Summary

In this thesis we report a series of experiments designed to discover factors that are responsible for the deformation of visual space. We looked at spatial and contextual parameters.

Spatial parameters

In chapter 2 we described three experiments in which we investigated whether the deformation of visual space was dependent on the visual angle of the two objects that were used as stimuli and on the relative distance of these two objects from the observer. We used three tasks. In the exocentric pointing task, the observer had to direct a pointer with a remote control towards a ball. In the second task, the collinearity task, the observer had to rotate two rods in such a way that they were in one line. The third task was the parallelity task; in this task the observer had to place a rod parallel to another rod. For the exocentric pointing task and the collinearity task we found that the visual angle had a linear effect and the relative distance had a non-linear effect on the deviations. For the parallelity task, however, we found no effect of relative distance. The dependence on the visual angle was linear just as in the other two experiments. Besides these two variables, we looked at the orientation of the reference rod in the parallelity task. For two out of four observers we found an effect of reference orientation, which led us to conclude that the observers probably differ in their use of contextual information.

In chapter 3 we extrapolated the results of a 2D exocentric pointing task to three dimensions. In the 3D exocentric pointing task the observers could rotate a pointer in the horizontal plane (slant) and in the vertical plane (tilt). This meant that we could place the pointer and the ball at various heights. In this experiment we varied the horizontal visual angle, the vertical visual angle and the relative distance. If Luneburg's conjecture is correct, visual space should be isotropic. This would mean that the deviation of the slant would depend on the horizontal visual angle in the same way as the tilt depends on the vertical visual angle. Furthermore, both dependent variables should depend in a similar way on the relative distance. This is not what we found in the experiments described in chapter 3. The inevitable conclusion is that visual space is anisotropic.

Contextual parameters

In addition to studying the effects of spatial parameters, we investigated the effects of contextual parameters. In previous experiments, we found small deviations when both the ball and the pointer were at the same distance from the observer. From these experiments, however, we cannot be certain whether this is due to the fact that the pointing-direction was parallel to one of the walls of the experimental room or to the fact that the pointing-direction was frontoparallel. Thus, in the experiments described in chapter 3, we varied the positions of pointer, ball and observer in such a way that we could discriminate between the effects of frontoparallelity, parallelity to a wall and possible interactions between these effects. We found differences between observers in the way their results were dependent on an egocentric factor like frontoparallelity or an allocentric factor like the walls of the experimental room.

In a 2D exocentric pointing task we investigated two other possible contextual effects on the deformation of visual space. We performed these experiments because in all the experiments with an exocentric pointing task performed so far we found an effect of relative distance. We wanted to find out why the deviations were larger when the pointer was closer to the observer than the ball, than when the pointer was further away from the observer than the ball. We examined two possible explanations for this observation: one concerning the possible effect of restricting the pointing angle, the other concerning the shape of the pointer. When the pointer is further away from the observer than the ball, the position of the observer restricts the pointing angle. In contrast, when the pointer is closer to the observer than the ball, there is no extra reference such as one's body position. This difference could explain the difference in the size of the deviations we found for the exocentric pointing task. We tested this by using poster-boards. We placed these boards between the pointer-positions close to the observer and a position on the other side of the room. In this way we restricted the pointing-direction by the same angle as the observer' body position restricted the pointing angle for the condition in which the pointer is further away from the observer than the ball. We found that the placing of the poster-boards did result in smaller deviations for the condition in which the pointer is closer to the observer than the ball, although the size of this deviation is not as small as in the other condition.

Our second possible explanation for the effect of relative distance on the size of the deviations was that the view of the pointer was different for the two conditions. When the pointer is further away from the observer than the ball and the pointer is rotated slightly, the observer's retinal image changes more than when the pointer is rotated when it is closer to the observer than the ball. Thus the two conditions differ in the amount of information that is available about the exact orientation of the pointer. Whether observers are influenced by this difference in the amount of information can be tested easily by using two pointers that differ in shape. This is exactly what we did. We used two extra pointers (in addition to the pointer we used in previous experiments): one with a single rod and another with two rods perpendicular to each other. This double-rod pointer contained the same amount of information in all experimental conditions, in contrast to the other two pointers. Although we found a difference in the standard deviations when we used the single-rod pointer and the double-rod pointer, we did not find an effect for the size of the deviations themselves. Thus, the only explanation we can find for the difference in the deviations we found by varying the relative distance is that the pointing angle is restricted by the position of the observer.

Ball-in-plane task

The last chapter of this thesis is about the ball-in-plane task. This task enables us to gain more insight into all three dimensions of visual space. Chapter 6 describes an experiment to test whether we can visualize planes tilted in visual space. The plane is defined by three red balls that are hung at different heights in the experimental room. The observer can adjust the height of a fourth ball that is suspended from the ceiling somewhere among the other balls. The task is to hang the fourth ball in the plane defined by the red balls. In particular, we investigated whether the deviations are dependent on the direction in which the plane is tilted. We tested this with three different configurations of red balls forming an acute, an obtuse and an equilateral triangle. For the three triangles we found small negative or positive deviations when the azimuthal angle was close to 0. When the azimuthal angle increases in size, the deviations are increasingly negative. This pattern can best be described as concave settings towards the observer. This has also been found for bisection tasks in the horizontal plane.

Conclusions and further directions

Looking at spatial parameters, we found similar patterns for the observers. For the ball-in-plane-task, we found a pattern with concave settings towards the observer. For the exocentric pointing task however, we found the deviations to be dependent on the relative distance in an unexpected way that cannot be easily described with a metric function. Possible descriptions are that positions of objects are overestimated proportional to the distance from an object or that the deviations are dependent on the visual angle. An effect of visual angle could be explained by the uneven distributions of photoreceptors in the retinae and the organization of the visual cortex. However, these ideas need to be elaborated further. Furthermore, we found that visual space is anisotropic, which is in contrast with Luneburg's conjecture. We can therefore conclude that visual space is not homogeneous in different sub-spaces.

For the experiments concerning contextual parameters, the results were less clear. Large differences occurred between observers for cues that were not crucial for doing the task, namely ones such as the presence of the walls and the frontoparallel plane of the observer. It seems that each observer has his own preferred information sources that he uses to solve a task. However, some sources of information are so prominent that observers cannot ignore them. An example is the restriction of pointing angles that is discussed in chapter 5. Furthermore, varying the shape of the pointer did not result in any differences between the settings. Thus, there was no difference in the amount of information provided by the pointers that could explain the forward-backward asymmetry. This is an interesting field of research that needs more attention than it has received so far. It fits into current visual space research since attention is gradually shifting from really sober environments to more elaborate ones. Thus a straightforward route for future research to follow is to investigate the contributions made by various information sources.