

## Effects of Attention on Depth Perception of Necker Cube

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### 1. INTRODUCTION

The Necker cube [Fig. 1 (a)] is an ambiguous figure with two possible interpretations in depth perception [cube D and cube U illustrated in Fig. 1 (b) and (c), respectively]. Kawabata<sup>1,2)</sup> argued that attention plays an important role in the perceptual interpretation of ambiguous figures. For instance, he proposed that, in the interpretation of the Necker cube, the attended angle tends to be perceived as a front part of the cube<sup>2)</sup>. However, the procedure used by the preceding study might have artifacts in assessing the effect of attention in the interpretation of the Necker cube. That is, in the stimuli used in that study, the lines in the Necker cube were thickened to attract observer's attention. The thickness of the lines might work as a depth cue to define the nearer parts in the cube, instead of attracting observer's attention. In order to assess the effects of attention in the interpretation of the cube, we should keep the depth cue included in the cube constant.

### 2. PURPOSE

In this study, we are interested in how to reduce the ambiguity in observing the Necker cube. In particular, we are interested in the effect of observer's attention in the interpretation of the Necker cube. We conducted experiments to

understand how the following three factors are effective in reduction of the ambiguity in the interpretation of the cube.

The first factor was the type of attention (voluntary attention and stimulus-driven attention). In present study, to attract observer's attention, we used the procedure in which preceding stimulus was presented prior to the Necker cube presentation. This procedure can keep depth cue in the Necker cube constant. Voluntary attention is, here, defined as the attention that is consciously directed to a certain part specified by a preceding stimulus. Stimulus-driven attention is defined as the attention that is lead out automatically and passively by a sudden presentation of a preceding stimulus. Previous studies demonstrated that both of voluntary attention and stimulus-driven attention are effective in local facilitation of the early visual processing<sup>3,4)</sup>. We investigated how each of the voluntary and stimulus-driven attentions is effective in reducing the ambiguity in the interpretation of the Necker cube.

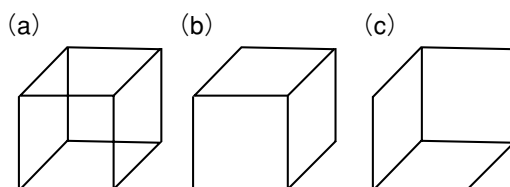


Fig.1 (a) Necker cube. (b) The cube D is a downward cube. (c) The cube U is an upward cube.

The second factor was the attended unit. Does the effect of the attention vary if observer attends to different unit in the Necker cube? We cannot find any answer to this question in the results of the previous study<sup>2)</sup> because in that experiment, the attended unit was always an angle in the cube. In present study, we used a point, line or square of the cube as a preceding stimulus to attract observer's attention. In present study, we used a point, line or square of the cube as a preceding stimulus to attract observer's attention.

The third factor was the location of the Necker cube relative to a fixation point. That is, the cube was presented above or below the fixation point. We expected that the location of the cube relative to the fixation point would affect on the interpretation of the cube; if the cube was presented below the fixation point, it would tend to be interpreted as downward cube, and if presented above, it would tend to be interpreted as upward cube (see Fig. 2).

### 3. METHODS

#### 3.1 Stimuli

Stimuli were presented on a 17-inch CRT display. Observers viewed the Necker cube (4 arc deg, thickness of the line was 0.5 arc min), with

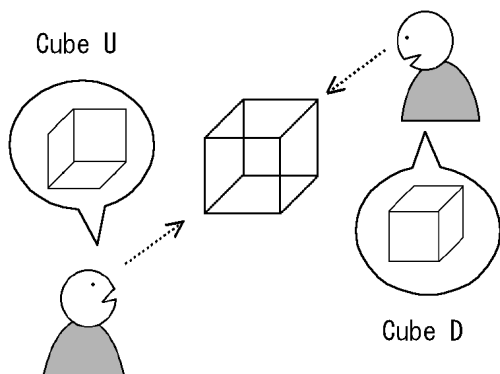


Fig.2 Illustration for the assumption on the relative location to the fixation point. When Necker cube is below (above) the fixation point, observer might interpret it as cube D (cube U) because, in the real space, a 3D cube below(above) a fixation point shows its top (bottom) surface like as cube D (cube U) does.

fixating the fixation point at the center of the display. The location of the cube was 2 arc deg above or below the fixation point. In each trial, before presentation of the cube, a preceding stimulus was presented to attract observer's attention. The preceding stimulus was a point (2.5 arc min), line, or square (thickness of the line was 1 arc min). The positions of the preceding stimuli were at either front surface of the cube D interpretation or cube U interpretation (Fig. 3).

#### 3.2 Procedure

We used two types of procedure to attract observer's attention. For Experiment 1 (voluntary attention condition, Fig. 4), ten observers were instructed to observe the Necker cube with attending the preceding stimulus. The preceding stimulus was presented for 1500 ms shortly after observer's key pressing. It was for 150 ms after the preceding stimulus disappeared until the cube appeared. The cube was presented for 500 ms. For Experiment 2 (stimulus-driven attention condition, Fig. 4), another ten observers were given no instruction about attentions. The

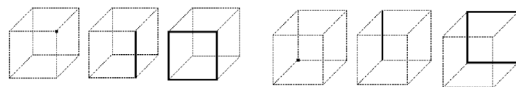


Fig.3 The positions of the preceding stimuli for the Necker cube. Left half shows the positions that are front part of the cube D interpretation, and right half shows the positions that are front part of the cube U interpretation.

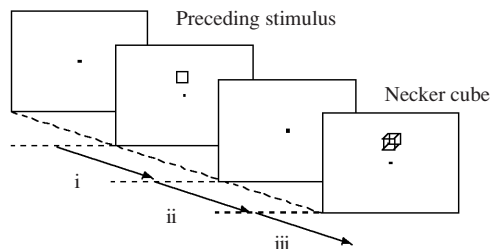


Fig.4 Time sequence in a trial. The interval for the procedure of voluntary attention (stimulus-driven attention) at each stage was respectively (i) 1500 ms (50 ms), (ii) 150 ms (200 ms), and (iii) 500 ms (500 ms).

preceding stimulus was presented for 50 ms. (This ISI is supposed to be appropriate to attract stimulus-driven attention in a previous study<sup>3,4</sup>) It was for 200 ms after the preceding stimulus disappeared until the cube appeared. The cube was presented for 500 ms.

In both procedures, for an observer each stimulus condition was presented 20 times in a random order. Observers answered which interpretation was perceived by key pressing.

#### 4. RESULTS

Fig. 5 (a) shows the results for Experiment 1 (voluntary attention condition). The frequency in which the cube was interpreted as the cube D (64%) was higher than that as the cube U (37%). This indicates that there is a tendency that the observers perceived the Necker cube more frequently as cube D, rather than cube U.

We conducted a 2 X 3 X 2 analysis of variance (ANOVA) for repeated measures on the frequency in which the attended part was interpreted as front part of the cube. The factors were relative cube location, type of preceding stimulus, and position of preceding stimulus. There are significant main effects of the position of the preceding stimulus [ $F(1, 9) = 6.043, p < .05$ ]. This result indicates that the voluntary attention has more effective in determining the front part of the Necker cube for the conditions in which observers attended to the part of the cube D, compared to the conditions in which observers attended to the part of the cube U. [In Fig. 5 (a), the frequencies for the left half conditions was significantly higher than those of the right half conditions]. Also, the interaction of three factors was significant [ $F(2, 18) = 4.633, p < .05$ ]. The significant differences ( $p < .05$ ) found by post hoc *HSD* test are denoted by brackets in Fig. 5 (a). The post hoc test show that, when observers attended to the line or square, the attended parts tended to be interpreted as front

part of the cube. This result indicates that attending voluntarily to line, or square, in the cube could reduce the ambiguity in interpreting the Necker cube. However, when observers attend to the point, the interpretation was still ambiguous.

Fig. 5 (b) shows the result for Experiment 2 (stimulus-driven attention condition). The frequency of interpretations as the cube D (65%) was higher than that as the cube U (35%). As in Experiment 1, there was a bias that the observers perceived the Necker cube as cube D.

For the results of Experiment 2, we conducted the same ANOVA as for those of Experiment 1. We could not find any significant main effect nor

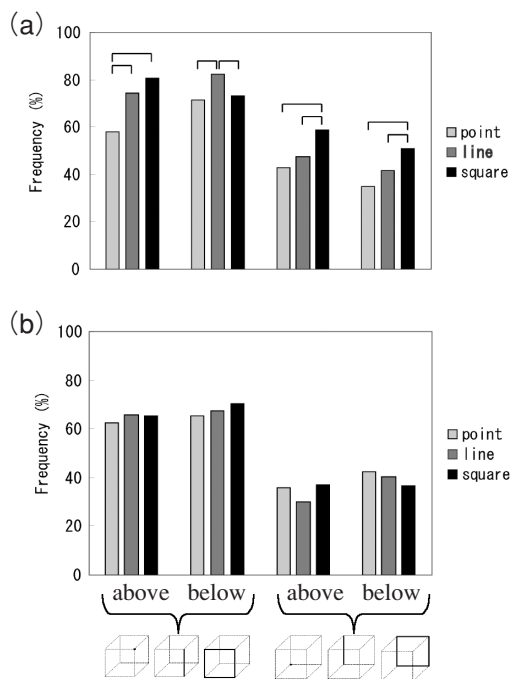


Fig.5 The averaged frequency in which the attended part was interpreted as a front part in Experiment 1 (a) and Experiment 2 (b). Left half of graph shows the results of the conditions in which the preceding stimuli were presented at the front surface of the cube D interpretation, and right half shows the results of the conditions in which the preceding stimuli were presented at the front surface of the cube U interpretation. The conditions in which the stimuli were presented above (or below) the fixation point are denoted by "above" (or "below") at the bottom of the figure.

interaction. [In Fig. 5 (b), although the frequencies of the left half conditions look higher than those of the right half conditions, this difference was not significant]. These results suggest that the stimulus-driven attention is not effective in reducing the ambiguity of the Necker cube interpretation.

## 5. GENERAL DISCUSSIONS

We found that the attention have effects in the interpretation of the Necker cube. Without presenting extra depth cue, we could confirm that attending a part of the Necker cube is effective in determining the interpretation of the cube, as proposed by a previous study<sup>1,2)</sup>. The location of the cube relative to the fixation point has no effect on the interpretation of the cube.

The most interesting point of our results is that directing voluntary attention to a local feature of the cube reduces ambiguity of the interpretation of Necker cube. Especially, voluntarily attending to large unit, such as a line or square, tends to reduce the ambiguity. Directing stimulus-driven attention, however, does not have such an effect for the interpretation of the Necker cube. These

results, that the effects of attention vary regarding with the type of attention, contrast with the result of the previous study about attentions which used simple perceptual task and found that the stimulus-driven attentions, as well as voluntary attention, facilitates early visual processing<sup>3,4)</sup>. Our results suggest that the reduction of the ambiguity in interpreting the Necker cube would require the voluntary attention, which is involved in the high level processing in vision to manipulate information about objects and space.

## REFERENCE

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