

## The effect of touch on a visually ambiguous three-dimensional figure

[In the case of a visually ambiguous figure (such as a wire cube) does simultaneous touch information prevent visual reversals? Does touch serve to prevent the visual system from selecting alternative interpretations of the retinal image when this is ambiguous? The answer turned out to be that touch does not prevent, though may reduce the frequency of, visual reversals of visually depth-ambiguous figures.

It is worth experiencing this situation. Particularly odd is the sensation of rotating the cube when visually reversed, for it is seen to rotate in the direction opposite to its true rotation and the direction in which it is *felt* as rotating. The sensation is that one's wrist has broken; or that one's hand belongs to someone else. Although it is vision which is accepted as correct, yet it is vision which fails to give the correct answer and which is, though powerlessly, contradicted by touch.

This experiment was personally important, in making me realize the significance of ambiguous figures: a theme which is developed at length in *The Intelligent Eye*. My colleague was Charmian Shopland.]

The Necker cube is a well-known example of a reversible figure. This simple line drawing (Fig. 19.1 *a*) is seen to represent a cube in either of two orientations. If, however, perspective or other cues are added (Figs. 19.1 *b* and *c*), the figure reverses less frequently, and there comes a point when it is no longer ambiguous.

Mach (1886) pointed out that solid objects could sometimes be seen reversed. Using a three-dimensional line cube we have confirmed this, provided one eye is kept closed and the subject is experienced. However, when we reduce the depth information more drastically, by painting the cube with self-luminous paint, placing it on a black cloth and viewing it monocularly in a completely dark room lined with black paper, we find that even naïve subjects experience reversals spontaneously.

When the cube is seen reversed the face apparently in front looks considerably smaller than the face apparently behind, and none of the corners square. After a little practice we can introduce head movement parallax without the cube returning to normal and this produces a very curious effect. The cube appears to rotate in the opposite direction from the normal one, the apparently nearer parts now moving *with* the head instead of in the opposite direction. The figure undergoes complex (but systematic) shape transformations, giving one the impression that it is made of an elastic material.

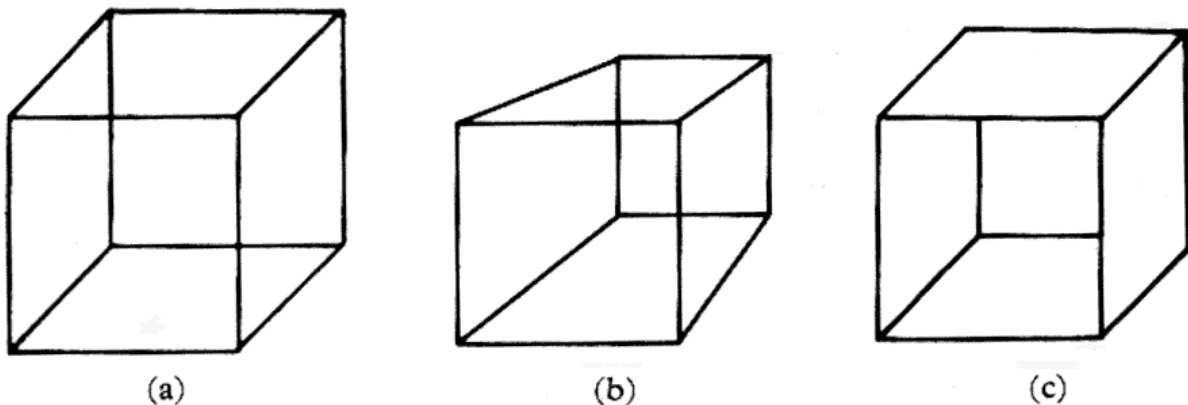


FIG. 19.1 *A simple Necker cube (a) and two examples (b) and (c) of added depth cues (perspective and masking) generally tending to stabilise orientation.*

Touching or holding the cube seems to make it more difficult for a naïve subject to see it reversed in the first place, but having once seen it, touching with the fingers or holding in the hands does not prevent reversal.

These preliminary observations led us to carry out the experiment described in this paper, in which we show some effects of touching and holding the cube. One would not expect touch to have any effect on the reversal of a Necker cube drawn on a piece of paper. If touch gave any information, it would be to the effect that the 'cube' was in fact flat, but merely looking at a two-dimensional Necker cube one is aware that it is flat - it gives the impression both of flatness and of depth. With the three-dimensional figure it is a different matter - the observer is certain that it is in fact a real cube in front of him and that to touch the front and to touch the back he must put his hands at different distances. One might expect haptic information to stabilize to some extent the perception of this cube, as do visual cues. Alternatively one might suggest that haptic information, being in another modality and not specifically attended to, might be ignored altogether; or one might expect that certain subjects would be greatly affected by haptic information, others hardly at all.

#### *Method*

The cube used in this experiment was self-luminous and glowed in the dark. Figure 19.2 shows its orientation to the (right-eyed) subject holding it, but in the experiment the hands were only faintly visible by the light coming from it. The cube was made of square section brass and had sides 34 in. long. The subject could cup it conveniently. in his hands, simultaneously feeling most of the edges and corners while the cube was fixed in position by a grooved wooden support underneath one edge. He was seated at the table to which the support was fixed, with an eyeshade over one eye and his chin on a rest. The table was covered with black cloth and the walls of the room with black paper.

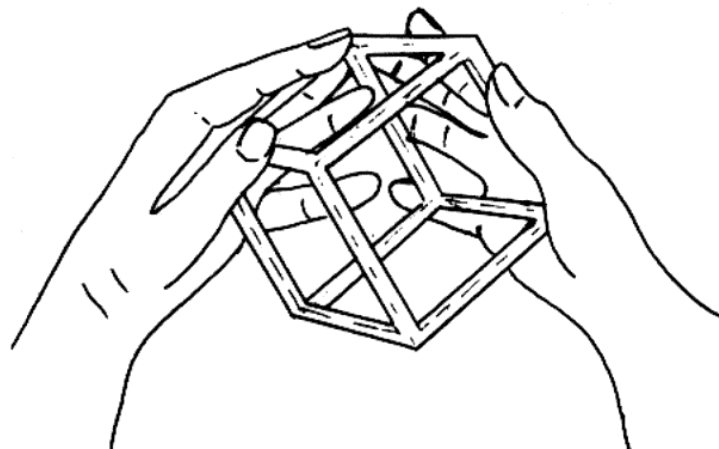


FIG. 19.2 *The orientation of the cube to the (right-eyed) subject holding it. The cube was self-luminous in an otherwise dark room. It was wedged into a support which is not shown. The hands were faintly visible by the light of the cube.*

The depth cues which were available to him were as follows: there was a considerable difference in retinal size of the nearer and further faces; he could tell which of two sides crossed in front of the other; the cube was close enough to him for there to be significant changes in accommodation from front to back of it; he could see his own hands faintly by the light coming from the cube. As he used only one eye and his head was kept still by the chin rest, neither binocular disparity nor head movement parallax were available as cues.

Twelve subjects were used in the experiment, all of them being undergraduate or research students in psychology. The subject was first reminded of the Necker figure (all of them had already experienced the reversal of such a figure) and told that we wanted to know whether the solid 'figure' in front of him would also reverse. He was asked to note at the beginning of each run whether the cube looked as it 'really' was - in which case he was to say 'normal', or whether the front and back corners had changed places - in which case he was to say 'reversed', or whether the cube looked like a plane figure - in which case he was to say 'flat'. If anything else was seen he was to say 'odd' and explain afterwards.

Each run lasted 1 min. and during that time he was asked to report any changes in the appearance of the cube at the time they occurred. Between each run he spent 10 sec. with his eyes closed. There were eight runs, then a pause for comment and re-activating the cube with a bright light, and then eight more runs. The runs were arranged in double alternations between the condition we call 'Vision' and the one we refer to as 'Touch'. During the 'Vision' run the subject sat with his arms resting on the table and simply looked at the cube; during the 'Touch' runs he cupped his hands round the cube and kept both hands moving continuously over its surface. This procedure was explained to him at the beginning of the session and he was told that both active and passive touch were to be used - that is, as well as running his finger tips along the edges of the cube and feeling its lines and corners (trying not to favour any particular lines or corners), he was to feel it with the whole hand (Fig. 19.2).

The reports and comments were recorded on magnetic tape which was played through afterwards so that the times of occurrence of each observation could be obtained.

The total time for which the cube appeared 'normal', 'reversed' or 'flat' during each of the 16 1-min. runs of the experiment were averaged for all subjects. When simply looked at, it appeared normal for an average of 30.8 sec. per min., reversed for an average of 25.5 sec. and flat for an average of 3.1 sec. per min. When explored with the hands as well, the corresponding figures are 40.9, 15.4 and 3.6 sec. per min. respectively.

### *Results*

Fig. 19.3 shows the total time for which the cube appeared 'normal', 'reversed', or 'flat' during each of the 1 min. runs of the experiment, averaged for all subjects.

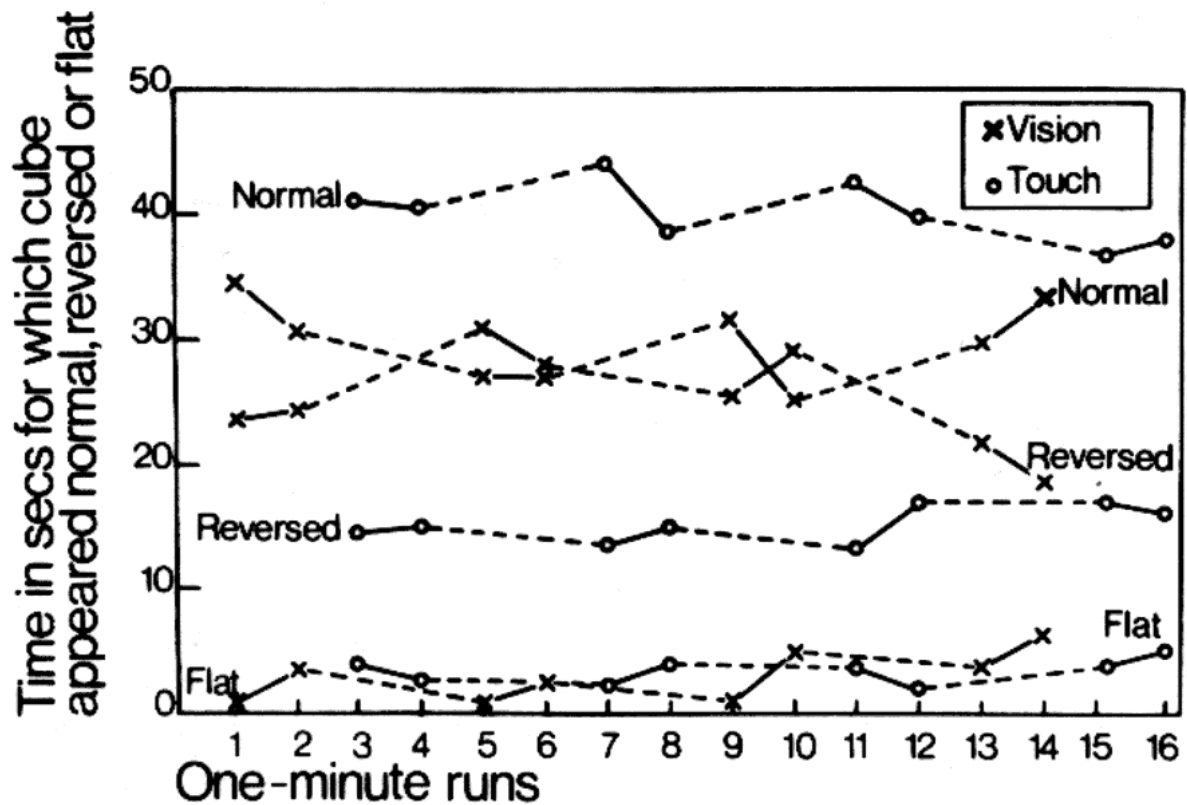


FIG. 19.3 The total time for which the cube appeared 'normal', 'reversed' or 'flat' during each of the 16 one-minute runs of the experiment, averaged for all subjects. When simply looked at, it appeared normal for an average of 30.8 sec. per min., reversed for an average of 25.5 sec. and flat for an average of 31 sec per min. When explored with the hands as well, the corresponding figures are 40.99, 15.4 and 3.6 sec. per min. respectively.

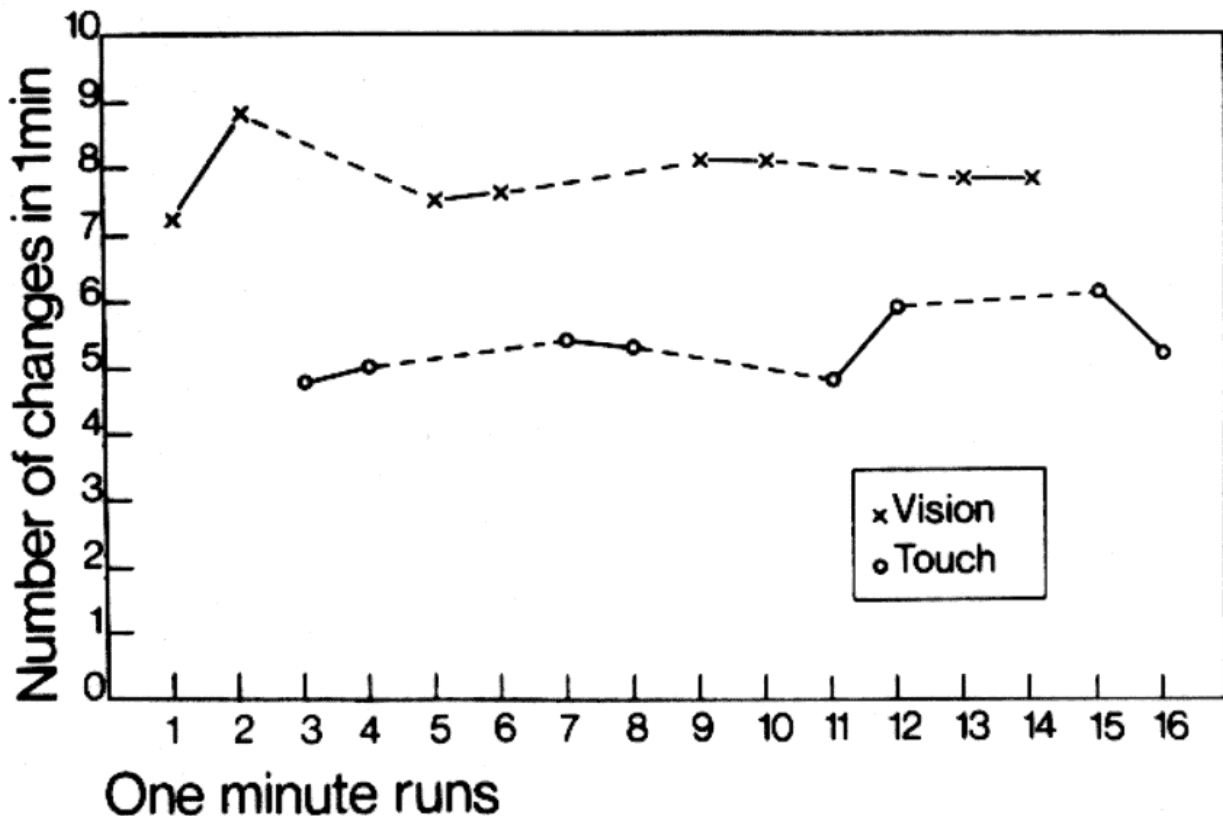


FIG. 19.4 *The number of changes in appearance of the cube during each of the one min. runs of the experiment, averaged for all subjects. It changed appearance an average of 7.9 times when simply looked at, 5.3 times when explored with the hands as well.*

It is clear from inspection alone that when the cube was explored with the hands it looked normal for more of the time and reversed for less of the time than when simply looked at. (Using the Binomial Theorem,  $p < 0.0004$  in both cases). While exploring with the hands it appeared normal for an average of 40.9 sec. in each 1-min. run and reversed for an average of 15.4 sec. (Binomial Theorem gives  $p < 0.004$ ). The corresponding figures when simply looking at the cube are 30.8 and 25.5 sec. respectively. (These are not significantly different: Wilcoxon 'T' test gives  $p > 0.05$ ). The cube appeared flat for an average of 3.6 sec. on each run when explored with the hands, for 3.1 sec. when simply looked at. This difference is not significant. (Wilcoxon 'T' test gives  $p > 0.05$ ).

The only 'odd' description of the cube was given by subject 5, on one occasion while using vision alone and on three occasions when using touch also. He reported seeing it in the normal orientation and in depth, but with the kind of distortion that typically occurred when the cube was seen reversed, that is, not as a regular cube but with a marked difference in the sizes of the nearer and further faces. This effect had already been observed by one of the authors (C.D.S.), but had not otherwise been reported by the 20 or so people who took part in the preliminary study. This percept seemed to be independent of any change of attitude on the part of the observer.

All the subjects observed that the cube looked distorted this way when reversed. Four subjects commented that fixation seemed to affect reversal (this has previously been observed (Glen, 1940)); one thought that blinks affected reversal, one that the amount of depth in the

figure varied; two thought they could will changes (Glen, 1940, has evidence of this also) but said they tried not to do so.

Two subjects thought that touch had no effect at all on what they saw, although they were touching lines they could not see, or failing to find with their hands lines they could see. Two subjects found that touching the front corner in particular seemed to make the cube go back to normal if it were reversed, and two found the same with the back corner. (They were both obscuring this corner with the hand, instead of keeping the hand behind the cube as instructed). One subject found that a corner would sometimes move forward or back with her hand, and another the part she was touching looked normal while the rest of the cube looked reversed.

Several subjects made the comment that touch gave them a clue to the real orientation of the cube at first, but later they 'grew to accept the difference between the visual and the tactile', or found that 'touch lost significance'. We therefore looked for a decrease in the duration of reports of 'normal' from the beginning of the session to the end. Inspection might suggest a very slight trend in the right direction but it is certainly not significant (Friedman Analysis of Variance by Rank gives  $p = 0.55$ ). Looking at the results of each subject separately, we found no more indication of variation with time among those who reported it than among the rest.

For all subjects except one there were more changes when using vision only than when using touch as well. (The probability of this distribution is  $O \sim 003$  on the Binomial Theorem). The difference in the case of the aberrant subject was nowhere near significant at the 0.05 level (Wilcoxon 'T' test), and in other ways his results were typical. Figure 19.4 shows the number of changes, averaged for all subjects, during each of the 16 1-min. runs of the experiment. Again there is no evidence of any changes with time, nor is there any suggestion of a trend when considering alone the subject who commented that the reversals became more frequent with time.

The reversal rate in our experiment is less in both conditions than is generally reported for two-dimensional Necker cubes, our average rates being 7.9 per min. with vision only and 5.3 with touch also, compared with average rates ranging from 15 to 30 in the literature (e.g. Tussing, 1941; Glen, 1940).

### *Discussion*

This experiment shows that haptic information does not prevent reversals of an ambiguous figure, nor does it prevent the figure from looking like a 'meaningless geometrical pattern'. It could well have been the case that when, say, the front of the cube was located by touch it would always appear to be the front visually, but in fact the cube seemed to split into two objects, one visual, the other tactile.

We may think of the Necker cube as presenting a problem to the perceptual mechanism for which there are only two possible solutions:

a Necker cube drawn on a plane surface is usually bi-stable, seeming to lie in either of two orientations. We thought it possible that touch would have an all-or-none effect on the choice of solution, but we find that touch can provide information that guides but does not dominate

the perceptual mechanism in its choice. Haptic information cuts down the reversal rate and increases the time during which the cube looks as it 'really' is, but does not prevent reversal.

We might contrast this situation with one in which the perceptual problem is to decide on the values of continuously varying parameters. An example of this is the apparent shape of a distorted room. Here we have walls which may be at any of an infinite number of angles to the line of sight, a floor and a ceiling which may be at any of an infinite number of angles to the horizontal. In this case the perceptual system makes a decision and sticks to it without vacillating. However, given information from touch, the perception is modified in the direction of the true shape of the room, and with more experience the perception corresponds still more with the true shape (Kilpatrick, 1954). With the cube there were some reports of this type - while touching it, it appeared reversed, but not extending as far in space as when seen unreversed. There was, however, no evidence of learning, nor do our results show any effect of haptic experience of the cube on its perception when using vision alone. From the reports of the subjects (but not from the numerical results) we might suggest that they learned not to use but to ignore haptic information as time went on. Perhaps if their task had been to ascertain which way round the cube in fact was, touch would have had more effect.

There were also reports that touching the front or back corner seemed to cause an immediate return to the normal orientation. Witkin et al. made a similar finding when putting vision and hearing into conflict: when attempting to judge the direction of a speaker's voice, opening the eyes could make the voice appear to change direction by about 30 degrees instantaneously (Witkin, Wapner and Leventhal 1952). However, in their experiment, the auditory stimulus was unambiguous and a more comparable situation is that of Warren and Gregory (1958 [No. 20]), where a word repeated on a loop of tape was found to change spontaneously to other words or sounds.