer perspectives.

To further assess whether differences in emotional intensity might account for differences in pupil size, we also conducted a repeated-measures ANCOVA with pupil size in the field and observer conditions as the within-subject variable and the emotional intensity in the two conditions as the covariates. The analysis demonstrated after controlling for emotional intensity a significant difference between pupil size in the field and observer conditions ($F(1, 42) = 8.94$, $p$ = .005, $\eta_p^2$ = .18). Thus, differences in pupil dilation between field and observer perspectives were not caused by the differences in emotional intensity.

## Discussion

We measured pupil diameter during the retrieval of autobiographical memories from a field or an observer perspective. The analyses demonstrated larger pupil size during the retrieval of memories from a field than during the retrieval of memories from an observer perspective. The analyses also demonstrated higher emotional load for memories retrieved from a field perspective than during retrieval of memories from an observer perspective, but the differences in pupil size could not be attributed to differences in emotional intensity. These findings provide the first evidence on how visual perspective during autobiographical memory retrieval may modulate pupil diameter.

Visual perspective during remembering has been typically assessed with introspective tools. Our study adds a valuable contribution to the study of visual perspective by demonstrating, for the first time, how pupil size can vary following the visual perspective from which memories are retrieved. The field perspective involves remembering through our own eyes, as we are looking outward, perceiving the retrieved event now much as we did before. Alternatively, the observer perspective involves a spectator's standpoint, which allows us to see ourselves as an actor in the retrieved mental scene [2, 3]. Our study demonstrates how field perspective activates larger pupil size than observer perspective. This larger pupil size can

possibly be attributed to stronger feelings of re-experiencing the original event, such as higher degrees of vividness and mental time travel, as typically observed when memories are retrieved from a field perspective [1, 4–6]. This larger pupil size can be attributed to factors such as the cognitive load, mind-wandering, daydreaming, or even fatigue as may occur during autobiographical retrieval.

Research has demonstrated that emotional memories, in non-pathological populations, are typically retrieved from a field perspective [7–9]. In a similar vein, research has demonstrated that imagining memories from a field perspective triggers strong affective reactions and physical sensations, whereas imagining memories from an observer perspective triggers more information concerning physical actions or spatial relations [5]. The emotional value of the field perspective was also observed in our study, as participants reported a higher emotional intensity for memories retrieved from a field than from an observer perspective. The larger pupil sizes, however, could not be attributed to the higher emotional intensity of the memories. Although previous research demonstrated how pupil typically dilates with increases of stimuli's emotional value [16, 17], we did not find that emotional intensity correlated with pupil dilation. In addition, according to the results of an analysis of covariance, the difference in pupil size remained after taking emotional intensity into account.

These findings suggest that, when examining the relation between emotional intensity and pupil dilation, we may have to distinguish situations when the stimuli are exogenous (e.g., the participant perceives a highly emotional image) and when they are endogenous (e.g., the participant is reminded of a highly emotional event). Furthermore, these findings suggest that both pupil size and emotional intensity may be driven by recollective experience. Visual perspective may influence recollective experience, which in turn may influence both emotional intensity and pupil size. Memories retrieved from a field perspective may be accompanied with stronger feelings of recollective experience and memories with stronger feelings of recollective experience may feel more emotionally intense and have more pupil dilation.

Although our study provides a new physiological assessment of visual perspective during autobiographical memory retrieval, it is important to acknowledge that neuroimaging research, using techniques, such as fMRI, has investigated neural basis of visual perspectives. Grol et al. [25] demonstrated that, compared to field perspective, observer perspective triggers greater activity in the right precuneus and the right temporoparietal junction. Similarly, Eich, Nelson [26] demonstrated that, compared to field perspective, observer perspective triggers less activity in the right posterior amygdala, bilateral insula, and left motor and somatosensory areas. Needless to say that the amygdala is one of the key areas involved in emotion [27]. The findings of Eich, Nelson [26] provide neurological support for the finding that the observer perspective is associated with less emotional load than the field perspective. That being said, although neuroimaging may provide a sensitive evaluation of visual perspective, it is typically expensive and requires dedicated infrastructure. Unlike neuroimaging, the evaluation of pupil dilation is based on a cheap and ecologically valid tool.

Our study paves the for several clinical applications. For instance, it would be of interest to investigate whether pupillometry can be used to assess the decline of autobiographical in amnesia. Because patients with Alzheimer's disease demonstrate decreased autobiographical retrieval as well as decreased visual imagery during retrieval [28–30], it would be of interest to investigate whether pupillometry may index the decreased autobiographical retrieval in these patients. Ultimately, this may improve diagnosis of memory decline in Alzheimer's disease as this diagnosis is mainly based on pencil-and-papers tests.

One limitation of our study is that, besides emotional intensity, it did not assess any additional memory characteristics that may influence pupil dilation, such as emotional valence, age of the memory, vividness, mental time travel, or retrieval frequency. However, regarding emotional valence (i.e., whether the retrieved memories were positive or negative), previous research has shown substantial differences in pupil size between neutral and emotional memories but not between positive and negative memories [30]. In other words, emotional valence seems to have little effect on pupil dilation during autobiographical memory retrieval. Regarding age of the memory, vividness, mental time travel, and retrieval frequency, there is, to the best of our knowledge, no published research on the effects of these factors on pupil dilation during autobiographical memory retrieval. Although the effect of these memory characteristics on pupil dilation remains an open question, we believe that our study provides a useful starting point for their assessment.

Research has mainly assessed visual perspective with methodologies based on introspection and subjective reports (e.g., the field/observer paradigm). Our study provides preliminary support for a physiological assessment that can complement the traditional subjective assessments of visual perspective. Our study also paves the way for clinical applications. For instance, depression has been associated with memory retrieval from an observer perspective [31]. It would therefore also be interesting to evaluate whether pupil size varies following the visual perspective during memory retrieval in depression.

## Declarations

**Research involving human participants** All procedures performed in studies involving human participants were in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** Authors certify the Consent.

**Conflict of interest** Informed consent was obtained from all individual participants included in the study.

**Ethics approval** None.

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