A New Hypothesis and its Verification Explaining Exaggeration of Horizon Moon

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Abstract

Image recognition is an essential theme to be studied for image reproduction with better satisfaction by observers. Study of visual illusion is one of approaches for clarifying recognition process in our eyes and brain. That is why we have chosen the moon illusion as a study theme of imaging technology. A full moon just above the horizon is often recognized as much larger than an elevated moon. The reason remains an open question in spite of having been studied since the ancient Greece period. Here we show a new explanation for this illusion.

We suggested a new explanation that miss-understanding of distance to the horizon moon causes inappropriate compensation of size recognition of the moon.

The validity of our new hypothesis was checked by our simulated observation of a moon. Exaggeration of a moon image was observed by our simulation to look at a moon through a deep corridor as a projected image on a screen. The deeper was the corridor, the larger moon was observed. The observed results were as our hypothesis had predicted; our hypothesis was agreed by our experimental results.

1. Introduction

A full moon just above the horizon is often recognized as much larger than the elevated moon. The reason remains an open question in spite of having been studied since the ancient Greece period.

The various theories for the moon illusion [1, 2] fall into two categories. One group attributes the reason to a physical enlargement of viewing angle to the horizon moon; it is known that Aristotle of ancient Greece (4th C B.C.) suggested this kind of explanation. The other group attributes the reason to the human eye or brain. Theories in the first group, which typically invoke the angle of incidence to the earth's atmosphere, have already been denied by a comparison of moon photographs.

The surviving second group can be further divided into two subgroups. One attributes the reason to the effect of raising our eyes or heads to the zenith moon [3 - 5]. A typical explanation involves a change in shape of the crystalline lens in our eyes; that is, the size of the retinal image varies. The other attributes the reason to the existence of terrain as the foreground for the horizon moon; constant size of the retinal image is supposed. Arguments have been continuing between these two groups up to now.

The effect of terrain as the foreground was asserted in recent exhaustive experimental studies [6 - 8] carried out by Kaufman et al. They use the explanation that the horizon moon is recognized to be more distant than the elevated moon because of the existence of the terrain and we accordingly recognize the distant moon as larger than the near moon. This type of explanation originated from Ptolemaeus, the famous astronomer of the 2nd century, and has not been able to escape from the contradiction that it does not agree with our common experience: the horizon moon is felt to be far closer than the elevated moon.

Our standpoint is to agree that the existence of terrain is the trigger for the moon illusion, but we introduce an explanation that does not conflict with our common perception of the horizon moon being closer than the elevated moon. The originality of our explanation lies in our assumption that the horizon moon is perceived at no greater distance beyond the horizon; that is, we perceive it to be far closer than it really is. The horizon moon is implicitly regarded by the brain as one of the objects in the foreground terrain, and thus we tend to subject it to the same distance-size compensation applied to the foreground objects. The resulting false compensation yields the horizon moon effect. This effect is missing for the elevated moon since there are no foreground objects.

2. Introduction of our hypothesis

2.1. Similarity to another typical illusion

We know another illusion that we often feel a distant mountain enlarged when we watch it through a long corridor [9, 10]. We consider this illusion has the same reason as that for the moon illusion [11]. Thus we are now going to suggest our hypothesis, first of all, to explain the illusion of a distant mountain looked through a long corridor.

2.2. Exaggeration of a distant object looked through a long corridor

Figure 1 (a) is a schematic diagram of a situation when an observer is looking at a distant mountain through a long corridor. So-called perspective shape of the corridor must be projected on the retina of the observer. However, the observer never recognize a tapered shape, as shown in Figure 1 (b), but a rectangular shape of corridor in spite of the tapered shape of perspectively projected retinal image of the corridor. It is because our brain knows empirically that a projected image, on our retina, should be smaller when the distance to the object is longer.

Now, how the distant mountain that is observed through the corridor should be recognized? An observer generally cannot know the distance to the mountain because the observer can see almost no visual information for perceiving the distance between the mountain and the end of the corridor especially when a moon is looked through from a deep position of a corridor distant from its end [12]. The observer probably perceives, the mountain's position just beyond the end of the corridor because the observer has almost no information with which the observer can know how far is the mountain from the end of the corridor; the end of the corridor is the most distant position that can be identified by the observer.

Figure 1 (b) illustrates a possible primitive image for the observer before the final image recognition after a certain compensation in a brain; the distant mountain is stuck to the end of the tapered corridor. The observer must finally recognize not tapered but rectangular shape of the corridor and may finally recognize an enlarged shape of the mountain, as illustrated in Figure 1 (c), simultaneously when the observer understands that the end of the corridor is not shrunken. That is, the mountain may consequently be exaggeratedly recognized when its position is misunderstood as almost the same as the end of the corridor. This kind of exaggeration must not occur when the mountain's position is correctly perceived, as illustrated in Figure 1 (d), to be at a correct position infinitely far from the end of the corridor.

Thus, now we can explain the reason why a distant mountain is often exaggeratedly seen through a long corridor.

2.3. Exaggeration of a horizon moon

The exaggeration of a horizon moon can be explained with the same kind of reason as was explained above. Figure 2 (a) illustrates a scene when an observer is looking at a horizon moon through a long load going straight to the horizon. Observer probably perceive the moon floating just beyond the horizon because the observer has no information with which the observer can know how far is the moon from the end of the horizon; the horizon is the most distant position that can be identified by the observer. Figure 2 (b) illustrates a possible primitive image for the observer before the final image recognition after a certain compensation in a brain; the moon image is stuck to the end of the tapered load. The observer must finally recognize not tapered but rectangular shape of the load and may consequently recognize an enlarged shape of the moon, as illustrated in Figure 2 (c), simultaneously when the observer understands that the end of the load is not shrunken.

This kind of exaggeration must not occur when the moon's position is correctly perceived, as illustrated in Figure 2 (d), to be at a correct position infinitely far from the horizon. An elevated moon in the middle of the sky can be free from such an exaggeration because there is no perspective foreground whose correct shape must be compensated in a brain by using its distance information and because there is no reference position by which we may misunderstand the position of the moon.

Thus, now we can explain the moon illusion by using the same reason why a distant mountain can be exaggeratedly seen through a long corridor.

2.4. Comparison with the conventional theory

An essence of our explanation to the moon illusion is that misapplication of an automatic distance-size compensation process, with which we can recognize a correct size of an object standing at a definite distance, to an infinitely distant object standing out of the range where the same scale of distance-size compensation should be applied.

Our explanation dose not always request a strict mispositioning of the moon sticking to the end of a terrain, as typically shown in Figure 2 (a) and (b), of a moon image to the horizon. We consider that misperceiving of the moon in a definite distance not so far from the horizon must trigger the inappropriate distance-size compensation process, in our brain, which should be applied for only an object standing at a definite position.

By the way, the conventional theory by Kaufman [6 - 8] requests that we perceive the horizon moon more distant than the elevated moon; this is a fatal defect of the conventional theory because we actually perceive the horizon moon nearer than the elevated moon. In contrast to the conventional theory, our hypothesis uses the closer perception that is familiar for everyone, of the horizon moon as the basis of our explanation.

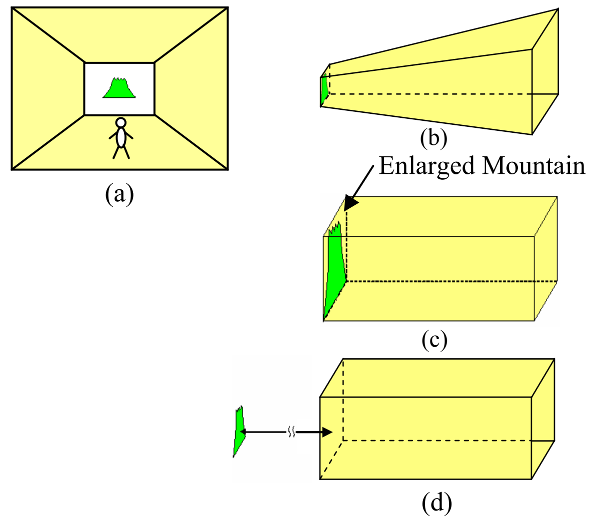


Fig. 1 Mechanism of exaggerated recognition of a distant mountain observed through a long corridor.

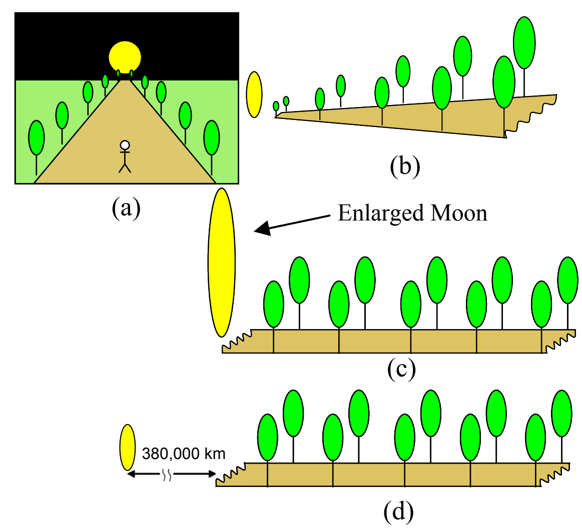


Fig. 2 Mechanism of exaggerated recognition of a horizon moon.

3. Experiments

3.1. Purpose and essence of experiments

Our hypothesis generally predicts that an infinitely distant object must be exaggerated when it is looked through a perspective foreground. Our hypothesis also predicts that the greater the extent of perspective in the foreground the stronger the exaggeration of the infinitely distant object looked through the foreground. A long corridor can provide a typical foreground with strong perspective, where the ratio of each projected image size on a retina is extremely large between for the far end part of the corridor and for the nearest, for an observer, part of the corridor.

Strong compensation in our brain must be requested for us in order to recognize not a tapered shape but the rectangular shape of the corridor correctly. Please note this kind of compensation should only be applied to objects whose distances have been identified within a definite range. An unavoidable misapplication of such a large compensation to an infinitely distant object must bring us a great exaggeration of the distant object. And besides, our hypothesis predicts that the closer, not in distance but in viewing angle, a infinitely distant object to a perspective foreground the greater the exaggeration of the distant object because the miscompensation must be applied easier to the closer object in viewing angle.

Subjects were ordered to observe, on a big screen, a projected image of scenes in which a moon is looked though a corridor. We evaluated answers from the subjects about the size of the moon images. The purpose of this evaluation is to verify if the answers are as our hypothesis predicts. We also used non-perspective foreground images without texture, for reference.

3.2. Experimental method

Table 1 is a list of typical images shown for subjects. Six different depths of corridor images were used as foregrounds of a moon image. We also used another six different images in which wall-like textures were removed from the original corridor images. A moon image without foreground image was also used as a reference. Figure 3 shows the layout of our experiments. The size of a screen image is 1.15 x 1.15 m for a big projection screen and 187 x 187 mm for a computer screen. We placed a personal computer beside of a subject and displayed moon images on its screen; subjects can precisely control the size (increment: 0.5 % in length) of the moon images by typing certain keys of a computer.

Subjects (10 students: twenties) were requested to choose, by their impression, the same size of moon image on the computer screen as that of another moon image on the big screen shown with various foreground images. The subjects were ordered to sit on a chair and fix their head position in order to maintain the distance between their head and the two screens constant. They were certainly allowed to rotate their head in order to compare the moon images which were on the two (big and small) screens at perpendicular positions.

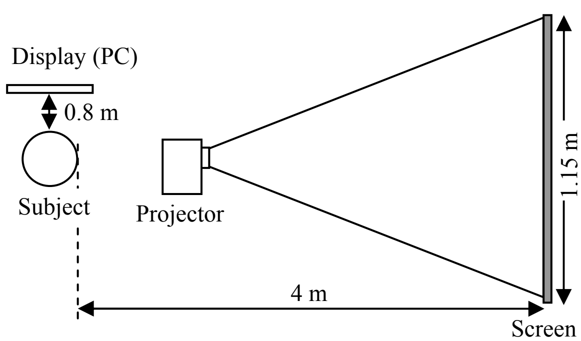
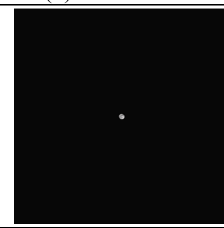
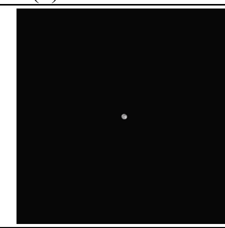
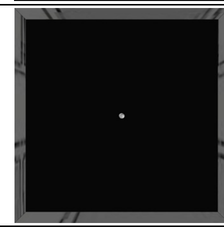
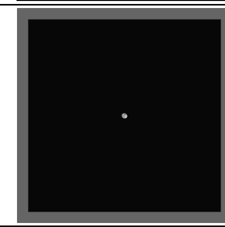
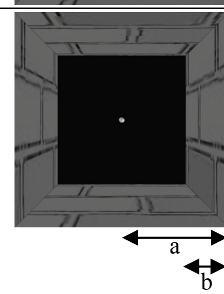
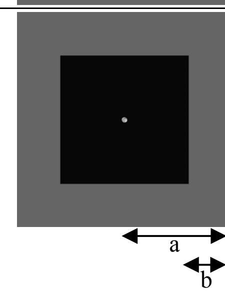
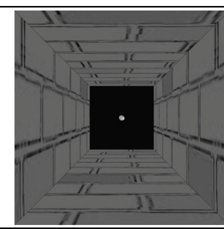
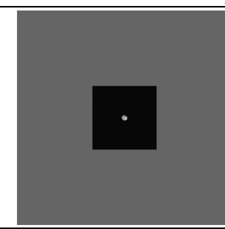
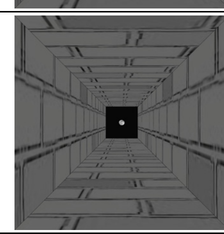
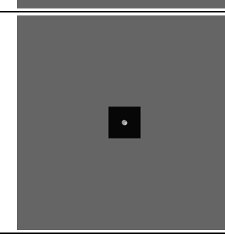
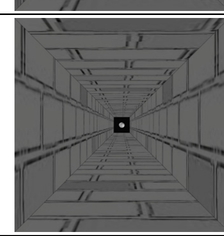
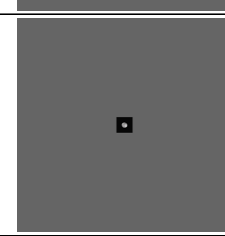
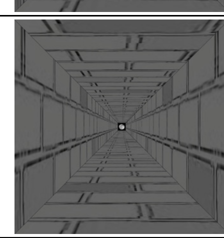
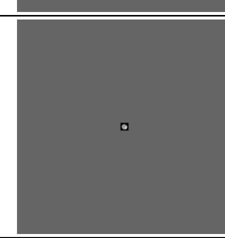


Fig. 3 Layout of our experiment.

Table 1 Projected test images on a screen

b/a	(1) With texture	(2) Without texture
0		
0.13		
0.42		
0.71		
0.85		
0.93		
0.96		

Ratio b/a was used as an index of the depth of corridor when "a" is a half width of the whole image and "b" is a width of the corridor wall. Apparent depth of the corridor image was controlled by varying the width "b" of the corridor wall. Projected image with the lager value of index b/a provides a foreground with the greater perspective created by a deeper corridor and also the closer view angle between the moon image and the surrounding foreground image. Index b/a was also varied on the simple foreground images with no texture on their wall parts. Test images with the corridor-like texture (1) were first shown for subjects in the order starting from the smallest b/a and then progressing to larger b/a (b/a = 0 - 0.96). Test images without texture (2) were then shown for subjects in the same order: smaller b/a to larger b/a.

Effect of foreground image can be evaluated using a relative enlargement ratio calculated by the following formula:

$$\text{Relative enlargement ratio} = \frac{\text{Answered moon size through foreground image}}{\text{Answered moon size without foreground image *}}$$

*) Answered moon size without foreground image is the answered size when b/a = 0

3.3. Results

Figure 4 shows averaged results of relative enlargement ratio for the moon image with perspective and non-perspective foregrounds. The ratio increases as the value b/a increases and reaches to 1.21 for the moon image with the perspective foreground (with texture). On the other hand, the ratio is almost flat for the moon image with the non-perspective foreground (without texture).

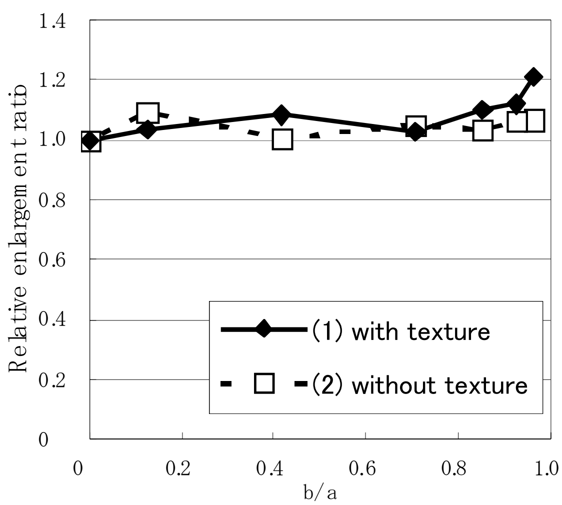


Fig.4 Measured exaggeration effects for simulated moon images.

3.4. Discussion

Larger value of b/a for the perspective foreground brings a subject a scene in which the subject looks the moon through a deeper corridor. Our results have indicated, as our hypothesis predicted, that larger moon was observed when a subject looks the moon through a foreground with greater perspective appearance. Our results also have indicated that lager moon was not observed when a subject looked the moon through a foreground without perspective appearance. It was confirmed that a perspective appearance of foreground image, for which size-distance compensation must be performed in our brain, is necessary for exaggeration of moon image. The observed results were as our hypothesis had predicted.

4. Conclusion

1) We have suggested a new hypothesis to explain the moon illusion as follows:
   Exaggeration of an infinitely distant object (moon) must occur when an observer misuse the size recognition procedure, which should be used only for objects at definite distances in a foreground (perspective terrain), to the infinitely distant object. Our hypothesis premises that the distance to the infinitely distant object must be misunderstood as if it exists in almost the same range of the foreground. That is, the position of a horizon moon must be perceived at just beyond a horizon.
2) Exaggeration of a moon image was observed by our simulation to look at a moon through a deep corridor as a projected image on a screen. The deeper was the corridor, the larger moon was observed.
3) The observed results were as our hypothesis had predicted; our hypothesis was agreed by our experimental results.

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Author Biography

Shinya Uematsu was born in 1987. He received his B.E. degree in 2010 from Tokai University. He is expected to receive his M.E. degree from the graduate school of Tokai University in 2012. He is now engaged in a study of Mechanism of the Exaggerated Recognition of the Horizon Moon.