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Self and world: large scale installations at science museums

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Abstract

This paper describes three examples of illusion installation in a science museum environment from the author's collaboration with the artist and architect. The installations amplify the illusory effects, such asvection (visually-induced sensation of self motion) and motion-induced blindness, to emphasize that perception is not just to obtain structure and features of objects, but rather to grasp the dynamic relationship between the self and the world. Scaling up the size and utilizing the live human body turned out to be keys for installations with higher emotional impact.

Keywords

Visual illusion;vection; motion-induced blindness; science museum

INTRODUCTION

Art and science meet at illusions

Traditionally, artists and visual scientists both dealt with perceptual experience, but usually from different viewpoints. Artists were mainly interested in the representational content and emotional effects of visual perception, whereas scientists were interested more in the neural mechanisms or mental processes underlying perception. Recently, however, there is a noticeable overlap between their approaches, and as a result they interact and collaborate more.

Retrospectively, several factors seem to have contributed to such changes. First, scientific studies of visual perception in psychophysics, neuroscience, and cognitive sciences have advanced, and the results have been disseminated outside the scientific community. Under such influences, artists have become more experimental and analytical, with increased awareness about mechanisms underlying perception. Second, scientists' interests used to be restricted to quantitative and objective analyses of the relationship between stimulus and behavior, partly because of influence by the behaviorism movement within the field of psychology. Many now express interest in conscious and subjective experience of perception, perhaps partly owing to a gradual recovery from the behaviorist's taboos, the development of cognitive science approaches to internal processes, and noninvasive human brain-imaging techniques, but more importantly to enriched phenomenology of perception way beyond what used to be studied scientifically.

Such trends should be welcomed for a strong and obvious reason, i.e. science education, and outreach activities in particular. Perceptual illusions provide ample opportunities for such efforts, mainly owing to the vigorous impact of the perceptual experience. The current paper

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aims to contribute to such trends by describing the author's own creation of visual illusion demonstrations at science museum in collaboration with an artist.

To be more specific, this paper describes three pieces of large-scale installations in a science museum, which have a common theme: *perception is ambient and proprioceptive* (Gibson, 1950, 1979). Through direct experience, the observers realize that visual perception is not just for recognizing objects in the external world, but also to grasp the spatial relationship of self to the world. I will explain what type of mechanical setups can be built to demonstrate perceptual illusions such as vection (or visually-induced sensation of self motion) and switching of the spatial frame of reference.

The first piece utilizes a motor-driven rotation of a physical structure to generate dynamic optical stimulation in the observer's visual field. As a result, the audience unanimously experiences a robust effect of vection. The second exhibition carries a similar message (i.e. perception is ambient and proprioceptive), except that the setup is 'minimal' in the sense that it is a solid stable structure without anything physically or optically moving. It demonstrates dynamical changes in the spatial frame of reference as a result of interaction between the tilted structure and the observer's own posture. This turned out to yield not only bistable, but rather intriguing tristable percepts which were dependent on the observer's position and posture, and which may deserve some detailed qualitative analysis for its scientific merits. The last exhibition piece employs a rotating mirror ball to demonstrate vection, a similar effect to the first piece, except that it creates the effect without physically rotating a large structure, but just by generating optical flows. Moreover, it turned out to be very effective for demonstrating yet another type of stunning perceptual illusion, namely, MIB (Motion-Induced Blindness) on a large scale.

The core visual effects demonstrated in these examples are already known in the literature, yet these installations eloquently demonstrate that scientific finding is one thing, and demonstrating it to a general audience is another. There is much room for improvement in terms of technique, device, design, scale, materials etc. for artists and educators to create demonstrations that have higher impacts to non-expert audiences, including children. Such efforts do not just make the same scientific finding more impressive, but also qualitatively change the direct perceptual experience. Through these examples, similarities and differences between demonstrations for vision science and those for arts/education will hopefully be revealed.

(1) ROTATING CYLINDER (see Note 1)

As shown in Figs 1A and 1B, there is a large cylinder (2.35 m diameter) with its axis horizontal being rotated by a motor (1.5–2.0 rpm). Inside the cylinder, there is a stationary and horizontal platform upon which the observer stands and stares at the center of the cylinder's rotating base. The inner surfaces of the cylinder were striped in a spiral, whose spatial parameters were optimized for the effect. Note that the observer's entire visual field is covered by this rotating spiral. The cylinder is rotating in one direction (say, clockwise) for a while, stops, and then rotates again in the opposite direction (counterclockwise). This is only meant to let the observer notice the difference in perception between the rotating and the static conditions, and that the effect occurs symmetrically in both directions of rotation.

The perceptual phenomenon is very robust and unanimous across naïve and non-naïve observers: during the first 5–8 s, the percept faithfully reflects what is physically happening,

¹This installation was originally created by collaboration between the author and artist Noriyuki Tanaka in 1996, and has been, and still is, shown as a part of permanent exhibition titled 'FOREST' at Science Museum Tokyo, Kitanomaru Koen, Tokyo.

i.e. the observer feels upright and still while the cylinder rotates in one direction (say, clockwise). After this initial period however, the perceived spatial frame of reference suddenly switches. Now the entire cylinder appears to be nearly stopped, while both body of the observer and the stationary platform is perceived to start rotating in the opposite direction (counterclockwise, in this case). This effect is not limited to perceptual judgment, but also can be reflected in behavior. When the observers stand on one leg, they lose their balance to one side immediately. When the cylinder physically stops and starts rotating again in the reversed direction, the same experience occurs but in the reversed direction. The cylinder again appears to be stopped and the observers feel that they are rotating in the direction opposite to that of the cylinder. Due to the spiral configuration of the inner pattern, analogous effects are experienced though somewhat weaker in the forward-backward direction. The observer feels in the initial 5–8 s that the cylinder is coming closer. When the illusion occurs, however, the observer feels to move towards the bottom of the cylinder, which now appears stationary.

One may interpret this phenomenon as a variation ofvection, or visually induced sensation of self motion (Fisher and Kornmueller, 1930). In this category of phenomena, a proprioceptive, or vestibular-like sensation of self motion is induced by a large-field optical flow without vestibular stimulation. In the present example, the optical flow is induced by physical rotation of surfaces surrounding the observer.

What is noticeable in the current example, however, is that the relative rotating motion between the cylinder and the observer is always perceived constantly. The stationary frame of reference is ambiguous, and the percept switches only with this regard. The switch of the frame of reference is actually triggered by a delayed onset ofvection, and this delayed switching may be due to fatigue of motion detectors that signal a particular direction of rotation (the human homologue of MST may be activated by global patterns of dynamic visual stimuli such as rotation and expansion/shrinkage: Smith *et al.*, 2006). Theoretically, this may also imply at least two levels of motion processing: one to detect and to measure relative motion between the observer and the environment; and the other to determine which is stationary and which is actually moving.

As some readers may have noticed, similar demonstrations have been installed in some psychophysics laboratories as well as amusement parks (see Note 2). In the latter, the observers are typically on a train or a vehicle running into a tunnel, and the tunnel itself is physically rotating around the vehicle, resulting in a similar effect, i.e. the vehicle with the observers appear to rotate in the spiral trajectory. Although the cylinder installation is similar, note that it induces qualitatively the same vigorous effect in a relatively small space without physically stimulating the vestibular system. Moreover, since the observers are allowed to look at the setup before they step up on the platform, they know with confidence that it is physically fixed as the horizontal. This point is not trivial from a scientific viewpoint because it demonstrates convincingly that perception sometimes *betrays* the observer's own knowledge no matter how convincing the knowledge is (Kanizsa, 1979; Koffka, 1935). Also the vigor and the emotional effects of this installation, which may be critical from an educator's or artist's viewpoint, come from the exact fact that the illusion of self rotation occurs against the obvious fact that the body and the platform are stationary.

The cylinder physically rotates in order to create a rotation of stimuli (the stripes), which occupies the entire visual field of the observer. This coverage of the entire visual field with

²Ian Howard's laboratory at York University is well known for a long list of publications with such an experimental setup, where the entire visual field surrounding the observer can rotate, and the observer's posture can be adjusted to study interactions among visual cues, vestibular stimulation, and objects' own orientation. As for the example in a science museum, Universal Studios (Universal City, California) has a train moving through a tunnel that is rotating around it for a similar effect.

stimulation seemed to be necessary in relation to the main theme of demonstration (i.e. perception is ambient and proprioceptive). Yet, physical rotation of such a big and heavy structure was problematic from more practical viewpoints (say, cost, maintenance in a long term, safety, etc.). The two pieces that will be described in the subsequent sections overcome this problem in two different ways. Moreover, each came with a surprising bonus in either a scientific or artistic sense, as will be mentioned.

The moving display in this, as well as the Mirror ball installation (which will be described in Section (3)), may cause motion sickness in some individuals. The observers should be given a warning before they try.

(2) TILTED ROOM (see Note 3)

The previous installation demonstrates dynamic perception of the self–world relationship *via*vection and the switching of the spatial frame of reference. The current piece aims to demonstrate related effects of visual frame of reference and the observer's posture, but in a much more naturalistic and static environment.

In Fig. 2A the entire structure of a room is tilted except for the floor, which is physically horizontal (it may be easier for the readers to imagine as follows: lift an ordinary house or room, rotate it in the air and then dump it on the ground such that the ground remains as flat and horizontal). The angle of the tilt may be within the range of 40–50 deg. The room size can be anything larger than the minimum space where 2–3 people can lie in the supine position (although the particular installation in the photograph can accommodate 5–6 people). The entrance to the room has to be low enough so that it will not allow the outside of the room to serve as a visible frame of reference for the observer. It is even more effective if the interior of the room, such as shelves, frames of paintings, pillars, etc. are orthogonal to the tilted frame of reference rather than the physical horizontal and vertical.

The mutistable illusion is vigorous. When the observer stands or sits in the upright position, nothing happens. Perception of the surrounding space is as it is physically, i.e. the floor on which the observer lies is horizontal, and all the other surfaces of the room including the walls and the ceiling appear to tilt veridically (Fig. 2B(a)). When the observer lies flat on the floor, however, the percept changes dramatically (Fig. 2B(c) and (d); Fig. 2C). Now the entire room appears upright and normal, the surface immediately above the observer appears as a horizontal ceiling. Meanwhile, the floor appears to tilt and indeed, the observer feels that s/he is about to slip down on a steep slope. This perceptual switch of frame of reference is instantly noticeable, and the orientation of everything inside the room is judged in accordance with this new frame of reference (defined by the walls and the ceiling), rather than the physical frame. Thus, a surface of water in a glass, a pendulum, a person standing on one foot, a balloon constrained by a string, and a balancing toy all appear to tilt. A ball on a rail (which is slightly tilted with regard to the physical coordinate) may appear to spontaneously roll up, etc.

Similar effects have been reported by Ian Howard and his group (Howard and Childerson, 1994; Howard and Hu, 2001; Howard *et al.*, 2005). In particular, the ‘visual righting effect’ (Howard *et al.*, 2005) seems to be similar, except that we demonstrate the effect in real physical space, instead of appealing to a mirror or any other optical device. Matin and his collaborators have published an extended series of experiments to investigate effects of visual cues and the observer's posture on perceptual judgment about ‘eye level’ or ‘visual horizontal’

³This installation was originally created by collaboration between the author and artist Noriyuki Tanaka in 1996, and has been, and still is, shown as a part of permanent exhibition titled ‘FOREST’ at the Science Museum Tokyo, Kitanomaru Koen, Tokyo. Some variations are now shown at Kansas Science City (Kansas City, Missouri) and at Toyama Science & Culture Center. Meanwhile, a portable version of it was exhibited in the VSS ‘demo night’ in May 2005.

in the pitch direction (Hudson *et al.*, 2000; Matin and Li, 1992, 1995). Their manipulation has mainly focused on limited visual cues (such as bars) and the effects reported been relatively minor. The effect demonstrated here is similar, but the effect is much larger (40–50 deg.) and robust. Moreover, unlike their effect, the phenomenology has a switching, or all-or-nothing quality: indeed, it is extremely rare for the observer to perceive the orientation of the room as somewhere between the physical tilt and the up-right orientation.

Among other demonstrations of ‘tilted room’, the current demonstration is distinctively unique particularly in one aspect. Unlike typical laboratory setups, we allow observers to freely change their postures in a very natural living room type of environment, to demonstrate how critical is the posture as a factor in experiencing the illusion. Indeed in the supine position, the room typically appears to be precisely upright (not just towards that direction), and it is again very difficult to ‘correct’ the percept by knowledge.

This freedom of posture for the observer makes this demonstration particularly suitable for a museum type of setting. By the same token, the freedom of posture allows us to obtain some theoretically critical observations. First, the effect occurs only when the observer lies along the direction of the tilt, that is, only when the observer's spinal axis is perpendicular to the axis of rotation of the room (Fig. 2D, posture 1). When the observer lies along the axis of room rotation, for example, the percept is veridical and very stable (Fig. 2D, posture 2). Second, when the supine observer lies in the direction of room tilt, and slowly raises their head and upper body towards an upright posture, the perceptual frame of reference suddenly shifts from the illusory one to the veridical one at one point. Thus, the perceptual switch in the frame of reference is immediate and decisive (non-linear). Third and most intriguingly, there is a third percept possible when the observer is in the supine position in the direction of rotation, but with the head on the opposite side with regard to the direction of the room rotation (Fig. 2B (c)). Thus, this installation effectively demonstrates tristable, not just bistable, perception that is dependent on the observer's posture (Fig. 2B).

Why is the posture so critical, and why does the illusion occur only in the supine posture? The orientation of self with regard to the environment may be affected by several distinctive factors, such as visual frame, the visual object's own orientation (axes), vestibular and proprioceptive inputs, etc. (Howard and Templeton, 1980). Furthermore, (in)visibility of the floor and the angular relationship between it and the body axis, and effectiveness of gravity cue may be additional factors involved in the underlying perceptual integration process in this case.

Thousands of people have experienced this in several science museums (see Note 3), and very few reported a lack of such illusion to the author's knowledge. Thus, this installation induces a most robust illusion related to spatial frame of reference in a minimal static setup.

(3) MIRROR BALL (see Note 4)

A mirror ball, such as that which can often be found in a discotheque, is installed with light sources on a ceiling of a room (we used an ellipsoid-shaped, rather than the typical spherical mirror ball for an ideal effect, but a spherical one will work as well; see Fig. 3A and 3B). The mirror ball rotates by an electric servo motor whose rotation speed must be adjusted at a relatively low and stable level (0.7 ~ 1.1 m/s velocity in the projection onto the front wall). It is preferable if one can reverse the direction of rotation *via* a switch box, though this is not mandatory. The light source can be any type of spotlight targetting the mirror ball. The number of light sources that is necessary for the demonstration depends on the resulting density of light

⁴This installation was originally created by the author and artist Noriyuki Tanaka in 2004, and is still in Shizuoka Children's Science Museum ‘RU·KU·RU’ (Shizuoka City, Shizuoka, Japan). A portable version of it was exhibited in the VSS ‘demo night’ in May 2004.

blobs drifting on the room walls (we typically use two light sources). It has to be sufficiently dense for a better effect, although our preliminary observations suggested that it would work for a wide range of blob density. One potential complication may stem from shadows of the observers themselves, particularly if they are projected large on the front wall. For this reason, it may be better to install all the light sources on the ceiling.

This simple set-up with a mirror ball effectively demonstrates two different perceptual illusions. The first effect isvection (Fisher and Kornmüller, 1930). To experience this, the observer stands still in the central area on the floor, and fixates at the fixation marker on the front wall. Typically within 10–15 s the observers feel themselves to start rotating backward (if the optical flow is downward), or rotating forward (if upward). More strikingly, the entire room appears to rotate as if it were yoked with the observer. The effect is very similar to that observed in the cylinder exhibition (see the first section), except that: (a) the rotation and the inducedvection are around a different axis (in pitch direction this time); (b) when concentrating on the optical flow in the front wall, the observer often has a sensation of their own body not just rotating with the room, but also sinking down (floating up) when the optical flow is upwards (downwards); and (c) at a practical level, the optical flow is created by reflected light, thus nothing heavy or large is physically rotating around the observer(s), unlike the case of the cylinder. In comparison with our second example, the tilted room, they are similar in that both demonstrate bistability and switching between two frames of reference, particularly in the pitch direction. The main difference is that the tilted room demonstration relies on a combination between a static structure and changes of the observer's posture, whereas in the current demonstration there is a dynamic optical flow with a stationary observer.

The second illusion that may be demonstrated with the same setup is the motion induced blindness (MIB). In Bonnef and his colleagues' original report (2001), a stationary target surrounded by moving dots disappears. There are a couple of critical questions that led to the current demonstration. First, how large of a target can be perceptually erased? Second, Can the target be a live human body? Here, we are successful in erasing the entire human body. To experience it, the observer needs to have somebody standing very still along the front wall. The effect may be stronger in the periphery, but it works in the parafovea or even the fovea as well. The observer should fixate at the marker in the middle of the front wall. Typically within 15–20 s, the person's body starts fading and disappears partly or entirely. Even when the person is speaking aloud, that will not prevent them from disappearing. Often, their shadow remains on the wall or the floor while the body is mostly invisible. When the person starts moving his head or arm, only that part of the body reappears.

Since the installation is based on relatively simple mechanics and optics, yet efficiently induces two high-impact illusory effects, it is particularly suitable for out-reach activity or a science-museum type of context. There may be a couple of lessons one can take from the success of this particular installation, with regard to how visual psychophysics can be applied to science and education. The impact of direct perceptual experience may be greatly enhanced by scaling up in size (the room itself appears to rotate with the observer), and by utilizing the human body as the target of the effect (live human bodies can disappear).

CONCLUDING REMARKS

I have described three installation pieces centered on the same theme and similar perceptual illusions. One thing that is obvious from these examples would be the difference in objectives between scientists and artists. Visual scientists aim to discover a new effect or illusion, which does have general implications to the functions of visual perception. Once they have found such effects, they are interested in how the effect behaves in the stimulus parameter space to obtain insight into the neural mechanisms. Artists and educators tend not to pay too much

attention to the scientific merit of the effect, but more to tuning the perceptual experience for higher emotional impact and greater stimulation for thinking. Size scaling and involvement of the human body are factors in such manipulations, as mentioned earlier.

Regardless of such differences in objectives, these examples also show that knowledge and analytic skills of visual scientists may amplify creative possibilities in artistic and educational domains, particularly when applied appropriately to a common theme. More importantly, the benefit is not one way. Scientists, both those who create installations and those who just visit to experience, often obtain new insights into good scientific questions and new experiments. For example, some of the observations described here on the tilted room may have such a merit.

Clearly, more interactions in the near future would be desirable.

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(A)

(B)

Figure 1.
(See color Plate V) 'Amazing Cylinder' at the Science Museum Tokyo (photo by Noriyuki Tanaka) (A) View from outside. (B) Illustration of the structure. The observer is standing on a stationary and flat platform, around which a large cylinder is rotating. The inside surface is striped in a spiral.

(A)

(B)

(C)

Figure 2.

(See color Plates VI and VII) 'Room of coordinate' at the Science Museum Tokyo. (A) Outside view. (B) Illustration of the main effects. Depending on the observer's posture, three stable percepts are possible as shown in (a), (b) and (c). (C) Inside view. Children lie flat on the horizontal floor and attempt to toss and catch balls. (D) Illustration of different effects of the observer's body main axis relative to the rotation axis of the room (photographs by the Science Museum Tokyo).

(A)

Possible standpoints for people "to be erased"

(B)

Figure 3.

(See color Plate VIII) 'Illusion screen' at Shizuoka Children's Science Museum Ru·Ku·Ru. (A) View from the observer (photo by Shizuoka Children's Science Museum Ru·Ku·Ru). (B) Top view of the setup. Positions of the mirror ball, observing zone, and possible positions for the people to be 'erased'.