The influence of locative expressions on context-dependency of endpoint control in aiming

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ABSTRACT

It has been claimed that increased reliance on context, or allocentric information, develops when aiming movements are more consciously monitored and/or controlled. Since verbalizing target features requires strong conscious monitoring, we expected an increased reliance on allocentric information when verbalizing a target label (i.e. target number) during movement execution. We examined swiping actions towards a global array of targets embedded in different local array configurations on a tablet under no-verbalization and verbalization conditions. The patterns of constant errors in the target direction were used to assess differences between conditions. Variation in the target context configuration systematically biased movement endpoints in both the no-verbalization and verbalization conditions. Ultimately, our results do not support the assertion that calling out target numbers during movement execution increases the context-dependency of targeted actions.

1. Introduction

Accurate perception is essential for directing actions towards and around objects in our immediate surroundings. We use visual information to perceive the distance between objects and to gauge our position relative to these objects. In target-directed actions actors are thought to primarily define the spatial position of objects or targets by the absolute distance of the body from the target (i.e., egocentric information). However, certain circumstances are predicted to increase the reliance on object-to-object spatial relationships, locating a target with respect to other objects irrespective of the actor’s location (i.e., allocentric information) (Milner & Goodale, 2008; Willingham, 1998).

According to the dual-mode principle (Willingham, 1998), goal-directed movements can be executed unconsciously and automatically, or consciously monitored and controlled. It is proposed that automatic movements are guided primarily by egocentric information, using online task relevant spatial information in dimensions of the object location relative to the actor. Conversely, movements supported by the conscious mode mainly utilize allocentric information, locating objects in a worldly context, independent of the actor’s vantage point (see also Milner & Goodale, 2008). For example, it is demonstrated that when participants consciously

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perceive a target location and maintain this information for a delayed, memory-based action, they make use of context-dependent allocentric information (Goodale & Milner, 1992; Hu & Goodale, 2000; Olthuis, Van Der Kamp, & Caljouw, 2017; Westwood & Goodale, 2003; Westwood, Heath, & Roy, 2000). Since conscious perception is also needed for communication (i.e., telling about the environment), it stands to reason that calling out target attributes during movement execution will increase conscious monitoring and control of the movement (Rossetti & Régnier, 1995; Rossetti et al., 1995, as cited in Rossetti 1998). Indeed, Rossetti and Régnier (1995) and Rossetti et al. (1995) reported that identifying and verbalizing the target for action amidst other potential targets during execution induced an action more contingent upon the visual context (i.e. target array). In both studies, participants moved towards an array of six targets under a delay condition (i.e., 0 sec or 8 sec) and a verbal condition (i.e., with or without verbalization of the active target location from farthest-left (i.e., 1) to farthest-right (i.e., 6) (see example Fig. 1). The orientation of the confidence ellipse for variable error relative to the movement direction demonstrated that endpoints in the no-verbalization condition were only oriented with the targets in the 8 sec-delay condition, while in the verbalization of target number condition both the 0 sec and 8 sec-delay conditions showed endpoints dispersed towards the targets. This led the authors to conclude that the target number verbalization had the same effect as a memory delay, and thus endpoints became dependent on the visual context of the experimental design, indicating an increased allocentric influence on movement control. These findings are consistent with the argument that conscious monitoring of the targets for action, through delay or verbalization, can alter the type of visual information used to guide movement (Willingham, 1998).

By contrast, in a far aiming task where participants verbally judged target-properties during execution, Olthuis, Van Der Kamp, & Caljouw, 2017 did not observe a shift towards the use of context-dependent allocentric information. Contextual elements were found to bias the ball landing location in both the verbalization and no-verbalization conditions. One explanation may be that far-aiming in extra-personal space is more consciously controlled and monitored than pointing movements in peri-personal space, thereby making the exploitation of allocentric information more ubiquitous (see also Navarro, van der Kamp, Ranvaud, & Savelsbergh, 2013).

Although verbalization of target attributes may have led to an increase in contextual reliance in the Rossetti & Régnier, 1995; Rossetti et al., 1995 studies, it is also possible that the distribution shift towards the line of the targets resulted from a target number bias. In the abovementioned studies of Rossetti and colleagues the possibility of a numerical magnitude effect was ignored, all endpoints, regardless of the actual target location, were mapped relative to a reference target set at 0°. Some targets having a clockwise constant endpoint bias and others a counter-clockwise constant endpoint bias might therefore explain the wider error distribution observed perpendicular to the movement direction. Calling out numbers may have triggered a numerical magnitude bias, that is, calling out smaller numbers for the eccentric left targets may have biased movements more to the left and calling out larger numbers for the eccentric right targets may have biased movement endpoints more to the right.

This so-called spatial-numerical association of response codes or SNARC effect (Dehaene, 2001; Dehaene, Bossini, & Giraux, 1993) is largely supported by studies using stimulus–response compatibility tasks, during which faster button press reaction times are observed for small numbers when congruent responses are located on the left side, and vice versa, faster responses to large numbers when congruent responses are on the right side. Impacts of spatial numerical magnitude on movement kinematics have also been

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**Fig. 1.** The confidence ellipses of the pointing scatter endpoints, egocentric localization is indicated when the targeted endpoints are independent of the surrounding visual objects and aligned with movement direction (dashed). In contrast, allocentric localization is indicated by distortions in the direction of other contextual elements within the scene (solid). Adapted from “Implicit Perception in Action Implicit short-lived motor representations of space in brain damaged and healthy subjects,” by Yves Rossetti, 1998, *Consciousness and Cognition, 7*(3), p.546-p.547.
of these manipulations we can gain insight into whether the larger error distribution as found by Rossetti can be attributed to a nu
other half from Right-to-Left (i.e., R-to-L). By evaluating the direction of the error (clockwise or counter-clockwise) in response to both 
from the visual context bias. We ask half of the participants to verbalize the target numbers from Left-to-Right (i.e., L-to-R) and the 
14 participants were required. All participants had normal or corrected-to-normal vision and no known history of visual or neur 
and colleagues. 

In the current study, we aim to determine if the bias aligned with the targets is influenced by verbalization giving rise to a numerical magnitude effect or because verbalization leads to an increased visual context effect, as claimed by Rossetti and Regnier (1995) and Rossetti et al. (1995). In line with the task set-up of Rossetti, participants will move from a center position to a target that is presented within a global target array (see Fig. 2), however we also present some setup expansions to delineate the numerical magnitude bias from the visual context bias. We ask half of the participants to verbalize the target numbers from Left-to-Right (i.e., L-to-R) and the other half from Right-to-Left (i.e., R-to-L). By evaluating the direction of the error (clockwise or counter-clockwise) in response to both of these manipulations we can gain insight into whether the larger error distribution as found by Rossetti can be attributed to a numerical magnitude bias, a contextual bias, or both. For the L-to-R group, where the order of numbers is consistent with the small-left and large-right mental number line (Bächtold, Baumüller, & Brugger, 1998; Ishihara et al., 2006), we expect leftward endpoint biases for smaller numbers associated with the left targets and rightward endpoint biases for larger numbers associated with the targets on the right side. Based on evidence that the spatial numerical magnitude bias can be reversed in various settings, including when imagining a reversed number line prior to movement initiation (Abrahamse, van Dijck, & Fias, 2016; Bächtold, Baumüller, & Brugger, 1998; Ristic, Wright, & Kingstone, 2006; Shaki, Fischer, & Petrusic, 2009), we expect the numerical magnitude bias between the L-to-R and R-to-L groups to result in an opposite bias. To investigate the influence of the visual context we introduce a local array around the active target (i.e., vary contextual elements) (see Fig. 2). While each target occupies a fixed (x, y) absolute location within the global array (of all 7 targets), on any given trial, a local array consisting of three consecutive targets (i.e., including the target for movement) will be visually more conspicuous than the four remaining targets. In line with the work of Rossetti, we hypothesize an increased context bias in the verbalization condition compared to the no-verbalization condition. We therefore expect, in the verbalization condition, a systematic direction effect of active target position within the local array, on the movement endpoint. This constant error can be deduced as a visual context (allocentric) effect rather than a numerical magnitude effect. After all, in the verbalization condition, participants call out the active global target number (the targets absolute position within the global array), not the position within the local array. Meanwhile, any numerical magnitude influences should be impervious to variances in the relative target position (local array).

2. Method

2.1. Participants

Forty right-handed, young adults (17 females and 23 males) aged 22.3 +/- 2.8 years with right-to-left reading habits participated in the study, 20 per group. We conducted an a priori power analysis using G*Power 3.1.9.7 (Faul, Erdfelder, Lang, & Buchner, 2007), an alpha value of 0.05, and power of 0.95, which indicated that for a moderate effect size (f = 0.25), which confirmed that a minimum of 14 participants were required. All participants had normal or corrected-to-normal vision and no known history of visual or neuromuscular deficits. All participants were in good health and functionally able to complete the task without fatigue. Participants did not receive financial compensation for participating in the experiment. Approval from the local ethics committee was granted and a written informed consent from each participant was acquired after explanation of the task and experimental procedures.

Fig. 2. Aiming to Target-C, Position-Left (A); Target-C, Position-Middle (B); Target-C, Position-Right (C). In the L-to-R verbalization group (1:7) this was the third target, so participants called out “three”; while in the R-to-L verbalization (7:1) this was the fifth target so participants called out “five”. 
2.2. Apparatus and task

A 12.9-inch iPad Pro (Apple Inc., Cupertino, CA, USA) size 305.7 × 220.6 × 6.9 mm (l × w × h) with Liquid Retina display (2732 × 2048-pixel resolution at 264 pixels per inch) was used for this study. The device screen is a 12.9-inch (diagonal) LED-backlit Multi-Touch display with IPS technology. Brightness was set at 100%. A first-generation Apple Pencil with length of 175.7 mm, diameter of 8.9 mm, and weight of 20.7 g was used together with a custom application that logged all interactions of the Apple Pencil with the screen. We chose to use a stylus rather than a finger since we are reporting on movement accuracies and earlier research on pointing, particularly with small targets, shows that movements with styli are more accurate than fingers (Cockburn, Ahlström, & Gutwin, 2012; Lee & Zhai, 2009). Furthermore, since finger size has been found to affect the reliability of a touch input (Kurosu, 2017), and given the small size of our targets, using a stylus provides more precise and reliable results. The iPad Pro has an iOS 11 operating system with ProMotion technology which records swipe movements on the display at a frequency of 120 Hz. With the Apple Pencil the full movements were recorded and sent to the iPad Pro with a tracking frequency of 240 Hz in combination with the ProMotion technology of the iPad Pro.

Participants held the stylus between their thumb and index finger and moved it from the home position to one of seven possible targets presented on the screen. The iPad Pro was positioned horizontally and centered in front of participants on a table that was approximately 76.2 cm high. Participants were seated comfortably in a chair with their feet touching the ground and their arms able to move comfortably for all required actions. When oriented horizontally the top-left corner of the tablet is the origin (i.e., 0, 0 px). In each condition the start screen showed only the fixed home zone (black circle on a white background) in the bottom center of the screen (683, 900 px). Once the Apple Pencil made contact with the home position a semi-circular global array of seven targets appeared. Each target was equidistance from the home position. The targets in the global array hereafter referred to as Target-A - Target-G were in the following locations in px (x, y): Target-A (272, 662), Target-B (378, 536), Target-C (526, 454), Target-D (683, 427), Target-E (845, 454), Target-F (988, 536) and Target-G (1094, 663). All targets and the home position had a diameter of 16 px (see array example, Fig. 2). Note that, in the verbal condition half of the participants called out 1–7 from L-to-R (Target-A to Target-G) while the other half called out 1–7 from R-L (Target-G to Target-A).

The actual or active target within a trial was indicated by colour (solid red), positioned either beside or flanked by, two dark grey targets (i.e., grey value of 40%), forming a local array of three targets. In other words, within the local array of three targets the active target could be positioned to the left of, in the middle of, or to the right of the other two targets; this position of the active target differed across trials. The four remaining targets in the global array of seven targets were light grey (i.e., grey value of 4%) and only moderately visible (Fig. 2). Only movements towards the three middle targets of the global array, Target-C, Target-D and Target-E, were included in the analysis because these are the only targets that could occupy all three positions within a local array (i.e., left, middle, and right). Participants were given 2 s of visibility to locate the active target after which an audio stimulus signalled the participants to begin the movement. To ensure that visual information could not be used for correction of endpoint errors, all targets were visually removed as soon as the stylus left contact with the home area that was defined as a 50-pixel radius around the home target. On average, vision of the targets was available for 24% (±/- 2.6%) of the total movement time. Trials were marked as incomplete if the stylus left the home target prior to the auditory start stimulus, or if the endpoint was >90% of the inter target-distance away from the active target. In trials with the aforementioned violations an error auditory signal sounded and the trial was aborted, these violations were not included in the analysis.

2.3. Procedure and design

Participants were instructed to place the stylus in the home position when they were ready to start and to keep the stylus steadily placed there until the auditory go stimulus sounded. Once they heard the tone, they were to move as quickly and accurately as possible to the active target location in a single, uncorrected swiping movement, while maintaining contact with the screen. Participants were also told to stop and lift the stylus vertically from the screen when they reached the target, rather than swiping through the target. If participants were unable to spot the active target, they were instructed to move and lift the stylus off the screen next to the home position, so the trial would be recorded as a technical error.

The task fitted in a single session of approximately one hour. All performers completed the task under two different conditions: a no-verbalization (control) condition and a verbalization condition. In the verbalization condition participants were given an extra task of calling out the number associated with the position of the active target in the global array during movement execution. Half of the participants were asked to verbalize the number of the targets consecutively from L-to-R (i.e., consistent with SNARC number magnitude), starting with 1 for the outer left target in the global array (Target-A) and 7 for the outer right target in the global array (Target-G). The other half of the participants verbalized the targets in reversed order from R-to-L, thus starting with 1 for the outer right in the global array (Target-G) and 7 for the outer left target in the global array (Target-A). The number being verbalized was always relevant to the location of the target within the seven-target global array, irrespective of its position within the local array.

The session began with instructions on the general task requirements, during which the participants performed 24 practice trials. To rule out any effects of initial learning, this was followed by an additional 72 trials of no-verbalization practice. Participants were
then divided into two counter-balanced groups, one group starting with the no-verbalization condition and the other group starting with the verbalization condition\(^1\). Each condition (i.e., no-verbalization and verbalization) consisted of five blocks of 72 trials, resulting in a total of 720 experimental trials. Between each block participants rested for 1.5 min. After the fifth block of the first condition participants received a 5-minute break before commencing the first block of the second condition. Target-C, Target-D and Target-E, which could occupy all three positions within a local array (i.e., left, middle, and right) were analyzed. In each block, Target-C, Target-D and Target-E were each the active target 18 times, thus up to 540 trials were included in the analysis per participant. The order the targets and their local arrays were presented within each block was random.

### 2.4. Data collection and analysis

The iPad Pro registered the \(x\) and \(y\) coordinates in pixels (px) on initial connection with the screen at the home position until immediately before the stylus lost connection with the screen at the movement endpoint. Movement onset was defined as the moment the movement reached 5\% of the peak velocity and the endpoint was defined as when the movement velocity declined to 5\% of peak velocity. In rare cases the movement ended at a velocity larger than 5\% of peak, in these observations the end of movement was recorded as the last point before lifting the stylus off the screen. Constant error and variable error both in the direction of movement (overshooting and undershooting the target - distance error) and perpendicular to the direction of movement (counter-clockwise and clockwise error of the target - direction error) were measured. Constant error provides information about movement bias and the direction of any such bias, whereas variable error is the standard deviation of the mean constant error. We report exclusively on the constant direction error (in radians) since, for the goal of this study, we are primarily interested in error trends along the line of the targets. However, constant and variable distance and direction error (in pixels) are presented in the supplementary material. The end positions were analyzed to assess the directional error from the center of a given target. Target direction was defined as the orientation of a straight line from the home position to the target, while movement direction was described as the orientation of a straight line from the home position to the movement endpoint. Directional error was the angle (in radians) between the target direction and the movement direction. A positive angle indicates a clockwise bias and a negative angle indicates a counter-clockwise error.

Before statistically analyzing the dependent variables, technical errors and outliers were excluded. Technical errors were defined as trials where the iPad failed to save the endpoint, or where the distance of the registered endpoint was larger than 90\% of the inter-target distance. This may have occurred if the stylus lost contact with the touchscreen during the movement, if the movement was initiated before the go-signal, or if a trial was aborted or aimed towards the wrong target. Values less than Q1-3(IQR) or greater than Q3 + 3(IQR) were considered outliers and removed from analysis. Overall, 1.8\% of all trials were eliminated after the technical error analyses and 1.6\% of trials were eliminated after outlier analysis.

To isolate the numerical magnitude bias from the contextual bias we performed a repeated-measures ANOVA with 3 (Global Target: C, D, E) by 2 (Condition: No-Verbalization, Verbalization) by 3 (Local Position: Left, Middle, Right) as within-subject factors and 2 (Group: L-to-R, R-to-L) between-subjects factor. All tests were subjected to Mauchly’s test for sphericity. Whenever the Mauchly’s sphericity assumption was violated, the ANOVA results were adjusted using the Huynh-Feldt adjustment for non-sphericity. For post-hoc tests on interactions with targets we performed repeated measures ANOVAs. Paired \(t\) tests, with a Bonferroni adjustment of the \(\alpha\) level, were used for all other post-hoc comparisons.

### 3. Results

The swiping movements made from the home position to the targets were relatively straight. Fig. 4A shows representative movement trajectories produced by a participant aiming to the different targets. The directional errors per target per condition for both participant groups (L-to-R and R-to-L) are presented in the supplementary material.

The ANOVA for median directional error (radians) did not reveal any significant main or interaction effects, for Condition [\(F(1,38) = 0.96, p = .33, \eta^2 = 0.03\)] or Group [\(F(1,38) = 0.28, p = .60, \eta^2 = 0.01\)]. Thus, contrary to expectations, no evidence found that verbalization influenced constant error in the movement direction or that reversing the direction of the numbering did evoke a reversed numerical magnitude\(^2\). The ANOVA did reveal significant effects for Global Target [\(F(2,76) = 145.67, p < .001, \eta^2 = 0.79\)] and Local Position [\(F(2,76) = 32.65, p < .001, \eta^2 = 0.46\)]. No further main or interaction effects were found (\(F\)’s < 2.37 & \(p\)’s > 0.70). The main effect of Target (C, D, E), presented in Fig. 3, indicates that errors were biased by the global array, specifically errors to Target-C were the most counter-clockwise and errors to Target-E were the most clockwise. The Position effect shows that errors were also influenced by the local array (context effect), with overall error significantly different for all positions (see Fig. 3). The median trajectories for all participants across all conditions and positions is also illustrated per target in Fig. 4B. The Mean and SD of median directional error (radians) for each condition and group is presented in a table in the supplementary material.

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1. To assess if verbalization of the global target numbers was carried over to the no-verbalization condition, we performed a separate analysis on the endpoint data for each of the two subgroups (group that started in the no-verbalization condition and the group that started in the verbalization condition). Neither ANOVA showed any main or interaction effects of condition. So, carry-over effects were not found.

2. There was also no evidence found that initiation time (defined as the time between start contact and 5\% of peak velocity) was influenced by the numerical magnitude called out. The Target x Group ANOVA on the initiation times in the verbalization trials only revealed a Target effect (\(F(2,76) = 21.74, p < .001\)), i.e. reaction time is longest for the right Target-E in both groups, see supplementary material.
4. Discussion

Research supports the conjecture that actions are guided by a combination of egocentric and allocentric visual information, with the relative contribution of each being triggered by particular circumstances, such as the visibility of the target during movement execution. It is demonstrated that unconsciously controlled automatic movements are guided primarily by body-dependent egocentric information and consciously monitored and/or controlled movements mainly utilize context-dependent allocentric information (Goodale & Milner, 1992; Milner & Goodale, 1995; Milner & Goodale, 2008; Willingham, 1998). However, the supporting evidence comes primarily from delay studies, where participants make memory-guided reaches and grasps (Diedrichsen, Werner, Schmidt, & Trommershäuser, 2004; Krigolson, Clark, Heath, & Binsted, 2007; Krigolson & Heath, 2004; Obhi & Goodale, 2005; Olthuis, Van Der Kamp, Lemmin, & Caljouw, 2020), with less evidence from studies where conscious monitoring was directly manipulated. According to Rossetti (1998) and Rossetti and Régnier (1995) an increased reliance on context, or allocentric information, can be induced by consciously monitoring and/or controlling movements through verbalizing target numbers during movement execution. However, an
alternative explanation for this directional spatial bias is that verbalizing the target number evoked a spatial numerical association, a numerical magnitude effect triggered from specifically calling out numbers. By expanding the experimental setup in the aforementioned studies and reporting on the signed constant error instead of variable error, we attempted to delineate if the influence of verbalization on constant direction error can be attributed to the calling out of numbers (numerical magnitude effect), or an influence of allocentric information (visual context effect). We manipulated the numerical magnitude bias by reversing the direction the targets were remembered and verbalized in the global array of 7 targets (L-to-R or R-to-L) and changing the sources of allocentric information available during movement execution, via the introduction of a local array (visual context effect). There was no evidence that verbalization significantly affected the magnitude of direction errors and also no evidence to support the contention that the order participants verbalized the target affected movement endpoints. Thus, we were unable to show that verbalization induced a SNARC effect or increased the use of allocentric information (although verbalization did increase reaction time, see supplementary material). However, an effect of both the global and local array on movement endpoint was found in both the verbalization and no-verbalization conditions.

It is proposed that allocentric information plays an increasingly prominent role when performing actions at a higher conscious level (Glover, 2004; Keele, Ivy, Mayr, Hazeltine, & Heuer, 2003; Willingham, 1998). For example, the intention of moving towards a briefly presented target for future action requires a degree of conscious attention/monitoring to recall the target location. Many studies appear to support this supposition, reporting increases in allocentric influence for movements in trials incorporating temporal delays between visual stimulus and motor response (Bridgeman, 1991; Gentilucci, Chieffi, Daprati, Saetti, & Toni, 1996; Rossetti, 1998). In particular, using a similar set-up to the current study, when swiping towards targets in an array, relative increases of error in the direction of the other targets were observed when a delay of 5-s instead of 0-s was introduced between target presentation and movement initiation (Olthuis, Van Der Kamp, Lemmink, & Caljouw, 2020). Rossetti (1998) further suggested that verbalizing target position during movement execution activates a connection to the target leading to context-dependent localization of the target. Ultimately, our results do not support this assertion, as we did not observe an increased effect of position within the local array in conjunction with verbalization. However, it is important to note that in our study full visual control was not available during the entire movement, but only during the initial segment. Studies have shown that actions are mediated by interacting egocentric and allocentric information, with a larger egocentric weighting when vision of the limb and target are available during execution than in conditions of 0-s or more delay (Westwood, Heath, & Roy, 2000). Based on our findings we therefore conclude that although increases in the reliance of allocentric information can be task induced, for instance with memory-guided movements (Olthuis, Van Der Kamp, & Caljouw, 2017) including those with comparable experimental set-ups (Olthuis, Van Der Kamp, Lemmink, & Caljouw, 2020), similar increased allocentric effects are not induced by verbalizing the target number during action towards that target.

We also sought to uncover if observed errors along the target line in the verbalization trials were influenced by the left-small, right-large numerical magnitude effect. We predicted that in trials with consciously monitored and/or controlled movements, through verbalization, constant direction error would demonstrate this small number-left and large number-right bias. That is, by including one group that verbalized the targets from L-to-R and another that verbalized them from R-to-L, we expected any numerical magnitude effect to show reversed bias between these groups, since the increase in target number magnitude was in opposite directions. This is supported by research suggesting that it is possible to reverse the default L-to-R order of the spatial orientation of numbers, for example, when representing numbers as time on a clock-face, a small-right and large-left association was triggered in Western participants (Bächtold, Baumüller, & Brugger, 1998). Ultimately, we found no evidence that the order of the target numbers, L-to-R or R-to-L did significantly bias endpoints in the direction of the target array. This implies that the order targets were numbered/labeled by participants was irrelevant to how they located these targets for aiming. Further, in the case of a numerical magnitude effect, constant direction errors were expected to be resistant to the relative position of the target (local array), however position was seen to influence movement endpoints. Thus, the numerical magnitude orientation (i.e. L-to-R and R-to-L) does not appear to induce effects on movement endpoints, at least not with recently learned spatial-numerical associations.

We also discovered some general allocentric effects that were not increased by verbalization of the task. Interestingly, the direction of the error was counter-clockwise for Target-C in the left of the action space, while it was clockwise for Target-E in the right side of the workspace. The smallest bias was found for the center Target-D. This global Target effect is in line with the directional bias towards the diagonal reported in the literature on 2D planar reaching (Ghilardi, Gordon, & Ghez, 1995) and is consistent with a perceptual bias whereby participants categorize circular workspaces into quadrants established by the horizontal and sagittal axes (Gourtzelidis, Smyris, Evdokimidis, & Balogh, 2001; Huttenlocher, Hedges, & Duncan, 1991). Analyses of the directional error in this study also showed a robust influence of Position within the local array. Thus, the movements were susceptible to local contextual position effects brought on by clusters of landmarks. In line with the centroid bias phenomenon, in which actions tend to be biased toward the centroid of a series of targets, a bias towards the center of the saliently presented local array may be expected (Morgan, Hole, & Glennerster, 1990). That is, a clockwise bias when the active target occupies the left position and a counter-clockwise bias when the target occupies the right position, in the local array. However, the position effect we observed was increased error in the clockwise direction from Position-Left to Position-Right. Thus, the observed contextual bias cannot be explained by the centroid bias.

Overall, we postulated that verbalizing target number during movement execution would enhance conscious control of the action leading to increased error in the direction of the neighbouring targets. We expected this to be induced by a context-effect. To support this conjecture we assessed if a numerical magnitude effect could be ruled out. However, verbalization was not found to provoke either a numerical magnitude- or an increased context-effect. This was somewhat surprising given that consciously controlled actions have been seen to increase reliance on allocentric information for localizing targets in studies with delay (Gentilucci, Chieffi, Daprati, Saetti, & Toni, 1996; Gentilucci, Daprati, Gangitano, & Toni, 1997; Olthuis, Van Der Kamp, & Caljouw, 2017; Rossetti, 1998). Poletiek (2001) argued that a major function of consciousness is hypothesis testing, comparing internal thoughts with external facts to engage with the
environment (as cited by Masters, 2012). Perhaps verbalizing the target number was relatively intuitive, while a more analytical consideration may be required to influence the movement. In other words, verbalizations that exclusively monitor a target location may not be sufficient to impact changes in the movement endpoint. Verbalizations that induce conscious control may be required for such a change. It is also possible that verbalization mainly affects movement planning, rather than movement execution. Future research should include more consciously demanding verbalizations to assess this speculation (see van Ginneken et al., 2017). On the other hand, given that there was an allocentric influence identified in both conditions for the eccentric targets, it is possible that the setting of the experiment, with limited visibility of the target during movement execution, induced a relatively strong conscious monitoring and control, thereby obscuring any possible effects of verbalization.

CRediT authorship contribution statement

Raimey Othuis: Conceptualization, Methodology, Investigation, Writing - review & editing. John Kamp: Conceptualization, Supervision, Writing - review & editing. Koen Lemmink: Supervision, Writing - review & editing. Simone Caljouw: Conceptualization, Methodology, Writing - review & editing, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concof.2020.103056.

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