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Large Systematic Deviations In The Haptic Perception Of Parallellity

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There is increasing evidence that haptic space is not veridical. One of the first to report on this phenomenon was Blumenfeld (1937). Recently, Kappers and Koenderink (1998) showed that what subjects haptically perceive as parallel often deviates largely from what is actually physically parallel. These deviations are not random but show distinctive patterns.

This study is an extension of their experiment: (1) The possible positions of the stimuli cover a much larger area, so that the distances between the stimuli can also be much larger. (2) Experiments are done both unimanually (right and left hand) and bimanually.

Method

The set-up consisted of a large table on which 15 protractors were printed (see Figure 1). Two aluminium bars of 20 cm length were used as reference and test bars. In the middle of the bars a small pin was attached which fitted exactly in holes at the centres of the protractors. In this way, the bars could be rotated without being displaced.

The reference bar appeared under four possible orientations: 0, 45, 90, and 135 deg at all five locations. For a given reference bar, the test bar was positioned at all other four locations. All 80 combinations of reference and test bar location and orientation were presented three times in random order. Both unimanual (right and left hand separately) and bimanual conditions were measured.

Three naive paid subjects participated. They were seated blindfolded behind the table. The experimenter took their hand and positioned it first on the reference bar and subsequently on the test bar. In the bimanual condition, the two hands always touched different bars.

Subjects were instructed to rotate the test bar in such a way that it felt parallel to the reference bar. On average, subjects needed about one minute to complete one trial.

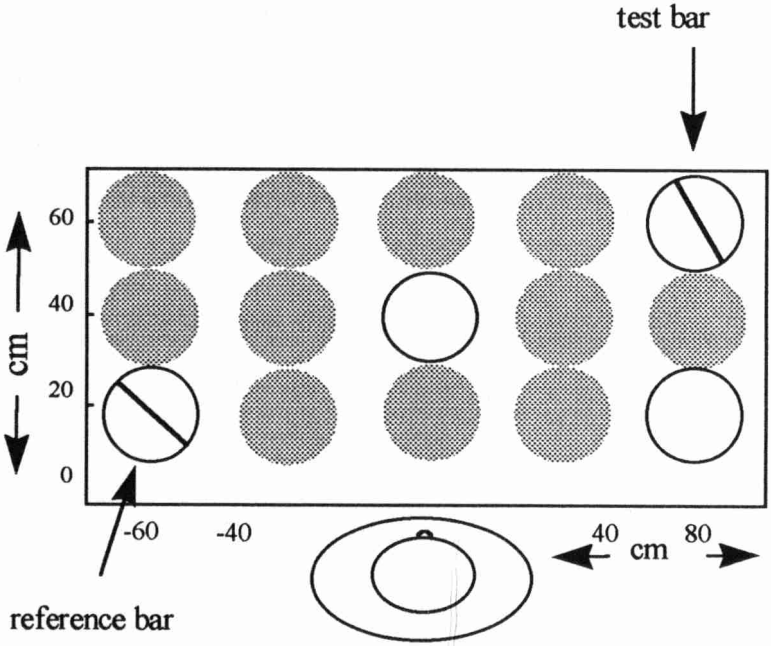

Figure 1. Top view of the set-up. The open circles indicate protractors in use in the current experiment.

Results

A representative example of the results can be seen in Figure 2 (subject ML, right hand, averaged over three trials). Each rectangular box gives a top view of the set-up. The thick and thin lines indicate the positions of the reference and test bars, respectively. In the horizontal direction the orientation of the reference bar varies systematically, in the vertical direction its position varies.

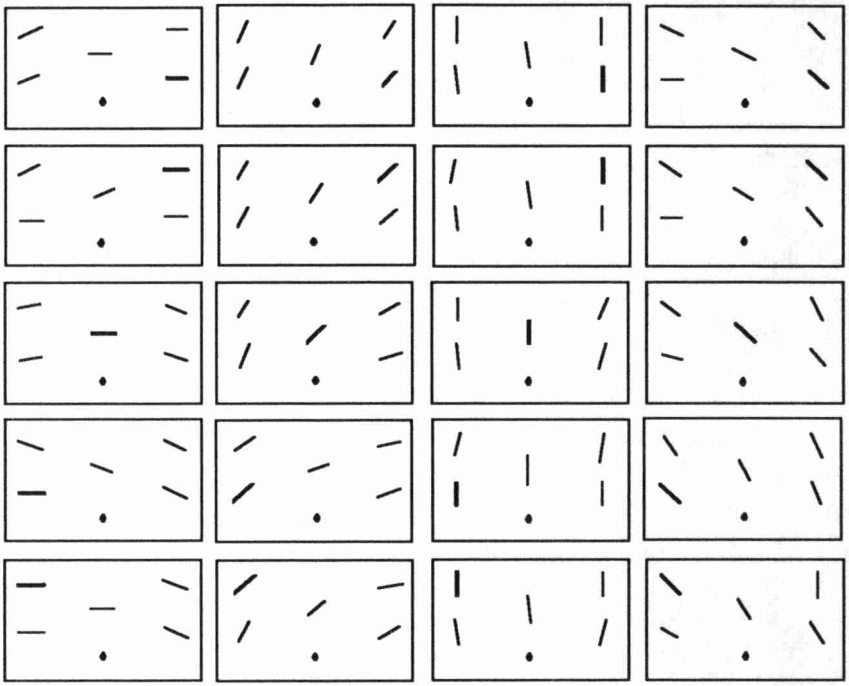

Figure 2. Results for subject ML obtained with her right hand. The dot indicates the position of the subject, the thick line indicates the reference bar and the thin lines indicate the test bars. Settings are averaged over three trials.

If the subject had responded veridically, all bars within a box would have been parallel. Clearly this is not the case. In this example, deviations as large as 43 deg (upper right box) can be seen (for subject RH even a deviation of 62 deg occurred!). The average standard deviation is only 5.97 deg (averaged over all trials of all subjects in all conditions) whereas the average absolute deviation is 14.14 deg, indicating that the deviations are indeed significant. However, the deviations are far from random. A number of features can be distinguished in the patterns of deviations of all subjects in all conditions. (1) If the test bar is on the left side of the reference bar, the settings deviate in counter-clockwise direction (and vice versa). (2) The larger the horizontal direction between the two bars, the larger the deviation. The vertical distance hardly influences the result. (3) Although the size of the deviations depends only

slightly on the reference orientation, deviations are often smallest for a reference orientation of 90 deg followed by 0 deg. This indicates a haptic oblique effect.

Another finding (which cannot be seen in the figure) is that the results for the different conditions (right hand, left hand, two hands) are very similar. This is surprising since the movements that have to be made from the position of the reference bar to the position of the test bar, are very different in the three conditions.

Discussion

This study shows that the findings of Kappers and Koenderink (1998) that were obtained with stimulus positions at the right side of the median plane while subjects were using their right hand, have a much more general validity: The pattern of deviations continues over the whole reachable horizontal plane and is similar for unimanual and bimanual conditions.

Kappers and Koenderink (1998) could describe their deviation patterns by means of a subject-dependent horizontal gradient in the settings with respect to veridical. That is, given a certain reference position and orientation, the gradient can be used to predict the orientation of the test bar at any location. In the current experiment, the subject-dependent horizontal gradients range from -12 deg/m to -27 deg/m.

In conclusion it can be stated that the results provide strong evidence that haptic space is not Euclidean.

References

Blumenfeld, W.(1937). The relationship between the optical and haptic construction of space. *Acta Psychologica,* 2, 125-174.

Kappers, A.M.L., & Koenderink, J.J. (1999, in press). Haptic Perception of spatial relations. *Perception.*