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Influence of the gravitational vertical on geometric visual illusions

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Abstract

The occurrence of geometric orientation illusions and the perception of ambiguous figures were analyzed in 24 subjects during static body tilt relative to gravity on Earth. Results showed that illusions such as the Rock's diamond/square, the Ponzo illusion, and orientation contrast illusions occurred less frequently, and that depth reversal of ambiguous figures took more time when subjects were lying on their side or supine compared to upright, thus suggesting that the gravitational reference plays a significant role in these "visual" illusions. The structure of images, our representation of the environment, and orientation relative to gravity are all integral parts in interpreting visual images. In a weightless environment where no gravitational reference can be used, it is expected that similar alterations in visual perception will occur.

Keywords: Visual illusion; Perception; Frame of reference; Spatial orientation; Gravity; Vertical

1. Introduction

Spatial orientation depends on perception of position, orientation, and motion of external objects as well as on perception of one's own position, orientation, and motion. On Earth, the perceptual reference frames used to map a spatial object into a symbolic perceptual description strongly rely on the direction of the gravitational vertical. For example, Rock [1] found that a diamond is perceived as a diamond in an upright subject, but as a square in a tilted subject (Fig. 1). This result indicates that the perceived shape of an object generally depends more on the orientation of this object in world (spatial) coordinates than on its orientation in retinal coordinates. Because gravity is such an important factor in determining the orientational structure of the environment, in a weightless environment where there is no perceived gravitational vertical, the astronauts' reference frames seems to be based predominantly on features of the visual environment that normally align with gravity, such as spacecraft interiors, images of trees, and other crewmembers [2,3].

On Earth, there are well known visual illusions based on the geometric arrangements of vertical and horizontal lines. For example, when viewing two orthogonal lines (one horizontal and one vertical, in the

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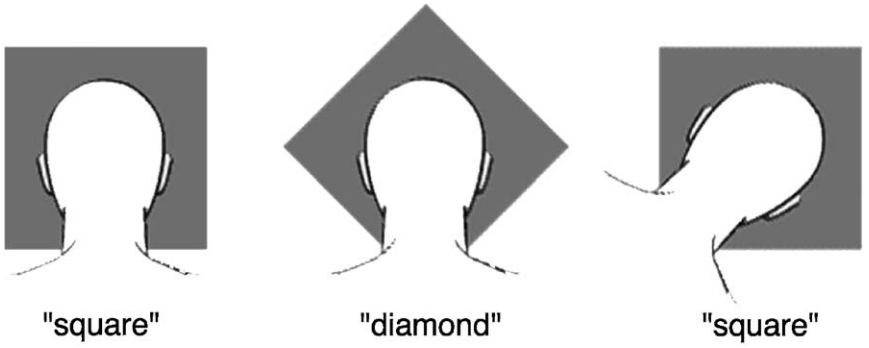

Fig. 1. Subjects presented with a diamond report seeing a diamond in an upright position but a square when they are tilted relative to gravity.

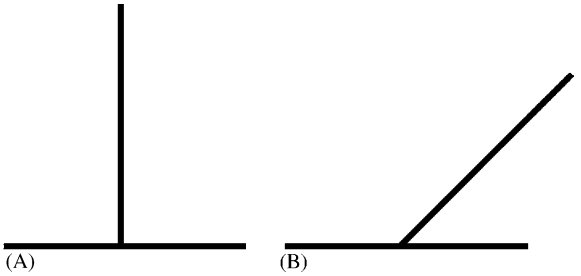

Fig. 2. The "Inversed T" Illusion (left) alongside a modified version where the vertical line is replaced by an oblique line (right). All lines have equal length. This geometric size illusion shows exaggerated vertical or oblique lines and minimized horizontal lines. Subjects were asked if the vertical or oblique line was longer than the horizontal line.

shape of an upside-down T) of the same length, the vertical line looks longer than the horizontal line (Fig. 2(A)). One interpretation for this illusion is that we have "orientation detectors" that exaggerate all vertical lines and minimize all horizontal lines. This theory has its basis in the exciting work of Hubel and Wiesel [4] who discovered that cells in the visual cortex of a cat "detect" contour orientation on the retina. Other interpretations attribute this distortion to asymmetry of the visual field and the eye movement system, or to inappropriate scaling due to misleading perspective and depth cues [5]. Another interpretation is that this effect is related to the presence of the gravitational reference. Arguments in favor of this interpretation are the results of electrophysiological studies in animals, which have shown that body tilt influences the sensitivity of the orientation detectors [6] and the orientation of receptive fields in the visual cortex [7]. We, therefore, investigated if the illusion that the vertical line is larger than the horizontal line changes when the body is tilted relative to gravity.

It is also known that three-dimensional figures represented in a two-dimensional perspective appear ambiguous on Earth. This for example is the case for the well-known Necker's cube [8], where a depth reversal generally occurs after several seconds of fixation. Such two-dimensional figure is unstable because in the real three-dimensional world this figure could equally exist in one of two different configurations. Due to the gravity constraints, however, some configurations are more often present than others.

The purpose of this experiment was to investigate whether the geometric visual illusions and the perception of ambiguous figures were altered when the observer was tilted relative to gravity on Earth. Compared with the upright condition, when the observer is lying on his/her side or in the supine position, there is a conflict between the perceived gravitational (extrinsic) vertical and the retinal or body-defined (intrinsic) vertical. We hypothesized that visual illusions based on a geometrical arrangement of vertical and horizontal lines could be affected by body tilt because of the misalignment of the gravitational and retinal vertical.

2. Methods

This experiment was performed by students of the International Space University (ISU) as a research project during the Summer Sessions in Pomona