Chapter 5
Forward-backward asymmetry: the effect of body position and pointer shapes

Abstract:
In previous experiments with an exocentric pointing task we found that deviations from veridical settings were larger when the pointer was closer to the observer than the ball but smaller when the pointer was further from the observer than the ball (the forward-backward asymmetry). We investigated possible origins of this asymmetry. First we tested whether, when the pointer is further from the observer than the ball, the observer can use his own position as a reference to orient the pointer. The pointing angle is restricted in this condition. We therefore tested whether restricting the pointing angle by poster-boards when the pointer was closer to the observer than the ball could cause a reduction in the size of the deviations. This turned out to be the case. Furthermore, we tested whether the observer's view of the pointer could also account for the differences we found. Therefore we tested whether a pointer providing the same amount of structure for the two combinations of pointer- and ball-positions that we used would induce settings that differed from those induced by a pointer not providing the same amount of structure in both conditions. However, the results show that the view of the pointer cannot explain the forward-backward asymmetry we found in our earlier experiments. From these studies we can conclude that people can use their own position as an egocentric reference for directing pointers to targets.

In preparation for publication

5.1 Introduction

Much of the research into visual space is concerned with describing the spatial structure. The structure of visual space varies with the viewing conditions. Different tasks often yield different results. For example, Koenderink and colleagues found conflicting results for an exocentric pointing task and an apparent frontoparallelity task (Koenderink, van Doorn, & Lappin, 2000; Koenderink, van Doorn, Kappers & Lappin 2002). It is probable that people need different kinds of information in order to perform adequately in experimental tasks (Cuijpers, Kappers, & Koenderink, 2002; Doumen, Kappers, & Koenderink, 2005 [Chapter 2]). This might be reflected in the results obtained in different experiments. Furthermore, the environment in which experiments are conducted also influences the data (Battro, di Pierro Nettro, Rozestraten, 1976). To what extent are the conditions constrained and do they simulate natural viewing conditions? By constrained conditions we mean that the stimulus is reduced to the point where some depth cues are no longer present. Some scientists investigate visual space by removing these depth cues. This way, other cues for the perception of positions of objects can be investigated directly (for example Cuijpers, Kappers & Koenderink, 2000). In another approach natural viewing conditions are used to investigate the perception of observers who have all the information that is present in normal situations (e.g. Kelly, Loomis, & Beall (2004) and Koenderink et al. (2002)). These two lines of research are both important for our understanding of visual space. Not only are there differences in viewing conditions, the distances used also vary considerably: from within arm's reach to distances of up to 25 meters. Since the deformation of visual space was found to vary with distance from the observer (Battro, et al., 1976; Koenderink et al., 2002), it is not surprising to find that similar experiments produce conflicting results.

Even with the same experimental conditions, we found some discrepancies that require an explanation. We have been working with a two-dimensional exocentric pointing task. During this task, observers had to orient a pointer in the horizontal plane at eye-height towards a ball in the same horizontal plane. We found a difference between the condition in which the pointer was further away from the observer than the ball and the condition in which the pointer was closer to the observer than the ball (i.e. when we vary the relative distance) (Doumen, et al., 2005 [Chapter 2]). The observers overshoot the target when the pointer is closer to the observer than the ball (situation A from Figure 5.1), whereas they point between themselves and the ball when the pointer is further away from the observer than the ball (situation B from Figure 5.1). However, the sizes of the deviations also differ for these two conditions. In situation B (when pointing backward), the deviation is smaller than in situation A (when pointing forward). For example, typical settings for an exocentric pointing task are deviations of 3° in situation B and 10° in situation A (mean over all observers in Doumen et al. (2005) [Chapter 2] with a separation angle of 60° and a relative distance of 3 or 1/3). In this paper we will refer to the difference in size of the deviations for the two situations as "forward-backward asymmetry".

We can think of a couple of explanations for this asymmetry. These explanations do not concern the sign of the deviations but they concern their size. Why the sign of the deviations changes when the relative positions of the pointer and the ball change, is another question that needs to be investigated. However, we will not address this question here. In situation B, the observer could be using his own body position as a reference. In this case the

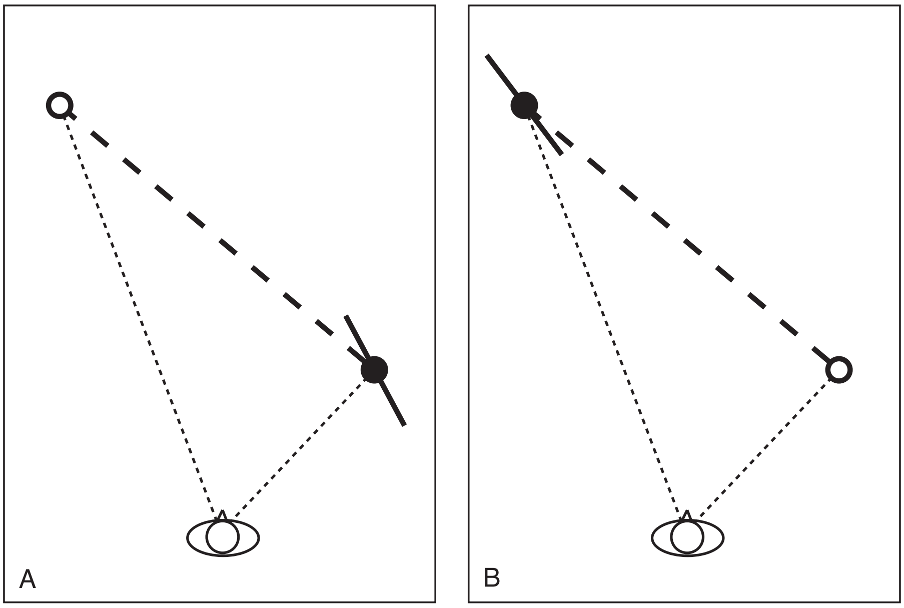

Figure 5.1
An example of typical settings in an exocentric pointing task. The thick dashed line is the veridical orientation between the pointer and the ball, the short lines the settings of the observer. Both conditions are plotted here: the pointer further away from the observer than the ball and vice versa.

angle between the lines connecting the pointer to the ball and the observer serve as a restriction for pointing to the ball. An observer, for example, will not point towards himself while trying to point at the ball. Another possible explanation concerns the view of the pointer. When the pointer consists only of a single rod, the observer can experience a difference in the amount of information when the pointer is at different positions in the room. For example, in situation B, a slight rotation of the pointer will induce a large change in the observer's retinal image of the pointer. This is in contrast with situation A in which a small rotation of the pointer will not change the observer's retinal image very much. In the latter condition, less information is supplied to in the retinal image of the observer.

In the present paper, we investigate the reasons for the difference that we found in the size of the deviations for different pointer and ball positions. To do this, we conducted two experiments with the exocentric pointing task. To address the first possible explanation, we restricted the space in situation A in the same way as in situation B. We did this by placing poster-boards in the room as depicted in Figure 5.2 (at the thick black and gray lines). We measured two conditions: the first with the poster-boards as described above and the second without boards. If the observer used himself as a reference and thereby pointed more veridically when the pointer was far away from him (situation B), then placing poster-boards on the other side of the room would give him the same restriction in pointing angle and would therefore result in smaller deviations than if the poster-boards were not present when the pointer was close to the observer (situation A).

In the second experiment, we varied the shapes of the pointer. One of the pointers consisted of two rods perpendicular to each other. This double-rod pointer contained the same amount of information for the various pointer positions that are used in experiment 2.

Another pointer consisted only of a rod (the single-rod pointer) and provided completely different information depending on whether pointing towards and away from the observer. If observers use the kind of information that is provided by the pointer, we would be unable to see any difference in the size of the deviations when the double-rod pointer was used in situation A or in situation B. However, we would see forward-backward asymmetry when the single-rod pointer was used.

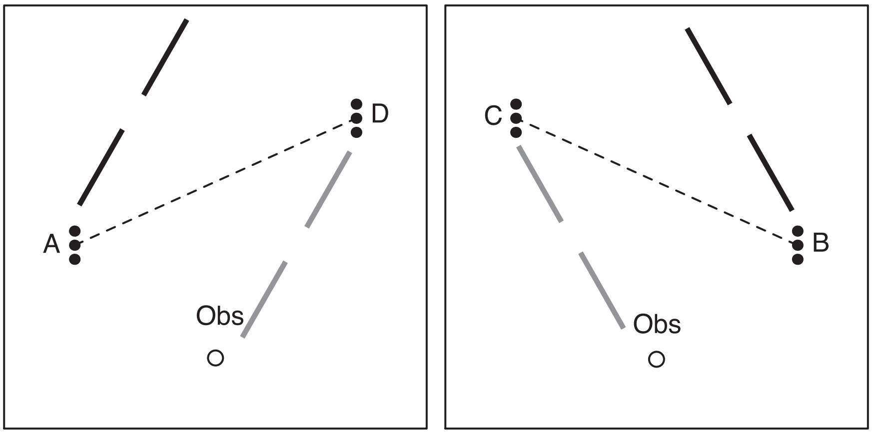

Figure 5.2
Two top-views of the experimental room for experiments 1. The squares represent the walls of the room, the circles the positions of the observer and the dots the positions of the ball and pointer. The pointer was always positioned on the middle dot, the ball could be positioned on all dots. The dashed lines connect the positions that are used together as pointer and ball-positions. The two panels give the situation for pointing between A and D and between C and B respectively. The black lines in these panels represent the positions of the poster-boards far away from the observer. The gray lines represent the poster-boards close to the observer.

5.2 General methods

Observers

Undergraduate students, who were paid for their efforts, participated in the experiments described below. They had little or no experience in psychophysical experiments and were naive as to the goals and purposes of the experiments. They all had normal or corrected-to-normal visual acuity. Before the start of the experiment, each observer was tested for stereovision. They all had a stereo-acuity of more than 60".

Experimental set-up

The experimental room measured 6 m by 6 m. The wall opposite to the observer was white, with some electrical sockets near the floor. The wall on the left-hand side of the observer contained four blinded windows with radiators underneath them. The wall on the right-hand side contained two grey doors. Markers were placed on the floor to mark the positions of the objects that were used in the experiments. From the ceiling a horizontal iron grid was suspended (3 m above the floor). Attached to this grid were some white cubes that were used for other experiments. The cubes measured 20 cm x 30 cm x 15 cm and did not interfere with the stimuli in the visual field of the observer. From the iron grid hung a green ball 1.5 meters above the ground. The ball had a diameter of 6 cm and could be placed on different positions. The pointer we used for the first experiment consisted of a horizontal green rod (25 cm long and 2 cm thick, with one sharp endpoint) bisected by a yellow disk (diameter 8.2 cm and thickness 1 cm) that was perpendicular to the rod. The rod passed through the center of the disk and the disk was attached to a vertical iron rod so that the height of the rod was 1.5 meters. The pointer is depicted in the third panel of Figure 5.5. The foot of the pointer contained the motor that rotated the pointer and a protractor that was used to read the settings of the observer. A screen in front of the foot prevented the observer from seeing the protractor and the square shape of the foot. The observer could rotate the pointer using a remote control. The observer was seated on a revolving chair that could be adjusted in height so that the eye-height of each observer was at 1.5 meters.

Procedure

In both experiments described below, the same procedure was followed. The observer sat on the revolving chair and the chair-height was adjusted. The experimenter explained the task: with the sharp endpoint of the rod point to the ball as accurately as possible. The observer was instructed to remain seated and not to move his upper-body. He was allowed to rotate his head and the chair. The observer always had a practice trial before starting the real experiment. After each trial, the observer had to close his eyes so that he could not see the experimenter reading the protractor and rearranging the objects for the next trial. The observer was also asked to rotate the pointer a little before opening his eyes again. This ensured that he did not have information about his previous setting.

Analysis

The dependent variable of the experiments discussed below is defined as follows: a positive deviation means that the observer overestimates the distance between the two objects in the y-direction. The deviation is negative when this distance is underestimated. This definition differs from the definition used in our previous experiments! We changed our definition because we wanted to be able to quantify differences in the size of the deviations for all relative distances.

For each experiment we did a number of paired t-tests in order to analyze the data. We chose this type of analysis because the more standard analyses could not answer our questions directly.

5.3 Experiment 1: The effect of body position

In experiment 1 we investigated the question whether we could influence the observer's settings when the pointer was positioned closer to the observer than the ball by placing poster-boards to restrict the pointing angle. The idea was to restrict the pointing angle in situation A to the same degree as was the case in situation B. Figure 5.2 depicts the lay-out of the floor of the experimental room. The observers always had to point from A to D, from B to C, from C to B or from D to A. In the figure, the angle between the black lines (representing the positions of the poster-boards) and the line connecting A and D in the first panel (B and C in the second panel) is the same size as the angle between the line between the observer and D (or C in the second panel) and the line connecting A and D (B and C in second panel). We used the poster-boards to restrict the angle of pointing just as the observer's body restricts the angle of pointing when the pointing-direction is towards the observer. Furthermore, we placed poster-boards on the gray lines in figure 5.2. We did this because the mere presence of the poster-boards close to the pointer might affect the data. Thus, in the experimental condition the pointing angle was restricted by poster-boards for both situations in Figure 5.1. In the control condition no poster-boards were visible to the observer.

Methods

Six male and two female observers participated in the experiment. They were all undergraduate students.

The experimental set-up consisted of a pointer, a ball, four poster-boards and a revolving chair. The poster-boards measured 200x90 cm (hxw) each board was covered with equally sized posters with a brick wall pattern on them. The posters were used to help the observer to see the orientation of the poster-boards clearly. The coordinates (in cm) of the positions of these objects were as follows: the observer was placed at (0, 0), the pointer and ball could be either at position A (-200, 160), B (200, 160), C (-200, 340) or (200, 340) as depicted in the two panels of Figure 5.2. We varied the positions of the ball to prevent the observer from using the information provided by his view of the pointer to guide his settings. The difference between the positions was 20 cm. For example, the coordinates of the ball at position A could be either (-200, 140), (-200,160) or (-200,180). The difference was large enough for the observer to notice the difference between the positions, but small enough not to change the relative distance too much. In addition to the experimental condition with the poster-boards we had a control condition without the boards. This resulted in 4x2x3 = 24 trials (# pointer & ball combinations, # experimental conditions, # repetitions). The experiment was measured in approximately half an hour for each observer.

Results

The data of experiment 1 are plotted in Figure 5.3. Each bar represents the mean of the values for all eight observers. The black bars represent the data for the control condition, i.e. without the poster-boards. The gray bars represent the data for the experimental condition, i.e. with the poster-boards. Each group of bars represents the results for one position of the pointer. The first two groups are the cases in which the pointing direction is forward, the second two groups of bars represent the cases in which the pointing-direction is backward.

The first thing to notice is that in the condition without poster-boards all deviations are positive and the deviations for positions A and B are larger than for C and D. Furthermore, the deviations are larger in the conditions without poster-boards than in the conditions with poster-boards.

We conducted three paired t-tests on these data ($\alpha = 0.0167$ (0.05 / 3)). We found a difference between pointer-positions far away and close by for both experimental conditions (without boards: $T = 6.925$, $p < 0.001$, with boards: $T = 5.411$, $p = 0.001$). Furthermore, we found a significant difference between the two experimental conditions when the pointer was closer to the observer than the ball ($T = 4.825$, $p = 0.002$).

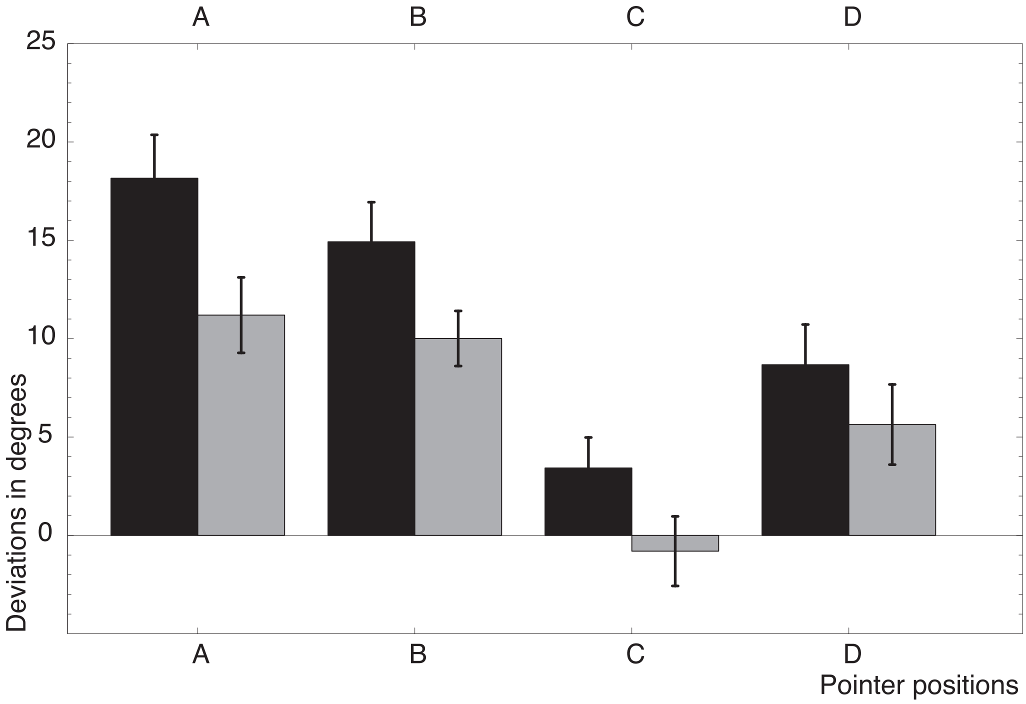

Figure 5.3
The data of experiment 1 for all observers together. The deviation in degrees is plotted against the pointer positions (A through D). The black bars represent the condition without poster-boards, the gray ones the condition with poster-boards. The error-bars represent the standard error of the means.

Discussion

The effect of the difference in the sign of the deviations when the pointer is close to the observer or far away, which we found in our earlier work and in the work of Cuijpers and colleagues (Cuijpers, et al., 2000; Doumen, et al. 2005 [Chapter 2], in press A [Chapter 3]]), is replicated in the present work. The observer overshoots the ball. We also replicated the forward-backward asymmetry.

The presence of the poster-boards seems to decrease the size of the deviations when the pointer is closer to the observer. However, if the restriction of the pointing angle were to be the complete explanation for the relative distance effect, there would be no difference in the size of the deviations when the pointer is at position A or B with boards and when the pointer is at position C or D. However, the deviations are larger for pointer positions A/B with poster-boards than for pointer-positions C/D. Hence, the restriction of the possible pointing-directions is not the whole story; possibly other factors play a role or the presence of the poster-boards is not as strong a cue as the presence of the observer himself.

5.4 Experiment 2: The effect of pointer shapes

In the introduction we suggested that the difference in the size of the deviations for different pointer-positions might be due to the different views that observers have of the pointer. In all our experiments conducted so far we used a pointer consisting of a rod and a circular disk perpendicular to the rod. Since the shape of a rod differs from the shape of a disk, one could say that, depending on the observer's view of the pointer, an observer can have different amounts of information about the orientation of the pointer. Consider a very simple pointer, a rod, positioned close to the observer and pointing towards a ball further away from the observer. Rotation of the pointer by a few degrees does not change the observer's retinal image of the pointer as much as it would if the pointer further away from the observer than the ball were rotated by the same amount. For example, in the experiment described below, the pointer has a visual angle of 7.38° when it is positioned at A or B and pointing towards D or C, respectively (see Figure 5.4). Rotating the pointer 2° to the left and 2° to the right results in visual angles that differ in size by 0.25°. This value divided by the total visual angle gives a ratio of 0.034. When the pointer is at positions C or D (and the ball at positions B or A), however, the total visual angle is 1.18°, the difference in visual angle is 0.21 and the ratio is 0.17. The ratio for situation B is five times larger than it is for situation A. Thus in situation A, the observer obtains less information from the pointer itself than in situation B. In the present experiment, we tested whether the difference in the amount of information given by the pointer can explain the forward-backward asymmetry. To do this, we constructed two new pointers. One pointer consisted of two rods, one perpendicular to the other. Since the angles between observer, pointer-position and ball-position for the two relative distances differ by exactly 90°, the pointer contains the same information for the two pointer-positions. The other pointer consisted of only one rod. If our hypothesis is correct, we would expect to find smaller deviations for situation B than for situation A with the single-rod pointer but no difference between the size of the deviations with a double-rod pointer. Furthermore, we compared the settings of these two pointers with the settings of the pointer with the disk that was used in our earlier experiments.

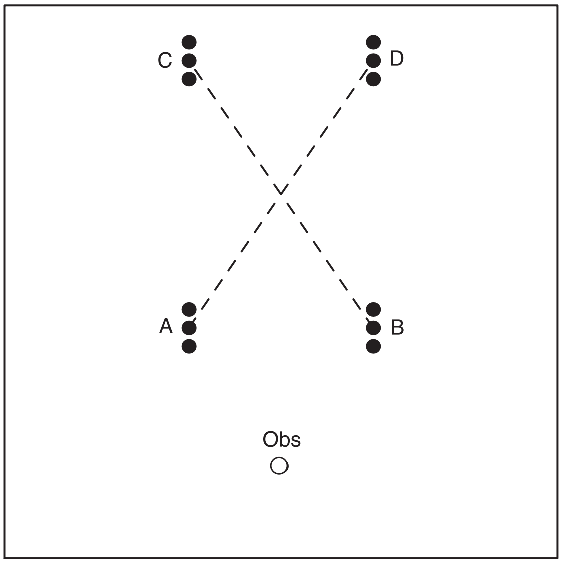

Figure 5.4
A top-view of the experimental room for experiment 2. The lines represent the walls of the room, the circle represents the position of the observer, and the black dots the positions of the ball and pointer. The pointer could be positioned only at the middle dots, the ball on all dots. The dashed lines connect the points that are used together as pointer and ball-positions.

Methods

In this experiment, eight undergraduate students (five male and three female) participated as observers. We did the experiment in the same experimental room as the previous experiments. However, the positions of the observer and the pointers and ball differed from the first experiment. We had to change the positions of the ball and pointer in order to obtain a difference in angle between the observer, pointer and ball of 90° for the two pointer-positions. The ball and pointer could be in four different positions (with the following coordinates in cm with the position of the observer at the origin): A(-100, 150), B(100, 150), C(-100, 440) or D (100, 440) (see Figure 5.4). The balls could be either at one of the given positions or 20 cm in front of beyond that point; thus the ball in position A was hanging at position (-100, 130), (-100, 150) or (-100, 170).

As mentioned above, we used three different pointers that could be positioned on the vertical iron rod at a fixed orientation. One pointer, the double-rod pointer, consisted of two blue rods 25 cm long and 1 cm thick, one rod having a sharp end-point 5 mm above and perpendicular to a rod without a sharp end-point. The upper-rod was at a height of 1.5 meters; this was the rod that the observer had to use to point to the ball. The difference in height was such that the observer had an (almost) unobstructed view of both rods at all times. The other pointer, the single-rod pointer, consisted of one blue rod 25 cm long and 1 cm thick with a sharp end-point in one direction. This rod was placed on a height of 1.5 meters. The third pointer was the pointer that was used in experiment 1. This pointer consisted of a green rod, with one sharp point, perpendicular to a yellow disk. Figure 5.5 depicts of the three pointers that were used.

We had three different pointers, four different pointer- and ball-positions, and three repetitions, which resulted in 3x4x3 = 36 trials.

Figure 5.5
Photographs of the three pointers used: and the double-rod pointer, the single-rod pointer, and the rod with disk pointer respectively.

Results

In figure 5.6 the data of experiment 2 are presented in a bar-chart. The groups of bars represent the four different pointer-positions, whereas the three bars in each group represent the three pointer-conditions, namely the double rod (dark bar), the single rod (gray bar) and the rod with disk (light bar). Just as in the previous plots, the deviations are positive when the position of the ball is overshot and negative when this position is undershot. Each bar represents the mean of the data for all eight observers who participated in this experiment. The error-bars represent the standard error of the means. The first thing to notice when looking at this bar-chart is that the deviations for the double-rod pointer are generally smaller than for the other two conditions. Furthermore, the deviations for pointer-positions A and B are slightly larger than for pointer-positions C and D.

For experiment 2 we did six paired t-tests ($\alpha = 0.0083$ (0.05 / 6)). We tested whether for each of the three experimental conditions there was a difference in the deviations for pointer-positions A/B and C/D. Furthermore, we tested whether there was a difference between the three experimental conditions for the pointer-positions A/B. The only trend we could find was a difference between the single-rod pointer and the double-rod pointer (for pointer-positions A/B: $T = 3.410$, $p = 0.011$). This difference, however, does not reach significance with the Bonferroni-correction. The results of all comparisons are given in Table 5.1.

Besides looking at the mean deviations, we investigated the effects of the pointer shapes and positions on the variance of the data. More specifically, we again conducted six paired t-tests. We tested whether the size of the standard deviations differed for the same groups of trials that were tested for the mean deviations. As can be seen in Table 5.1, there is a significant difference between situations A and B for the single-rod pointer ($T = 3.632$, $p = 0.008$) and a small trend towards a difference between the double-rod pointer and the single-rod pointer in situation A ($T = 3.163$, $p = 0.016$).

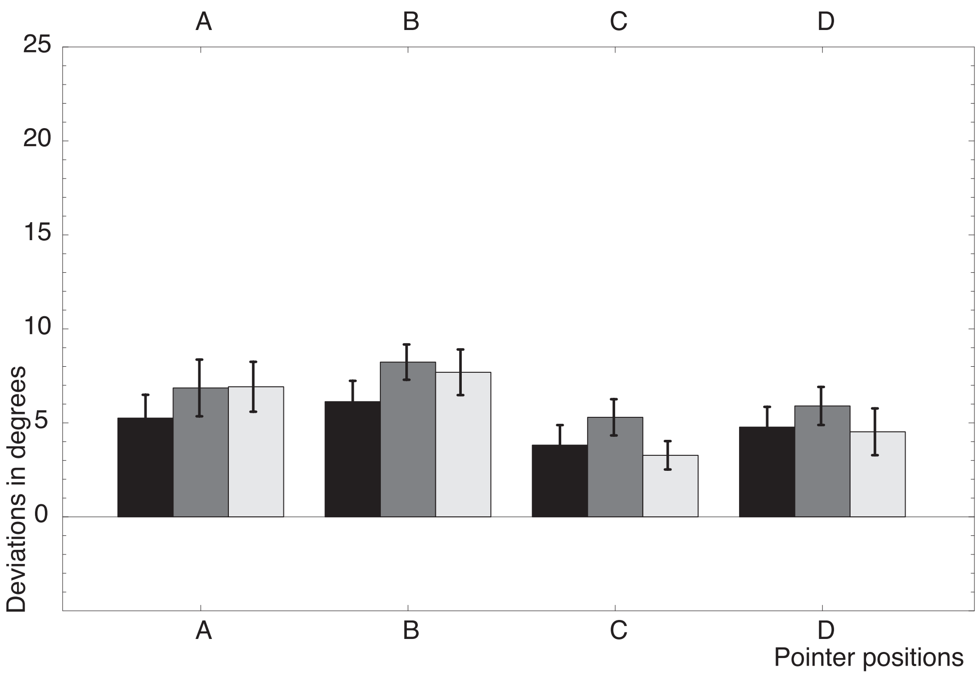

Figure 5.6

The data for experiment 2 for all observers together. The deviation in degrees is plotted against the pointer positions (A through D). The black bars represent the condition with the double rod pointer, the dark gray ones the condition with the single rod pointer, and the light gray ones with the rod with disk pointer. The error-bars represent the standard error of the means.

Discussion

We found no significant effect of the mean deviations for the different pointer positions for the three experimental conditions. Although the differences between the pointer positions A/B and C/D are largest for the pointer that we have been using so far, the differences do not reach significance in this experiment. When looking at the data for each observer separately, we see that there are differences between observers. Most observers show an effect of the relative distance of the pointer and ball, but some observers show a rather incoherent pattern. This might be due to the relatively small visual angle that was used in this experiment together with the short distance to the pointer- and ball-positions close to the observer.
However, we did find a significant difference between the standard deviations of the data for situations A and B for the single-rod pointer only. Thus, the difference in the amount of information of the single-rod pointer and the double-rod pointer reveals itself in the accuracy of the settings rather than in the mean deviations.

Table 5.1: *The results of the paired t-tests of experiment 2 for the mean values and for the standard deviations*

Group 1	Group 2	T mean	p* mean	T sd	p* sd
Double rod AB	Double rod CD	0.838	0.430	-1.259	0.248
Single rod AB	Single rod CD	1.145	0.290	3.632	0.008
Rod with disk AB	Rod with disk CD	1.985	0.088	-0.789	0.456
Double rod AB	Single rod AB	-3.410	0.011	-3.163	0.016
Double rod AB	Rod with disk AB	-2.055	0.079	-0.249	0.810
Single rod AB	Rod with disk AB	0.384	0.712	1.694	0.134

**The difference is significant at $\alpha = 0.0083$ (with Bonferroni correction)*

5.5 General discussion and conclusions

In this paper we presented two explanations for a difference we found in deviations in an exocentric pointing task with varying relative distances. We tried to explain why deviations are smaller for backward pointing than for forward pointing. We gave two possible explanations: one concerning the position of the observer that can be used as a reference point when the pointer is far away from the observer. The second explanation was the difference in the view of the pointer in the two conditions. The position of the observer restricts the pointing direction when the pointer is far away from the observer. Restricting the pointing direction to a similar degree in the other direction resulted in smaller deviations in the condition where the pointer is close to the observer and the ball far away. However, the size of the deviations was not reduced to the size of the deviations in the condition when the pointer is far away from the observer. From this we can conclude that the position of the observer restricts the pointing direction in the conditions where the pointer is further away from the observer than the ball more effectively than do the poster-boards when the pointer is closer to the observer than the ball. However, it could be that restriction of the pointing angle is not the whole story: another factor may be involved as well.

Our second explanation concerned the observer's view of the pointer. We found that although there is a trend towards a difference in the mean deviations between two extreme pointers (single rod or double rod) there was no difference in mean deviations for the double-rod pointer and the pointer used in the previous experiments. However, we did find a difference in standard deviations for the two situations for the single-rod pointer but not for the other two pointers. This means that the amount of information provided by the shape of the pointer does influence the accuracy of the settings in an exocentric pointing task.

There are a few other differences between pointing forward and backward. For example, in the backward pointing condition, the visual angle of the pointer is much smaller than for forward pointing. Furthermore, when pointing backward with the rod-with-disk pointer, a large part of the rod is occluded by the disk. This is not the case in the forward pointing condition. However, these differences would predict more veridical settings in the forward pointing condition than in the backward pointing condition. This is contradictory to our findings.

Although the shape of the pointer does affect the accuracy of the settings, it cannot explain the forward-backward asymmetry. However, the body position of the observer does seem to restrict the angle of pointing for conditions in which the pointer is further away from the observer than the ball. Apparently, people make effective use of an egocentric reference such as body position.