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New Findings of Volume Perception from Object Motion

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1. Introduction

Volume perception, the perception of enclosed partial space filled with some medium as a solid object, is considered to be an important function in human visual system. It has been found and studied in binocular stereopsis (**Fig. 1**)[1–5]. The existence of binocular unpaired regions on an object is the indispensable factor for the volume perception with binocular viewing[2–5].

Motion is the variations of image position over the retina or image changes in time course. In physical conditions, motion can be classified into two kinds: self-motion and object-motion[6]. The object motion can be considered as a combination of object translation and object rotation.

Human visual system can perceive not only the depth but also surface, structure and solid from motion[7–11].

2. Appearing and Disappearing Parts

In our preliminary study on the volume perception in motion, we used a rotating cylinder as an example (**Fig. 2**). When the cylinder is rotating from the left to the right, the front part B adjacent to the right occluding contour can be seen and will turn to the back and become invisible: which is called as the disappearing part; while the back part A adjacent to the left occluding contour cannot be seen and will turn to the front and become

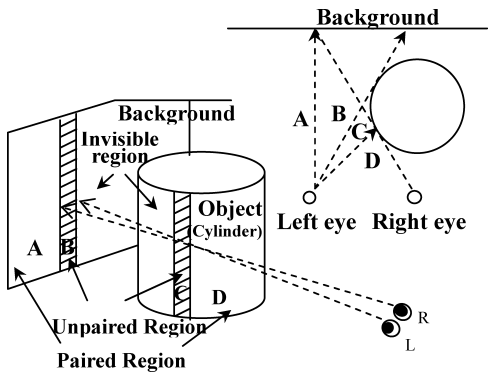

Fig. 1. Conceptual figure showing the binocular unpaired regions on a cylindrical object. {A: paired region on the background, B: unpaired region on the background, C: unpaired region on the object, D: paired region on the object} (From Iwamoto[2]).

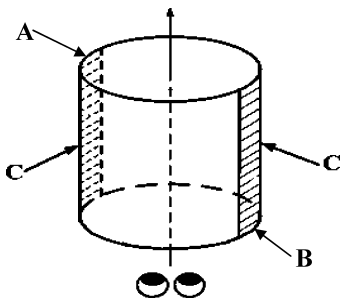

Fig. 2. Conceptual figure showing the appearing and the disappearing parts on a rotating cylindrical object {A: the part going to be appearing; B: the part going to be disappearing; C: occluding contour}.

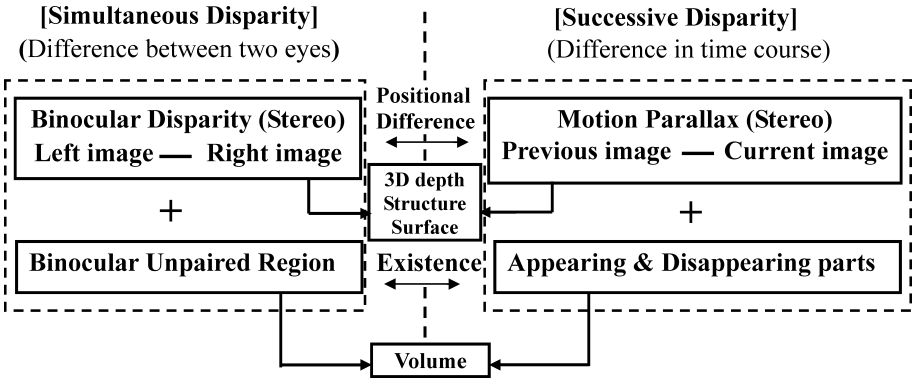

Fig. 3. The relation between simultaneous disparity and successive disparity.

visible: which is called as the appearing part. These two parts are called as appearing and disappearing parts (here in after we abbreviated as AD).

As shown in **Fig. 3**, we thought that the AD in the successive disparity is compatible with the binocular unpaired region in the simultaneous disparity. We speculated that AD in the motion plays an indispensable role for the volume perception, which were entirely the same as the binocularly unpaired regon in binocular viewing.

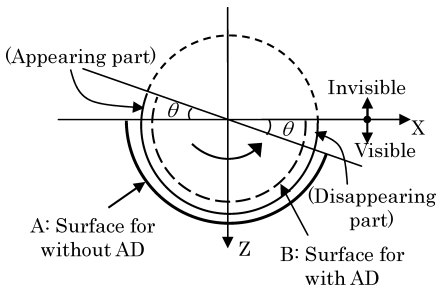

Fig. 4. Conceptual figure of the stimuli with and without the AD in shuttle rotational motion (the situation starting from lower limit position is shown).

3. Experiments

In order to prove the above speculation, we studied the volume perception of a cylindrical object in motion for the cases with and without the AD.

We focused on the object motion of rotation and translation. For the observation convenience, we used the shuttle motion: shuttle rotation, shuttle translation and shuttle rolling (combination of rotation and translation).

For each motion, both of the random dots image with and without AD were prepared.

Conceptual figure of the stimuli is shown in **Fig. 4**. In this figure, positive value on Z axis is visible; random dots were stuck on the surface of the cylindrical surface (A or B) and move them with the motion of cylinder. When the cylinder rotating, the parts adjacent to the depth Z=0 are going to appear and disappear (Fig. 4). For without AD, random dots were stuck on the surface A in Fig. 4 and no dots appear and disappear. For with AD, random dots were stuck on the surface B in Fig. 4, and the dots in the adjacent part Z=0 depth were appeared and disappeared.

In the shuttle translation, when an object is translating parallel to the observer, the visible part of the object for the observer is changing gradually according to the visual angle. For example, the object is translating from the left to the right, the visible part is changing as if the object is rotating from left to right relative to the observer in the angle of visual angle change. By

using the same method with shuttle rotation, we depicted the stimuli in the shuttle translation.

In the shuttle rolling, here rolling means the object is translating as well as rotating. On the basis of the above, we depicted the stimuli with and without AD.

In the experiment, we displayed the above six types of stimuli for six shuttling orientations {0, $\pi/6$, $\pi/3$, $\pi/2$, $2\pi/3$ and $5\pi/6$} respectively as shown in **Fig. 5**. The stimuli for each orientation are displayed 10 times in a random order.

The whole experiment was undertaken in a dark room; there are five subjects in this experiment, four of them haven't any knowledge about the volume perception before. The experimental results are shown as follows.

Fig. 6 is the volume perception percentage perceived in each motion pattern. From this figure, we could found that: in each motion pattern, for the objects with AD, almost all of the subjects had volume perception (more than 90%); while for the object without AD, a few subject had volume perception (less than 10%). From this result, we may deduce that: for a cylindrical object in motion, the AD is an important factor for the volume perception.

In this experiment, we also investigate the volume perception of the stimuli with and without AD for six different orientations of motion. The results were shown in **Fig. 7**: the vertical axis is the percentage of the volume perception and the horizontal axis indicate six different orientations. We found that no matter what the orientation it is, when the stimuli with AD, high percentage of volume perception can be got for any orientation; while without AD, it cannot be got.

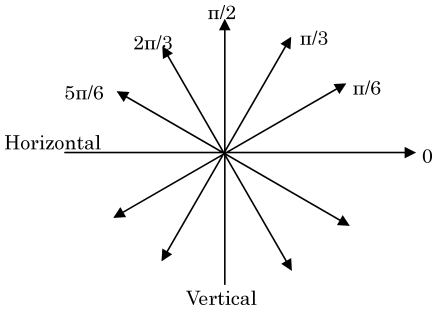

Fig. 5. Conceptual figure showing the shuttling orientation of the stimuli in motion of rotation, translation and rolling.

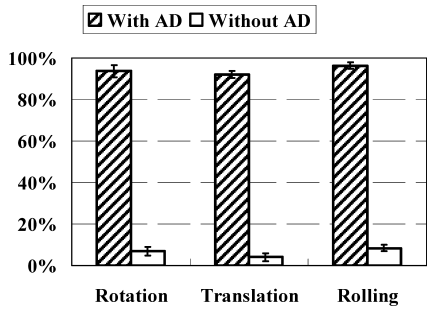

Fig. 6. Percentage of volume perception perceived in each motion pattern.

4. Conclusion

In this study, we investigated the role of the appearing and disappearing parts on an object with curved surface for volume perception in motion; we confirmed that the appearing and disappearing parts (AD) are indispensable for the volume perception in moving object. This means that AD in successive disparity could be

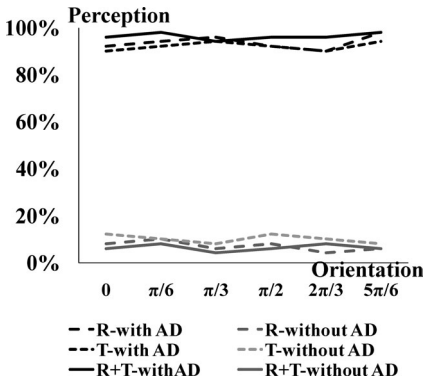

Fig. 7. Percentage of volume perception perceived under each orientation.

considered as compatible with binocular unpaired regions in binocular viewing.

We believe that this newly found evidence could provide a new clue to elucidating the 3-D perceptual mechanism in human visual system.

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