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The stone-base illusion

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ABSTRACT

A popular method used to construct the post structure in traditional Korean buildings is simply placing a stone base on the ground in the natural form and a wooden post on top of the stone base. Interestingly, an illusory visual completion often occurs at the joint where the stone base and the post join. Thus, even though the wooden post stands on the top surface of the stone base, observers tend to perceive the post as embedded in the stone base. In Experiment 1, photographs of real stone bases and wooden posts were presented, and the results showed that the more uneven the stone base was, the more the post was judged as embedded in the stone base. In Experiment 2, 3D graphic models with a similar size and color were presented, and the results again showed that the unevenness of the stone base influenced the perceptual embedment of the post. The results are discussed in relation to several potential hypotheses, including figural goodness, edge similarity, and physical knowledge.

1. Introduction

Only the surface regions of objects in the outside world that face toward the observer produce visual stimulation, while the other parts occluded by other objects or self-occluded parts do not. Nevertheless, we easily represent the occluded parts, surfaces, and volumes (Kellman & Shipley, 1991; van Lier & Gerbino, 2015). Traditionally, most studies investigating visual completion have been performed using line drawing stimuli depicted on 2D interfaces, such as monitors or paper. However, recently, a few investigators have started to explore visual completion using 3D real models, although these studies have not received much attention in the community (for example, Ekroll, Mertens, & Wagemans, 2018; Gagnier & Shipley, 2016; Gerbino & Zabai, 2003).

A representative example is the banana-and-brick illusion devised by Gerbino and Zabai (2003). In this illusion, a banana appears to be penetrating a brick. This illusion cannot easily be explained by good continuation or relatability, which was extensively tested in previous studies involving line drawing stimuli, because the good continuation of the brick is in conflict with the good continuation of the banana. Further, although observers have the general knowledge that softer objects, such as a banana, cannot penetrate harder objects, such as a brick, they still experience the illusion. Accordingly, these facts clearly suggest new research approaches that differs from those of line drawing stimuli, to understand the visual completion of real objects. Compared to line drawing stimuli, 3D real models are richer in their perceptual properties, such as color, shade and texture. Probably, it is possible that such perceptual richness may sensitively reveal the hidden factors underlying visual completion that are not easily tested with line drawing stimuli. For example, in the pencil-and-block illusion (Gerbino & Zabai, 2003), it has been suggested that when the pencil is placed on the top of the brick along the vertical axis, the impression of the pencil penetrating the brick is strong, while when the pencil is placed under the brick, the brick is strongly perceived to penetrate the pencil. Whether this gravity force effect can be uncovered by using a line drawing version of the illusion is unknown.

1.1. Visual completion in a post and base

This study focused on the visual completion occurring at the joint between a post and a base. Although this structure is physically determined in one way, it is perceptually undetermined because the proximal stimulus on the retina is by itself ambiguous. Thus, it is possible that the joint is perceived in alternative ways as follows: the post appears to penetrate the base or the post appears to be standing on the base without penetration. Arnheim (1977) suggested that a column or building that stood directly on the ground without the base appeared to penetrate the ground and continue (i.e., the bottom was visually completed under the ground). However, when the column or building stood on the base, the impression of penetration was weak since its shape was completed at the top of the base. In contrast, Gerbino and Zabai (2003) argued that the penetration impression of a cylindrical column could possibly occur depending on the direction of the standing post. Specifically, when a cylindrical column obliquely stands on a base, such as the Leaning Tower of Pisa, it may appear to penetrate the base. However, if the top and bottom surface of the cylindrical column is in parallel, it looks like it is standing on the base. Thus, it seems that the

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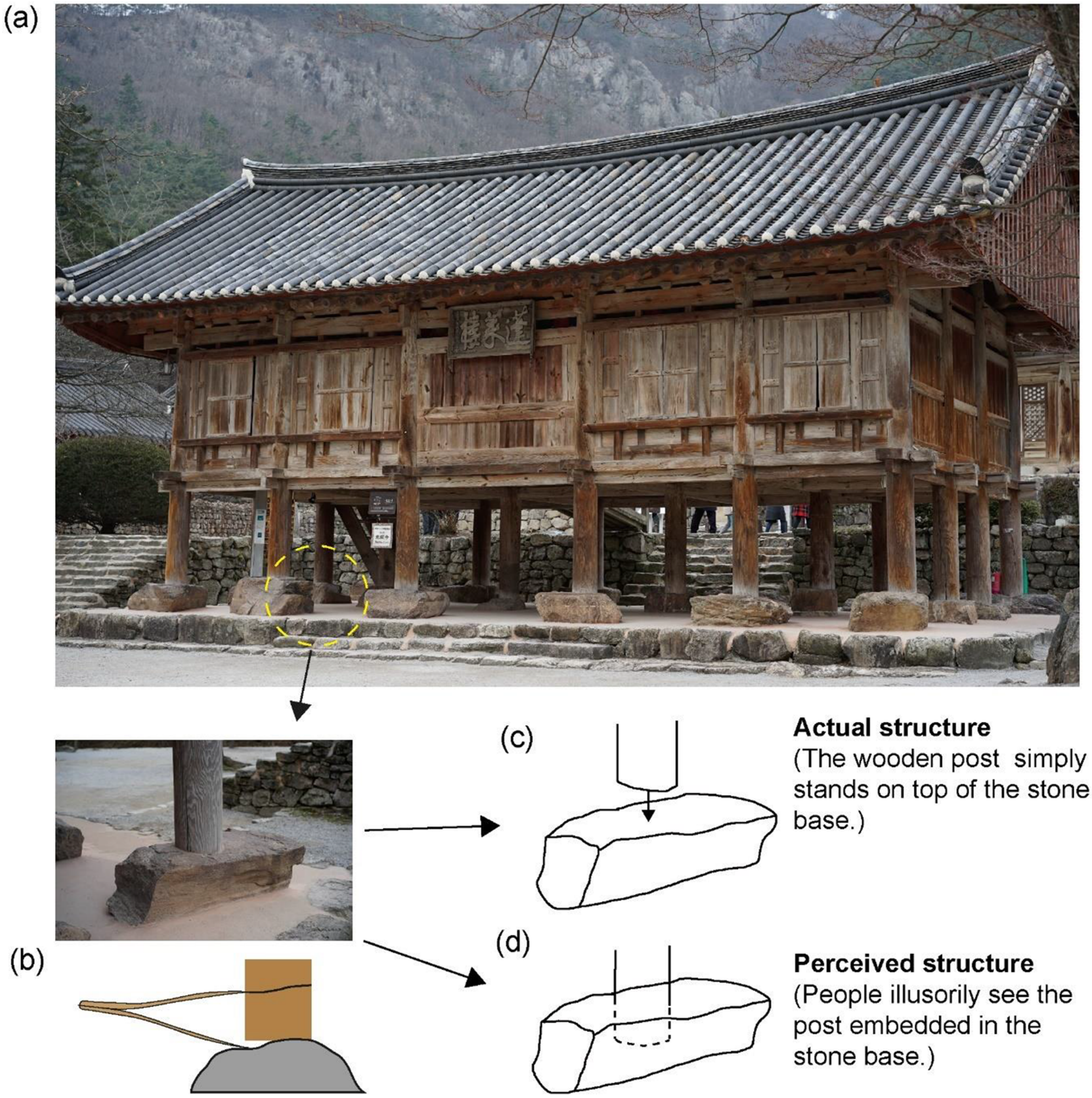

Fig. 1. Examples of post structures using the Grangee technique (Bonglae-lu, Naeso-sa Temple, Buan-gun, South Korea). (a) Wooden posts standing on top of stone bases. (b) Schematic illustration showing how to use a Grangee to copy the top edge of a stone base and draw it on a wooden post. (c) Actual depth relation between the post and the stone base. The post and stone base are joined along their edges. (d) Perceived depth relation. The bottom of the post may be illusorily perceived as embedded in the stone base.

visual system considers both the physical reality, such as gravity, and the figural features of the column, such as regularity or symmetry, to achieve visual completion.

Here, visual completion illusion occurring between a wooden post and a stone base is introduced. In this illusion, observers tend to see the wooden post penetrate (*hereafter embedded*) the stone base. This illusion is expected to shed light on and provide new insight into visual completion since the effect of the form of the base had not been tested to date.

1.2. Stone-base illusion

In traditional Korean buildings, the post structure comprises stone bases and wooden posts. Traditionally, there are two ways to build a wooden post on a stone base. The first approach is an artificial method in which carpenters cut stone bases to obtain regular shapes, such as circles or squares. The second method uses the stone base in its natural form. For example, Fig. 1a shows an affiliated building of a Buddhist temple that was constructed in 1,414 C.E. As shown in Fig. 1b, the stone base has an original uncut shape. The method of using a natural stone base originated in the Goguryeo Kingdom (37 B.C.E. – 668 C.E.) (Shin, 2003). Building a post structure in this way is unique to Korea, and this practice is difficult to find in other Asian countries (Yu, 1993). The artificial method is usually used in palace buildings or the principal buildings of temples, while the non-artificial method is used in private houses and the ancillary buildings of temples. It was likely that regular forms of stone bases were perceived as more beautiful and more valuable since they were symmetrical and simple.

Specifically, when adopting the non-artificial method, carpenters temporarily stand a wooden post on a stone base and copy and draw the curve of the stone base's top surface on the bottom of the wooden post. For this work, carpenters use a special tool called "그랭이" (Grangee, pronounced 'g-ræŋ-i'), which has a 'V' shape and is similar to a scriber in Western culture. As shown in Fig. 1b, the carpenter places the tip of the tool on the top of the stone base and places the other tip with ink on the side of the wooden post; then, the carpenter carefully moves the pieces together along the concave and convex top of the stone base. Thus, the edge curve of the stone base is copied onto the post, and the carpenter cuts the post's bottom along the inked line and stands the post on the stone base to fit them together (Fig. 1c). However, observers who do not know how the post structure was made often perceive the wooden post as embedded in the stone base (Fig. 1d). This illusion is simply an illusion of visual completion since the perceived joint differs from the actual joint.

Surprisingly, knowledge regarding this stone-base illusion in Korea is limited, even though this type of post structure has been widely found in daily life for at least several hundred years. The findings of psychological investigations indicate that it is extremely difficult for individuals to identify a visual illusion if they are unaware that they are viewing an illusion in advance (Girgus, Rock, & Egatz, 1977; Oh, 2011). Thus, why does the stone-base illusion occur and what conditions strength the illusion? The author's informal observations suggest that the more uneven or rough the top surface of the stone base, the more embedded the post appears. This hypothesis was tested in Experiments 1 and 2.

2. Experiment 1

2.1. Materials and methods

2.1.1. Participants

Thirty-one college students (17 females and 14 males, *mean age* = 20.7, *SD* = 1.8) participated in Experiment 1. All participants had normal or corrected-to-normal visual acuity and signed consent forms before participating in the study. The study was approved by the Seoul National University IRB.

2.1.2. Stimuli and procedures

Photographs of post structures freely taken from a distance approximately 1.5 *m* and the unconstrained perspective of tourists were prepared. Twenty-eight photographs were selected and presented in full color, and the size of each photograph was 25.3 × 15.5 *cm*. The participants estimated their impression of each photograph on a seven-point scale via a questionnaire. The questionnaire consisted of the following four sets: (1) how the post appears, i.e., whether the post appears to be standing or embedded in relation to the stone base (1: only standing; 7: highly embedded); (2) the unevenness of the top of the stone base (1: highly even, 7: highly uneven); (3) the relative size of the stone base compared to the post (1: not large; 7: very large); and (4) the hardness of the stone base (1: very soft; 7: very hard). Because visual estimations are relative across photographs, all 28 photographs in each set were presented simultaneously on one slide for the participants to have a subjective standard before beginning each set of questionnaires. In the main experiment, in total, 112 photographs (28 × 4) were individually presented in a random order. The stimuli were presented in high resolution (1920 × 1080, 119 *Hz*) on a 24-inch monitor (ViewSonic, XG2401), and the viewing distance was approximately 55 *cm*.

2.1.3. Results and discussion

As shown in Fig. 2a, the average value of the perception that the post was embedded was 3.8 (SD = 0.95) and ranged from 2.54 (SD = 1.85) to 5.64 (SD = 1.91). This result indicates that the stone-base illusion is an objective phenomenon. Subsequently, the perceived unevenness, relative size, and hardness of the stone bases were examined in relation to the perceived embedment. Fig. 2b-d show the correlations between the sizes of these three factors and the illusion. A simple linear regression was calculated to predict the perceived embedment based on the perceived unevenness. A significant correlation was found ($F(1, 26) = 15.26$, $p = 0.001$, $r^2 = 0.37$). Additionally, a significant correlation was found between the perceived embedment and the relative size ($F(1, 26) = 15.26$, $p = 0.001$, $r^2 = 0.37$). These results are consistent with previous findings (Gerbino & Zabai, 2003). Finally, a non-significant correlation was found between the perceived embedment and the hardness of stone bases ($F(1, 26) = 1.73$, $p = 0.199$, $r^2 = 0.062$), failing to support the effect of material on the perception of joints (Vrins, de Wit, & van Lier, 2009).

A multiple regression was performed to assess the relative contributions of the 3 factors to the perceived embedment. All 3 factors accounted for 54% ($r^2 = 0.54$) of the variance of the perceived embedment ($F(1, 26) = 9.396$, $p = 0.001$). However, of these three factors, only the correlation between unevenness and the illusion was significant after controlling for the other 2 factors (partial correlation = 0.454, $t(3) = 3.28$, $p = 0.003$), i.e., relative size (partial correlation = 0.163, $t(3) = 1.176$, $p = 0.251$) and hardness (partial correlation = 0.116, $t(3) = 0.836$, $p = 0.003$). Taken together, these results indicate that the unevenness of the stone base plays the most important role in the illusion.

3. Experiment 2

The stimuli used in Experiment 1 were not controlled in terms of the size, color or surface texture of the posts, and the stone bases varied. In Experiment 2, 3D models were used, and only the unevenness of the top surface of the stone base was manipulated by controlling the other visual properties (i.e., the size, color, and surface texture of the base and the post were similar).

3.1. Materials and methods

3.1.1. Participants

Thirty-two college students (10 females and 22 males, *mean age* = 21.05, *SD* = 2.37) participated in Experiment 2. All participants had normal or corrected-to-normal visual acuity and signed consent forms before participating in the study. The study was approved by the Seoul National University IRB.

3.1.2. Stimuli and procedures

The methodology was the same as that applied in Experiment 1, except for the stimuli. There were 5 basic models differing in the level of the unevenness of the top surface of the stone base. By randomly turning the basic models' orientations in the horizontal plane up to 360°, 4 other 3D models were created for each unevenness condition. Thus, in total, there were 25 3D models (5 unevenness categories × 5 orientations). The size of the basic model was 18 × 11 *cm*, and the viewing distance was approximately 55 *cm*. The stone base was presented in gray color, and the post was presented in brown color. All 3D models were created using Paint 3D software (Microsoft Co.).

The unevenness of the top surface of the stone base was defined as the difference in the distance between the lowest and highest points tangent to the post's bottom surface. At the unevenness level of 0, the top of the stone base was completely flat. The other levels differed by ¼, 2/4, ¾, and 4/4 from the lowest point and the highest point based on the width of the post (see Fig. 3a top). Observation viewpoints were prepared by randomly rotating along the horizontal plane with respect to the sides, and the top of the post was presented at an inclination of approximately 10° toward the participant to simulate the observation situation in which tourists see the actual post in the temple (Fig. 3a below). In this view, the upper part of the post was not truncated by the frame, so that the horizontal flat surface of the top of the post (i.e., the oval shape) was slightly visible (see Supplementary Material 2 to see the 3D models in more detail). However, the oval shape was exactly the same across all the stimuli, so that it should not be a critical factor for any difference in the perceived embodiment occurring across the five depth level conditions.

There were 5 variations in each experimental condition, resulting in

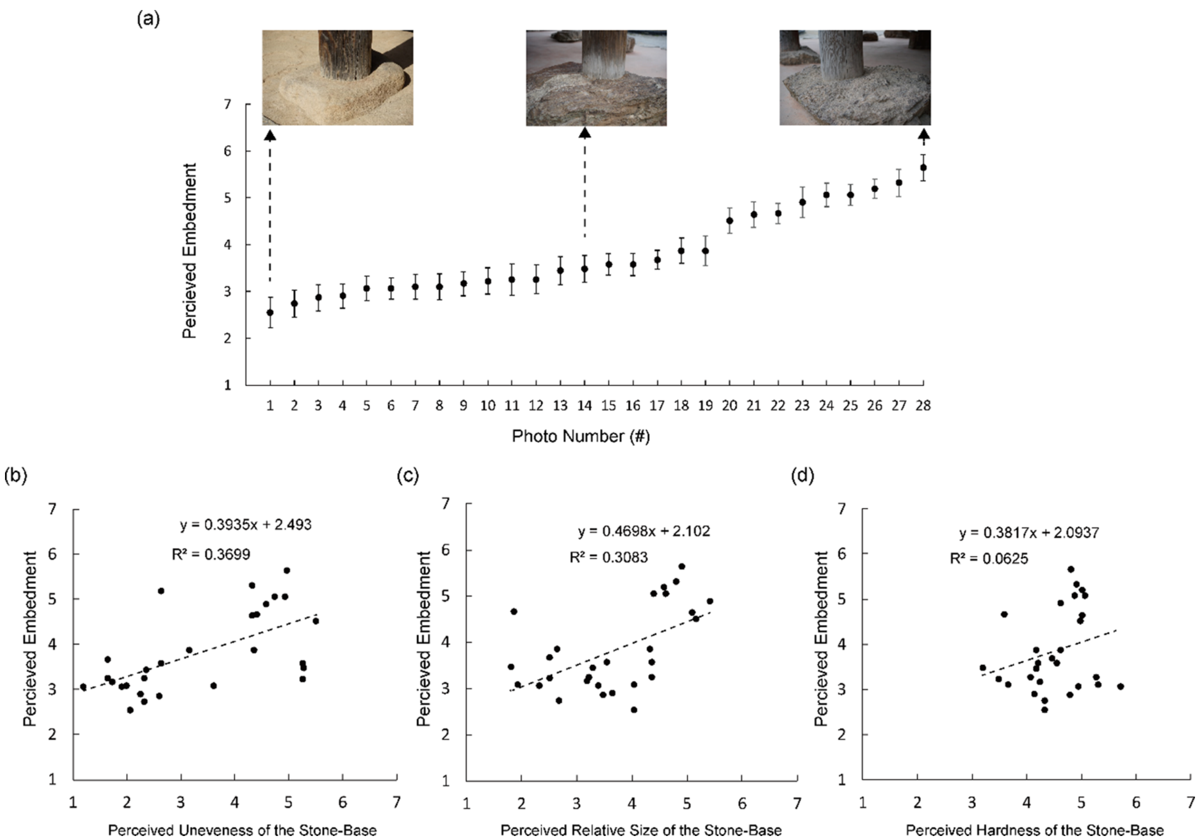

Fig. 2. The results of Experiment 1. (a) For each of the 28 photographs, the estimated values of how much the post seemed to be embedded in the stone base are shown from the lowest to the highest. The error bars indicate ± 1 S.E.M. (see Supplementary Material 1 for all cases' estimation results). Correlations between the perceived embedment and the following 3 characteristic impressions: (b) the unevenness of the top surface of the stone base, (c) the relative size of the stone base, and (d) the hardness of the stone base.

a total of 25 models (5 × 5). The experimental procedure was the same as that performed in Experiment 1, but the participants only judged the degree to which the post appeared embedded and the unevenness of the top of the stone base. It is expected that the higher the depth level, the greater the perception that the posts are embedded.

3.1.3. Results and discussion

The average value of the perception that the post was embedded was 4.8 (SD = 1.70). As shown in Fig. 3b, clearly, the perceived embedment increased as the depth level increased. However, the relation between the two variables seems to be non-linear rather than linear. The perceived embedment is sharply increased up to a depth level of 0.25, and then the tendency become weaker. This may suggest that the visual system is sensitive to small amounts of the unevenness of the base to see the embedment of the post.

A simple regression was calculated to predict the perceived

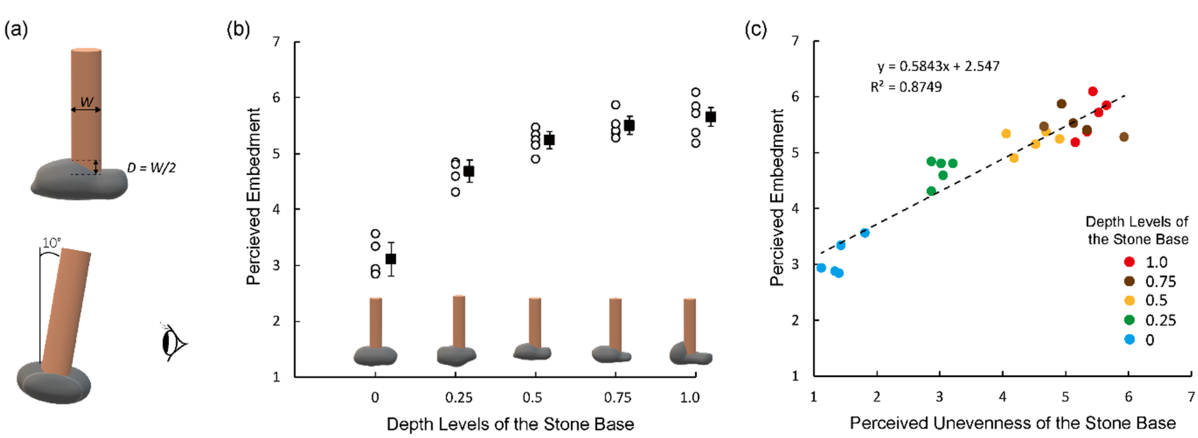

Fig. 3. The stimuli and results of Experiment 2. (a) Top: The unevenness of the top surface of the base was determined based on the width of the post. This example shows a 0.5 level of depth. Below: The stimulus was presented leaning toward the observers at an angle of 10° from the vertical axis. (b) The results of the perceived embedment of five categories of posts according to the depth level. The open circles are the average values of the perceived embedment of five orientation conditions for each of the five depth categories. The filled squares are the average values of the depth level, and the error bars indicate ± 1 S.E.M. The in-box 3D models are representative examples of each category. (c) The correlation between the perceived flatness and perceived embedding (See Supplementary Material 2 for all cases' estimation results).

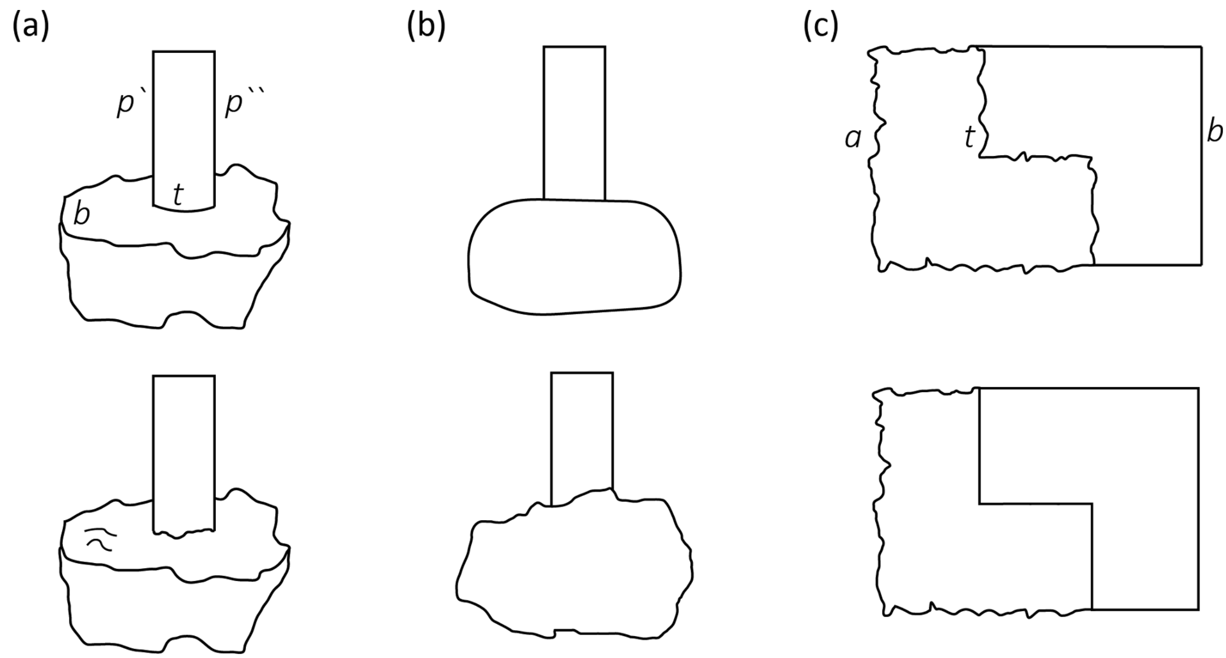

Fig. 4. Edge-edge similarity and grouping. (a) Tangent edge *t* is more likely to be grouped with the post's edges *p*' and *p*" in the top figure than the base's edge *b* in the bottom figure due to its figural similarity. (b) A cross-section view of a post and a base. (c) Figure-ground organization by edge-edge similarity. Tangent edge *t* is more likely to be grouped with edge *a* in the top figure than edge *b* in the bottom figure due to its figural similarity with the neighboring edges. As a result, the left region is likely to be perceived as the figure in the top figure, while it is likely to be perceived as the ground in the bottom figure.

embedment based on the depth levels of the top surfaces of the stone bases. A significant correlation was found ($F(1, 3) = 13.41$, $p = 0.035$, $r^2 = 0.81$). Additionally, as shown in Fig. 3c, the perceived unevenness and perceived embedment were highly correlated ($r(23) = 0.94$, $p < 0.001$). A simple regression was calculated to predict the perceived embedment based on the depth levels of the top surfaces of the stone bases. A significant correlation was found ($F(1, 3) = 53.72$, $p = 0.005$, $r^2 = 0.87$). These results indicate that the unevenness of the base independently influences the perceived embedment of the post.

4. General discussion

In this study, a real example of visual completion illusion was reported. In this illusion, the observers see a post embedded in a stone base, and the unevenness of the top surface of the stone base was tested as a major factor responsible for the illusion. Several different accounts may explain this illusion.

4.1. Good continuation and symmetry[1]

It has been extensively shown that figural simplicity or goodness is among the strongest factors underlying visual completion. According to this principle, the occluded part of a figure is completed to obtain the simplest form together with the remaining non-occluded, visible parts (Boselie, 1994; van Lier & Wagemans, 1999). According to this hypothesis, good continuation and figural symmetry are the most crucial characteristics responsible for the simplicity of a form. This idea may be adapted to account for the effect of surface unevenness found in the present study. In the present study, the tangent surfaces or edges between the stone and the post covaried such that when the top of the stone base was even, the bottom of the post was also even and *vice versa*. According to the simplicity principle, when the tangent surface or edge is even, the post is likely to be perceived as standing on top rather than embedded in the base since the top of the stone base is in good continuation, and the post is symmetric and simple in this interpretation. In contrast, when the tangent surface or edge is uneven, the post is likely to be perceived as embedded because of the perceptual system's tendency to complete the visible parts of the post in a way that yields a symmetrical interpretation. This interpretation based on surface parallelism is largely commensurate with the suggestion of Gerbino and Zabai (2003, Figs. 7 and 8). Taken together, according to this account, the Gestalt principle of the figural regularities of the stone base and the post plays a major role in the illusion.

4.2. Edge similarity

In the present study, the surfaces and edges of the stone bases varied from even to uneven, while the surfaces and edges of the wooden posts were generally smooth. This difference may be another factor responsible for the stone-base illusion. Specifically, as shown in Fig. 4a, the post structures can be simplified in line drawings. The tangent edge *t* between the post and the stone base is perceptually undetermined, i.e., it is ambiguous whether it belongs to the post, to the base, or to both. Here, we can consider the similarity principle in Gestalt psychology (Koffka, 1935; Wertheimer, 1923). When the top of the stone base is uneven or curved, edge *t* is likely to also be uneven or curved; accordingly, edge *t* is more likely to be grouped with the base's unsmooth edges than the post's smooth edges since these edges are figurally more similar. As a result, the post is likely to be perceived as embedded in the base. In contrast, when the top of the base is even and flat, edge *t* is also formed smoothly; thus, edge *t* is unlikely to be grouped with the post's edges since it is figurally similar to both the post's edges and the stone base's edges. Thus, the impression of the perceptual embedment of the post is weaker, and the bottom of the post is more likely to be perceived as jointly lying on the top of the stone base. These interpretations are consistent with the results of Experiments 1 and 2. Similarly, this edge-edge similarity is clearer when the post structure is displayed in a cross-section view (Fig. 4b) and explains why the post appears more embedded in the base in the bottom figure than the top figure. Furthermore, as shown in Fig. 4c, this edge-edge similarity principle may be extended to explain the process of figure-ground assignment known to

[1] This suggestion was noted by an anonymous reviewer.

be essential for depth organization (Peterson, 2015). In previous studies, the similarity between edges and regions across patterns has been shown to be effective (Palmer & Brooks, 2008). However, the effect of the similarity across edges has rarely received attention in the vision sciences.

Using line drawing stimuli, van Lier (1999) suggested that the principle of 'fuzzy regularities' is responsible for visual completion. For example, when a shape with irregular fuzzy edges, such as a chestnut bur, is partially occluded by a rectangle, the occluded part of the fuzzy shape is completed in a way reflecting the fuzziness of the visible part of the fuzzy shape. This fuzzy completion principle might principally be similar to the edge-edge similarity principle in this discussion.

Most objects worldwide, including stones, have unique characteristics in terms of the unevenness of their surface or margins. For example, many artificial objects, such as cars, have smooth surfaces; trees are differentiated by the waviness of their leaf margins, and animals have different serrations on their tooth edges. Similarly, when objects appear collectively, their edges have unique shapes, such as the roundness of clouds and the irregular spikiness of mountain ridge lines. Most likely, these unique shapes of edges may play some important role in visual completion in daily life. Additionally, this hypothesis is applicable to other types of edge properties, such as color, spatial frequency, density, and motion, as found in a study investigating the effect of edge-region grouping on figure-ground organization (Palmer & Brooks, 2008).

4.3. Physical knowledge

It has been suggested that physical reality is internalized in the visual system such that physically possible events are more sensitively favored by the visual system than physically impossible events. For example, when a rectangle or a human arm's motion was displayed in an apparent motion paradigm, the object was more likely to be observed to move along a physically possible pathway than a physically impossible pathway (Shepard, 1984; Shiffrar & Freyd, 1990). This hypothesis may possibly explain the stone-base illusion. For example, we know very well that a tumbler can stand on a table on its own since its bottom is flat, while a pencil cannot vertically stand on a table on its own since its tip is too small to balance its weight. Similarly, this physical knowledge could be involved in the perception of the joint of a wooden post and a stone base. Thus, if the base's top and the post's bottom are both even and flat, the post can stand on the base on its own, bit if the base's top is uneven, it is difficult for the post to stand on the base on its own. Accordingly, observers are more likely to see the post embedded in the base.

These explanations are largely consistent with Gerbino and Zabai (2003)'s findings implying that physical knowledge related to gravity influences the visual completion occurring at the joint between two wooden rectangular bars.

5. Conclusions

In the present study, a real example of an illusory visual completion in post structures was introduced. It was shown that the perceived unevenness and relative size of the stone base are positively related to the illusion, and some potential explanatory factors are discussed that probably influence the stone-base illusion interactively. Specifically, grouping based on edge similarity was highlighted. Future work needs to determine in more detail how this factor interacts with other factors to achieve visual completion.

CRediT authorship contribution statement

Songjoo Oh: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.visres.2020.04.001.

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Supplementary Material 1: Stimuli and Results in Experiment 1

#1

Mean = 2.55 (*SD* = 1.71)

#2

Mean = 2.74 (*SD* = 1.71)

#3

Mean = 2.87 (*SD* = 1.54)

#4

Mean = 2.90 (*SD* = 1.92)

#5

Mean = 3.06 (*SD* = 2.16)

#6

Mean = 3.06 (*SD* = 1.90)

#7

Mean = 3.10 (*SD* = 1.58)

#8

Mean = 3.10 (*SD* = 1.58)

#9

Mean = 3.17 (*SD* = 1.70)

#10

Mean = 3.23 (*SD* = 1.75)

#11

Mean = 3.26 (*SD* = 1.84)

#12

Mean = 3.26 (*SD* = 1.91)

#13

Mean = 3.45 (*SD* = 1.91)

#14

Mean = 3.48 (*SD* = 1.63)

#15

Mean = 3.58 (*SD* = 1.84)

#16

Mean = 3.58 (*SD* = 1.61)

#17

Mean = 3.68 (*SD* = 2.10)

#18

Mean = 3.87 (*SD* = 1.71)

#19

Mean = 3.87 (*SD* = 1.80)

#20

Mean = 4.52 (*SD* = 1.65)

#21

Mean = 4.65 (*SD* = 1.82)

#22

Mean = 4.67 (*SD* = 1.79)

#23

Mean = 4.90 (*SD* = 1.85)

#24

Mean = 5.06 (*SD* = 1.44

#25

Mean = 5.06 (*SD* = 1.73)

#26

Mean = 5.19 (*SD* = 1.51)

#27

Mean = 5.32 (*SD* = 1.74)

#28

Mean = 5.65 (*SD* = 1.54)

Supplementary Material 2: Stimuli and Results in Experiment 2