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Abstract

The role of head-direction disparity was examined in one experiment that compared verbal responding with pointing in a task that entailed locating objects from imagined perspectives. Participants studied text descriptions of spatial scenes and then localized from memory objects in them after adopting imagined perspectives (i.e., face x, find y). Responses were made by selecting keys on the numerical keypad marked with verbal labels or arrows pointing to the four canonical directions. Results showed that performance was equally accurate and fast for the two response modes. When responding with arrows, however, accuracy was substantially lower when the imagined heading was misaligned with the learned heading.

Introduction

Studies in the field of spatial updating typically require participants to first study a spatial scene and then localize target-objects by pointing to them without vision from novel standpoints adopted by imagination (e.g., Presson & Montello, 1994; Rieser, Guth, & Hill, 1986). The typical result is that, compared to pointing to targets from the learning standpoint, pointing performance from imaginal standpoints is inferior. This is especially the case when the learning and imaginal standpoints are misaligned. For example, Rieser (1989) has shown that latencies for pointing to targets increased as a function of the angular disparity of the imaginal standpoint from the initial learning standpoint.

The inferior pointing performance from imaginal standpoints in spatial updating studies has been often attributed to the lack of vestibular and proprioceptive information during imagined movement; these types of information are believed to be important factors allowing people to automatically update their spatial representations during actual physical movement (Loomis, Klatzky, Golledge, & Philbeck, 1999; Klatzky, Loomis, Beall, Chance, & Golledge, 1998; Rieser, 1989). The finding that performance does not suffer when the novel standpoint is adopted by physically moving, instead of only imagining the movement, corroborates the central role of vestibular and proprioceptive information in spatial updating.

However, the fact that studies in spatial updating have been predominantly using pointing as the response mode raises the possibility that processes specific to the response mode itself might be responsible for the decrement in performance associated with imagined headings. An alternative explanation to the traditional spatial updating account is that performance is worse from imagined standpoints because pointing itself is more difficult to perform from positions that are misaligned to the actual heading of one's body. The fact that in everyday life we typically use pointing from our own standpoint and seldom, if ever, from imagined standpoints suggests that it is possible that pointing has become so strongly anchored unto our bodies that it does not represent an ideal response mode to be used in spatial cognition tasks.

The strong coupling of pointing with the body is evidenced in studies that employ disorientation. In one study, May (1996) had people point to target-objects of a spatial layout under 3 conditions. In one condition, named *embodied repositioning*, participants were allowed to turn their bodies into the requested facing direction before pointing to a target. In another condition, termed *cognitive repositioning*, participants remained at their initial standpoint and simply imagined adopting the requested facing direction. Finally, the *disoriented repositioning* condition was similar to cognitive repositioning with the exception that participants were rotated to the left and right for 5 seconds after having studied the layout. Results revealed superior pointing performance for embodied repositioning. More importantly, however, performance was worse in the cognitive repositioning than in the disoriented repositioning condition. Similar results are provided by Waller, Montello, Richardson, & Hegarty (2002). This experiment showed that the alignment effect -- that is, the performance difference between trials in which the imagined heading is aligned with the body's actual orientation and those that it was misaligned --was diminished in a disorienting condition. The results by May (1996) and Waller et al. (2002) suggest that performance in perspective-taking tasks can be improved if the influence of discrepant bodily cues is diminished through disorientation.

Recently, May (2004) has proposed the *sensorimotor hypothesis* to explain why pointing performance suffers when responding from imagined standpoints. According to May, in order to point to the location of an object from an imagined standpoint, a person has to overcome conflicts that are caused by the discrepant physical (sensorimotor) and the imagined egocentric (i.e., relative to the imagined position) locations of objects. May argues that sensorimotor codes specifying the objects' locations relative to the actual position and orientation of the person are automatically activated. Therefore, the person needs to suppress this sensorimotor information in order to select the appropriate response. Suggestive of these conflicts is May's finding that reaction times for pointing toward targets from imagined standpoints vary as a function of *object-direction disparity* (i.e., the angular difference between the sensorimotor and the imaginal response vectors).

In addition to object-direction disparity, May proposes a second source of interference. He argues that even when the appropriate response vector is chosen, in order to be executed by pointing, it needs to be specified from a reference frame centered on and oriented with the person's body. This type of interference, termed *head-direction Disparity,* explains why performance from imagined standpoints suffers dramatically when adopting the imagined standpoint entails performing mental rotations instead of translations only.

In recent work, Avraamides & Ioannidou (2005) examined the effects of head-direction disparity in a perspective-taking task. Participants, in their experiment, viewed displays of a rectangular table portraying 6 people sitting around it in various arrangements. With the display perceptually available at all times, they were then instructed to adopt the perspective of one of the characters, and locate from that perspective a second character (e.g., "imagine you are person x, find person y"). Two conditions differing in terms of the response mode were included in the experiment. In the verbal response condition, participants responded with the verbal label describing the relative position of the target. In the pointing response condition, they responded by selecting an arrow pointing toward the desired direction. Results revealed faster and more accurate performance with verbal responding than pointing with arrows. Furthermore, the effect of imagined heading was more severe in pointing. Accuracy for pointing was lower as the angular deviation of the imagined heading from the participant's physical heading increased. Accuracy in the verbal responding condition was equal for all levels of imagined heading. In terms of latency, response times increased with greater misalignment of the imagined heading but the increase was substantially steeper in the pointing response mode.

Based on these results, Avraamides and Ioannidou (2005) argued that the problem of head-direction disparity is present only with response modes that depend on the body. Pointing, along with other manual responses, poses rather complex and unnatural demands on participants in spatial tasks because it requires from them to first ignore their body location in order to determine the correct response vector but then use their body to execute the response. It is not surprising that participants in experiments often find it difficult to understand how they should respond (see Presson & Montello, 1994).

The results from Avraamides & Ioannidou (2005) suggest that language might be a more flexible response medium for use from imagined standpoints. Results from other studies further support this hypothesis (e.g., Avraamides, Klatzky, Loomis, & Golledge, 2004; DeVega & Rodrigo, 2001; Wraga 2003).

To sum up, the results from studies using disorientation have shown that performance on spatial tasks is prone to interference from sensorimotor cues. Studies using language have also suggested that language is more resilient to sensorimotor conflicts. Based on May's hypothesizing (2004) there is no reason to expect that pointing and verbal responding should differ in terms of object direction disparity effects. However, because responding linguistically does not make use of the human body during the execution phase, no head-direction disparity influences should be present with verbal responding. Therefore, the advantage of verbal present in studies comparing verbal and manual responses either directly (e.g., Avraamides et al., 2004; Avraamides & Ioannidou, 2005) or indirectly (e.g., De Vega & Rodrigo, 2001; Wraga, 2003) could be only attributed to head-direction disparity.

The goal of the present experiment is to examine whether the two tasks differ in terms of head-direction disparity in situations in which no object-direction disparity influences are present. To eliminate object-direction disparity we use tasks requiring spatial reasoning in environments that are not immediate; that is, environments other than the one in which the participant is present. Using non-immediate environments allows the elimination of object-direction disparity effects because no automatic activation of sensorimotor codes can take place. In order to determine the role of head-direction disparity we contrast pointing performance with verbal responding. Any differences that we might obtain between the two response modes can be attributed to head-direction disparity.

Experiment

The purpose of the present experiment is to contrast performance for locating targets in a remote environment using either verbal labels or a response that depends more strongly on the physical body. The experiment was very similar to the experiments conducted by de Vega & Rodrigo (2001). In contrast to de Vega & Rodrigo who focused primarily on contrasting physical and imaginal rotations in pointing (Exp.1) and verbal responding (Exp. 2), we are more interested in directly comparing the two modes of responding after imaginal rotations.

Participants in the experiment read descriptions of fictitious environments, adopted imagined headings in them and located target-objects. Responses were made by pressing keys marked either with the initial of verbal labels or arrows. This response procedure was adopted (instead of real pointing and oral responding) to equate the motor demands of the two response modes. Previous studies have also implemented pointing and verbal responding in such a manner (De Vega & Rodrigo, 2001).

If head-direction disparity influences pointing but not verbal responding, we expect lower accuracy and longer latencies when responding from imagined headings that are misaligned with the learned heading. If head-direction disparity is not present when reasoning about imagined non-immediate environments performance should be either equal for the two response modes or superior for pointing. Better performance for pointing could occur because of some difficulty that exists when mapping verbal labels (especially the labels "left" and "right" to the appropriate regions of space from misaligned headings (see Avraamides, 2003).

Method

Participants Twenty-six (3 males) students from an introductory Psychology class at the University of Cyprus participated in the experiment in exchange of course credit or small monetary compensation**.**

Materials. Four narratives were used in the present study. The narratives were translations in Greek of the narratives used by Avraamides (2003), which were originally adopted from Franklin and Tversky (1990) and Bryant and Wright (1999). The narratives were modified to include 4 instead of 6 objects (i.e., no objects were described above the head or below the feet of the central character). Each participant performed two blocks of trials in each response mode (verbal responding and pointing). Therefore, for each participant 2 narratives were randomly assigned to pointing and 2 to verbal responding. Furthermore, half of the participants performed the pointing blocks first while the other half were given the reverse order. The narratives and the test trials that followed were presented on a desktop computer. The task was programmed and presented using E-Prime (2000). For both response modes the arrow buttons of the numeric keypad of the keyboard were used. For the pointing mode, arrows pointing to the front, back, left, and right were placed on the keys in the appropriate egocentric arrangement. For the labeling mode, the keys were marked with the greek letters Μ, Π, Α, Δ (initials of the greek equivalents of the terms "front", "back", "left", "right").

Design The experiment followed a 2 x 2 x 2 x 2 mixed-factorial design with *response mode* (verbal responding, vs. pointing), *imagined heading (*aligned vs. misaligned*)*, and *block* (first vs. second) being the within-subject factors. The order in which the pointing and labeling blocks were administered was the between-subject factor.

Procedure Prior to the experimental trials for each response mode, two types of practice trials were administered. First, participants were asked to imagine being at specific locations on campus or the nearby area and locate familiar landmarks. Before the pointing blocks, participants responded by extending their arm to point to the landmarks from their imagined position. Before the verbal blocks, they responded by describing the relative to their imagined position location of the landmarks. This block of trials stopped when the experimenter judged that the participant was competent in responding from an imagined position. Then, participants carried out a number of practice trials on the computer which aimed at familiarizing them with using the keys to select the appropriate response from the set of alternatives. For the verbal response mode, arrows were presented on the screen as probes and participants had to respond as fast as possible by pressing the key with the verbal label describing the pointing direction of the arrow. Similarly, for the pointing mode, participants pressed they key marked with arrow that pointed the same way with the probe.

Practice trials were followed by 2 blocks of experimental trials in the corresponding response mode. In each block a narrative was presented and participants were given unlimited time to study it, visualize themselves in it, and remember the objects around them. After two filler sentences were presented, 16 localization trials followed. For each trial, the sentence "Face x, Find y" (where x and y were objects from the narrative) was presented on the screen. At this point, participants had to imagine facing object x and locate object y relative to their imagined heading. The 16 trials for each block were created by presenting all possible combinations of the four objects as referents for the imagined heading and as targets. Trials were presented randomly for each participant. A total of 64 trials (32 in each response mode) were administered to each participant.

In the verbal response mode blocks participants indicated their response by pressing the key marked with the initial of the appropriate verbal term. For the pointing mode blocks, responses were indicated by pressing the key marked with the arrow pointing to the appropriate direction.

Results

Practice Phase

The data from the practice trials were analyzed to examine whether differences between the two response modes existed before the experimental trials. In both response modes participants responded to the orientation of a presented arrow-probe using the same 4 keys. The keys were marked with the initial of verbal labels or arrows depending on the response mode to be used in the succeeding experimental trials.

Because the practice phase involved no misaligned imagined heading we expected that performance would be either equal or superior for pointing. Pointing from one's actual perspective is a well-practiced task and is free of determining labels for the various regions of space.

Accuracy was very high (95%), therefore, latencies became the primary focus. A repeated-measures analysis of variance (ANOVA) with response mode and order as factors was used[1]. The only significant result was a main effect for response mode, $F(1,22)=22,04$, MSE=389586, $p<.001$. Participants were faster in the pointing (1134 ms) than in the verbal response mode (1980 ms).

Experimental Phase

Accuracy data and latencies for correct responses were analyzed using a repeated-measures ANOVA with response mode, imagined heading, and block as within-subject factors and order as between-subject factors. Data from two participants were discarded from all analyses because of very low accuracy. Furthermore, trials in which latency exceeded the mean latency in the response mode x block cell of each participant by 2.5 standard deviations were omitted from all analyses.

Accuracy

Overall accuracy was 87.4% and did not differ for the two response modes, $p=.32$. A significant alignment effect was observed, $F(1,22)=6.75$, MSE=.029, $p<.05$. Accuracy was higher for the aligned (90.6%) than the misaligned (84.2%) imagined heading. More importantly, however, a significant response mode x imagined heading interaction was obtained, $F(1,22)=9.11$, MSE=.02, $p<.01$. As seen in Figure 1 an alignment effect was present for the pointing mode but not for the verbal response mode, $t(23)=3.26$, $p<.01$ and $t(23)=.31$, $p=.76$ respectively.

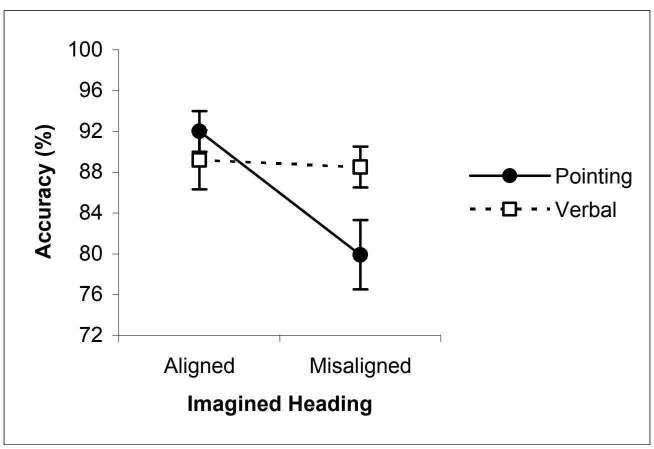

Figure 1: Mean Accuracy as a function of Response Mode and Imagined heading.

A significant response mode x order interaction was also obtained, $F(1,22)=4.29$, MSE=.04, $p<.05$. As seen in Figure 2, participants who performed the pointing task first were significantly more accurate with the verbal response mode (91.3%) than the pointing mode (82.5%). A pair-wise t-test showed that this difference was statistically significant, $t(11)=2.41$, $p<.05$. In contrast, participants who performed the verbal task first, were somewhat more accurate in the pointing task (89.4%) than the verbal task (86.4%) but this difference was not statistically significant, $p=.51$.

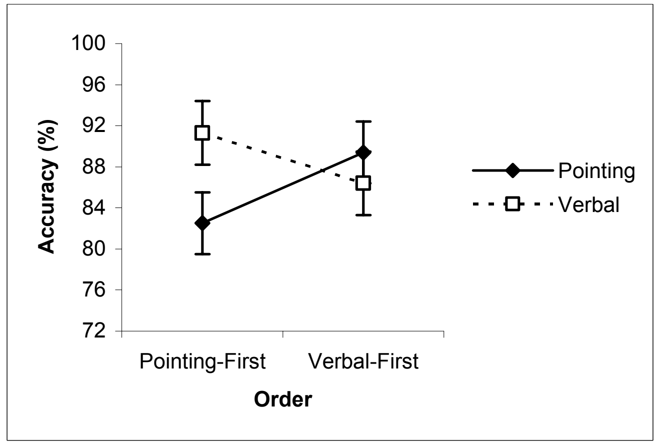

Figure 2: Mean Accuracy as a function of Response Mode and Order.

Latency

Latency was longer for the pointing (4732 ms) than the verbal (4454 ms) response mode but the difference was not statistically significant, $p=.44$. As with the accuracy data, the analysis of latency revealed an alignment effect, $F(1, 22)=7.03$, MSE=2287657, $p<.05$. Participants were faster responding from aligned than misaligned perspectives. However, the effect of imagined heading was present in both response modes, as indicated by the lack of a significant response mode x imagined heading interaction, $p=.85$ (Figure 3). No other main effects or interactions were significant.

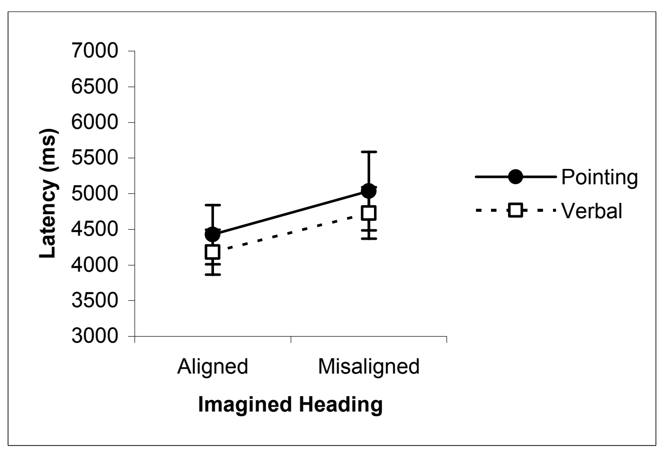

Figure 3: Mean Latency as a function of Response Mode and Imagined heading.

As with accuracy, a significant response mode x order interaction was obtained in the latency analysis, $F(1,22)=6.22$, $p<.05$. As shown in Figure 4, when the pointing task was completed first, pointing was particularly slow compared to verbal responding. When the verbal task was first, pointing was faster but the difference between the

[1] Data from two participants eliminated from experimental-trial analyses were also excluded from the practice-trial analyses.

two response modes was smaller and in fact did not reach statistical significance, $p=.18$.

In addition, a significant main effect for practice was obtained, $F(1,22)=13,82$, $p<.001$. Performance was faster in the second block of each response mode than the first. This effect did not interact with any other variables. No other main effects or interactions were present.

Finally, a separate ANOVA analyzed latencies for Spatial Framework results. Latencies were shorter for objects in the front (3172 ms), intermediate for objects in the back (5918 ms), and the longest for object on the left (7645 ms) and on the right (7029 ms) of the imagined heading, $F(3,69)=40.41$, $MSE=4655321$, $p<.001$. The unexpected difference between left and right did not reach statistical significance, $p=14$. The effect of target direction did not interact with the response mode. This finding replicates the results of De Vega & Rodrigo (2001) who found the spatial framework pattern in both pointing and verbal responding provided that physical rotations are not allowed.

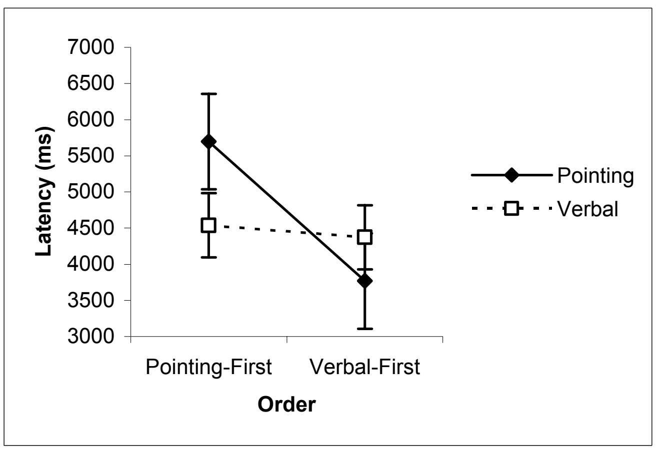

Figure 4: Mean Latency as a function of Response Mode and Order.

Discussion

The goal of the present experiment was to compare pointing and verbal responding in a task that entailed adopting imagined standpoints in remote environments. Reasoning about remote environments is believed to be free of any interference related to object-direction disparity.

In contrast to experiments with perceptual scenes (Avraamides & Ioannidou, 2005), we found no difference in the overall accuracy and latency between the two response modes. While, one could hastily conclude that this was the case because of the absence of any sensorimotor influence due to the use of non-immediate environments, other aspects of our results suggest that at least some interference was present.

First, the accuracy for locating the targets from misaligned headings was substantially lower for pointing than verbal responding. For aligned headings, performance was equally good for the two response modes. Furthermore, an alignment effect (i.e., better performance for aligned than misaligned trial) was present for pointing but not for verbal responding.

This pattern of results is compatible with a sensorimotor interference account positing interference due to head-direction disparity. Indeed, performance was less accurate for pointing in the cases in which the response vectors from the imagined and physical orientation were mismatched. This suggests that head-direction disparity effects were greater in the pointing response mode.

However, in contrast to the accuracy results, alignment effects for both tasks were found in the latency data. This result replicates findings from previous studies documenting such effects with verbal responding (Avraamides, 2003) and pointing (Hintzman, O'Dell, & Arndt, 1981). This could be interpreted as evidence of head-direction disparity effects in both tasks. Alternative explanations, however, exist.

A possible explanation comes from studies of spatial memory. Studies in this field often require participants to observe a spatial scene and then retrieve from memory spatial relations such as relative direction (e.g., imagine you are at x facing y, point to z). Many studies (e.g. Shelton & McNamara, 1997) using this paradigm report superior performance for cases in which the imagined heading is parallel to the learned view. The conclusion often reached for these alignment effects is that spatial memory is viewpoint-dependent; that is, people represent scenes in memory only from the view they experience during initial learning. Recently, however, McNamara and colleagues have provided convincing evidence that spatial memory is organized in terms of intrinsic referent axes, with egocentric experience being one of many possible cues, albeit the dominant cue, that can be used to orient a spatial representation in memory. Recently, Mou, Zhang, and McNamara (2004) showed that this account also applies for environments learned from text. Based on spatial memory accounts then, better performance is expected when adopting the studied viewpoint (or one parallel to it).

Another explanation is provided by Avraamides (2003). Although verbal responding is free on any interference, the mappings of egocentric terms such as front, back, left, and right to the appropriate regions of space is determined by the body orientation. As shown by Avraamides (2003; see also Avraamides & Sofroniou, in press) the use especially of the terms "left" and "right" is particularly difficult when it is done from an imagined perspective.

The important result from the latency analysis is not the presence of an alignment effect but that the size of the alignment effect was equal for the two tasks. As already mentioned, this was not the case for accuracy.

A second aspect of our findings suggesting a greater head-direction disparity effect for pointing is the nature of the interaction involving the order in which the two response modes were performed. Those interactions showed that the pointing response mode was particularly slow and error-prone when it was performed first. Comparing the two response modes and taking into consideration only the cases in which they were presented first, we can clearly see that pointing was more difficult than verbal responding. In fact, it seems the case that the absence of an overall effect of pointing was due to the increased pointing performance that was evidenced when verbal responding preceded the pointing task.

One possible explanation for why pointing benefited so much when it followed verbal responding is that participants performed the pointing task in a verbally-mediated fashion. That is, they first determined the verbal label describing the position of the target and then selected the arrow pointing to that direction. Our follow-up experiments will reduce the possibility of using verbally-mediated pointing by adopting between-subjects designs.

In summary, our accuracy results provide evidence that head-direction disparity influences are greater for pointing than verbal responding. The two tasks we have used were identical except for the type of the required response. The finding that performance from misaligned headings was less accurate for pointing than labeling can be only interpreted as evidence for a difference in the extent of the influence exerted by head-direction disparity in the two tasks.

In closing, we should point out an important limitation of our study. In the present study we have reduced pointing and verbal responding to selecting arrows or verbal labels on a computer keyboard. Although this is done in other experiments as well, we should acknowledge that pointing and verbal responding as used here differ a great deal -- at least in terms of the motor demands they involve -- from traditional pointing and verbal responding. Although we actually believe that the effects of head-direction disparity will be even greater with actual pointing than arrow pointing, this remains to be assessed.

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