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Listen up, eye movements play a role in verbal memory retrieval

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Abstract People fixate on blank spaces if visual stimuli previously occupied these regions of space. This so-called "looking at nothing" (LAN) phenomenon is said to be a part of information retrieval from internal memory representations, but the exact nature of the relationship between LAN and memory retrieval is unclear. While evidence exists for an influence of LAN on memory retrieval for visuospatial stimuli, evidence for verbal information is mixed. Here, we tested the relationship between LAN behavior and memory retrieval in an episodic retrieval task where verbal information was presented auditorily during encoding. When participants were allowed to gaze freely during subsequent memory retrieval, LAN occurred, and it was stronger for correct than for incorrect responses. When eye movements were manipulated during memory retrieval, retrieval performance was higher when participants fixated on the area associated with to-be-retrieved information than when fixating on another area. Our results provide evidence for a functional relationship between LAN and memory retrieval that extends to verbal information.

Introduction

While there is compelling evidence that eye movements are engaged in cognitive tasks like reading, scene perception and visual search (Rayner, 2009), eye movements also occur when the outside world is devoid of any task-relevant information. Coining the term "looking at nothing" (LAN) phenomenon, Richardson and colleagues (Hoover & Richardson, 2008; Richardson & Kirkham, 2004; Richardson & Spivey, 2000) have shown that the retrieval of verbal information from memory leads the gaze back to spatial locations that were previously associated with the retrieved information. Similar memory-driven eye movement behavior during retrieval of the past events has been shown in the context of language processing (Altmann, 2004), mental imagery (Brandt & Stark, 1997; Johansson, Holsanova, Dewhurst & Holmqvist, 2012; Johansson, Holsanova & Holmqvist, 2006; Laeng, Bloem, D'Ascenzo & Tommasi, 2014; Laeng & Teodorescu, 2002; Martarelli & Mast, 2010, 2013; Spivey & Geng, 2001), and reasoning and decision-making (Jahn & Braatz, 2014; Platzer, Idzikowski, Sala, Logie & Baddeley, 2014; Renkewitz & Jahn, 2012, Scholz, von Helversen, & Rieskamp, 2015).

Recently, a discussion has emerged as to whether such eye movements during memory retrieval are purely an epiphenomenon or whether they play a functional role in the retrieval of information from memory (Ferreira, Apel & Henderson, 2008; Richardson, Altmann, Spivey & Hoover, 2009). That is, does returning the eyes to a spatial location, which is associated with the to-be-retrieved information, facilitate the retrieval of this information from memory? Indeed, it is possible that eye movements are functionally related to memory performance. The chain of events might occur as follows: While encoding of information from the environment, eye movements are stored as part of an episodic memory representation (in the form of a spatial index, Pylyshyn, 2001; Richardson & Kirkham, 2004). Retrieving parts of the episodic trace, e.g., by probing for parts of the stored information, leads to the execution of the

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spatial index that elicits an eye movement to the location where a visual object was presented during encoding (Altmann & Kamide, 2007, 2009; Hoover & Richardson, 2008; Jahn & Braatz, 2014; Laeng & Teodorescu, 2002; Renkewitz & Jahn, 2012; Richardson & Kirkham, 2004; Richardson & Spivey, 2000, for overviews see Ferreira et al., 2008; Huettig, Mishra & Olivers, 2012; Huettig, Olivers & Hartsuiker, 2011; Richardson et al., 2009). The binding of information in an episodic trace is not limited to object-related features, but applies to action planning and sensorimotor processing (Hommel, 1998, 2004), i.e., the execution of an eye movement generated in the linked spatial index (Hoover & Richardson, 2008; Spivey & Dale, 2011). In recreating this eye movement, memory activation for other associated information increases (Altmann & Kamide, 2007; Huettig et al., 2012, 2011; Mayberry, Crocker & Knoeferle, 2009), and therefore increases the chance of successfully retrieving the probed information (Johansson et al., 2012; Johansson & Johansson, 2014; Laeng et al., 2014; Laeng & Teodorescu, 2002).

Enhanced memory performance by re-enacting processes that were engaged at encoding is consistent with the principles of "encoding-specificity" (Tulving & Thomson, 1973; Tulving, 1983) and "transfer appropriate processing" (Morris, Bransford & Franks, 1977), that state that memory performance is a function of the degree to which cognitive operations engaged at encoding are re-enacted at retrieval (see also Foulsham & Kingstone, 2013; Holm & Mäntylä, 2007; Mäntylä & Holm, 2006). Furthermore, it is in line with accumulating evidence demonstrating that retrieval activates the same brain regions that were active during encoding (for an overview, see Danker & Anderson, 2010; Kent & Lamberts, 2008; Rugg, Johnson, Park & Uncapher, 2008; Rugg & Wilding, 2000). Taken together, eye movements to empty spatial locations should be functional in the retrieval of both visuospatial and verbal information from memory.

Previous studies looking at LAN during retrieval of verbal information have reported null results on the relation between eye movements and memory performance (Hoover & Richardson, 2008; Richardson & Kirkham, 2004; Richardson & Spivey, 2000). In the classic LAN study, Richardson and Spivey (2000) auditorily presented participants with semantic statements, which were only loosely associated with a spatial location on a screen through a visual cue. For example, participants heard the sentence "Claire gave up her tennis career, when she injured her shoulder" while a spinning cross was presented in one of four areas of the screen (henceforth called the 'relevant area'). Subsequently, the screen went blank and participants answered a question about one of the presented statements. Participants exhibited LAN, that is, they tended to look back to the relevant area during the retrieval phase, even though the to-be-recalled information had been presented auditorily and the visual cue was not relevant to the task (Hoover & Richardson, 2008; Jahn & Braatz, 2014; Laeng et al., 2014). Richardson and Spivey (2000) compared participants' response accuracy between trials with at least one fixation on the relevant area (which they defined as "LAN trials"), to trials with no fixations on this area ("no LAN" trials). They found no significant difference between the trials. In a similar study, also testing verbal memory retrieval, Hoover and Richardson (2008) correlated gaze duration on relevant spatial locations with response accuracy. Again, they found no effect.

There is evidence of a functional relationship between eye movements and memory from studies testing visuospatial material (Johansson et al., 2012; Johansson & Johansson, 2014; Laeng et al., 2014; Laeng & Teodorescu, 2002; Martarelli & Mast, 2010). The general procedure in these studies was to first associate visuospatial information (e.g., characteristics of a tropical fish, see Laeng & Teodorescu, 2002) with distinct spatial locations during a preceding encoding phase. During a subsequent retrieval phase, the screen is blank and participants are instructed to retrieve the previously encoded information (e.g., the fish's color or orientation in space, see Laeng & Teodorescu, 2002). By analyzing participants' spontaneous gaze behavior during memory retrieval, Martarelli and Mast (2010) showed that children gazed more often at the location they were viewing, while the respective information was encoded when answering correctly than when answering incorrectly. Some studies induced an eye movement manipulation, i.e., manipulated eye movements as an independent variable to clarify the relation between eye movements and memory retrieval (Johansson et al., 2012; Johansson & Johansson, 2014; Laeng et al., 2014; Laeng & Teodorescu, 2002). For example, Johansson and Johansson (2014) asked participants to recall information about previously encountered objects, while fixating on either an area associated with the to-be-recalled information (congruent) or while fixating on another area (incongruent). They found impaired retrieval performance when participants fixated on the incongruent area compared to when they fixated on the congruent area. Additionally, participants' response times were longer when fixating on the incongruent compared to the congruent area. Taken together, these studies provide converging evidence that eye movements indeed play a functional role in memory retrieval of visuospatial information.

Can we, therefore, conclude that a functional relationship between eye movements and memory retrieval is restricted to the retrieval of visuospatial information and does not extend to the retrieval of verbal information? No, because the available evidence on the functional relationship between LAN and the retrieval of verbal information from memory is inconclusive for several reasons. First, measures that have been used to investigate the relationship in studies with verbal material (e.g., comparison between one-fixation and no-fixation trials) are not very sensitive: A single fixation in the relevant area could easily be caused by random gaze behavior. Second, the analyses of the relation between eye movements and memory retrieval by Richardson and colleagues were correlational, and thus, do not allow for a causal conclusion, because they did not experimentally manipulate gaze behavior. Therefore, Richardson et al. (2009) call for a stronger test of a possible functional relationship between LAN and verbal memory retrieval: "Until evidence is reported where eye movements are manipulated as an independent variable, and memory for linguistic information is affected, we choose to remain agnostic" (*p*. 235). Third, research findings from related fields suggest an interaction between visuospatial and verbal components of an episodic memory representation. For example, studies of spoken language comprehension found that object fixation can change the interpretation of spoken language (Allopenna, Magnuson & Tanenhaus, 1998; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995; for an overview see Anderson & Spivey, 2009). These findings indicate a strong coupling between eye movements and verbal information processing, which is consistent with a grounded perspective on cognition (Barsalou, Kyle Simmons, Barbey & Wilson, 2003; Barsalou, 2008; Kent & Lamberts, 2008; Spivey, 2007; Wilson, 2002). Therefore, the findings suggest that the relationship between gaze behavior and memory retrieval might also extend to the retrieval of verbal information.

The goal of the current study is to clarify the relationship between gaze behavior and the retrieval of verbal information from memory. To do so, we use a variation of the original LAN paradigm (Richardson & Spivey, 2000) in which memory of verbal information is tested by presenting auditory statements that are only loosely associated with a spatial location via a task-irrelevant visual cue. To clarify the relation between gaze behavior and verbal information retrieval performance, we test the relation in two different, but complementary, ways. During a first block of trials, effects of LAN on retrieval performance are assessed under a free gaze condition (i.e., participants are allowed to gaze freely) by comparing LAN trials with correct responses to those with incorrect responses. We hypothesize that if eye movements are related to the retrieval of associated verbal information, LAN should be stronger during retrievals that result in correct responses than during retrievals that result in incorrect responses. A second block tests the effects of a gaze manipulation on retrieval performance, by comparing retrieval performance on trials where a spatial cue is shown in an area associated with the to-be-recalled information (congruent) to trials where such a cue is shown in another area, i.e., adjacent or diagonal areas (incongruent). If eye movements are related to the retrieval of associated verbal information, response accuracy should be higher in the congruent than in any of the incongruent conditions. Furthermore, if the gaze manipulation affects the availability of information held in memory, response times should be shorter in the congruent compared to the incongruent conditions.

Methods

Participants

Twenty-eight native German speaking students from Technische Universität Chemnitz participated in the experiment (22 female, mean age 23.4 years, ranging from 19 to 39). All had normal or corrected to normal vision.

Apparatus

Participants were seated at a distance of 630 mm in front of a 22″ computer screen (1680 × 1050 pixels) with their head in a chin rest. Stimuli were presented with E-Prime 2.0 running on a separate computer. An SMI iView RED eye tracker sampled data from the right eye at 120 Hz with a precision of 0.05° that were recorded with iView X 2.5 following 5-point calibration. Data were analyzed with BeGaze 2.3. Fixation detection had a dispersion threshold of 100 pixels and a duration threshold of 100 ms (cf. Richardson & Spivey, 2000).

Materials

Visual stimuli in the encoding phase consisted of a grid dividing the screen into four equal-sized spatial areas (Fig. 1) and four black circles in the center of each spatial area. To associate spatial areas with the auditory stimuli, a symbol of a loudspeaker appeared in the circle of the respective area. During retrieval phases in the free gaze condition, participants saw the grid and circles only. During the retrieval phases in the gaze manipulation conditions, we manipulated gaze behavior with a spatial cue (cf. Mulckhuyse & Theeuwes, 2010; Theeuwes, 2010; Yantis & Jonides, 1981). The spatial cue was a red dot, blinking at 2 Hz that appeared in one of the four circles in the center of each spatial area.

Auditory stimuli during encoding consisted of 28 sentences. Each sentence was comprised of a name and four attributes describing an artificial city (e.g., "In Velbert you can find a bicycle museum, a sickle-shaped bay, a red lighthouse and an inland port."). City names were randomly selected small cities from an online resource for

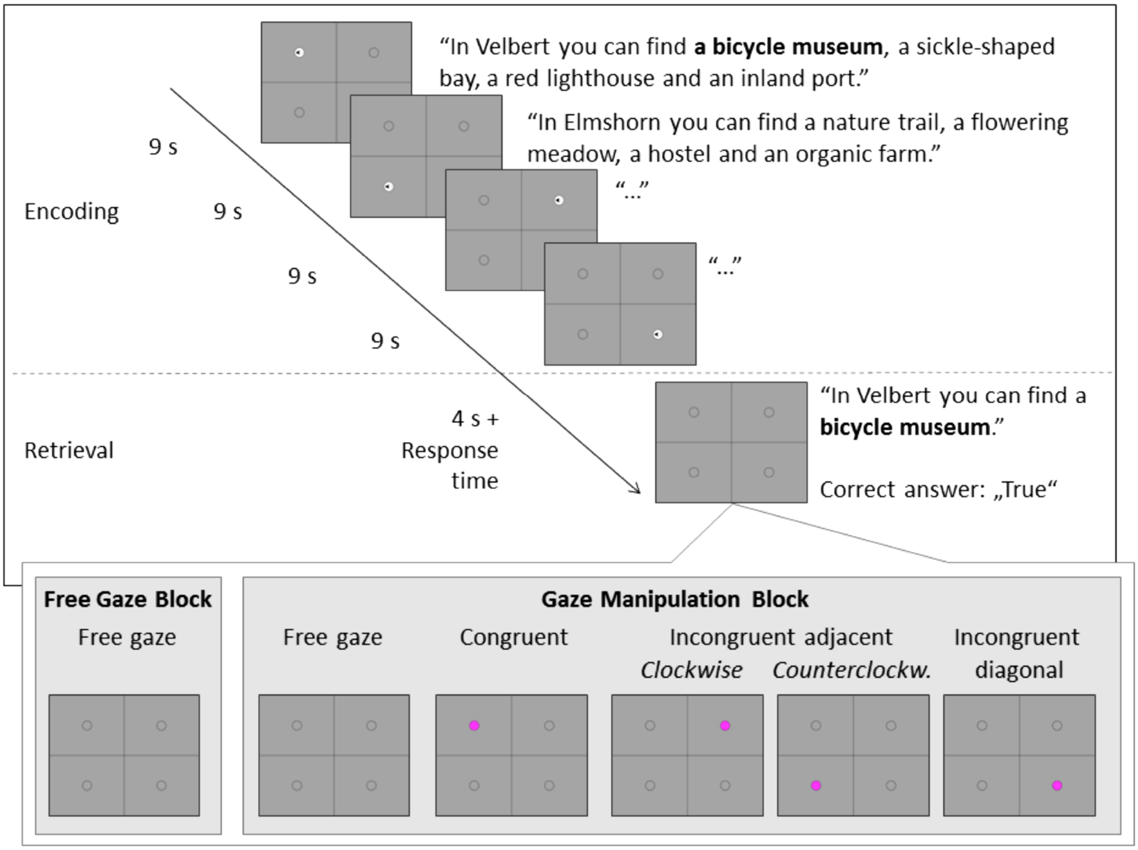

Fig. 1 Example trial with to-be-encoded sentences and a true statement probing the test sentence in the retrieval phase. In this example, the relevant area is the *top left* area, as this is the location associated with the test sentence. At the *bottom* of the figure, eye movement conditions in the retrieval phase of the *different experimental blocks* are illustrated (see main text for a more detailed description)

German postcodes (http://www.postdirekt.de/plzserver/). Attributes consisted of buildings, institutions, sights, leisure activities, and industrial sites. From the 28 sentences, 7 were randomly selected to be used as test sentences during the retrieval phase. For those test sentences, we generated a true and a false version for each of the four attributes (e.g., True: "In Velbert you can find a bicycle museum", False: "In Velbert you can find an aircraft museum"). This resulted in 56 test statements (7 sentences × 4 attributes × 2 correctness). To control for effects of city names, each sentence had two possible names (e.g., Velbert was replaced by Zehdenick for half of the participants). Eight additional sentences and their respective test statements were generated for the training block.

Procedure

The experiment starts with two practice trials, followed by a free gaze block (8 experimental trials), and a gaze manipulation block (20 experimental trials). Each trial consisted of an encoding phase, which was identical in all conditions, and a retrieval phase, which differed between conditions (see Fig. 1).

Encoding phase

In the encoding phase of each trial, four sentences were auditorily presented. For each sentence, a loudspeaker was shown in one of the four spatial areas. Importantly, the speaker symbol provided the only link between the sentence and the spatial area, and it was completely irrelevant for successful completion of the task.

Retrieval phase

In the retrieval phase, participants were auditorily presented with a test statement for one of the four encoded sentences and had to press one of two keys on the keyboard to indicate whether the statement was true or false (forced choice). Pressing the key was possible from the beginning of the retrieval phase. There was no time limit for the response, but participants were instructed to respond as quickly and accurately as possible.

The retrieval phase differed between gaze conditions as shown in the lower part of Fig. 1. To assess spontaneous LAN as a function of response accuracy, the experiment started with the free gaze block consisting of 8 trials in which participants gazed freely during the retrieval phase. Subsequently, participants completed the gaze manipulation block that consisted of 20 trials in which we assessed the effects of gaze behavior on response accuracy. In 12 trials of this block, gaze behavior during retrieval was manipulated by the spatial cue. In the congruent condition, the cue appeared in the area associated with the tested sentence (4 trials). In the incongruent condition, the cue appeared either in the diagonal area (four trials) or in one of the adjacent areas (clockwise or counterclockwise, four trials). Each participant saw the spatial cue only in one of the adjacent areas. Half of the participants saw it in the clockwise area, and the other half saw it in the counterclockwise area. Therefore, for each participant, the different cued locations (congruent, adjacent and diagonal) were tested equally often. In the remaining 8 trials of the gaze manipulation block, no spatial cue was presented. Trials with and without spatial cues were intermingled during the block. We selected this design, because it enabled us to maximize the salience of the spatial cue itself (because the gaze cue appeared only in 12 out of 20 trials) and ensured that the different cued locations were equally salient (because they were tested with equal frequency). Equal salience of the locations is important, because otherwise differences in gaze behavior might be caused by differences in salience, rather than by effects of memory retrieval.

The order of assignment of sentences to blocks and conditions was counterbalanced in four ways—the order of presentation and the position of the speaker symbol during encoding, as well as the order of statement presentation and gaze manipulation conditions during retrieval.

Results

Mean fixation proportion, based on number of fixations (cf. Richardson & Spivey, 2000), was aggregated per trial and participant. Practice trials were not analyzed. A total of ten experimental trials were excluded (1.3 % of all trials), because participants pressed the answer button before listening to the statement (Response time <1 s).

Spontaneous LAN during memory retrieval in the free gaze block

LAN across all trials

To assess spontaneous LAN during memory retrieval, we analyzed fixation proportions in the 8 trials of the free gaze block. The spatial area that corresponded with the to-be-retrieved sentence was coded as a relevant area and the other three areas as irrelevant areas 1–3 in a clockwise direction. Table 1 shows mean fixation proportions and results of contrast tests (Rosenthal, Rosnow & Rubin, 2000). A contrast weight of three indicates the relevant spatial area in which participants were expected to fixate most if they exhibited LAN. The three irrelevant spatial areas were given a contrast weight of −1. Overall, participants exhibited LAN behavior, as indicated by the higher proportion of fixations in the relevant area, than in any of the irrelevant areas.

LAN for correct and incorrect responses

To test the relationship between spontaneous eye movements and response accuracy, we analyzed fixation proportions in trials with correct responses (74.1 % of trials in the free gaze block) and trials with incorrect responses (25.9 % of trials in the free gaze block). LAN behavior was indeed stronger when participants answered correctly, than when they answered incorrectly. Strong LAN behavior is defined as fixating most often on the relevant area during a correct trial. During incorrect trials, the proportion of fixations in the relevant area decreased and participants showed an increased tendency to gaze in the diagonal area (Table 1). To compare eye movement patterns between correct and incorrect trials, we analyzed the fixation proportions in the four spatial areas for those 24 participants who gave both correct and incorrect responses. A repeated-

Table 1 Mean fixation proportions (SD *s*); effect sizes (Hedges' *g*), *t* statistics, and *p* values for the contrasts of spatial area for all cases, only correct and only incorrect responses during the free gaze block

	Spatial area				Contrast			
	Relevant	Irrelevant 1	Irrelevant 2	Irrelevant 3	*n*	*t*	*p*	*g*
Contrast weight	**3**	−1	−1	−1				
Fixation proportions								
All cases	**0.36 (0.12)**	0.23 (0.08)	0.21 (0.09)	0.20 (0.07)	28	13.0	<0.001	2.5
Correct responses	**0.38 (0.13)**	0.26 (0.10)	0.18 (0.09)	0.18 (0.09)	28	12.2	<0.001	2.3
Incorrect responses	**0.30 (0.23)**	0.14 (0.11)	0.36 (0.23)	0.21 (0.16)	24	4.9	<0.001	1.0

Bold values indicate the spatial area with a contrast weight of 3, i.e., in which participants were expected to fixate most in each condition measures ANOVA testing fixation proportions confirmed a significant interaction between the spatial area (rel, irrel1, irrel2, irrel3) and Response Accuracy (correct, incorrect) factors, $F(3,69) = 6.32$, $p = 0.001$, $\eta_p^2 = 0.22$, indicating that fixation patterns indeed differed between correct and incorrect trials.

Eye movements and response accuracy in the gaze manipulation block

Manipulation check

Before analyzing response accuracy and response times as an effect of gaze manipulation, we tested whether the gaze manipulation was successful. Therefore, we analyzed fixation proportions in each of the gaze conditions (congruent, incongruent clockwise, counterclockwise, and diagonal). In each of those conditions, the manipulation of gaze behavior would be successful if participants showed more fixations in the area with the spatial cue than in any other area. To test this, contrast weights were set to +3 for the area where the cue was presented and to −1 for the other three areas. The upper part of Table 2 shows mean fixation proportions and results of contrast tests for each location of the spatial cue in each of the gaze conditions. In each condition, participants fixated significantly more often in the area where the spatial cue was presented than in any other area, confirming that the gaze manipulation was successful. The lower part of Table 2 shows that in the absence of the spatial cue (i.e., during the free gaze trials of the manipulation block), participants showed LAN as expected.

Response accuracy

To test effects of the gaze manipulation on response accuracy, we compared response accuracy between congruent, incongruent adjacent and incongruent diagonal trials. As predicted, response accuracy was higher in the congruent than in both incongruent conditions (Fig. 2, left panel). This result was confirmed by a contrast test assigning a weight of +2 to the congruent and −1 to the adjacent and diagonal conditions, $t(27) = 2.209$, $p = 0.04$, $g = 0.42$. Response accuracy in the free gaze trials of the gaze manipulation block was 81.5 % (SD = 16.4 %), which was right in between the congruent and incongruent conditions and did not differ significantly from either one [congruent: $t(27) = 1.20$, $p = 0.24$; $g = 0.23$; incongruent adjacent: $t(27) = 0.76$, $p = 0.45$, $g = 0.14$; incongruent diagonal: $t(27) = 0.88$, $p = 0.39$, $g = 0.17$].

Response times

As a second measure indicating the availability of information held in memory, we compared response times between the congruent and the two incongruent conditions (Fig. 2, right panel). As expected, averaged median response times were shorter in the congruent condition, than in the incongruent adjacent and incongruent diagonal conditions. This result was confirmed by a contrast test assigning a weight of −2 to the congruent and +1 to the adjacent and diagonal conditions, $t(27) = 2.210$, $p = 0.04$, $g = 0.42$. Median response times in the free gaze trials of the gaze manipulation block was 1688 ms (SD = 283 ms),

Table 2 Mean fixation proportions (SDs); effect sizes (Hedges' g), t statistics, and p values for the contrasts of spatial area for the congruent, incongruent and free gaze conditions during the gaze manipulation block

	Spatial area				Contrast			
	Relevant	Irrelevant 1	Irrelevant 2	Irrelevant 3	*n*	*t*	*p*	*g*
Congruent								
Contrast weight	**3**	−1	−1	−1				
Fixation proportions	**0.47 (0.23)**	0.16 (0.09)	0.19 (0.09)	0.17 (0.10)	28	9.10	<0.001	1.7
Incongruent clockwise								
Contrast weight	−1	**3**	−1	−1				
Fixation proportions	0.28 (0.19)	**0.37 (0.27)**	0.16 (0.09)	0.19 (0.15)	14	12.61	<0.001	3.4
Incongruent counter-clockwise								
Contrast weight	−1	−1	−1	**3**				
Fixation proportions	0.20 (0.15)	0.18 (0.12)	0.15 (0.10)	**0.48 (0.27)**	14	5.12	<0.001	1.7
Incongruent diagonal								
Contrast weight	−1	−1	**3**	−1				
Fixation proportions	0.21 (0.16)	0.15 (0.10)	**0.48 (0.25)**	0.17 (0.11)	28	15.25	<0.001	2.9
Free gaze								
Contrast weight	**3**	−1	−1	−1				
Fixation proportions	**0.29 (0.12)**	0.22 (0.07)	0.25 (0.10)	0.24 (0.08)	28	9.11	<0.001	1.7

Bold values indicate the spatial area with a contrast weight of 3, i.e., in which participants were expected to fixate most in each condition

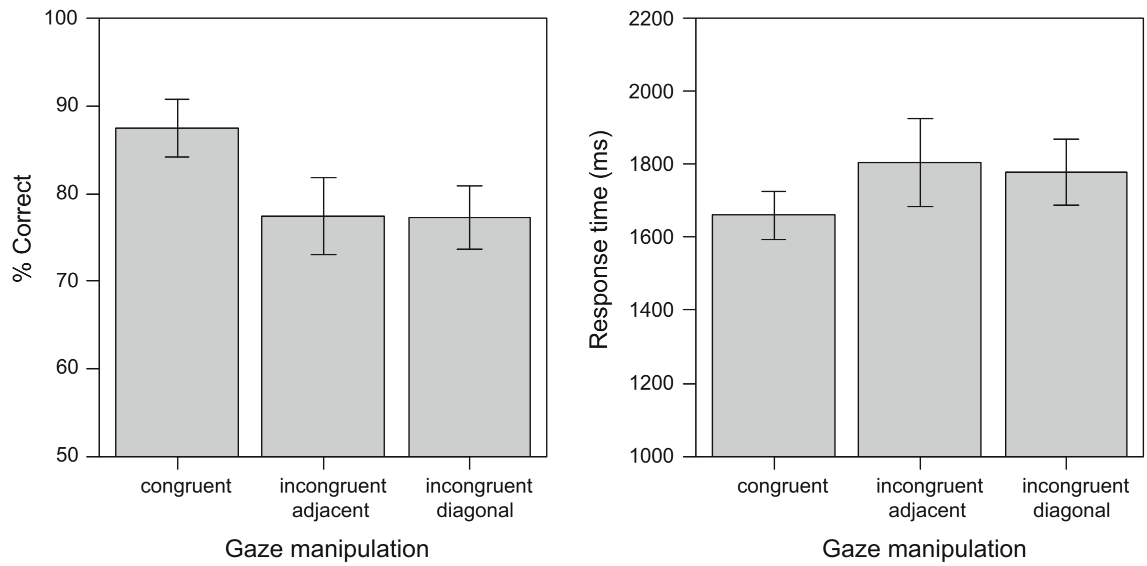

Fig. 2 Mean percent correct responses (*left*) and average median response times (*right*) for the congruent, incongruent adjacent and incongruent diagonal conditions. *Error bars* represent one standard error

which was right in between the congruent and incongruent conditions and did not differ significantly from either one [congruent: $t(27) = 0.61$, $p = 0.55$; $g = 0.12$; incongruent adjacent: $t(27) = 1.11$, $p = 0.28$, $g = 0.21$; incongruent diagonal: $t(27) = 1.33$, $p = 0.19$, $g = 0.25$].

Discussion

Recent studies have found a functional relationship between eye movements and the retrieval of visuospatial information from memory (Johansson et al., 2012; Johansson & Johansson, 2014; Laeng et al., 2014; Laeng & Teodorescu, 2002). However, it is unclear whether such a relationship extends to the retrieval of verbal information (Richardson et al., 2009). Our results help to answer this question by clarifying the relationship between gaze behavior and the retrieval of verbal information in two different ways: we tested (a) gaze behavior as a function of retrieval performance by comparing LAN during correct and incorrect responses and (b) retrieval performance as a function of gaze behavior by comparing response accuracy and response times during congruent and incongruent fixation conditions.

An analysis of LAN as a function of response accuracy in the memory retrieval task revealed stronger LAN when participants correctly retrieved information than when they responded incorrectly. This finding is comparable to the results from Martarelli and Mast (2010), who demonstrated a similar effect for preschool children on visuospatial material. The decrease of LAN during incorrect responses could be an indication of the utility of LAN in the memory retrieval process. However, this effect should be interpreted with caution, because the direction of the assumed causal relationship is not clear. When responding incorrectly, a failure to retrieve the correct information from memory might have reduced the likelihood of activating the related spatial index, thereby causing reduced LAN. At the same time, a failure to activate the relevant spatial index might have reduced the likelihood of retrieving the correct information, thereby causing an incorrect response.

The only method that allows for drawing a causal conclusion about the effect of eye movements on memory retrieval is the explicit manipulation of eye movements as independent variable (cf. Richardson et al., 2009), as implemented in the second block of our experiment. Our results from this block provide evidence for a functional relationship between LAN and retrieval of verbal information from memory. Response accuracy in the retrieval phase was higher and response times were shorter if participants' gazes in the retrieval phase had been manipulated towards the relevant spatial location (congruent condition); compared to when gaze has been manipulated away from the relevant location (incongruent adjacent and diagonal conditions). To our knowledge, this is the first evidence that clearly shows a functional relationship between eye movements and the retrieval of verbal information from memory.

The functional relationship between eye movements and memory retrieval for visuospatial information has previously been explained as an overlap between processes engaged in encoding and retrieval of a past event stored in episodic memory (Johansson et al., 2012; Johansson &

Johansson, 2014; Laeng et al., 2014; Laeng & Teodorescu, 2002). Our results extend this literature by showing that eye movements also play a functional role in the retrieval of verbal information from memory. This holds even if the spatial information is not relevant to the task and there is no demand to learn the spatial information (e.g., Richardson & Spivey, 2000).

Furthermore, our results are consistent with a grounded perspective on cognition, which assumes that behavioral re-enactment (including body posture, hand- and eye movements) of the encoding stage aids retrieval (Barsalou et al., 2003; Barsalou, 2008; Kent & Lamberts, 2008; Spivey, 2007; Wilson, 2002). Cognitive processes, like memory retrieval of verbal information, are not independent of oculomotor processing. Instead, they interact with each other and form continuous perception–action cycles out of which cognition emerges (Anderson & Spivey, 2009; Neisser, 1976; Spivey & Dale, 2011). Thus, oculomotor processes like gazing towards a presently empty, but previously associated spatial location can impact retrieval performance.

Re-enactment of processes that occur during encoding can account for superior memory performance in the congruent condition. In the incongruent conditions, memory retrieval might have been disrupted, because the salient spatial cue that we introduced to manipulate gaze behavior prevented participants from gazing at the relevant spatial location (Laeng et al., 2014; Postle et al., 2006). Thus, the gaze manipulation interfered with the participants' tendency to look at the associated spatial location, thereby degrading memory retrieval performance. The fact that retrieval performance in the free gaze condition of our experiment was observed to fall in between the congruent and incongruent conditions suggests that facilitation (in the congruent condition) as well as impairment (in the incongruent condition) might play a role. It should be noted that conclusions drawn from a comparison between gaze behavior under free gaze conditions and gaze manipulation conditions are difficult, because gaze manipulation might impose an additional cognitive load, thereby reducing retrieval performance relative to free gaze (Johansson et al., 2012; Martarelli & Mast, 2013; Mast & Kosslyn, 2002). Still, future research should investigate the degree to which processes of facilitation and impairment affect retrieval performance in the LAN paradigm, thereby advancing our understanding of the nature of the functional relationship between eye movements and memory retrieval.

In the current study, gaze was manipulated using a salient spatial cue, which attracted participants' attention either towards (congruent) or away (incongruent) from the relevant location. Our results show that the effects of gaze manipulation on retrieval performance persist even with a primarily attention-driven manipulation. This finding is consistent with Richardson and Spivey (2000) who found that it is not the oculomotor movement of the eyes per se that guides the eyes back to the associated spatial locations, but instead gaze is driven by shifts in visuospatial attention (see also Godijn & Theeuwes, 2012). It is also in line with research by Grant and Spivey (2003) and Thomas and Lleras (2009), who showed that shifting ones' attention, in comparison to moving ones' eyes in a way that corresponds to the solution of an insight problem, was sufficient to raise success rates. A possible interpretation of the above results could be that it is the shift in attention, rather than the eye movements per se, that causes the functional relationship between LAN and memory retrieval (cf. Huettig et al., 2011; Theeuwes, Belopolsky & Olivers, 2009). A more detailed investigation of this assumption will improve our understanding of the utility of gaze behavior and should be a topic for future research.

In conclusion, our results show that even if verbal information, that is only loosely associated with a spatial location, is retrieved from memory, the process of remembering is accompanied by eye movements to the associated spatial locations. In addition, we found that retrieval performance varies as a function of gaze behavior. Therefore, our results provide additional support for the idea that re-enactment of processes that occur during encoding increases the likelihood of successful episodic memory retrieval (cf. Tulving, 1983) and show that this phenomenon holds regardless of the nature of the to-be-retrieved information.

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