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SHORT COMMUNICATION

When looking back to nothing goes back to nothing

Andrea L. Wantz[1] · Corinna S. Martarelli[1] · Fred W. Mast[1]

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Abstract Previous research showed that the eyes revisit the location in which the stimulus has been encoded when visual or verbal information is retrieved from memory. A recent study showed that this behavior still occurs 1 week after encoding, suggesting that visual, spatial and linguistic information is tightly associated with the oculomotor trace and stored as an integrated memory representation. However, it is yet unclear whether looking behavior simply remains stable between encoding and recall or whether it changes over time in a more fine-tuned manner. Here, we investigate the time course of looking behavior during recall in multiple sessions across 1 week. Participants encoded visual objects presented in one of the four locations on the computer screen. In five sessions during the week after encoding, they performed on a visual memory recall task. During retrieval, participants looked back to the encoding location, but only in the recall sessions within 1 day of encoding. We discuss different explanations for the temporal dynamics of looking behavior during recall, searching for the role of eye movements in memory.

Keywords Eye movements · Eye position · Memory · Recall · Mental imagery

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✉ Andrea L. Wantz
andrea.wantz@psy.unibe.ch

[1] Department of Psychology and Center for Cognition, Learning and Memory, University of Bern, Fabrikstrasse 8, 3012 Bern, Switzerland

Introduction

“Look”! One simple word or gesture causes humans to direct their gaze to a certain location in space in order to see what is happening there. The eyes’ fixations crucially determine what we encode and what is stored in memory. Interestingly, eye movements also play a role in processes of memory retrieval when there is no perceptual stimulus to be processed.

A large body of research demonstrated that the eyes revisit the location where the stimulus has been encoded, when this information is later retrieved from memory (Altmann 2004; Bourlon et al. 2011; Hoover and Richardson 2008; Johansson and Johansson 2014; Laeng et al. 2014; Laeng and Teodorescu 2002; Martarelli and Mast 2011, 2013; Richardson and Kirkham 2004; Richardson and Spivey 2000). The eyes also move to specific locations when participants listen to a description of a scene or describe a previously encoded scene (Johansson et al. 2006, 2012; Spivey et al. 2000). People revisit the encoding locations of *visual* information during recall despite the fact that no visual information is available at that time (Johansson and Johansson 2014; Laeng and Teodorescu 2002; Martarelli and Mast 2013; Spivey and Geng 2001). This “corresponding area effect” was also found in preschool children (Martarelli and Mast 2011; Richardson and Kirkham 2004).

Despite empirical evidence from numerous studies, it is still debated whether eye movements during memory recall are functional or whether they rather represent an epiphenomenal by-product of mental image generation (Mast and Kosslyn 2002). There is evidence pleading for a functional role of eye movements during recall (Johansson et al. 2012; Johansson and Johansson 2014; Laeng et al. 2014; Laeng and Teodorescu 2002; Scholz et al. in press). Recently, Laeng et al. (2014) found that participants are less accurate in answering questions about previously encoded stimuli when they are forced to maintain fixation compared to a condition without eye movement restriction during recall. These results are in line with previous findings (Johansson et al. 2012; Johansson and Johansson 2014; Laeng and Teodorescu 2002). However, in other studies memory performance did not depend on whether participants looked back to the encoding location during recall or not (Hoover and Richardson 2008; Richardson and Kirkham 2004; Richardson and Spivey 2000; Spivey and Geng 2001). Given this pattern of diverging evidence, the debate about a functional role of eye movements during memory recall is still ongoing.

One explanation of why eye movements may be functional for memory recall is the idea that oculomotor traces enacted during encoding are integrated in memory representations (Laeng and Teodorescu 2002; Martarelli and Mast 2013; see also Ferreira et al. 2008; Richardson et al. 2009). When, for example, visual information is later retrieved, this process would be facilitated when associated eye movements are re-enacted. By testing whether general principles of memory also apply to looking behavior, one could obtain evidence for the hypothesis that oculomotor information is integrated in memory representations and therefore functional for recall. One prominent factor that influences memory retrieval is time between encoding and recall.

The vast majority of studies on the role of eye movements during recall have in common that they administered recall immediately after encoding or very shortly thereafter. This leaves open the question whether looking behavior during recall persists over time or whether it decays with longer encoding–retrieval intervals. In order to study the time course of looking behavior during long-term memory recall, it is necessary to test recall repeatedly across sessions. Humphrey and Underwood (2008) showed that scan patterns during imagery of photographs immediately after encoding and after 48 h are similar. Moreover, a recent study demonstrated that recognition memory performance is superior when properties are fixated in the same temporal order as during encoding (Bochynska and Laeng 2015).

So far, there is—to our knowledge—only one other study with an encoding–recall interval longer than a few minutes, demonstrating the "corresponding area effect" even 1 week after encoding (Martarelli and Mast 2013). Participants encoded images in one of the four quadrants on the computer screen. Immediately after the encoding block, participants answered questions about the visual appearance of the images while their gaze was either directed to the encoding location or to any other location. Gaze direction was manipulated by instructing participants to restrict eye movements to a red frame marking one quadrant on the now empty screen. After 1 week, the same recall task was repeated with different questions and without eye position manipulation. Participants still spent more time looking at the initial encoding location, independent of whether their eye position has been manipulated to or away from that encoding location in the previous session. The authors concluded that eye position leaves a robust memory trace that is difficult to disentangle from the episodic representation obtained during encoding. The purpose of the present study was to assess multiple measurements of the "corresponding area effect" with a finer resolution across time.

To date, it is not clear yet whether the "corresponding area effect" simply remains stable between encoding and recall after 1 week or whether it dynamically interacts with recall repetitions. Studying the time course of gaze behavior across recall sessions can help to better understand the relationship between oculomotor behavior and different stages of memory processing. In the present study, participants encoded objects in different locations on the computer screen and performed on a recall task in five sessions during 1 week. Previous studies on eye movements during memory retrieval tested recall right after each stimulus/set presentation (Laeng and Teodorescu 2002; Richardson and Kirkham 2004; Richardson and Spivey 2000; Spivey and Geng 2001; Scholz et al. in press) or after encoding all stimuli (Martarelli and Mast 2013). In order to compare looking behavior right after stimulus presentation and shortly thereafter, we tested recall immediately after encoding and after 5 min. In addition, we tested recall during different stages of memory formation. Since synaptic changes in memory formation involve early long-term potentiation (LTP) and late LTP (see for example Siegelbaum and Kandel 2013), we tested recall accordingly, both 1 and 24 h after encoding. Finally, to replicate a previous study demonstrating "looking back to nothing" even 1 week after encoding, we tested recall to this time point. On some trials, eye position was manipulated toward (congruent) or away from the initial encoding location (incongruent), and on other trials, no eye position manipulation took place. We were interested in "looking back to nothing" and in the effect of eye position manipulation on memory recall performance.

Methods

Participants

A sample of 19 participants (13 females) was recruited from the Department of Psychology of the University of Bern. The age span ranged from 22 to 36 years

($M = 27.84$, $SD = 4.6$). All participants gave written semi-informed consent to participation prior to the study. The study was approved by the local ethics committee and was conducted in accordance with the Declaration of Helsinki.

Material

Twenty-four object images of the bank of standardized stimuli (BOSS; Brodeur et al. 2010) served as stimuli (see "Appendix"). The viewing angle of the stimuli was 10.6°. Five recall statements about the specific physical appearance of the objects per image were prerecorded as audio files (e.g., "the Viking mask had orange braids"). Furthermore, we used blank slides for recall trials without manipulation and slides with one quarter marked with a red frame for trials with eye position manipulation. In order to ensure comparability of the stimulus material, two versions of the experiment were created that differed in terms of what statements appeared in which sessions (recall statement set order in version A was 1-2-3-4-5 and 4-5-1-2-3 in version B). The two versions were compared in terms of item difficulty using a pretest. In the pretest, all stimuli were presented centrally and participants were asked to perform on the recall task as in the actual experiment: immediately after encoding, after 5 min, after 1 h, after 24 h and after 1 week. Importantly, a repeated-measures mixed analysis of variance (ANOVA; $n = 7$) with the within-subject factor session (immediately after encoding, after 5 min, after 1 h, after 24 h and after 1 week) and the between factor version (A and B) confirmed that there was no effect of version on accuracy ($p = .692$) and no interaction between version and session ($p = .712$). Thus, we conducted the study with the same stimulus material and versions.

Apparatus

The experiment was programmed using ExperimentCenter (SensoMotoric Instruments, Teltow, Germany). Eye movement parameters were measured using an SMI RED system (SensoMotoric Instruments, Teltow, Germany) with a sampling rate of 50 Hz, a spatial resolution of 0.1° and a gaze position accuracy of 0.5°.

Procedure

The procedure of the experiment is illustrated in Fig. 1. Participants were seated 70 cm from the monitor. All sessions started with a five-point calibration, followed by a four-point validation. The experiment consisted of an encoding block and five recall sessions. In order to

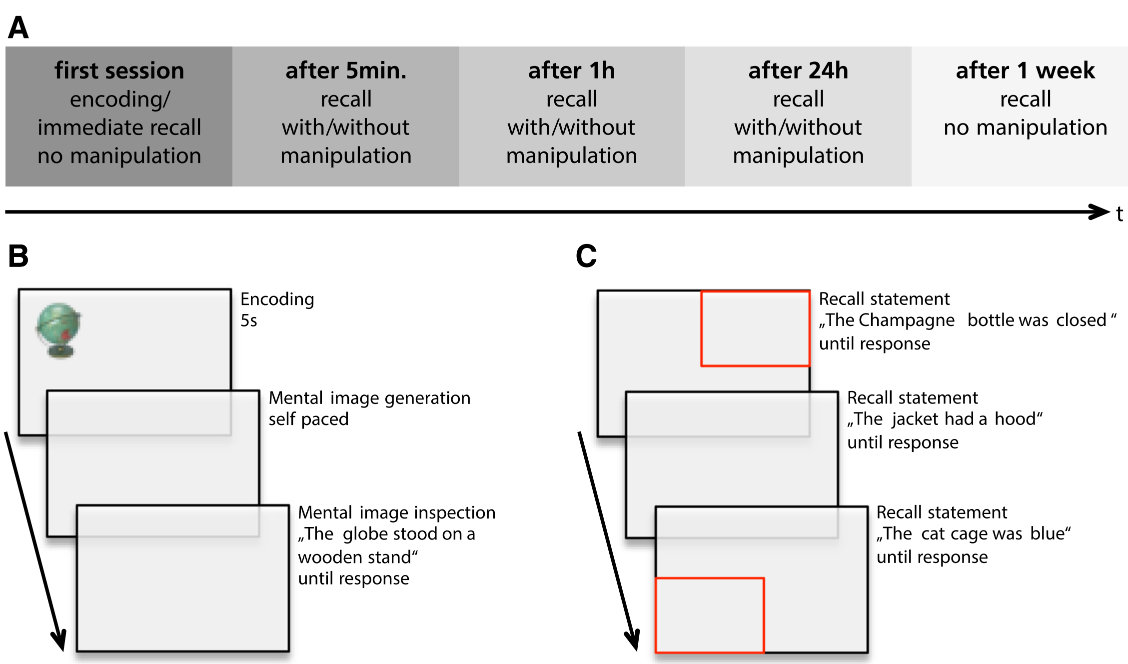

Fig. 1 **a** The experiment consisted of an encoding phase and five consecutive recall phases (immediately, 5 min, 1, 24 h and 1 week after encoding). **b** In the first session, participants visually encoded object images and were asked to form a mental image before performing on the immediate recall task (mental image inspection). **c** In the remaining recall sessions, participants were presented with auditory statements about the objects and were asked to decide whether the statements were correct or incorrect. Eye position was manipulated only in three recall sessions (5 min, 1 and 24 h after encoding) by asking participants to restrict their eye movements to a *red* frame presented on the computer screen (color figure online)

counterbalance effects of repeated measurements and to control for stimulus difficulty, participants were randomly assigned to either of the two pretested versions of the experiment. As a cover story, participants were told that the study involves eye tracking in order to investigate pupil size and imagery. Importantly, participants were informed about the true nature of the study at the end of the experiment and were asked to guess the hypothesis. Although some participants (13 out of 19) reckoned that the study might be about eye movements during recall, crucially, none of the participants guessed that we were interested in changes in looking behavior from session to session and, importantly, these participants did not differ on any variable from participants who were blind about the goal of the study.

The encoding task consisted of 24 trials presented in random order. Each trial consisted of three slides: First, an image was presented in one of the four quadrants for 5 s. Participants were instructed to memorize the images as precisely as possible. Second, after the image disappeared, the screen turned blank and they visualized the object they just saw. They indicated when they had generated the image. Third, in the immediate recall phase, the participants heard a prerecorded statement about the specific physical appearance of the object and had to decide whether the statement was correct or false. This phase assured that participants properly encoded the stimuli.

In each of the following recall sessions (5 min, 1, 24 h and 1 week after encoding), participants heard 24 new statements about the objects they had seen in the encoding task. The statements were presented in random order, and the participants were asked to decide whether the statements were correct or false. Participants gave a verbal response ("true," "false") which was then administered via key presses by the experimenter in order to prevent participants from making eye movements away from the display. Eye positions were manipulated in the recall sessions 5 min, 1 and 24 h after encoding. In one third of the trials, the red frame was congruent with the encoding location (AOI). In one third of the trials, eye position was manipulated away from the AOI (i.e., the red frame was incongruent with the AOI). No manipulation took place in the remaining third of the trials. Importantly, in order to gain insight into the consequences of repeated eye position manipulation on looking behavior after 1 week, no manipulation was applied in the last recall session. The stimuli appeared in the same manipulation condition throughout all recall sessions (e.g., if the globe was encoded in the left upper corner and belonged to the congruent manipulation condition, the red frame was presented in the upper left corner in subsequent recall sessions). The amount of correct and false statements was the same in all recall phases.

In sum, the experimental design consisted of two within factors: session (immediate recall, 5 min, 1, 24 h, 1 week after encoding) and manipulation condition (no manipulation, to the AOI, away from the AOI), thus leading to a 5×3 within design.

Results

Eye movement analyses were based on BeGaze software (SensoMotoric Instruments, Teltow, Germany). We were interested in the percentage of fixation time in the AOI of correctly solved trials in the period from auditory recall statement onset until the participant responded. Fixations were detected when the sum of the dispersion of the gaze stream on the X and Y axes was below 100 pixels (around 2 visual degrees) and when the duration exceeded 80 ms. Because each AOI takes up one quadrant of the screen, the chance level for the percentage fixating the AOI is 25 %.

Looking back to nothing during long-term memory recall

In order to test whether participants looked back to the encoding location (AOI) during memory recall, we compared fixation proportions of trials without eye position manipulation to chance level (25 %). As dependent variables, we calculated the percentage of time participants spent fixating the AOI and the percentage of fixation counts in the AOI per trial. Trials on which participants failed to give a correct response were excluded from all eye tracking analyses. Figure 2 provides an overview of the time course of fixation proportions in the AOI during long-term memory recall. One-sample *t* tests against chance level (25 %) revealed above chance level fixation time (%) in the AOI during mental image generation after encoding, $t(18) = 11.224$, $p < .001$, during immediate recall, $t(18) = 5.731$, $p < .001$, 5 min after encoding, $t(18) = 2.243$, $p = .038$, and 1 h after encoding, $t(18) = 2.276$, $p = .035$, but not 24 h after encoding, $t(18) < 1$, or after 1 week (trials without previous manipulation), $t(18) = -1.444$, $p = .166$.

Similar analyses for fixation counts (%) revealed that participants made more fixations to the AOI than chance level (%) during mental image generation after encoding, $t(18) = 10.644$, $p < .001$, during immediate recall, $t(18) = 5.460$, $p < .001$, during recall 1 h after encoding, $t(18) = 2.645$, $p = .016$, but not 5 min after encoding, $t(18) = 1.568$, $p = .134$, after 24 h, $t(18) < 1$, or after 1 week, $t(18) = -2.070$, $p = .053$. Note that applying Bonferroni–Holm corrections for multiple comparisons to one-tailed *t* tests of these analyses reduces alpha, but this did not change the pattern of our results.

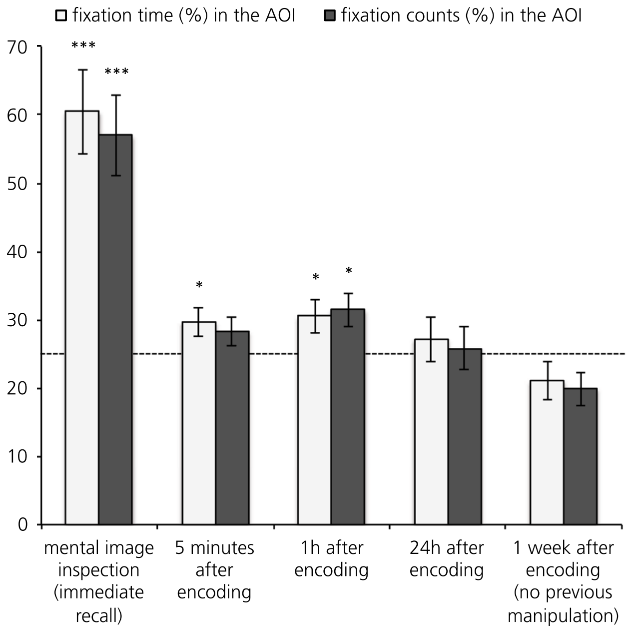

Fig. 2 Proportions of fixation time (%) and fixation counts (%) in the AOI during recall on correctly solved trials when no eye position manipulation took place. The *dashed line* indicates chance level (25 %). *Error bars* represent standard errors. *Significant at .05 level, ***significant at .001 level

In order to compare fixation proportions between sessions, separate ANOVAs with the within-subject factor session (immediately after encoding, after 5 min, after 1 h, after 24 h and after 1 week) have been calculated for fixation time (%) and fixation counts (%) in the AOI of correctly solved trials. Wherever Mauchly tests of sphericity reached significance, Huynh–Feldt corrections have been applied to the degrees of freedom.

The results revealed a significant main effect of session for the fixation time (%) data, $F(2.996, 53.933) = 18.031$, $p < .001$, $\eta_p^2 = .500$, indicating that fixation time in the AOI differed between recall sessions. Bonferroni corrected post hoc comparisons revealed that fixation time in the AOI was larger in the immediate recall session compared to after 5 min ($p = .002$), after 1 h ($p = .001$), after 24 h ($p = .001$) and after 1 week ($p < .001$). No other difference reached significance (all p's $> .195$). A similar ANOVA on the fixation count (%) data confirmed these results.

Memory performance across 1 week

Aiming at exploring the time course of repeated memory recall performance across 1 week, we computed a repeated-measures ANOVA on the accuracy data with session (immediately after encoding, after 5 min, after 1 h, after 24 h and after 1 week) as a within-subjects factor. We only

Table 1 Mean accuracy (standard deviations) across sessions and eye position manipulation conditions

	No manipulation	Congruent	Incongruent
Immediate recall	0.89 (0.07)		
After 5 min	0.87 (0.11)	0.93 (0.11)	0.87 (0.15)
After 1 h	0.82 (0.15)	0.82 (0.13)	0.82 (0.14)
After 24 h	0.79 (0.16)	0.82 (0.15)	0.86 (0.14)
After 1 week	0.77 (0.14)		

included data from trials on which no eye position manipulation was applied (after 5 min, after 1 h and after 24 h) or which have not been previously manipulated (after 1 week). The descriptive data of all accuracy levels are summarized in Table 1. Memory recall performance dynamically changed with time between encoding and recall, as indicated by a significant main effect of session, $F(4, 72) = 3.042$, $p = .022$, $\eta_p^2 = .145$). Bonferroni corrected post hoc comparisons revealed marginally better performance during immediate recall compared to after 24 h ($p = .054$), but no other comparison reached significance (all p's $> .134$).

Effects of eye position manipulation

As manipulation check, we tested whether participants looked above chance level (25 %) into the AOI during congruent manipulation and below chance level during incongruent manipulation. As expected, participants' eyes spent more time in the AOI, $t(18) = 17.782$, $p < .001$, and made more fixations to the AOI, $t(18) = 17.138$, $p < .001$, during congruent eye position manipulation. In contrast, they were highly below chance level to fixate the AOI during incongruent manipulation both in terms of fixation time (%), $t(18) = -78.731$, $p < .001$, as well as of fixation counts (%), $t(18) = -42.639$, $p < .001$.

In order to test the effect of eye position manipulation on memory performance, we computed a repeated-measures ANOVA on the accuracy data with session (5 min after encoding, after 1 h and after 24 h) and manipulation (no manipulation, congruent, incongruent) on the accuracy data. Table 1 summarizes the descriptives of the accuracy data. The results reveal a main effect of session, $F(2, 36) = 9.235$, $p = .001$, $\eta_p^2 = .339$. Bonferroni corrected post hoc comparisons indicated that recall accuracy was higher 5 min after encoding compared to after 1 h ($p < .001$) and after 24 h ($p = .011$), but memory performance did not differ between 1 and 24 h after encoding ($p > .999$). Manipulation did not generally affect recall accuracy, $F(2, 36) < 1$, and session and manipulation did not interact, $F(4, 72) = 1.045$, $p = .390$.

One could criticize that eye position manipulation was not effective, because within the red frame, participants were still free to move their eyes. Thus, it is possible that participants still preferred to look at the region within the incongruent frame, which would correspond to the AOI. In order to test this hypothesis, we re-analyzed correct trials with incongruent manipulation (from the sessions 5 min, 1 and 24 h after encoding) accordingly. For each trial, we defined the "new AOI" within the incongruent frame. As an example, given that the globe was encoded in the top right corner, when eye position is later manipulated to an incongruent location, such as the lower left corner for example, the "new AOI" would then correspond to the top right corner within this smaller frame. In fact, the percentage of fixation time within this "new AOI" ($M = 29.31$ %, SD = 5.62 %) was larger than chance level (25 %), $t(18) = 3.342$, $p = .004$. Similarly, the proportion of fixations in the "new AOI" ($M = 28.10$ %, SD = 6.14 %) was above chance level, $t(18) = 2.2$, $p = .041$. Thus, even though participants' gaze was directed to a location incongruent to the encoding location during these trials, they seemed to "zoom out" the whole screen onto this smaller frame and tended to move their eyes back to the relative encoding location.

In order to test, whether repeated eye position manipulation affected recall accuracy 1 week after encoding, a repeated-measures ANOVA was calculated on the accuracy data of the last recall session with the within-subject factor manipulation (no previous manipulation, previous congruent manipulation and previous incongruent manipulation). Repeated eye position manipulation did not significantly influence recall performance 1 week after encoding, $F(2, 36) = 2.789$, $p = .075$.

Further, we were interested in the effect of repeated manipulation (5 min after encoding, after 1 h, after 24 h) on looking behavior 1 week after encoding. Thus, a repeated-measures ANOVA was calculated on the fixation time (%) data in the AOI 1 week after encoding with the within-subject factor manipulation (no previous manipulation, previous congruent manipulation and previous incongruent manipulation). Repeated eye position manipulation did not affect fixation times (%) in the AOI, $F(2, 36) = 1.709$, $p = .195$. A similar ANOVA on the fixation counts (%) confirmed this result, $F(1.589, 28.598) = 1.345$, $p = .272$.

Last but not least, we asked whether repeated manipulation to an incongruent location "reprogrammed" the effect of looking back to the encoding location. Thus, we defined the "new AOI" for all trials in the recall session 1 week after encoding, on which eye position was previously manipulated to a quadrant incongruent with the initial encoding location. On average, participants spent 23.8 % (SD = 13.99) fixating the new AOI and made 22.3 % (SD = 13.28) of the fixations to the AOI 1 week after incongruent manipulation. However, one-tailed one-sample t tests showed that these fixation proportions were not different from chance level (both p's $> .192$).

Discussion

The goal of this study was to investigate the time course of looking behavior across recall sessions. After encoding objects in different locations on the computer screen, participants spent more time fixating the AOI during recall immediately after encoding, after 5 min and after 1 h but not after 24 h or after 1 week. We discuss different explanations for the temporal dynamics of looking behavior during long-term memory recall.

During recall, participants looked back to the encoding location in the recall sessions within 1 day but not in later sessions. These findings converge well with a previous study showing that looking behavior during recall decreases with trial repetition within one session (Scholz et al. 2011). In Scholz et al.'s (2011) study, participants fixated the AOI more frequently during the first recall but only at chance level during subsequent recalls. In contrast, recall performance increased with trial repetition. The authors concluded that looking to nothing decreases as memory representations get more stable and suggest that the use of an "external memory," as indicated by looking behavior, depends on working memory load. Thus, eye movements might be functional for recalling information that is not yet well rehearsed.

In fact, practice is a plausible explanation for why "looking back to nothing" did not occur 24 h and 1 week after encoding in our study. Throughout the course of the experiment, participants recalled the same objects five times. Thus, it is possible that practice eased mental image generation and participants no longer needed to rely on "external memory." However, in another study, "looking back to nothing" still occurred 1 week after encoding (Martarelli and Mast 2013). Because Martarelli and Mast (2013) did only administer recall accuracy once, 1 week after encoding, without repeating recall, we think that it is rehearsal rather than time between encoding and recall that changed the "corresponding area effect." Nevertheless, future research will be needed to address the specific question how time between encoding and recall and recall repetition interact in "looking back to nothing."

Previous findings suggest that repeated recall of pictures improves memory performance (Erdelyi 2010; Erdelyi and Becker 1974). Although performance in our task did not increase but remained stable across recall sessions throughout the week, one might hypothesize that memory representations become more robust as a function of recall repetition and therefore oculomotor information is no longer informative (Scholz et al. 2011). This explanation supports the hypothesis that eye movements during recall are helpful when the task is difficult and loose their influence when the representation becomes stronger (Ferreira et al. 2008; but see Richardson et al. 2009). Thus, eye movements might be regarded as memory strategy and the use of which depends on task difficulty.

Regarding eye movements as a memory strategy, Laeng et al. (2014) hypothesized that eye movements are functional for recalling visual or spatial but not for verbal information. It is possible that participants in our study used a visual strategy when they looked back to the AOI during recall. However, it remains a speculation whether participants used a visual strategy in the first recall sessions and switched to a verbal strategy the day after encoding. As an alternative to such a switch in strategy, it is possible that the nature of the memory representation changed. The fact that participants seemed to "forget" the encoding locations across recall sessions (no "looking back to nothing" after 24 h after encoding) although recall performance remained stable might indicate that memory representations loose their context with repeated recall as a process of semantization.

Another reason for why "looking back to nothing" decreased might be forgetting. Possibly, memory representations weaken over time, and thus, participants also forget about the encoding location of the stimuli. Thus, "looking back to nothing" would decrease. However, it is unlikely that participants forgot much because accuracy did not differ between sessions 5 min and 1 week after encoding.

Yet another explanation for the time course of looking behavior during recall in our study is disruption by interference. During three recall sessions (5 min, 1 and 24 h after encoding), eye position was manipulated by instructing participants to restrict their gaze to a visually presented red frame. On some trials, the red frame was incongruent to the initial encoding location. Thus, incongruent eye position manipulation might have caused interference what decreased "looking back to nothing" in subsequent recall sessions. However, eye position manipulation did not affect looking behavior 1 week after encoding and accuracy did not differ between trials that have been previously manipulated (congruent or incongruent) and stimuli that have never been manipulated. Moreover, after repeated incongruent manipulation, participants did not look into the "new" region of interest. Thus, we think it is unlikely that repeated eye position manipulation disrupted "looking back to nothing."

Eye position manipulation did not affect visual memory recall performance in our study. This finding is in line with previous research (Martarelli and Mast 2013; but see Johansson and Johansson 2014). It has to be noted that the red square did not impede participants from making eye movements within the frame (Laeng et al. 2014). This is a critical difference to studies where participants were asked to maintain their gaze on a fixation cross during recall what resulted in decreased performance (Johansson et al. 2012; Johansson and Johansson 2014; Laeng et al. 2014; Laeng and Teodorescu 2002). The frames we used for eye position manipulation were twice as big as in another study investigating visual memory (Johansson and Johansson 2014). Thus, the larger frames used in our and in a previous study (Martarelli and Mast 2013) may not have affected accuracy because eye movement restriction was not strong enough. The fact that participants are still able to move their eyes within a frame (even when this frame is in a place incongruent to the encoding location) is a plausible explanation for why recall performance is not impaired by such eye position manipulation. Indeed, participants in our study still looked longer into the region within the incongruent frame that corresponded to the encoding location, relatively.

Whereas central fixation during recall impaired accuracy in some studies (Johansson et al. 2012; Laeng et al. 2014; Laeng and Teodorescu 2002), other studies did not find accuracy differences between trials on which participants spontaneously looked back to the encoding location or not (Hoover and Richardson 2008; Richardson and Kirkham 2004; Richardson and Spivey 2000; Spivey and Geng 2001). It is noteworthy that these studies differ conceptually. In some studies, participants memorized visual information (Johansson et al. 2012; Laeng et al. 2014; Laeng and Teodorescu 2002; Martarelli and Mast 2013; Spivey and Geng 2001), whereas in other studies, they were asked to recall verbal information (Hoover and Richardson 2008; Richardson and Kirkham 2004; Richardson and Spivey 2000; Scholz et al. in press; Spivey and Geng 2001). It is important to take into account differences in memory systems since a recent study demonstrated that eye movements are relevant for establishing spatial relationships between encoded objects but not for the absolute locations of objects (Olsen et al. 2014).

Seemingly subtle variations in gaze manipulation can affect comparability between studies (e.g., small vs. large frames). In future research, it might be fruitful to introduce novel approaches to eye movement manipulation in order to investigate oculomotor contributions to memory mechanisms. One such approach might be to disrupt a key node of the oculomotor system temporarily by means of theta burst stimulation (cTBS) over the frontal eye field (FEF; Müri et al. 1991; Nyffeler et al. 2006a, b). While restricting gaze to a visually presented frame influences eye position, cTBS over the FEF would disrupt the *control* of eye movements. Thus, one would be able to distinguish between the effects of "looking back to nothing" and eye movement execution on memory recall.

To summarize, the results of our study demonstrate that "looking back to nothing" during memory retrieval decreases with repeated recall. Thus, eye movements may accompany memory retrieval when stimuli are not yet well rehearsed but become less important when mental representations stabilize and loose contextual information.

Acknowledgments We would like to thank Corina Schöne and Markus Lauber for helping with data collection.

Appendix

See Table 2.

Table 2 List of the 24 stimuli and of the five statements per stimulus used in the experiment

Stimulus	Recall statements
Backpack	The backpack had an elasticated exterior pocket
	On the right side of the backpack, there was a water bottle in the side pocket
	The backpack had a carry handle
	The backpack was gray-blue
	The backpack had loose ribbons
Bib	On the bib, there were printed crayons
	The bib had a Velcro® fastener
	The bib was made from fluffy terry cloth
	The bib had a striped hem
	The cloth of the bib had a blue background
Bonnet	The bonnet was colorfully striped
	The bonnet had a folded hem
	The bonnet had a point
	The bonnet was knitted from finespun wool
	The bonnet had ear flaps
Brooch	The brooch had a hole pattern
	The brooch had turquoise and orange gem stones
	The brooch was made of silver
	The brooch had pearls on it
	The brooch was studded with dark blue sapphires
Cap	The backside of the cap was made from net cloth
	On the cap, there was a logo
	Under the ripped cloth of the cap, the red lining was visible
	On the cap, there was a star
	The cap was mainly made from white cloth
Cat cage	In the cat cage, there was a red blanket
	The cat cage had a carry handle
	The cat cage was blue
	The grating of the cat cage was closed
	In the cat cage, there was a cat

Table 2 continued

Stimulus	Recall statements
Champagne	The champagne bottle was closed
	The champagne bottle had a star on the closure foil
	The champagne bottle had a red seal
	Next to the champagne bottle, there was a glass
	The champagne bottle was in an ice bucket
Washing-up liquid	The washing-up liquid bottle was open
	The label of the washing-up liquid was blue
	The washing-up liquid was yellow
	There was foam coming out of the washing-up liquid bottle
	On the label of the washing-up liquid, there was a brand logo
Drill	There was an extension plugged into the drill
	The drill had a cable
	The drill was made out of red and black plastic
	The drill had a nubby handle
	The drill had a logo
Drum	The drum had a dark brown handle made out of wood
	The drum had a shoulder strap
	Next to the drum, there were wooden drum sticks
	The drum was painted with a colorful ethno pattern
	The drumhead was mounted with string cords
Globe	The globe had a relief
	The globe stood on a wooden stand
	The globe had a cable
	The globe was made from antique, beige paper
	On the globe, Australia was visible
Jacket	The jacket had black elbow patches
	The jacket was made out of dark brown small checked cloth
	The jacket had a collar
	The jacket had a hood
	The jacket had buttons
Laptop bag	The laptop bag was black
	The laptop bag had an exterior pocket
	The laptop bag had a brown leather handle
	The laptop bag had a cuddly toy pendant
	The laptop bag was made out of leather
Life jacket	The life jacket had a neon orange strap
	The life jacket was made out of yellow and blue cloth
	The life jacket had a whistle on a ribbon
	The zipper of the life jacket was open
	The life jacket had a collar
Office chair	The office chair had a head rest
	The frame of the office chair was made out of silver chrome steel
	The office chair had a cushion made out of leather
	The office chair had arm rests
	The office chair had a handle for level adjustments

Table 2 continued

Stimulus	Recall statements
Radio	The radio had two cassette compartments
	The radio had a CD compartment
	The radio was made out of black plastic
	The antenna of the radio was extended
	The radio had a carry handle
Shoe	The shoe had laces
	The shoe had an ankle ribbon
	The shoe was made out of black leather
	The shoe had a metal buckle
	The shoe had high heels
Umbrella	The umbrella had a brown, wooden handle
	The umbrella had a beige checked pattern
	The umbrella had a carry strap
	The umbrella was blue
	The umbrella was in a cover
Wallet	The wallet had a zipper
	The wallet had a snap fastener
	The wallet was mainly made out of leather
	The wallet had a strap to attach a bundle of keys
	The wallet had a fabric application on the cover
Watch	On the clock face of the watch, there was a date display
	The watch was studded with twinkling diamonds
	The watch had a red Swiss flag on the clock face
	The watch had a wristband made out of metal
	The watch had golden hands
Watering can	The watering can had a sprinkler head
	The watering can was dark green
	The watering can had a curved pipe
	The watering can was attached to a garden hose
	The watering can was made out of plastic
Viking mask	The Viking mask had a golden dragon head on the front
	The Viking mask had furry ear flaps
	The Viking mask was made out of plastic
	The Viking mask had orange braids
	The Viking mask had a strap
Wine bottle	The wine bottle had a beige label
	The closure of the wine bottle was sealed with a foil
	The cork of the wine bottle was visible
	The wine bottle had a bottle pourer plugged into it
	Next to the wine bottle, there was a wine glass
Xylophone	The xylophone was mounted on rolls
	The xylophone stick was yellow
	The sounding parts of the xylophone were colorful
	The frame of the xylophone was red
	The xylophone was made out of wood

In each session, we used a new statement associated with either a blank screen or with a congruent or incongruent frame. Participants were asked to judge the correctness of the statements

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