CORTEX 142 (2021) 204–212

Available online at www.sciencedirect.com

ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex

Special Issue "Cognitive and Motor Processes in Visuospatial Attention": Research Report

A nearby distractor does not influence hand movements

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ARTICLE INFO

Article history:
Received 15 May 2020
Reviewed 1 July 2020
Revised 28 January 2021
Accepted 26 April 2021
Published online 26 June 2021

Keywords:
Hand movement
Selection
Averaging
Accuracy
Motor plan

ABSTRACT

When interacting with the environment, our manual actions are often preceded by an eye movement. This suggests that the processes underlying target selection in hand and eye movements may be coupled. It is known that when a distractor is presented close to a target, the endpoint of an eye movement will be biased towards the distractor. The size of this so-called global effect decreases when more viewing time is available. Here we investigate whether a similar effect is also present in hand movements. If the processes underlying target selection for hand and eye movements are indeed coupled, a similar bias should be present in hand movements as well. To test this, we adopted a classic global effect paradigm but applied it to goal-directed hand movements. We show that the endpoints of hand movements are unbiased for all but one participant, irrespective of the viewing time. These results suggest that the processes underlying target selection for hand movements operate independently from those for eye movements.

1. Introduction

Combined eye-hand actions dominate our daily activities. For instance, picking up a pen involves not only a movement of the hand, but also a saccadic eye movement: we generally look at an object before we act upon it (Johansson, Westling, Backstrom, & Flanagan, 2001; Land, 2006; Land & Hayhoe, 2001), presumably to improve visual guidance. Therefore, it seems obvious that the decision where to move (target selection) is coupled for eye and hand (Belopolsky, Olivers, & Theeuwes, 2008). Indeed, there are many studies showing a relationship between hand and eye movements, in particular when both movements are instructed to be directed towards the same target area. Amongst others, these studies have reported a consistent relationship between the latencies (e.g., Bekkering, Pratt, & Abrams, 1996; Pratt, Bekkering, Abrams, & Adam, 1999), the amplitudes (Bekkering, Abrams, & Pratt, 1995; de Grave, Franz, & Gegenfurtner, 2006), the trajectories (Jana & Murthy, 2021), and the endpoints (Bekkering et al.,

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https://doi.org/10.1016/j.cortex.2021.04.021

1995; de Grave et al., 2006; Song & McPeek, 2009) of hand and eye movements.

However, other studies have reported various dissociations between hand and eye movements (Issen & Knill, 2012; Jonikaitis & Deubel, 2011; Lisi & Cavanagh, 2017; McIntosh & Buonocore, 2012; Sailer, Eggert, Ditterich, Hassenzahl, & Straube, 2003; Sailer, Eggert, Ditterich, & Straube, 2000; Stritzke & Trommershauser, 2007; Thompson & Westwood, 2007). For instance, Thompson and Westwood (2007) had observers make an eye and/or a hand movement to a single red circle in a peripherally presented Müller-Lyer figure and found that primary saccades were substantially affected by the specific layout of the Müller-Lyer figure, whereas hand movements were not. Results like these suggest that target selection for hand and eye movements might be based on different mechanisms and might even rely on entirely different target representations.

A fruitful approach to determine commonalities between the two effector systems and draw inferences about the extent to which target selection in hand and eye movements rely on a common representation is to examine whether distinct phenomena that are well established in eye movements also occur in hand movements. Indeed, there are various studies that examined the occurrence of well-known saccadic effects in hand movements such as the gap effect (Bekkering et al., 1996; Pratt et al., 1999), adaptation effects (Bekkering et al., 1995), salience effects (Kerzel & Schönhammer, 2013; van Zoest & Kerzel, 2015; Zehetleitner, Hegenloh, & Müller, 2011), and the remote distractor effect (Bompas, Hedge, & Sumner, 2017; Heath & DeSimone, 2016; McIntosh & Buonocore, 2012).

One saccadic effect that is particularly suited to be studied in hand movements is the global effect. The global effect refers to the finding that when a distractor is presented in close proximity to a saccadic target, saccades are biased towards the distractor location (Arkesteijn, Smeets, Donk, & Belopolsky, 2018; Coren & Hoenig, 1972; Findlay, 1982). The global effect is a robust and well-established phenomenon and has been demonstrated to be influenced by multiple factors (see Van der Stigchel & Nijboer, 2011 for an overview), such as the location of the distractor relative to the target (Coëffé & O'Regan, 1987), the relative size (Findlay, 1982), and the intensity of both items (Deubel, Wolf, & Hauske, 1984). The global effect is strongest when target and distractor location are unpredictable (He & Kowler, 1989), when the distractor is presented between the initial fixation point and the target (Coëffé & O'Regan, 1987; Coren & Hoenig, 1972; Findlay, 1982), and when saccades have short latencies or stimuli are briefly presented (Arkesteijn, Donk, Smeets, & Belopolsky, 2020; Arkesteijn et al., 2018; Findlay, 1982; Heeman, Theeuwes, & Van der Stigchel, 2014; Ottes, Van Gisbergen, & Eggermont, 1985).

The global effect is thought to reflect competitive interactions between different locations in a retinotopic saccade map (but see Findlay & Walker, 1999; Godijn & Theeuwes, 2002; Trappenberg, Dorris, Munoz, & Klein, 2001) which presumably underlies saccadic target selection. When a target and a distractor are simultaneously presented, both evoke a stimulus-driven activation peak in the saccade map (Meeter, Van der Stigchel, & Theeuwes, 2010). Activity generated at one location inhibits distant locations but spreads to neighboring locations (Godijn & Theeuwes, 2002). The global effect can be regarded as a the result of a weighted average of the activations at the target and distractor locations. However, activation generated in the saccade map is not only subject to stimulus-driven influences, but can also be modulated in a top-down fashion such that the activation at the target location can be increased at the expense of the distractor location. As this process takes time (Van Zoest & Donk, 2008; van Zoest, Donk, & Theeuwes, 2004), saccades with shorter latencies are more likely to end up in between the target and the distractor (Heeman et al., 2014). This saccade map is presumably located in the intermediate layers of the superior colliculus (Dorris, Paré, & Munoz, 1997; McPeek, Han, & Keller, 2003; McPeek & Keller, 2004; Munoz & Wurtz, 1995). The intermediate layers of the superior colliculus also have been shown to contribute to target selection for hand movements (Song & McPeek, 2015; Song, Rafal, & McPeek, 2011; Stuphorn, Bauswein, & Hoffmann, 2000). This suggests that the saccade map may be an effector-independent target selection map, underlying the generation of both hand and eye movements.

To investigate whether hand movements rely on the same representation as eye movements, Sailer, Eggert, Ditterich, and Straube (2002) examined the presence of a global effect in both eye and hand movements. They asked participants to perform a hand and/or an eye movement to a target which was presented simultaneously with a distractor. Both target and distractor were presented at the horizontal meridian, either to the right or left of central fixation. Overall, the results showed that the distractor affected movement amplitude of both hand and eye, albeit the effect was considerably smaller for the hand than for the eye. Importantly, they also showed several differences between hand and eye movements. For instance, the size of the global effect in hand movements did not reduce with increasing latency whereas it did in eye movements. Moreover, in Experiment 4, they showed that when the distractor was presented at a less eccentric location than the target, hand movements were no longer affected by the distractor whereas eye movements were. On the basis of their results, Sailer et al. (2002) concluded that hand and eye movements most likely rely on separate representations. Yet, both representations were assumed to be coupled through the exchange of spatial information regarding the target and distractor location.

The question as to whether hand movements are subject to a global effect has also been addressed by Heath and DeSimone (2016), although this study was primarily concerned with the remote distractor effect (see also Bompas et al., 2017; McIntosh & Buonocore, 2012), Amongst others, Heath and DeSimone (2016) compared reach movements between conditions in which a target was presented in isolation with conditions in which a target was presented concurrently with a remote or a proximal distractor. Both target and distractor were presented at the meridian. The results obtained in the proximal distractor conditions were remarkably similar to those obtained by Sailer et al. (2002). The endpoints of the hand movements were found to be biased towards the distractor, however, these effects were only obtained when distractors were presented at more eccentric locations than the target. When distractors were presented at less eccentric locations, no global effect was observed. Heath and DeSimone

(2016) also showed that hand movement latencies increased in the presence of a remote distractor but decreased in the presence of a proximal distractor (see also Bompas et al., 2017; but see; McIntosh & Buonocore, 2012), a finding similar to the remote distractor effect observed in eye movements (Walker, Deubel, Schneider, & Findlay, 1997). On the basis of their results, Heath and DeSimone (2016) concluded that both hand and eye movements are generated on the basis of a single effector-independent target selection map.

It is important to note that both aforementioned studies (Heath & DeSimone, 2016; Sailer et al., 2002) reported a diminished global effect in hand movements when the distractor was positioned in between the target and the starting position of the hand as compared to when it was positioned beyond the target. These results are inconsistent with those found in eye movement studies that typically report a larger global effect when the distractor is presented closer to fixation than the target (Coren & Hoenig, 1972; Findlay, 1982). Sailer et al. (2000), (see also Heath & DeSimone, 2016) speculated that the variations in the global effect across distractor eccentricity might have been related to differences in distractor salience which in turn might have led to differences in the possibility to apply inhibition.

However, these differential effects might also have been reflections of specific motor biases such as obstacle avoidance (Tipper, Howard, & Jackson, 1997; Tresilian, 1998) rather than of changes in target-distractor competition. For instance, it has been reported that the hand tends to move away from distractors when located along the movement path so as to avoid collision (Dean & Brüwer, 1994; Haffenden, Schiff, & Goodale, 2001; Khoozani, Voudouris, Blohm, & Fiehler, 2020; Menger, Dijkerman, & Van der Stigchel, 2013). Not only the trajectory towards a target, but also target selection for the hand is biased away from the position of obstacles (for instance when selecting grasping points on an object; Voudouris, Smeets, & Brenner, 2012) and even away from distracting disks (de Grave, Biegstraaten, Smeets, & Brenner, 2005). If these processes would co-occur, any bias towards a distractor will be reduced even though this might be fully unrelated to changes in the underlying target-selection map. Here, we investigated whether a distractor biases the endpoint of a fast goal-directed hand movement while controlling for distractor eccentricity by positioning the target and the distractor next to each other. Many previous studies examining the global effect in eye movements positioned the distractor at the same eccentricity as the target and consistently reported a robust global effect (e.g., Arkesteijn et al., 2020; Arkesteijn et al., 2018; Heeman et al., 2014; Van der Stigchel & Nijboer, 2011; Walker et al., 1997). The present study aims to use the same stimulus configuration as in these previous studies not only to avoid differential effects across distractor eccentricity but also to examine how the presence of an irrelevant distractor affects the direction of a hand movement, which might well be planned independently from its amplitude (Davare, Zénon, Desmurget, & Olivier, 2015; Gordon, Ghilardi, & Ghez, 1994; Vindras, Desmurget, & Viviani, 2005).

For this, we utilized the same configuration we used before for studying the global effect in saccades (Arkesteijn et al., 2018, 2020). Arkesteijn et al. (2020) dissociated viewing time of target and distractor and saccade preparation, and showed that the former was critical for the size of the global effect. A larger global effect was observed when target and distractor were both viewed for a shorter time. We used two different viewing times to investigate whether the viewing time influenced the size of the global effect in hand movements in a similar way as in saccades. If target-distractor competition in hand movements is similar to the competition when planning eye movements, a clear global effect should be present in hand movement endpoints for short presentation times, but not for long presentation times.

2. Methods

2.1. *Participants*

Nineteen students (aged: 18–36, mean: 21, five male) of the Vrije Universiteit Amsterdam participated in this study. The data of one participant were excluded from the analysis because too many trials were excluded (see section data analysis). All had normal or corrected-to-normal vision and were naive to the purpose of the study. Informed consent was obtained from all participants and the experiment was approved by the Ethical Committee of the faculty of Behavioral and Movement Sciences of the Vrije Universiteit Amsterdam. We report how we determined our sample size, all data exclusions (if any), all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

2.2. *Apparatus*

The experiment was conducted in a dimly lit room. A 42" touchscreen monitor (Iiyama ProLite) with a 1920 × 1080 pixel resolution and a 60 Hz refresh rate displayed the stimuli. The monitor was laying on a table, oriented at 31° so that participants could look down on it. We wrote software to control the stimulus presentation and touch responses in Python (Anaconda Software Distribution, 2019) using a Pygame back-end.

2.3. *Stimuli, design and procedure*

Participants stood in front of the touchscreen at a distance of 50 cm from the display to the head with their right index finger on a starting position. Distances and dimensions are reported in cm; as the head is free to move, we can only roughly convert these distances into the angular measures that are frequently used in eye-movement studies: 1 cm $\cong$ 1.2°. We presented the stimuli on a 29 cd/m^2 grey background. In the center of the screen there was a white ring (diameter 1.75 cm), which served as the starting position for the finger (see Fig. 1). The target was a 15 cd/m^2 blue dot (diameter 1.31 cm) and could appear randomly in the top hemifield on an imaginary half-circle (radius 8.73 cm) around the starting position. A black distractor (diameter 1.75 cm) was presented on the imaginary circle at 1/18th of the circle circumference either counterclockwise (CCW) or clockwise

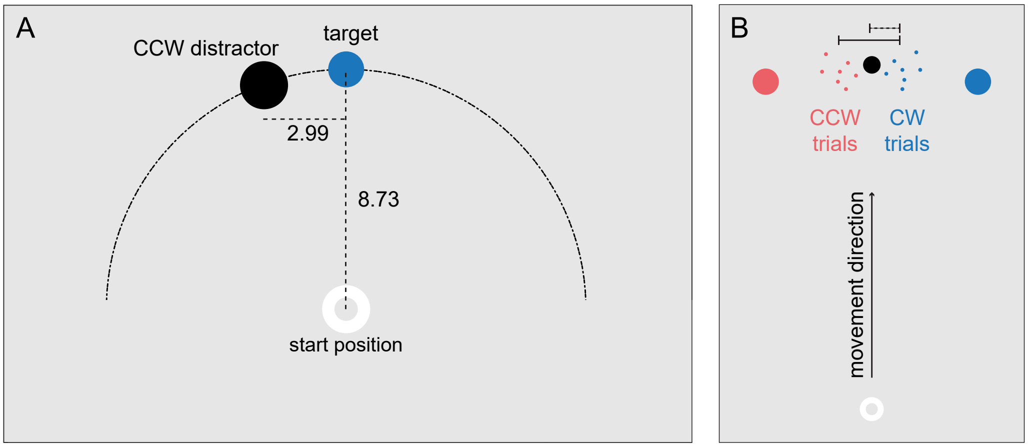

Fig. 1 – Lay-out of the experiment. A) Spatial lay-out of the stimuli with dimensions in cm. Target and distractor were only presented in the top hemifield of the circle. B) An example of calculation of the tapping bias (dotted line) as half of the distance between the averaged tap positions of CW and CCW trials (solid line).

(CW) from the target. We ensured that the target, as well as the distractor, appeared in the top hemifield, so the possible locations of the target depended on whether the distractor was CW or CCW.

Participants were instructed to place their index finger on the starting position and to respond to the appearance of a target as quickly as possible by moving their finger to tap the target as quickly as possible. Participants received a warning if their total response time (from stimulus onset until they tapped the target) exceeded 600 msec. The presentation time was either short or long. In the 'short' condition, the target and distractor were only presented for 100 msec and in the 'long' condition, the target was presented until the finger moved away from the starting position. The two conditions, target and distractor locations were presented in random order within a block. The experiment consisted of 360 trials, tested in 6 blocks. Participants were allowed short breaks in between the blocks. The total duration of the experiment was approximately 30 min.

2.4. *Data analysis*

Hand movement data were analyzed offline using a custom code written in Python (Anaconda Software Distribution, 2019). The response to the stimuli was considered valid when the following criteria were met: the finger lost contact with the screen within 1.75 cm of the starting position not earlier than 100 msec after stimulus onset, and the finger tapped the screen within 3.5 cm of the target position and no longer than 600 msec after stimulus onset. We excluded one participant who produced less than 50% valid trials. For the remaining participants, 5636 trials (87%) were included in the subsequent data analysis.

For the data analysis, we rotated all stimuli and tap positions so that the target position was at the top position (see Fig. 1B). The mean lateral tap position of trials in which the distractor was presented CCW was subtracted from the mean lateral tap position of CW distractor trials and divided by two. In this way, a positive value would indicate a tapping bias towards the distractor (where a value of 1.50 cm would indicate a lateral tap position at the distractor), whereas a negative value would mean a tapping bias in the opposite direction of the distractor (i.e., obstacle avoidance). To assess if participants would tap at the target (null hypothesis) or if the taps were influenced by the distractor (alternative hypothesis) a Bayesian two-side one-sample hypothesis against zero was performed using the default Cauchy prior (scale: .707) by JASP .9.2.0 (JASP Team, 2018). A two-sided paired sample *t*-test was performed to assess differences between the 'short' and 'long' conditions. A BF_{10} is reported when there is evidence in favor of the alternative hypothesis compared to the null hypothesis and a BF_{01} is reported when there is evidence in favor of the null hypothesis over the alternative hypothesis (Wagenmakers, Lodewyckx, Kuriyal, & Grasman, 2010). A $BF > 3$ indicates that there is substantial evidence, a $BF > 10$ indicates that there is strong evidence, and a $BF > 100$ indicates that there is decisive evidence for a hypothesis to be true (Raftery, 1995).

To assess if the tapping bias would depend on latency in a similar way as it does for saccades (Heeman et al., 2014; Ottes et al., 1985), and whether this dependency indeed does not hold for hand movements (as reported by Sailer et al., 2002), we reconstructed the time-course of the tapping bias as a function of tapping response times for the 'short' and 'long' conditions using the SMART method (van Leeuwen, Smeets, & Belopolsky, 2019). First, for each participant and condition, the landing position data was smoothed with a Gaussian kernel ($\sigma = 15$ msec) for tapping responses ranging from 150 to 300 msec. This was done both for the CW and CCW trials. Subsequently, the difference between the smoothed time series obtained in the CW and CCW trails were divided by two to acquire the tapping bias as a function tapping response times. As the landing bias reduces linearly with saccade latency for visually guided saccades (Heeman et al., 2014), a linear regression line was fit to the smoothed time series, separately for the "short" and "long" conditions and for every participant in a similar way as we did for saccades (Arkesteijn et al., 2020). The resulting slopes were again tested against zero using a Bayesian two-side one-sample hypothesis.

3. Results

The response times for the 'short' and 'long' conditions were similar (Fig. 2). In both conditions, the subjects' median latency was on average 233 msec (interquartile range: 210–257 msec). The subjects' median tap times were on average 393 msec (interquartile range: 361–417 msec) for the 'short' condition and 396 msec (interquartile range: 361–418 msec) for the 'long' condition.

For 17 of our 18 participants, the distractor did not affect the tap position. The tapping biases of these participants ranged from −.22 cm to .18 cm (mean .01 cm) in the 'short' condition and from −.10 cm to .17 cm (mean −.03 cm) in the 'long' condition. The variability in the tap positions was larger in the direction of the target (sagittal) than in the direction of the distractor (lateral). The mean standard deviation in the lateral direction was .50 cm in the 'short' and .46 cm in the 'long' conditions respectively. The mean standard deviation in the sagittal direction was .53 cm in the 'short' condition, and .51 cm in the 'long' condition (Fig. 3). This bias was independent of the hand movement latency in both conditions (Fig. 4A; 'short': slope .000 ± .004 cm/sec, 'long': slope .000 ± .003 cm/sec). We also examined whether the tapping bias depended on the duration of the tapping movement (see Fig. 4B). The results indicate that the tapping bias did not vary with movement duration and was zero across its full range.

One participant, however, behaved differently, with a mean tap position that was two standard deviations away from all other participants (see Fig. 3). The mean tapping bias of that participant was 1.69 cm both in the 'short' and 'long' condition. This participant differed not only in the bias: also the variability in tap position was larger in the direction of the distractor: .77 cm and .82 cm in the 'short' and 'long' condition, compared to an average of .49 cm and .44 cm in the 'short' and 'long' condition respectively, for the other 17 participants. However, the hand movement latencies were very similar (229 msec in the 'short' and 230 msec in the 'long' condition).

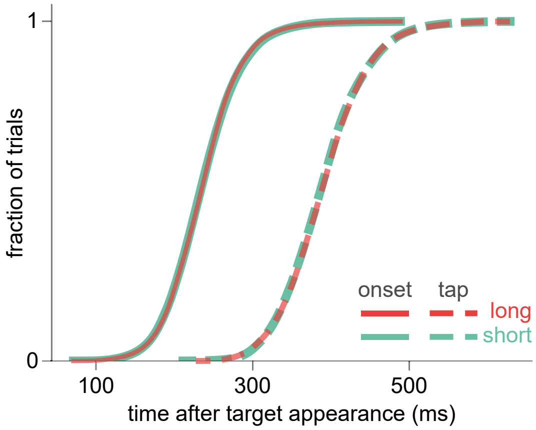

Fig. 2 – Response times. Hand movement latency (continuous curve) and tapping times (dotted curves) plotted as cumulative distributions for the 'short' and long' conditions. Data are pooled across all participants. Solid lines indicate the latency times of the hand movement; dotted lines indicate the times at which the hand tapped on the screen. The response time distributions are similar for the two conditions.

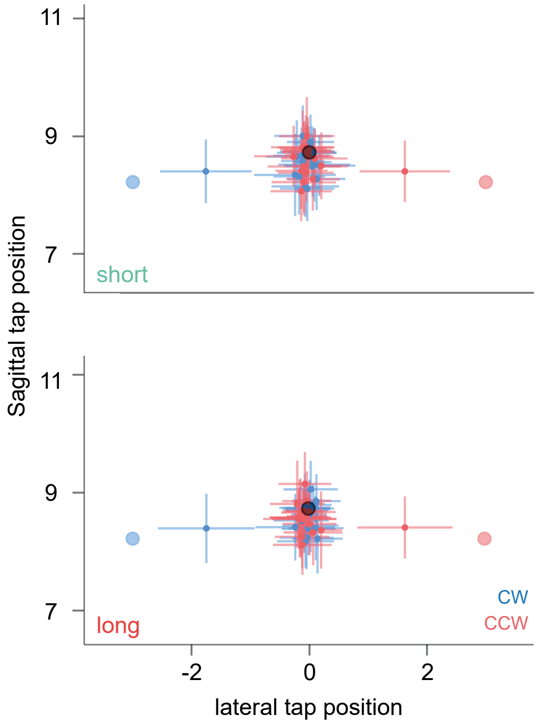

Fig. 3 – Finger tap positions for all participants. Mean tap positions for each participant in trials with the CW (blue) and CCW (red) distractor location for the 'short' and 'long' condition (upper and lower panel, respectively). Error bars denote the participants' standard deviation. The black disk indicates the target position; the colored disks the possible distractor positions. The four data-points that lie outside the group are from the same participant; for the other 17 participants, the mean endpoints are within one standard deviation from the target location.

According to our planned tests, there was no evidence that the tapping bias differed from zero in both conditions ('short': $BF_{10} = .27$ & 'long': $BF_{10} = 1.24$), on the contrary, there was substantial evidence that the hand movements showed no tapping bias in the 'short' condition ($BF_{01} = 3.74$). Furthermore, there was no support for the hypothesis that the tapping bias differed between the two conditions ($BF_{10} = .89$). There was substantial evidence that the slopes of a function relating bias and tapping time did not differ from zero in both the 'short' ($BF_{01} = 3.70$) and 'long' ($BF_{01} = 3.44$) condition.

4. Discussion

The present study shows that expression of the target-distractor competition is less apparent when measured in

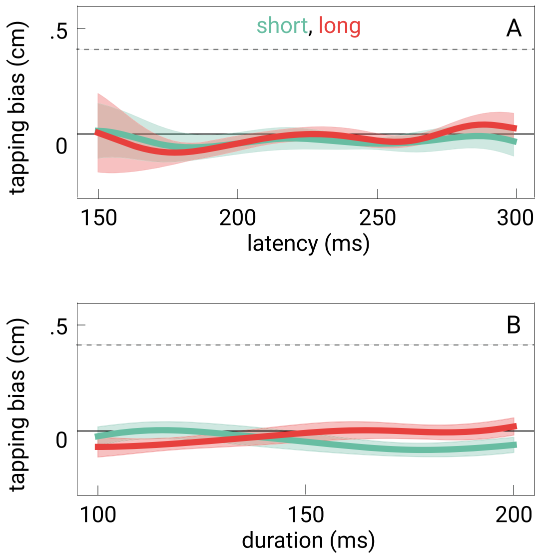

Fig. 4 – Tapping bias as function of the timing of the hand movement. For both presentation times (color), the tapping bias was close to zero, independent of the latency (A) and the duration (B) of the hand movement. Smoothed time series averaged across participants using the SMART method. The transparent areas indicate the 95% confidence interval of the mean. The horizontal dashed line corresponds to the landing biases that we have reported for saccades in a similar configuration (Arkesteijn et al., 2020).

hand movements. Except for one participant, no global effect was found for the endpoints of tapping movements. This was the case both when participants could examine the visual scene up until the onset of the hand movement and when access to visual information was restricted (stimuli were visible for 100 msec). In contrast with results reported for saccades, the tapped positions did not vary with latency. No differences were found between the two conditions in either the tap position of the finger or in the hand movement latencies. From this, we conclude that target selection process for hand and eye movements are not coupled.

One participant showed an average tap position that was biased towards the distractor. One might argue that for this participant, the global effect was present. If so, one would expect the global effect to reduce with viewing time (Arkesteijn et al., 2020). The bias of this participant was not reduced in the 'long' condition (the same bias in both panels of Fig. 3). This lack of effect of viewing time indicates that the effect of the distractor on participant's tapping behavior is unrelated to the global effect that is observed in eye movements. So, also for this participant, it is unlikely that target selection for hand and eye movements were spatially coupled.

The absence of a global effect in our experiment differs from the results of Sailer et al. (2002) and Heath and DeSimone (2016). Both studies investigated the effect of distractors on the amplitude of hand movements and found a clear effect in the same direction as was found for saccades: a bias towards the distractor. However, in contrast to the saccadic global effect, the effect that was reported by Sailer et al. (2002) and Heath and DeSimone (2016) did not vary with latency. Moreover, the effect was only consistently present when the distractor was presented at a more eccentric location than the target, whereas for saccades, the effect is typically found for distractors both nearer and farther than the target (Coren & Hoenig, 1972; Findlay, 1982; Walker et al., 1997). Lastly, overall the distractors tended to have a smaller effect on the hand than on the eye. Nevertheless, Sailer et al. (2002) and Heath and DeSimone (2016) also reported various similarities between hand and eye movements supporting the notion that hand and eye movements are coupled. The present data are not in line with this notion. If target selection for hand and eye movements would have been coupled, the distractor should have elicited a global effect comparable to the one observed for saccades in similar stimulus configurations (Arkesteijn et al., 2020), which is clearly not what we found.

Even though we used flanking distractors, one might argue that the lack of global effect in our experiment might have been due to a possible masking by an obstacle avoidance mechanism, previously demonstrated in hand movements (de Grave et al., 2005; Tresilian, 1998; Voudouris et al., 2012). If so, these two effects should have exactly counteracted each other for 17 of the 18 participants in order to obtain the very consistent results presented in Fig. 3. As there is a large inter-individual variability in the strength of the global effect (e.g., Figure 2b in Arkesteijn et al., 2020), this would require that the amount of obstacle avoidance and global effect would be strongly correlated across participants: for those with a large global effect, the hand should have avoided the distractor more. Moreover, as the global effect decreases with viewing time, one would expect the net effect to shift in the direction of obstacle avoidance in the 'long' condition. This pattern was not observed. Therefore, the current data is likely not in accordance with the hypothesis of information exchange combined with obstacle avoidance. Instead, the hands tapped on the target with high precision, especially in the lateral direction: i.e., the variation of tap position was smaller in the direction of the distractor than in the movement direction. We thus conclude that our data provide evidence against the hypothesis of information exchange between the target selection for eye and hand (except for the one participant).

It is unclear why distractors affected the hand movements for a single participant in our experiment and why primarily distractors in positions farther than the target affected the hand position in the experiments by Sailer et al. (2002) and Heath and DeSimone (2016). The main difference between our study and the two previous studies is the position of the distractor. In our study, the distractor was presented on an axis perpendicular to the movement axis, i.e., left or right from the target as seen from the starting point, and thus neither farther nor nearer than the target. It might be that if we would have used distractors that were slightly farther away, we might have seen effects for all participants. An alternative line of explanation capitalizes on the fact that the distractor in our experiment was expected to affect the direction of the movement. In contrast, in both previous studies the distractor was expected to influence the amplitude of the movement. It has been suggested, that the amplitude of hand movements is programmed differently than the direction of hand movements (Favilla, Hening, & Ghez, 1989; Gordon et al., 1994).

Further experimentation is needed to test these lines of explanation.

It is important to note that we did not measure eye movements in our study. We can therefore not rule out the theoretical possibility that the absence of a global effect in the present study was related to the specific stimulus configuration we used. However, it is important to note that previous studies, including our own (Arkesteijn et al., 2018, 2020), have consistently shown the presence of a global effect in eye movements using a similar stimulus configuration. Moreover, the global effect in eye movements has been demonstrated to be strongest when target and distractor locations are unpredictable (e.g., He & Kowler, 1989) and when stimuli are briefly presented (Arkesteijn et al., 2018, 2020; Heeman et al., 2014), two conditions that were also realized in the present study. It is therefore unlikely that our current set-up was inadequate to evoke a global effect in eye movements.

Another possibility would be that both the hand and the eyes were initially biased to move in the direction of the distractor but rapidly adjusted to be redirected to the target, via a short-latency corrective eye movement and an online adjustment in the hand movement trajectory. There are several reasons why this is implausible. First, the results in our previous study with eye movements did not show any evidence for the presence of corrective saccades (see Arkesteijn et al., 2020; Arkesteijn et al., 2018). Moreover, there is no reason to expect corrective saccades in our configuration because the errors induced by the global effect are relatively small (<2°) and well below the typical error range to be typically followed by corrective saccades (Tian, Ying, & Zee, 2013). Furthermore, corrective saccades usually do not occur in the absence of visual information and if they do occur, they are less accurate compared to corrective saccades made in the presence of visual information (Tian et al., 2013). This implies that if such saccades would have occurred in our experiment, they should have been less precise in the short as compared to the long condition which should also be reflected in the endpoints of the hand movements. Yet, the finding that the tapping bias did not vary across both conditions renders such an explanation unlikely. Finally, if participants would have adjusted their hand movements online, the tapping bias should have been smaller with increasing movement time, for any adjustment requires some time (Brenner & Smeets, 1997; Smeets, Oostwoud Wijdenes, & Brenner, 2016). The results (Fig. 4B) clearly show that this was not the case.

There might be an ecological explanation that the selected target for hand and eye movements differ in the presence of a distractor. If the eye does not accurately ‘hit’ the target but instead skews towards an unexpected nearby distractor, perception benefits from this. Namely, the fovea can cover both objects partly, and thus can process information from both stimuli. If the hand is biased towards the distractor, it simply misses the target. Perhaps, the system coding for hand and eye movements allows for a wider distribution for eye movement endpoints than it does for hand movements. Indeed, the standard deviations of saccades (Figure 2C of Arkesteijn et al., 2020) is much larger than that of hand movements (Fig. 3).

Together these results show that even though the amplitude of hand movements can in some configurations be affected by distractors (Heath & DeSimone, 2016; Sailer et al., 2002), there is no effect of distractors in the direction of hand movements. This lack of effect is independent of presentation time and latency. In contrast, both the amplitude and direction of the endpoints of eye movements are clearly affected by a distractor (Coren & Hoenig, 1972; Findlay, 1982; Van der Stigchel & Nijboer, 2011), and this effect reduces with presentation time (Arkesteijn et al., 2020; Findlay, 1982; Heeman et al., 2014). This shows that even although the eye and hand show overlap in systems that are responsible for the generations of their movements, those systems are not rigidly coupled.

Funding information

This research was supported by an Open Research Area Grant from the Netherlands Organization for Scientific Research to Artem Belopolsky [ORA 464-15-193].

Additional information

No part of the study procedures was pre-registered prior to the research being conducted and no part of the study analyses was pre-registered prior to the research being conducted.

Data and experimental code can be found following this link: https://osf.io/xrvs6/.

Open practices

The study in this article earned Open Data and Open Materials badges for transparent practices. Materials and data are available at https://osf.io/xrvs6/.

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