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Memory for the position of stationary objects: disentangling foveal bias and memory averaging

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Abstract

The perceived and remembered position of stationary target objects is subject to a large number of distortions. Objects are localized toward the fovea, and when an additional object (distractor) is presented, a tendency to average target and distractor position was observed. These distortions in visual short-term memory have been referred to as foveal bias and memory averaging, respectively. Because most studies on memory averaging did not monitor eye fixation, foveal bias and memory averaging may have been confounded. That is, observers may have fixated the distractor. To disentangle these factors, target and distractor were presented in the periphery, and fixation was monitored. Memory averaging was not observed. Rather a bias away from the distractor occurred when the distractor was briefly presented during the retention interval, or when it was visible throughout the trial. In contrast, a foveal bias was observed regardless of whether an additional object was present. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Localization; Space perception; Memory averaging; Foveal bias

1. Introduction

The perceived position of stationary objects is known to be subject to a large number of distortions. Two factors that are assumed to affect the perceived position were investigated. First, the retinal location of the object determines its perceived position. Generally, stationary and moving objects that are presented in the retinal periphery are mislocalized toward the fovea (*foveal bias*, Kerzel, 2000; Mateeff & Gourevich, 1983; Müsseler, Van Der Heijden, Mahmud, Deubel, & Ertsey, 1999; O'Regan, 1984; Sheth & Shimojo, 2001; van der Heijden, van der Geest, de Leeuw, Krikke, & Müsseler, 1999). Typically, the perceived position of a peripheral target object is probed with a certain temporal asynchrony relative to target presentation. For instance, a probe stimulus is presented after target offset and observers have to judge the target's relative position, or observers have to point to the perceived target position with a cursor (for a comparison of these methods see van der Heijden et al. (1999)). Thus, visual short-term memory is to some degree involved in the foveal bias. That is, it may be the case that short-term memory traces are biased toward the fovea. In support of this idea, the foveal bias increases with retention interval (Sheth & Shimojo, 2001) pointing to memory as the root source of the error.

Second, it has been claimed that the remembered location of objects is biased towards other elements in the display (*memory averaging*). Memory averaging was investigated with moving and with stationary objects. For instance, when observers were asked to judge the final position of a stimulus that moved along a second, stationary object, the remembered target position was biased toward the second, stationary object that was presented during the trial, but was not permanently visible (Hubbard, 1995, 1998; Hubbard & Ruppel, 1999). Even when the distracting element was only briefly presented at the time of target disappearance, a bias to localize the final position of a moving object toward the distracting element was observed (Kerzel, in press-a). In the latter study, it was argued that attention shifts away from the target object biased memory, if the shift occurred close to the retention interval. Also, the remembered position of a stationary target was biased toward a second object presented in the center of the

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screen. This bias increased with distance between the two objects (Hubbard & Ruppel, 2000).

Additionally, it was observed that there is a tendency to localize objects too far down (e.g. Hubbard, 1995; Kerzel, in press-b). This *downward bias* in visual short-term memory may indicate cognitive analogs of gravity. Alternatively, it may be that the perceived center of the stimulus is shifted downwards (Bingham & Muchisky, 1993a,b; Kerzel, in press-b), implying a perceptual locus of the distortion.

From a methodological point of view, the interpretation of studies on memory averaging suffers from a potential confound: as eye movements were not monitored, it may be possible that observers fixated the irrelevant object. If that was the case, the foveal bias may underlie memory averaging. In support of such a hypothesis, both the foveal bias and memory averaging were shown to increase with distance between target and distractor or fovea (e.g. Hubbard & Ruppel, 2000; van der Heijden et al., 1999).

In a better controlled study (Sheth & Shimojo, 2001), it was found that judgements of peripheral, stationary targets became less biased towards the fovea when a permanently visible landmark was presented. The landmark was more eccentric than the target. However, it remains unclear whether this reduction was due to averaging of landmark and target position, or whether it was due to improved accuracy. The reason for this ambiguity is that memory averaging and foveal bias acted in opposing directions. In another experiment, Sheth and Shimojo found that when observers were free to look around, a strong bias toward the distractor was noted. However, this finding is hard to interpret, as it is not clear where observers fixated.

2. Experiment 1

To disentangle the independent contributions of memory averaging and foveal bias, the point of fixation was separated from the position of the second, irrelevant object. The second irrelevant object is referred to as distractor. Further, the study was designed such that memory averaging and foveal bias would act in orthogonal directions. Therefore, target and distractor were presented peripherally, and the distractor was vertically displaced from the target, which was horizontally displaced from the point of fixation (see Fig. 1). No fixation point was presented. As the position of the fixation point is typically fixed, it may be used as a landmark. To avoid interactions between effects of the distractor and usage of such a landmark, the fixation point was omitted. The target was presented for 260 ms followed by a retention interval of 260 ms during which the target was invisible. After the 260 ms retention interval, a probe stimulus was presented, and observers had to judge whether the probe was at the same, or at a different position relative to the target position. In previous studies on memory for the final position of a moving target, a retention interval of about 250 ms had been shown to yield maximal memory distortions (Freyd & Johnson, 1987; Kerzel, 2000), and retention intervals of about 150–250 ms have been widely used in studies on visual short-term memory (Finke & Freyd, 1985; Finke & Shyi, 1988; Freyd & Finke, 1984, 1985; Freyd & Jones, 1994; Freyd, Pantzer, & Cheng, 1988; Halpern & Kelly, 1993; Verfaillie & D'Ydewalle, 1991).

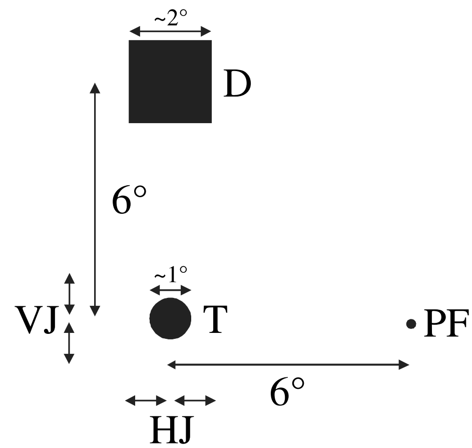

Fig. 1. Stimuli presented in Experiments 1 and 2. The center of the screen is indicated by the point of fixation (PF). No fixation point was presented, but observers were instructed to look at the center of the screen. Horizontal (HJ) and vertical jitter (VJ) was added to the target (T) position in most Experiments. The target appeared either 6° to the left or right from the screen center. The distractor (D) appeared either 6° above or below the vertical screen center at 6° left or right from the horizontal screen center.

In Experiment 1, the distractor was presented during different time intervals. In previous studies with moving targets, the distractor was either presented while the target was visible (e.g. Hubbard, 1995, 1998), or only briefly at the time of target disappearance (Kerzel, in press-a). In a previous study with stationary targets, the distractor was presented either throughout a trial (i.e., until a judgement was made) or during target presentation (Hubbard & Ruppel, 2000). Memory averaging was found to be smaller when the distractor was presented throughout. In the present experiment, the distractor was presented either throughout the trial, during the retention interval, or only during the retention interval (see Fig. 2).

2.1. Method

2.1.1. Participants

Forty-five students at the Ludwig-Maximilians University of Munich were paid for their participation. All reported normal or corrected-to-normal vision and were naive as to the purpose of the experiment. Nine observers participated in Experiment 1a, eight observers in

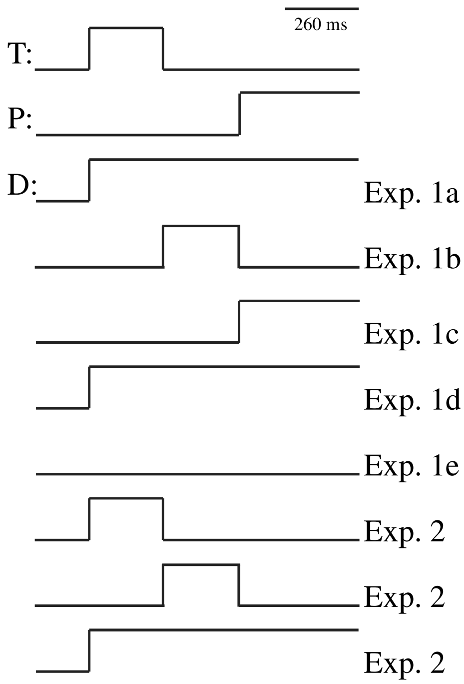

Fig. 2. Presentation times for target (T), probe stimulus (P) and distractor (D) in Experiments 1 and 2. Time runs from left to right. Presentation of a stimulus (on-time) is indicated by a rise from baseline (off-time).

Experiments 1b and 1c, 12 observers in Experiment 1d, and eight observers in Experiment 1e. Most observers served only in a single experiment.

2.1.2. Apparatus and stimuli

The stimuli were created using a Matrox Millenium II graphics card on a 21 in. (diagonal) screen with a refresh rate of 96 Hz. The display had a resolution of 1280 (H) $\times$ 1024 (V) pixels. The background was white (76 cd/m^2), the stimuli were black (0 cd/m^2).

The horizontal position of the left eye was monitored with a head-mounted, infrared, light-reflecting eyetracker (Skalar Medical B.V., IRIS Model 6500). The analog signal was digitized at a rate of 250 Hz by a DataTranslation A/D-D/A converter (DT 2821). Fixation had to be maintained within 2° of central fixation.

The target was a filled black circle (diameter of 0.98°) and the distractor was a filled black square (diameter of 1.95°). The probe stimulus was identical to the target. It was presented in the center of the screen and was visible throughout a trial. The target was presented at a horizontal distance of 6° from central fixation. Its lateral position (left or right from fixation) varied randomly, and some jitter was added to its vertical and horizontal position. The distractor was presented 6° above or below the vertical center of the screen. It appeared on the same side of fixation as the target at a distance of 6° from horizontal center of the screen (see Fig. 1). The target was presented for 260 ms. After an interval of 260 ms, a probe stimulus appeared at a position that differed vertically or horizontally from the target.

The two horizontal target positions (left, right), the vertical jitter ($\pm$1, 0°), the horizontal jitter ($\pm$1, 0°), the five probe positions (see below) and the two possible distractor positions (above, below, when applicable) were fully crossed and presented once in three consecutive blocks for a total of 360 trials. In Experiment 1b, no horizontal jitter was presented as pilot studies had shown this condition to be particularly difficult.

2.1.3. Probe positions

In Experiment 1a, the probes deviated vertically by $\pm$1.6, $\pm$0.6, and 0° from the target position. In Experiments 1b and 1c, the probes deviated vertically by $\pm$1.8, $\pm$0.9, and 0°. In Experiments 1d and 1e, the probes deviated horizontally by $\pm$1.0, $\pm$0.5, and 0° from the target position. In Experiments 1a–1c, positive values indicate an upward deviation, and negative values indicate a downward deviation. In Experiments 1d and 1e, positive values indicate a deviation towards the right, and negative values indicate a deviation toward the left.

2.1.4. Distractor presentation

In Experiments 1a and 1d the distractor was visible throughout a trial. In Experiment 1b, the distractor appeared during the retention interval. In Experiment 1c, it appeared at the same time as the probe and in Experiment 1e, no distractor was visible (see Fig. 2).

2.1.5. Procedure

Participants sat in a dimly lit room 50 cm from the screen. Head movements were restricted by a chin and cheek rest, and viewing was binocular. Observers' task was to indicate whether the target and the probe stimulus were at the same position or not. To this end, observers pressed one of two mouse buttons. Each trial was started by pressing the two mouse buttons simultaneously. No feedback was provided. When a fixation error occurred, the trial was aborted immediately. The trial was repeated in the remainder of the experiment. The different conditions were randomly interleaved.

2.2. Results

Proportions of 'same' judgements are shown in Figs. 3 and 4. The weighted sum of same judgements was calculated as a measure of the remembered target position. With vertical probe placement, positive and negative scores indicate mislocalization higher and lower than the target position, respectively. With horizontal probe placement, positive and negative scores indicate mislocalization towards the right and left, respectively. This score was calculated from the proportion of times that a participant responded same for each probe displacement, weighted by the actual value of the displacement (i.e.,

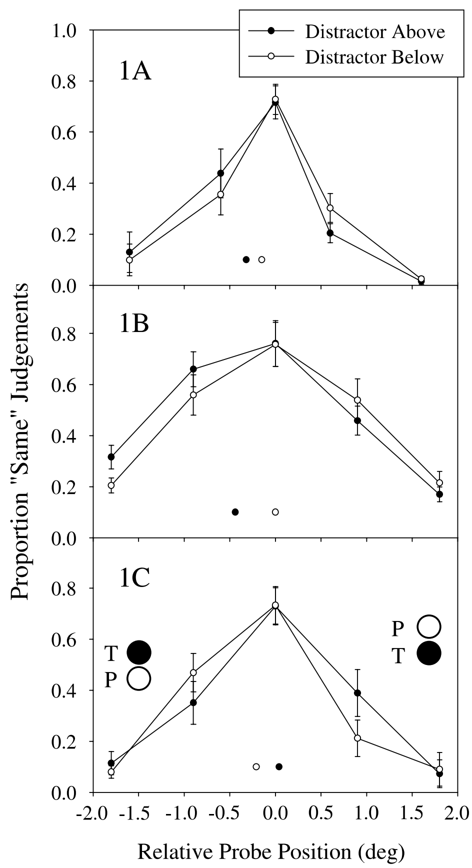

Fig. 3. Mean proportions of same judgements as a function of probe position, distractor placement, and Experiment (1a–1c). Negative relative probe positions indicate that the probe (P) was above the target (T) position, positive values indicate that it was below. The weighted means for each condition are shown as a single circles. In Experiments 1a and 1b, the distribution of same judgements was shifted downwards when a distractor was presented above, such that the weighted mean was smaller than when a distractor was presented below. In Experiment 1c, no such difference occurred.

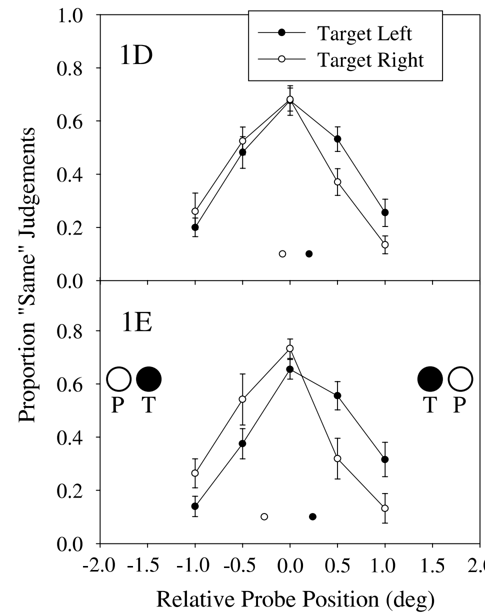

Fig. 4. Mean proportions of same judgements as a function of probe position, distractor placement, and Experiments (1d and 1e). In Experiment 1d, the distractor was visible throughout a trial, whereas no distractor was presented in Experiment 1e. Negative relative probe positions indicate that the probe (P) was to the left of the target (T) position, and positive values indicate that it was to the right of the target position. When the target appeared on the left, the distribution of same responses was shifted to the right. Conversely, the distribution was shifted to the left when the target was on the right. The weighted means (single circles) reflect this shift.

$-1.8°$ to $+1.8°$). For instance, if an observer had proportions of same values of 0.1, 0.5, 1.0, 0.8, and 0.5 for vertical probe displacements of 1.8, 0.9, 0.0, -0.9, and $-1.8°$, respectively, the weighted sum would be $0.1 \times 1.8 + 0.5 \times 0.9 + 1.0 \times 0.0 + 0.8 \times -0.9 + 0.5 \times -0.9$. The result ($-0.99°$) indicates downward displacement. Mean absolute displacement (i.e., displacement independent of distractor placement) was calculated by averaging the remembered target position across the two distractor placements. Mean bias to localize the target toward the distractor was calculated by reversing the sign of the remembered target position with distractors placed below the target, and averaging across the two distractor positions. Thus, a positive bias indicates localization toward the distractor.

2.2.1. Experiment 1a

In 1.8% of the trials, a fixation error occurred. When the distractor appeared above, the remembered target position was shifted downward ($-0.32°$), $t(8) = 2.24$, $p = 0.055$. No significant displacement was observed with a distractor below the target ($-0.15°$), $p = 0.31$. Mean bias away from the distractor element, collapsed across the two distractor placements, was significant ($-0.09°$), $t(8) = -2.63$, $p < 0.05$. Mean absolute displacement, collapsed across the two distractor placements, was not significant ($-0.24°$), $p = 0.12$.

2.2.2. Experiment 1b

In 3.9% of the trials, a fixation error occurred. When the distractor appeared above, the remembered target position was shifted downward ($-0.44°$), $t(7) = 2.53$, $p < 0.05$. No significant displacement was observed with a distractor below the target ($0.0°$), $p = 1$. Mean bias away from the distractor element, collapsed across the two distractor placements, was significant ($-0.22°$), $t(8) = -2.48$, $p < 0.05$. Mean absolute displacement, collapsed across the two distractor placements, was not significant ($-0.22°$), $p = 0.15$.

2.2.3. Experiment 1c

In 2.9% of the trials, a fixation error occurred. No displacement was noted when the distractor appeared above ($-0.04°$) or below ($-0.21°$) the target. Collapsed across distractor placement, neither mean bias toward the distractor (0.08°), nor mean absolute displacement (−0.13°) were significantly different from zero (all $ps > 0.24$).

2.2.4. Experiment 1d

In 5.5% of the trials, a fixation error occurred. When the target was presented on the left, the remembered target position was shifted toward the right (0.2°), $t(11) = 3.01$, $p < 0.05$. No significant displacement was observed for targets on the right (−0.08°), $p = 0.35$. The bias toward the point of fixation, collapsed across left and right target positions, was significant (0.14°), $t(11) = 2.47$, $p < 0.05$. Mean absolute displacement, collapsed across the two distractor placements, was not significant (0.06°), $p = 0.24$.

2.2.5. Experiment 1e

In 5.9% of the trials, a fixation error occurred. No significant displacement was observed for targets on the left (0.24°), $p = 0.16$. When the target was presented on the right, the remembered target position was shifted towards the left (−0.27°), $t(7) = -4.14$, $p < 0.01$. Mean bias towards the point of fixation, collapsed across left and right target positions, was significant (0.25°), $t(7) = 3.08$, $p < 0.05$. Mean absolute displacement, collapsed across the two target positions, was not significant (−0.01°), $p = 0.89$.

2.3. Discussion

Experiments 1a–1c showed that there was no tendency to localize a target object toward a second, irrelevant distractor which was visible throughout, during the retention interval, or during probe presentation. Rather, the opposite was true. A small bias to localize the target away from the distractor was observed when the target was presented throughout (Experiment 1a), or during the retention interval (Experiment 1b). In Experiment 1c, the distractor was only present during probe presentation, and no bias was observed.

Experiments 1d and 1e confirmed that observers tend to localize the target toward the fovea. This tendency was present regardless of whether an additional (reference) object was visible (see also Sheth & Shimojo, 2001). In a previous study (Eggert, Ditterich, & Straube, 2001), a bias to localize targets more peripherally was reported in a condition without a fixation dot. This finding appears inconsistent with the present results. However, the present experiments were not run in the dark, and this differences may explain the discrepancy: In the dark, only egocentric localization is possible when no additional reference objects are presented. In the light, a combination of egocentric and exocentric localization may be possible because objects other than the fixation point may be used as references. Eggert et al. suggested that a conflict between egocentric and exocentric localization is responsible for the bias, which is consistent with the present stimulus arrangement.

In Experiments 1a–1c, a numerical trend to mislocalize the target downward was observed. This trend reached significance when the three experiments were combined [−0.20°, $t(25) = -2.31$, $p < 0.05$]. Thus, a small, and rather inconsistent downward bias may exist.

3. Experiment 2

In sum, Experiment 1 showed that there was a trend to localize the object away from the additional object that was presented. Thus, it may have been the case that previous reports of memory averaging that did not control for fixation (Hubbard, 1995, 1998; Hubbard & Ruppel, 1999, 2000) were due to observers' fixation of the irrelevant object. Two objections may be raised against this conclusion. First, all of these studies used localization by mouse pointing and not a relative judgement task as in Experiment 1. In previous studies, observers were asked to position a cursor on the remembered position of the target. Second, the time interval between stimulus presentation and judgement was longer than in Experiment 1. That is, whereas the retention interval was exactly 260 ms in Experiment 1, it may have been longer with unconstrained mouse pointing. To extend the findings from Experiment 1 to longer retention intervals and a different task, observers were asked to localize the target with a mouse-adjustable cursor that appeared 260 ms after target offset. Three different distractor presentation intervals were realized. Either the distractor was presented throughout a trial, with the target, or during the retention interval (see Fig. 2).

3.1. Method

3.1.1. Participants

12 students at the Ludwig-Maximilians University of Munich fulfilling the same criteria as in Experiment 1 participated.

3.1.2. Apparatus, stimuli, and procedure

The same apparatus, stimuli, and procedure was used as in Experiment 1 with the following exceptions. 260 ms after target offset, a 0.98° cross-hair cursor appeared at a random position within a square 6° region centered around the target stimulus. Observers were instructed to point toward the position of the target stimulus. The distractor appeared either during target presentation, during the retention interval, or throughout the trial (see Fig. 2).

The three distractor presentation intervals (with target, during retention interval, throughout), two horizontal target positions (left, right), the vertical jitter (±1, 0°), the horizontal jitter (±1, 0°), and the two possible distractor positions (above, below) were fully crossed and presented once in three consecutive blocks for a total of 324 trials.

3.2. Results

In 7% of the trials, a fixation error occurred. The deviation of the judged from the actual position of the target was determined. Vertical and horizontal deviations were analyzed separately. Downward and upward deviations received negative and positive signs, respectively. Leftward and rightward deviations received negative and positive signs, respectively. Mean vertical and horizontal deviations are shown in Fig. 5.

3.2.1. Vertical deviations

A 3 (distractor presentation intervals) × 2 (distractor positions) ANOVA was run on the vertical deviation.

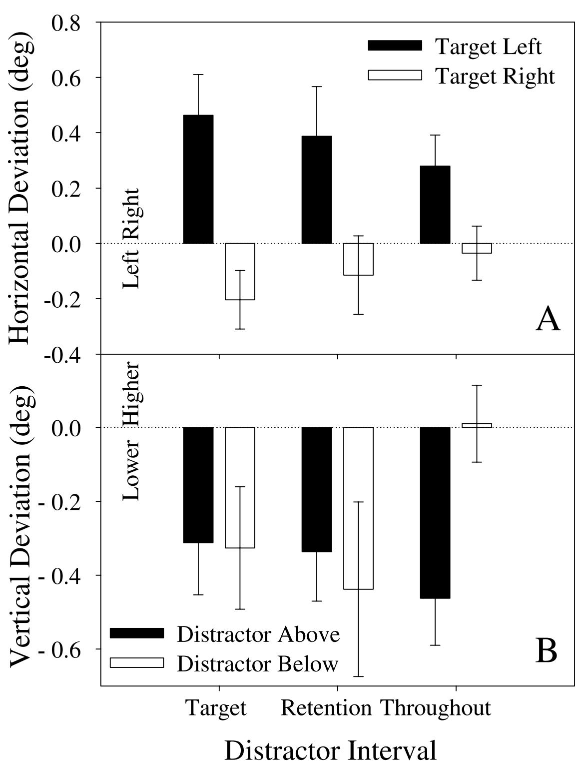

Fig. 5. Mean horizontal (panel A) and vertical (panel B) deviations from the actual position of the target as a function of distractor presentation interval. Error bars indicate the standard error of the mean (between subjects). Downward and upward deviations received negative and positive signs, respectively. Leftward and rightward deviations received negative and positive signs, respectively. When the distractor was visible throughout, judgements were lower with a target presented above than with a distractor presented below. This bias away from the distractor was not present when the distractor was presented with the target or during the retention interval. Horizontal judgements deviated towards the right with left targets, and towards the left with right targets. This bias toward the fovea was most pronounced when the distractor was presented with the target, but was present for all distractor presentation intervals.

There was a significant effect of distractor presentation interval, $F(2,22) = 6.06$, $p < 0.01$. The downward deviation was smaller when the distractor was always present (−0.22°), than when the distractor was presented with the target (−0.31°) or during the retention interval (−0.38°). Also, there was a significant interaction between distractor presentation interval and distractor position, $F(2,22) = 8.25$, $p < 0.01$. When the distractor was always visible, mislocalization was further down with a distractor presented above than with a distractor presented below (−0.46° vs. 0.01°), $t(11) = 5.79$, $p < 0.01$. The difference between distractors above and below was not significant with a distractor presented with the target (−0.31° vs. −0.33°), $t(11) = 0.12$, $p > 0.9$, and during the retention interval (−0.34° vs. −0.44°), $t(11) = 0.46$, $p > 0.6$. The difference between distractors presented above and below corresponds (also in terms of statistical significance) to a significant −0.24° bias away from the distractor when the distractor was presented throughout, and to nonsignificant biases toward the distractor when the distractor was presented with the target (0.007°) and during the retention interval (0.05°). Overall, there was a significant downward bias (−0.31°), $t(11) = 2.31$, $p < 0.05$.

3.2.2. Horizontal deviations

A 3 (distractor presentation intervals) × 2 (target positions) ANOVA was run on the horizontal deviation. There was a significant effect of target position, $F(1, 11) = 4.89$, $p < 0.05$. Mean deviation was 0.37° to the right with targets on the left, and −0.11° to the left with targets on the right. Target position interacted with distractor presentation interval, $F(2,22) = 5.44$, $p < 0.05$. The difference between left and right target presentations was more pronounced when the distractor was presented with the target (0.46° vs. −0.20°), $t(11) = 3.13$, $p < 0.01$, than when the target was presented during the retention interval (0.39° vs. −0.11°), $t(11) = 1.73$, $p = 0.11$, or throughout (0.28° vs. −0.04°), $t(11) = 1.75$, $p = 0.11$. The differences between left and right target positions correspond to biases toward the fovea of 0.33, 0.25, and 0.16° for distractors presented with the target, during the retention interval and throughout, respectively. Overall, there was a tendency to localize the object too far to the right (0.13°), $t(11) = 2.03$, $p = 0.067$.

3.3. Discussion

When observers were asked to point toward the position of a peripheral target, no evidence for memory averaging was found: when the distractor was presented with the target or during the retention interval, no bias was observed. In contrast, a robust bias away from the distractor was observed when the additional element was visible throughout. Thus, the bias away from the distractor may be observed with relative judgements ("same-different") and with mouse pointing. Further, a bias toward the fovea was observed for all distractor presentation intervals. However, this bias was larger and more reliable when the distractor was presented with the target than when the distractor was presented throughout.

Comparison of these results with those of the relative judgement procedure in Experiment 1 suggests that the longer retention interval with mouse pointing changed the pattern of results, in particular the effect of distractor presentation interval. With pointing, the bias away from the distractor was only observed when the distractor was visible throughout. Distractors presented briefly during the retention interval affected target localization when the retention interval was short, as in Experiment 1, but not when it was long, as in Experiment 2. Possibly, the effects of distractor presentation interval in Experiments 1 and 2 were due to different reference frames used in localizing the target (exocentric vs. egocentric localization). This issue is discussed in the following section.

4. General discussion

In the present research, contributions of memory averaging and foveal bias to target displacement in visual short-term memory were investigated. It has been hypothesized that the position of a target and the position of an irrelevant distractor are averaged in visual short-term memory. That is, a tendency to localize a target object toward a second, irrelevant element was observed. Additionally, a tendency to localize objects toward the fovea has been reported. As previous studies investigating memory averaging did not monitor eye fixation, it may have been that memory averaging was attributable to observers' fixating the distractor. To disentangle memory averaging and foveal bias, target and distractor were presented peripherally and eye fixation was monitored. Further, no fixation point was provided in order to avoid interactions between a permanently visible landmark and distractor presentation. In Experiments 1a–1c, no indication of memory averaging was observed. In contrast, when the distractor was presented throughout the trial (i.e., until a judgement was given) or during the retention interval, a bias away from the distractor was observed. In Experiment 2, the relative judgement task from Experiment 1 was replaced by a pointing task that prolonged the retention interval. This method is more compatible with previous research on memory averaging. A bias away from the distractor was observed when the distractor was visible throughout, but not when the distractor was presented with the target or during the retention interval. The foveal bias was confirmed when the distractor was presented throughout the trial and when no distractor was presented (Experiments 1d and 1e).

4.1. Previous studies

In sum, memory averaging may not be a mechanism that operates independently of the foveal bias. The present study shows that memory averaging does not occur with relative judgements or pointing responses. In contrast, a foveal bias was observed regardless of other reference objects being presented. Because no fixation point was presented and fixation was not monitored in previous reports of memory averaging (Hubbard, 1995, 1998; Hubbard & Ruppel, 1999, 2000), this result suggests that the foveal bias may have contributed to the bias.

However, in at least one study, foveal bias and memory averaging were not confounded. Kerzel (in press-a) presented a linearly moving target that vanished at a random position. Around the time of target disappearance, a distractor was briefly flashed above or below the target's trajectory. When the distractor was presented at the time of target disappearance or briefly thereafter, a bias toward the distractor was noted. In this study, observer's pursuit eye movements were monitored, and presentation time was too short to allow for fixation of the distractor. Thus, memory averaging occurred even though observers did not fixate the distractor. It was argued that the shift of attention from the attended target position caused the displacement. In contrast to the present study, observers were fixating the target. When fixation is on the target, its position may be retained in a deictic manner (Ballard, Hayhoe, Pook, & Rao, 1997) by gaze direction. Possibly, shifts of attention perturb this pointing device. In the case of peripheral target presentation, fixation is decoupled from the target and may not be used as a pointer. In this case, target position may be coded exocentrically if the stimulus allows for such a strategy. However, other differences may play a role, most notably the fact that Kerzel (in press-a) presented moving targets, whereas the present study used stationary targets.

4.2. Egocentric vs. exocentric localization

Two ways of localizing an object in space are possible. The object may be localized with respect to the observer (egocentric localization), or it may be localized with respect to other objects (exocentric localization). In Experiment 1, exocentric localization was possible. Observers may have estimated the distance between the target and the distractor, and compared this estimate to the distance between probe stimulus and distractor. Such a strategy was feasible when the target was presented throughout or during the retention interval, but not when the distractor was presented with the probe stimulus. In the latter condition, no bias away from the target was noted. In Experiment 2, exocentric localization was possible only when the distractor was presented throughout. After estimating the distance between target and distractor, observers may have used this estimate to adjust the distance between distractor and cursor. Thus, one may conclude that the bias away from the distractor is due to a tendency to overestimate the distance between target and distractor relative to the distance between probe and distractor. In other words, the estimated target–distractor distance was magnified in memory. Further, the pattern of results in Experiment 2 points to different sources of the bias toward the fovea and the bias away from the distractor. In conditions requiring egocentric localization (i.e. when the distractor was absent or presented with the target), the bias toward the fovea was large whereas the bias away from the distractor was small. Conversely, in conditions that made exocentric localization possible (i.e., when the distractor was visible throughout), the bias toward the fovea was small, whereas the bias away from the distractor was large. Thus, the foveal bias may be an error in judging egocentric position, whereas the bias away from the distractor may be an error in judging exocentric position.

Further evidence for such an interpretation is provided by pilot experiments in which some of the presented experiments were rerun with a fixation point. With a fixation point in the center of the screen, exocentric localization with respect to the fixation point is encouraged. This manipulation changed the pattern of results dramatically: instead of a tendency to localize the target away from the distractor, a tendency to localize the target toward the distractor was observed. Although the exact reasons for this reversal are not entirely clear, they point to the importance of distance judgements for the localization task.

In general, a tendency to overestimate the distance between distractor and target is consistent with previous reports of magnification of picture boundaries (Intraub, 1997; Intraub & Richardson, 1989), that is, the length of the borders of a pictures are overestimated. However, the finding that the distance between target and distractor was overestimated is in contrast with previous reports of underestimation of distance (e.g., Fukusima & Faubert, 2001; Loomis, da-Silva, Fujita, & Fukusima, 1992). It may be possible that the discrepancy is due to the larger involvement of short-term memory in the present task.

4.3. Position vs. velocity

In general, it has been found that visual short-term is almost perfect for dimensions of early visual processing, such as spatial frequency, orientation, motion, and contrast (for an overview, see Magnussen & Greenlee, 1999). However, distracting information presented during the retention interval increases discrimination thresholds in such tasks, suggesting that visual short-term memory may experience interference from perception. For instance, when velocity information has to be stored in visual short-term memory, presentation of a distractor with a similar, but unequal velocity during the presentation interval, increases thresholds (Magnussen & Greenlee, 1992). Similarly, it may be observed that visual information is blended with distracting velocity information presented in the visual (Kerzel, Bekkering, Wohlschlager, & Prinz, 2000) and in the haptic (Kerzel, 2001) modalities. In particular, the content of visual short-term memory is assimilated to the distracting information. For instance, the remembered velocity is increased when a distractor is presented that is faster than the target velocity (Kerzel et al., 2000). In the present experiment, however, rather the opposite tendency was noted: The position of target and distractor were not assimilated, but contrasted. In other words, the remembered target position was remembered to be further away from the distractor than it actually was. Thus, the derivative of position with respect to time, velocity, shows assimilation with distracting information presented during retention, whereas position shows contrast.

In sum, the present results show that memory averaging does not occur for targets presented in the periphery. Rather, judgements are biased away from an additional irrelevant distractor. It is suggested that the bias occurs in conditions that allow for exocentric localization. The bias may result from a tendency to overestimate the distance between distractor and target in memory.

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