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DOES FLATTENED SKY DOME REDUCES PERCEIVED MOON SIZE

O. TOŠKOVIĆ[1,2]

[1] *Department of psychology, Faculty of Philosophy, Kosovska Mitrovica, Serbia*

[2] *Laboratory for experimental psychology, Faculty of Philosophy, Belgrade, Serbia*

E–mail: otoskovi@f.bg.ac.rs

Abstract. The aim of this study was to examine the Flattened sky dome model as an explanation of the Moon illusion. Two experiments were done, in a dark room, in which distribution of depth cues is the same towards horizon as towards zenith. In the first experiment 14 participants had the task to equalize the perceived distances of three stimuli in three directions (horizontal, tilted 45 degrees and vertical). In the second experiment 16 participants had the task to estimate the perceived sizes of three stimuli in the same three directions. For distance estimates we found differences among three directions in a way, that as the head tilts upwards, the perceived space is being elongated, which is the opposite to flattened sky dome. For size estimates we found no difference among the three directions.

1. INTRODUCTION

Visual illusions are phenomena that result in non-veridical perception (Luckiesh 1965). Namely, visual system functioning is based on certain principles, or heuristics, which usually result in veridical percepts. Sometimes, these principles result in seeing things that do not exist (illusionary contours), or in not seeing things that do exist (camouflage), or in seeing things in a different way than they really appear (illusions). Most visual illusions are made in artificial, laboratory conditions. One of illusions that appear in natural viewing conditions is the so-called Moon illusion. This phenomenon results in perceiving the Moon near horizon as bigger in zenith. It also affects other celestial bodies, such as the Sun or star configurations (Ross and Plug 2002). A lot of studies have shown that average increase in perceived size of the Moon on horizon is between 50% and 100% (Ross and Plug 2002, Kaufman and Rock 1962, Holway and Boring 1940).

According to one of theories, difference in perceived size of the Moon in two positions can be caused by angular turns of the eye (Holway and Boring 1940). When we look upwards, our eyes turn upwards too, and the muscles which regulate eye movements change their tension. Holway and Boring claimed that this change in eye muscles tension results in diminishing the size of perceived objects. Although change in eye muscles tension can affect perceived size, its effect is not as strong as it appears in Moon illusion. According to some data, angular turn of the eye can reduce perceived size up to 7%, which is much less than in Moon illusion (around 50% on average) (Ross and Plug 2002).

One of the theories suggests that change in perceived size of the Moon is due to a change in perceived distance (Kaufman and Rock 1962). Kaufman and Rock suggested the so-called Flattened sky dome model, presuming that perceived distance towards zenith is shorter than perceived distance towards horizon. These authors suggest that perceived sky dome is flattened compared to physical sky dome, i.e. that perceived distance towards zenith is shorter than physical distance. Namely, if perceived distance of zenith Moon is shorter, and the Moon subtends the same visual angle as it is on the horizon, visual system could conclude that zenith Moon is smaller. Kaufman and Rock presumed that distance towards zenith is perceived as shorter because of lack of distance cues, according to which visual system estimates distance. Distance is not directly perceived since projection on the retina is two-dimensional, and visual system reconstructs distance based on additional information called depth cues (accommodation, convergence, stereopsis, perspective, relative size, motion parallax, edges, shadows. . .). This theory relies on existence of linear relation between perceived size and distance, it explains change in perceived size trough change in perceived distance.

According to principles of projection, size of projected image and its distance should be correlated in such a way that further the object is, size of its projected image should be smaller. But, there are a lot of studies which show that relation between perceived size and distance is not linear, as it would be expected from projection principles (Epstein 1961, Ross and Nawaz 2003). In some cases changes in perceived distance are not followed by changes in perceived size. So, according to these studies, we can doubt that perceived distance mismatch is the cause of perceived size mismatch in Moon illusion.

2. AIM

Aim of the present study was to verify if Flattened sky dome model can explain the Moon illusion. More precisely, the aim was to examine whether changes in perceived size are a consequence of changes in perceived distance, and whether those changes are a consequence of distribution of depth cues.

We presume that changes in perceived size in different viewing directions are not correlated with changes in perceived distance, since there are some data showing that perceived size is not in linear relation with perceived distance (Epstein 1961). We also presume that changes in perceived distance in different viewing directions exist, but they are not a consequence of depth cue distribution. According to some research, information about position and movements of the body can affect visual perception (Lackner and DiZio 2005). So, we presume that this kind of information can be the cause of a change in perceived distance in different viewing directions.

3. METHOD

SAMPLE. There were 30 participants in this study, psychology undergraduates. They were divided in two groups that participated in two different experiments, 14 in the first, and 16 in the second. All participants had normal, or corrected to normal vision.

STIMULI. In the first experiment we used three small rectangular dim lights, 7 cm × 5 cm in size, as stimuli. In the second experiment we used also dim lights, but different in size. Three of them were 7 cm × 1 cm, and other three 14 cm × 1 cm in size.

VARIABLES. In both experiments independent variables were: (1) viewing direction – categorical variable with three levels (horizontal 0^o, middle 45^o, and vertical 90^o); (2) distance of the stimuli – categorical variable with three levels (1 m, 3 m and 5 m). In the second experiment we had one more independent variable: (3) size of the stimuli – categorical variable with two levels (7 cm × 1 cm and 14 cm × 1 cm). Dependent variable in the first experiment was the estimated distance of stimuli, based on its matching with the standard, measured in meters. Dependent variable in the second experiment was the estimated size of stimuli, measured by touch, in centimeters.

PROCEDURE. Two experiments were done, in a dark room, in which distribution of depth cues is the same towards horizon as towards zenith, that is in all viewing directions. In the first experiment participants had to equalize the perceived distances of three stimuli in three directions. One of the stimuli was considered as the standard, and participants told to experimenter to move the other two until they appear approximately at the same egocentric distance. In the second experiment participants had to estimate the perceived sizes of three stimuli in the same three directions. They estimated sizes by touching and choosing one of the bars which appeared similar in size the observed stimuli. Participants in both experiments performed estimates while sitting on the floor, wearing special glasses (with 1 mm wide aperture) in order to prevent the eye movements. So, they could only move their head from horizontal to vertical direction.

4. RESULTS

Data from the first experiment were tested with two-factorial analysis of variance. We separately tested differences between each two directions, because a standard stimulus was not the same in all conditions, so we could not average them. As two factors we used viewing direction and standard distance. In this analysis null hypotheses were that there is no effect of direction, no effect of distance, and no interaction. Alternative hypotheses were that there is an effect of direction, effect of distance, and interaction. Results have shown that there is a significant main effect of direction and distance, and their interaction *(all statistical results are available on personal request to the author)*. The data show that perceived distance differs in different viewing directions, but only for larger distances from the observer. At 1 m distance, perceived distance is the same in all viewing directions. At 3 m and 5 m distance, smaller distances towards zenith are equalized with larger distances towards horizon (Fig. 1).

Data from the second experiment were tested with three-factorial analysis of variance. As factors we used viewing direction, standard distance, and standard size. In this analysis null hypotheses were that there is no effect of direction, no effect of size, no effect of distance, and no interactions. Alternative hypotheses were that there is an effect of direction, effect of size, effect of distance, and interactions. Results have shown that there is a significant main effect of size and distance, but not the effect of direction. Three way interaction of factors was not significant. These data show that perceived size does not differ in different viewing directions, for all tested distances (1 m, 3 m and 5 m) (Fig. 2).

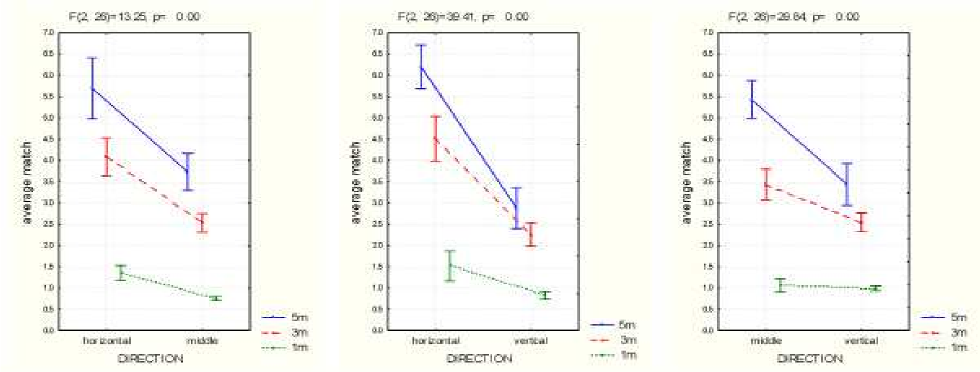

Figure 1: Average matched distances in three viewing directions.

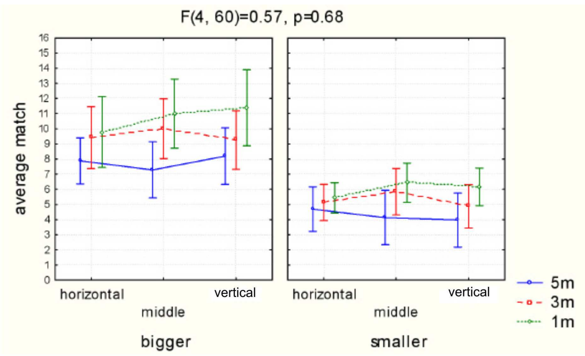

Figure 2: Average estimated sizes in all viewing directions for stimuli different in size.

5. DISCUSSION

Results of the first experiment show that for small distances, such as 1 m, perceived distance does not change with viewing direction. For larger distances from the observer, such as 3 m and 5 m, shorter vertical distances are equalized with longer horizontal distances. These results actually show that vertical distances (towards zenith) are perceived as being larger than physically identical horizontal distances. In other words, if observers perceive shorter vertical distances as equal to physically longer horizontal, they perceive the vertical ones as longer than they are. Hence, as the head tilts upwards, the perceived space is being elongated, which is the opposite to flattened sky dome. That is, perceived distance towards zenith is longer than perceived distance towards horizon. This inequality of perceived distances in different viewing directions is called anisotropy.

We can ask why this anisotropy occurs. The assumption is that visual system integrates vestibular and kinesthetic information (information about position and movement of the body) in perception-action schemes. This actually means that visual system takes into account forces that affect the observer. It is shown, in some studies, that small inertial forces change the perception of location. (Lackner and DiZio 2005). In this case, visual system would include direction of gravity in perception of distance, that is, in localization of perceived targets.

In the second experiment, in size estimates we found no difference among the three directions. For all tested distances (1 m, 3 m and 5 m), for both stimuli sizes (7 cm × 1 cm and 14 cm × 1 cm) estimated sizes were the same in horizontal, middle and vertical direction. So, anisotropy that we found for perceived distance does not exist for perceived size.

Results from both experiments suggest that perceived size and distance are not directly correlated, so they coincide with other studies that also showed non-linearity between perceived size and distance (Epstein 1961). This could be interesting issue, since it indicates incoherence of two processes, perception of size and perception of distance. This incoherence shows that visual perception sometimes deviates from the simple projection principles.

Results also show that perceived distance is probably not the cause of differences in perceived Moon size in two directions, since changes in perceived distances were not followed by changes in perceived sizes. Our data also show that perceived dome is not flattened, it is elongated. If difference in perceived distance would be the cause of Moon illusion, perceived dome should be flattened, which is not the case. So, we can say that Moon illusion is not the consequence of differences in perceived distance. On the other hand, we must emphasize that in our experiment perceived distances and sizes were much smaller than the size and distance of the Moon. In these experiments we used distances ranging from 1 m to 5 m, and sizes ranging from 7 cm to 14 cm, and the Moon distance from Earth is 384 400 km on average. But, even if distances and sizes used in experiments were much smaller than the distance of the Moon, we believe that these results can be extrapolated to the Moon illusion problem, because there are no reasons to believe that perception regularities would significantly change over different distances. That is, if perceived distance changes are not correlated with perceived size changes on small distances, they probably would not be correlated on larger distances, too. Although, Kaufman and Rock's idea on influence of distribution of depth cues can still be a good candidate for explanation of Moon illusion, if we presume that change in number of depth cues affects perceived size directly, and not trough perceived distance. So, perceived sky dome is probably not flattened by lack of depth cues, but maybe size itself can be diminished by lack of depth cues.

References

Epstein, W., Park, J., Casey, A.: 1961, *Psychological Bulletin*, **58**, 491.

Holway, A. H. and Boring, E. H.: 1940, *American Journal of Psychology*, **53**, 109.

Kaufman, L. and Rock, I.: 1962, The Moon Illusion, *eds. Held R. Richards W*, Perception: Mechanisms and Models 260, San Francisco: W.H. Freeman and Company.

Lackner, J. R. and DiZio, P.: 2005, *Annual Review of Psychology*, **56**, 115.

Luckiesh M.: 1965, Visual Illusions, New York: Dover Publications.

Ross, H. E. and Nawaz, S.: 2003, Arquivos Brasileiros de Oftalmologia, **66**, 69.

Ross, H. and Plug, C.: 2002, The mystery of the moon illusion, New York: Oxford University Press.