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SHORT AND SWEET

A Single Solid That Can Generate Two Impossible Motion Illusions

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Abstract

We discovered three-dimensional solids that can generate two different impossible motion illusions. When such a solid is seen from two particular viewpoints, two different shapes are perceived. In both cases, the perceived physical motion appears to be impossible.

Keywords: optical illusion, impossible motion, multiple depths

The author coined the term "impossible motion" to label a new type of optical illusion in which viewers perceive objects that appear to move in physically impossible patterns (Sugihara 2005, 2014). These motion patterns are generated by a three-dimensional solid seen from a special viewpoint, in which the solid appears to have ordinary shape but, when motion is added, viewers perceive robust motion patterns that are physically impossible. A typical example of an impossible motion is the one generated by "Magnet-Like Slopes," which won first prize in the Sixth Best Illusion of the Year Contest held in Florida in 2010 (Neural Correlate Society 2010).

This illusion might occur due to the tendency of humans to perceive the most plausible interpretation of the visual input (Gregory 1970, Robinson 1998) although there are an infinite number of solids that can project the same input image. What is really happening is that the shape of the solid we perceive is different from the true shape, whereas the motion is physically natural in spite of the impression of being impossible.[1]

An interesting observation in this class of illusion is that even though we feel that the motion is impossible, our brains would not correct the interpretation of the shape of

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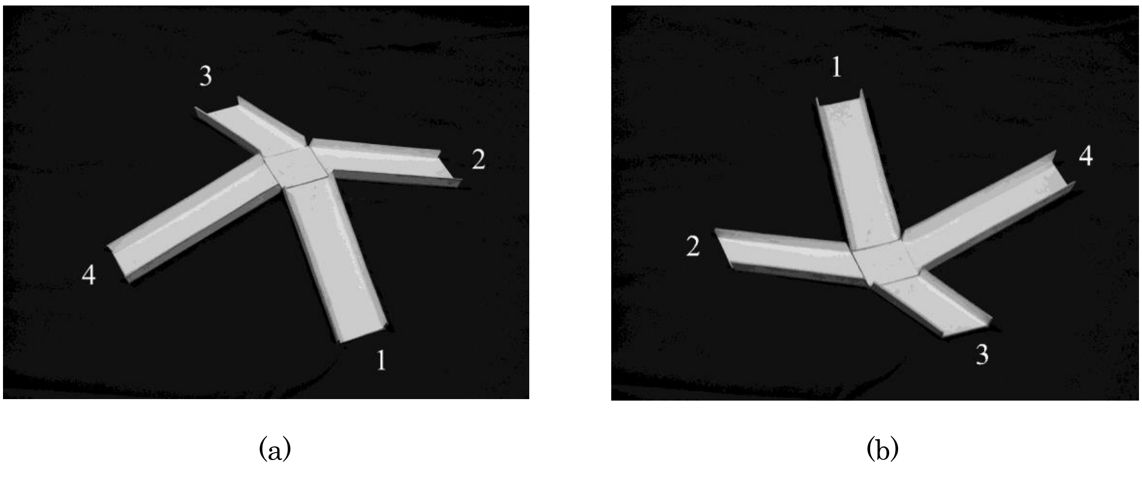
the solid. Moreover, the correction would not be done, even if we know the true shape of the solid. Suppose that a viewer changes the viewpoint, to understand the true shape of the solid, and goes back to the initial viewpoint again. Then, the impossible motion illusion still occurs to that viewer. In this sense this illusion is strong and robust.

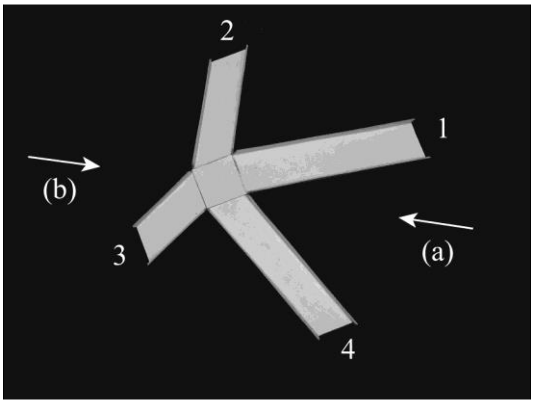
We can say that the fundamental part of this illusion is the incorrect interpretation of the retinal image of the solid and that the added motion is of secondary importance. However, we cannot neglect the fact that the added motion does not correct the interpretation of the shape of the solid, although it tells us the incorrectness of the interpretation. In other words, the impossible motion is a phenomenon in which the inconsistency between the perceived shape and the perceived motion does not help in correcting the incorrect interpretation in our visual system. In this sense the impossible motion illusion comes from the interaction between the shape perception and the motion perception.

In this paper, we aimed to determine whether it is possible to construct a solid that can generate two different impossible motion illusions. The answer is affirmative.

An example is the solid titled “Peak or Valley?,” which is shown in figure 1; figures 1a, 1b, and 1c are each images of the same solid taken from different viewpoints. When this solid is seen from the first special viewpoint, it creates the image of figure 1a and we perceive that the four slopes meet at the highest peak. When it is seen from the second special viewpoint, it creates the image of figure 1b and we perceive that the four slopes meet at the lowest valley. In fact, the four slopes are coplanar. The top view is as shown in figure 1c; the four slopes all have different lengths, and they meet at non-orthogonal angles. The arrows (a) and (b) in figure 1c represent the directions of view along which the photos of figures 1a and 1b were obtained, respectively. In figure 1, the labels 1, 2, 3 and 4 are also assigned to the slopes in order to establish the correspondences of the slopes in different views.



(a) (b)

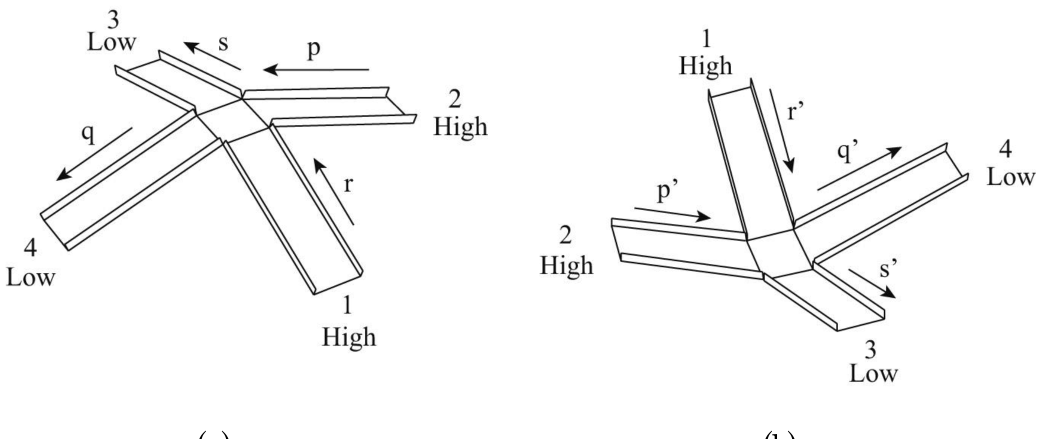


(c)

Figure 1. Multiple impossible “Peak or Valley?” The four slopes are labeled as 1, 2, 3 and 4 to establish the correspondence in the three figures.

This planar shape of figure 1c was placed on a plane surface with an orientation that has a slight slant, i.e., it is not horizontal; all the four slopes were slanted in the same direction. Therefore, if we place a ball on the edge of one slope that is slightly higher because of the slant, the ball will roll downhill along that slope and will continue to roll on the next slope, after it crossed the intersection in the middle.

Suppose that we observe the motion of the ball from the first special viewpoint of figure 1a, where the plane is slanted such that the edges of slopes 1 and 2 are high and the other two are low, as shown in figure 2a. Then the ball moves along arrow p followed by arrow q, or along arrow r followed by arrow s. The motions along p and r look impossible because the ball appears to be rolling uphill and defying the law of gravity.



(a) (b)

Figure 2. Motion of a ball in “Peak or Valley?”

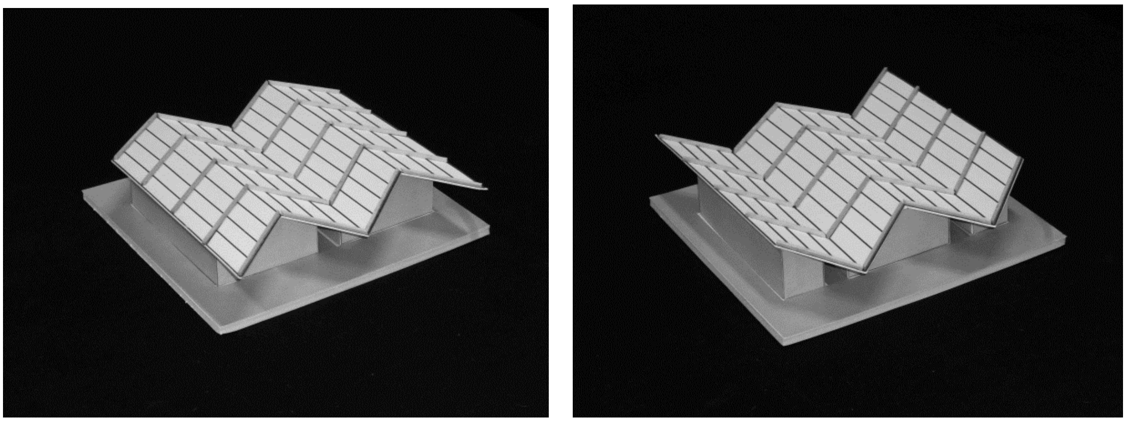
Next, suppose that we observe the same slanted plane from the second special viewpoint of figure 1b. Then, as shown in figure 2b, the ball moves along p' and then q', or along r' and then s'. The motions along q' and s' look impossible because the ball appears to be rolling uphill.

Note that the motions of the ball along p and p' are physically the same motion; similarly, the motions along q and q', r and r', as well as s and s' are the same physical motions. Thus, the same solid with the same motion generates two different impossible motion illusions.

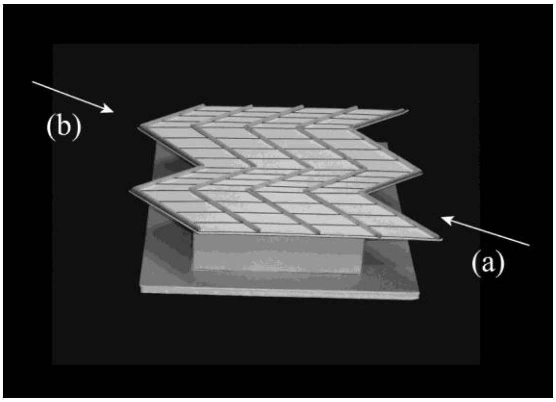
Readers who are familiar with the "Magnet-Like Slopes" illusion (Neural Correlate Society 2010) might think that the solid in figure 1 is nothing but the upper part of the Magnet-Like Slopes apparatus, i.e., the solid obtained by removing the supporting columns. However, this is not the case. In the "Magnet-Like Slopes" apparatus, the center is at the lowest height, while in the "Peak or Valley?" apparatus, the four slopes are coplanar and hence, the center is not at the lowest height; it is at the same height at the slopes. This difference is the source of obtaining multiple impossible motions.

Another example is given in figure 3, under the title "Reversible Antigravity Twin Roofs". When we observe this setup from the first special viewpoint, the solid looks like two houses, each of which has a two-sided roof, and in which the two roofs are connected, as shown in figure 3a. On the other hand, when we observe it from the second special viewpoint, it looks like three houses, one of which has a two-sided roof and the other two of which have one-sided roofs, all of which are connected, as shown in figure 3b.

In reality, the roof structure is flat, as shown in figure 3c, which is an image of the solid seen from a general viewpoint. The arrows (a) and (b) in figure 3c represent the directions of view along which the photos of figures 3a and 3b were obtained, respectively.



(a) (b)



(c)

Figure 3. “Reversible Antigravity Twin Roofs”

Because the roof structure is a little slanted, a ball placed on the roof will roll from one side to the other. If we observe this ball motion from the first special viewpoint (figure 3a), as it travels from the right edge to the left edge, it appears to be rolling uphill, downhill, uphill, and then downhill in sequence. On the other hand, if we observe the ball motion from the second special viewpoint (figure 3b), it appears to be rolling from the left edge to the right edge downhill, uphill, downhill, and then uphill in sequence. In both cases, some part of the ball motion looks impossible because it appears to be rolling uphill.

Finally, let us compare the present illusion with other types of multiple depth illusions.

First, there is a class of sculptures that produce two different three-dimensional shapes, depending on the view direction. Italian sculptor Guido Moretti and Japanese sculptor Shigeo Fukuda are two artists who have created such sculptures. Fukuda’s typical works, “Encore”, for example, produces silhouette of a pianist when seen from one direction and a silhouette of a violinist when seen from the second direction that is orthogonal to the first direction (Seckel 2006). This class of solids is similar to the solids presented in this paper in that a single solid can produce two different meaningful shapes when seen from different directions. However, these two classes of solids are quite different. The two silhouettes in “Encore” are realized in mutually orthogonal directions; the faces visible in the first direction are completely hidden in the second direction. On the other hand, in the “Peak or Valley?” illusion, the same solid is visible from both directions, but it still produces different three-dimensional interpretations. In this sense, these multiple-illusion solids are a novel concept.

The second type of multiple-depth phenomenon is the depth-reversal illusion including the crater illusion (Seckel 2006, Kitaoka 2010). In the crater illusion, the depth we perceive when we see an image of craters is reversed if the image is rotated by 180 degrees to make it upside down. A similar depth reversal occurs when a real surface is illuminated from below (Tomoeda and Sugihara 2002). This class of illusion might occur because the human brain is apt to assume implicitly that the scene is illuminated from above. Hence, the shading information plays the main role (Liu and Todd 2004, Adams 2008).

The multiple impossible motions introduced in this paper, on the other hand, do not depend on the shading; it depends on the geometry of the solid. Hence, this multiple illusion might be regarded as a double anamorphosis, that is, a structure that has two special directions along which meaningful shapes are perceived.

The third type of multiple depth illusions is evoked by depth-reversible figures such as the Necker cube, the Schroeder staircase and the Mach book (Gregory 1970, Shepard 1990, Robinson 1998, Unruh 2001). The objects represented by those figures have ambiguity in depth. They have typically two depth interpretations, which are reverse of each other. The two interpretations flip in the human brain even though the orientation of the figure is fixed. In the case of the Schroeder staircase, rotation of the figure upside down stimulates the flipping of the depth more easily. Indeed there is a class of line drawings that evokes depth reversal when the figures are rotated by 180 degrees around the line of sight. The line drawing obtained from figure 2a by removing the side walls of the slopes admits this type of depth reversal. However, the rotation of the figures 1a or 2a by 180 degrees around the line of sight does not evoke such reversal; indeed the side walls are not consistent with the depth reversal if we rotate the figure around the line of sight. In this sense the present illusion is different from them.

As for the multiple-silhouette sculptures, we succeeded in extending them to three-silhouette solids (Ohgami and Sugihara 2008). When we go around such a solid, three meaningful silhouettes appear one by one. In that case, the special view directions hat realize the silhouettes are not mutually orthogonal, and hence a face visible in one special view direction may also be visible in another special direction. The success of that extension of multiple-silhouette solids evokes the new question of whether there are any solids that generate three or more different impossible-motion illusions. Answering this question is the goal of one of our future project.

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