Perception of Parallelism in Perspective Images

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Abstract. This contribution presents a study in which subjects are shown perspective views of simple shapes. The subject's task was to decide whether the shape's outlines were parallel to each other or not. It was observed that the subjects were strongly misled by perspective depth cues. Real parallels in orthographic projections were rarely detected. In contrast a minor convergent alignment of the outlines like in a linear perspective projection were perceived as parallel.

Keywords: Linear Perspective, Reverse Perspective, Visual Perception, Parallelism, Projection.

1 Introduction

The rediscovery of the linear perspective in the early renaissance marks one of the most important steps for the evolution of western art and culture. This procedure of projection has become the norm for most realistic looking images. No matter where linear perspective dominates painting, photography, motion pictures or computer graphics. Linear perspective images are two-dimensional presentations of a spatial environment. Parallels of the three-dimensional space are shown in a linear perspective image with a convergent alignment towards a vanishing point.

The permanent use of the linear perspective in most pictorial media, and thus its constant impact on the human system of perception, has a significant effect on the way one expects a representation of its environment to be in linear perspective. It is often discussed that an observer needs to learn how to read a perspective image before it appears natural [1], [2]. Without a doubt, the linear perspective is a powerful and deceitful illusion [3] and it may be a good and solid representation of the three-dimensional environment [4]. However, the linear perspective is only one way to project the three-dimensional space onto a flat surface and it is not the ultimately ’right’ way to do it [2], [5-8]. Further research indicates the strong impact of the adaption to the linear perspective. It even influences the perception of the real world [6-8]. On closer examination, it is necessary to discuss possible side-effects of this progress and it is beneficial to achieve a comprehensive understanding of the linear perspective's effect on

C. Stephanidis (Ed.): HCII 2014 Posters, Part I, CCIS 434, pp. 373–378, 2014.

the human system of perception. This is also valid for the field of human-computer interaction since linear perspective dominates virtual three-dimensional worlds and is even the most common projection system in virtual reality systems.

This contribution is focused on the human sensation of parallelism in mathematical accurate and abstract images. In the following section an experimental approach is described.

2 Description of the Study

Judgments on parallelism in the three-dimensional space are often inaccurate or wrong [9-13]. While the detection of parallelism is relatively well reviewed for spatial environments, it is widely unclear how subjects judge parallelism on plane images which show three-dimensional scenes. In [14] it is supposed that the apparent convergence of parallels in linear perspective pictures is used by observers as a cue to construct a spatial comprehension of the pictured three-dimensional space.

The goal of the presented study is to find the circumstances under which parallels of three-dimensional objects appear also parallel in the two-dimensional images of these objects. Three projection systems are used to render images of geometric objects with parallel properties. The linear perspective maps parallel properties to convergent lines. The reverse perspective projection creates divergent lines out of parallels and the orthographic projection preserves all parallel properties. It is supposed that parallels in an orthographic projection are not always perceived as parallels.

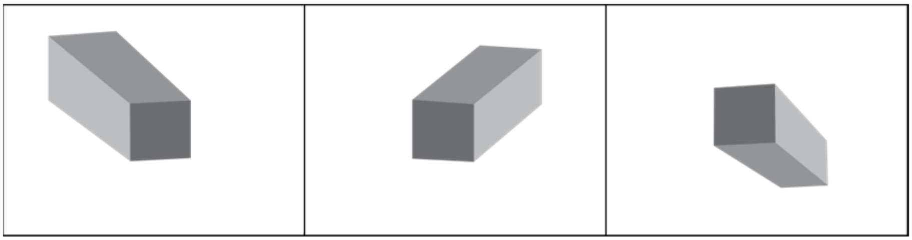

Fig. 1. Three examples of the presented computer generated stimuli. Shown is a cuboid object in different orientations. The field of view of the virtual camera is set to -12° angular degree (left - reverse perspective), to 0° angular degree (mid - orthographic projection) and to 20° angular degree (right - linear perspective).

The subjects were requested to determine whether particular lines in an image were parallel to each other or not. By pressing one of two specified keys on a normal keyboard the subjects logged their decision and the following image was presented. The images were presented in random order on a 22inch computer screen aligned as a frontoparallel plane. Although there was no time limit for pressing a key, the subjects were asked to decide fast and the response time was measured. 23 subjects (10 women, 13 men) without visual impairment took part. The relevant lines for which the decision was made spread in each case from the middle of the screen to one of its edges (figure 1). The lines were actually the depth lines of objects which were shown with different degrees of perspective distortion. One of the three basic shapes (square, circle or equilateral triangle) formed the base area for the three used objects (cuboid, cylinder, prism). With the base area in the middle of the screen and the spatial orientation towards one of the screen edges, the object's justification brings to mind an arrangement similar to the often used cavalier or cabinet projection. Overall 204 images were shown to each subject (three objects, four rotations and 17 different degrees of perspective distortion). The perspective distortion was controlled by the field of view of the virtual camera and its distance to the object. The stimuli images were screenshots created with a self programmed plugin for BiLL (Bildsprache Live Lab - an openGL based framework for viewing and manipulating virtual scenes which is developed at Technische Universität Dresden) [15].

3 Results

For the analysis of the data a one-factored variance analysis (ANOVA) (17 different angles of field of view) with a Bonferroni correction as post-hoc test was applied. For every angle of the field of view there were 12 repetitions of rating (three different objects each with four spatial orientations).

As depicted in figure 2, most images (94.20%; 260 out of 276) with a field of view of 10° angular degree were rated as parallel. Except for the two nearby measurements 8° (86.96%; 240 out of 276) and 12° (86.23%; 238 out of 276) this is a significant difference to all the other angles, $p < .03$. These ratings are surprisingly high in comparison to images where the lines were actual parallel. Less than one out of five of these images were rated as parallel and therefore correct (18.11%; 50 out of 276). The commonness of misjudgment is very clear for the angles of degree between 8 to 12. Nearly no misjudgment was to be observed for images in reverse perspective. Only every fiftieth image was rated as parallel (2.11%, 35 out of 1656).

In additional examinations we could suspend the assumption that the grade of knowledge about perspective projections influenced the subject's ratings. Also there was no significant difference for the ratings of the three objects nor the four object rotations. However, there was a noticeable difference in the mean reaction time. It took the subjects significant more time to make a decision for linear perspective images (2500ms) than for reverse perspective images (1052ms).

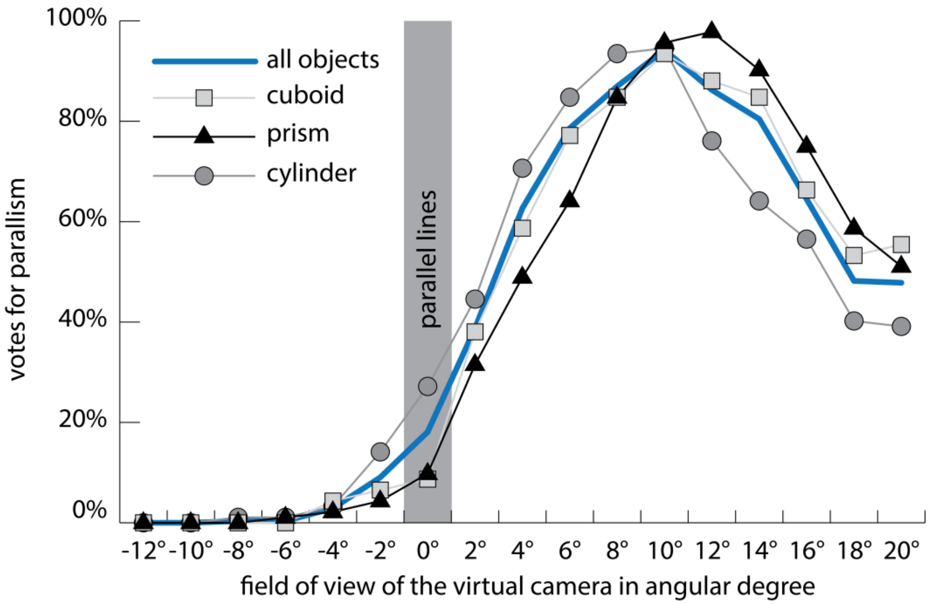

Fig. 2. The subject's perception of parallelism for all three objects over the used values of the computer generated image's field of view

4 Discussion

The misjudgment on the perception of parallelism was consistent and similar for every spatial orientation. That is why we assume that the subjects were clearly misled by the three-dimensional impression of the stimuli. The images were interpreted as illustrations of three-dimensional objects like cuboid or cylinder. In difference, another possible interpretation of the stimuli as flat and separated shapes, should have led to a discrepancy. The effect of perceived depth in the image is to return to the rare depth cues like linear perspective. In addition, the effective mapping of the actual flat stimuli to a well understood representation of a three-dimensional object seems to play an important role. As known, the illusion of linear perspective is successful because the human perception system is well trained in mapping flat images to equivalent spatial ideas of the shown scene [2-3]. As described in the previous section, nearly every image (94.2%) which showed an object under the field of view of 10° angular degree, was rated as parallel. The clearness of this result seems to be caused by the illusion of seeing a spatial object due to the perspective presentation. Only in rare occasions the lines in reverse perspective pictures were rated as parallel. This result seems to support the theory of an adaption to the linear perspective [1-2], [7]. That means that there could be an awareness, when viewing pictures with a spatial impression: depth parallels need to converge towards a vanishing point. In the case of the study this awareness could be an explanation for the consequent misjudgment of the subjects. Figure 3 shows the obviousness of this misjudgment.

It seems that it was more 'easy' for the subjects to except parallelism for pictures in reverse perspective. The decisions were significant faster and mostly correct. It should be more likely to detect parallels on an object where you know that it has clearly parallel structures (like the cuboid). So maybe the 'odd' representation in reverse perspective prevented the detection of the a e.g. cuboid-like structure. Due to the experience of the subjects with linear perspective, the perspective distortion in reverse perspective is against the expectance. Therefore it could have been more easy for the subjects to make the right decision against parallelism.

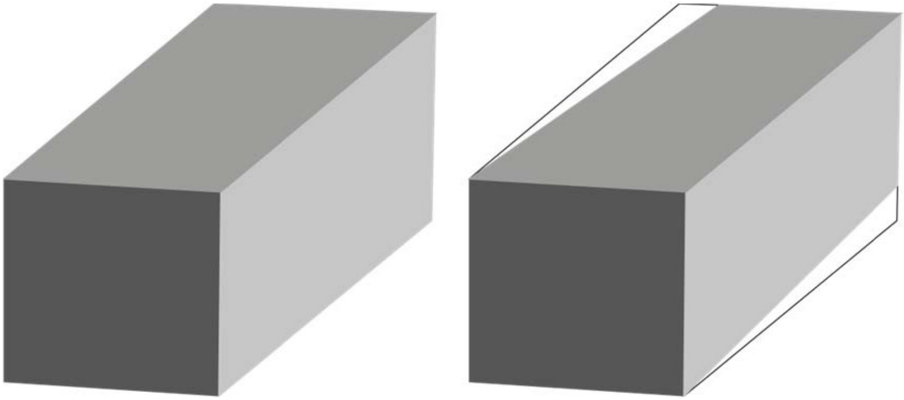

Fig. 3. Comparison between a cuboid in orthographic projection with real parallel lines (left) and a cuboid in linear perspective with perceived parallel lines (right). The black outline depicts the difference to real parallelism.

5 Conclusion

In this paper we discussed the effect of the frequent usage of linear perspective for drawing, photography, moving pictures and computer graphics. In study, we asked 23 subjects to determine, whether or not outlines of shapes are parallel to each other. The shapes were part of spatial seeming and simple objects like a cuboid, a cylinder and a prism. All the images were created with different degrees of perspective distortion. As expected, apparent parallels in an image does not have to be perceived as parallel. The subjects detected parallels very often in slightly linear perspective images, where the seeming parallels were actual not parallel at all (figure 3). These findings seem to support the thesis, that the adaption of the human perception system to linear perspective images influences the visual perception [6-8].

Acknowledgements. This work has been supported by the European Social Fund and the Free State of Saxony (Young Investigators Group CogITo, project no. 100076040).

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