TRANSFORMATIONS OF PERCEPTION WITH PROLONGED OBSERVATION[1]

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IT HAS LONG BEEN RECOGNIZED that certain pictures appear to change from one form to a second and back again with continued observation. The Necker Cube is a familiar example of such a "reversible" figure. Warren and Gregory (1958) found reversing changes of apparently the same character in the perception of continuously repeated verbal patterns, but Warren (1961a, 1961b) later claimed that these "verbal transformations" showed several features that distinguished them from the visual reversing figures. He considered the verbal transformation effect to be more akin to the continuous distortions observed by Marks (1949) and studied by Honisett and Oldfield (1961).

On the other hand, Sakurabayashi (1954) found that the perceived organization of simple line drawings almost always changed abruptly with continued inspection, that the perceived forms differed from individual to individual, that distortions of the stimulus occurred, and that the fluctuations were among many forms. These were the characteristic features of the verbal transformation effect that led Warren to make the distinction between it and the visual reversing figure effect.

Axelrod and Thompson (1962) showed that the time course of the rate of change followed the same pattern for the verbal transformation effect as for both the Necker Cube and the rotating spike pattern used by Brown (1955). This observation also suggests that the verbal transformation effect is due to the same mechanism as the reversing figure effect, although Axelrod and Thompson found low correlations among the numbers of changes reported by the same subjects on different tasks.

A further possible method of comparing the verbal transformation effect with the visual reversing figures depends on the demonstration (Taylor & Henning, 1963) of a close relationship between the number of different forms and the number of transitions reported in the verbal transformation effect. At any sufficiently late stage in the observation, the number of transitions that had been given was directly proportional to the number of possible different transitions among the reported forms. The same relation seemed to hold for data that Warren published

[1]DRML Report no. 503.

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(Warren, 1961a, 1961b), although the proportionality constant was somewhat lower than that found by Taylor and Henning.

Preliminary observation suggested that the more or less strict alternation between two forms ordinarily studied for such figures as the Necker Cube might be due to the effect of instructions or of training, and that naïve subjects might not give such a restricted range of responses if asked merely to report what they saw. With an unlimited range of permissible responses, the applicability of the empirical relation between the number of forms and transitions might provide a test of the similarity of the mechanism for visual and verbal transitions.

Method

Four stimulus patterns were prepared for prolonged observation. These were drawings, about three inches on a diagonal, of a Necker Cube and of a hexagon with its diagonals drawn, a rotating spike pattern in which vertical spikes mounted on a rotating horizontal disc were viewed through a rectangular aperture, and an auditory beep pattern consisting of a 650 c/s tone switched on four times a second with a duty ratio of 0.5.

During a one-hour session S observed each of the stimulus patterns for one ten-minute trial. Some Ss viewed one or more of the visual stimuli monocularly, the unused eye being covered. Though the analysis of the earlier verbal transition experiment showed that the order of presentation had no effect on the results, the order of presentation was varied from S to S. All possible orders were used, with the restriction that the two drawings were always presented either first and third or second and fourth.

For the visual stimuli, the responses were recorded in the manner described for the verbal transformation experiment (Taylor & Henning, 1963). S described verbally what she saw, and her description was recorded both on magnetic tape and on pressure sensitive tape (which gives a visible indication of the instantaneous amplitude of the speech). *E* wrote an identifying mark on the pressure sensitive tape, and after the session the magnetic tape record was transcribed and correlated with the record on the pressure sensitive tape. In this way, with an articulate S, it was possible to obtain a reasonably good record of the changes in percept with time. When the drawings were used as stimulus patterns, Ss in preliminary tests often failed to describe the initial percept. In the experimental trials, *E* asked S what she saw as soon as the drawing was displayed. If S gave a three-dimensional response (box, cube, etc.,) *E* then asked which corner was nearest to S. Thereafter *E* spoke only when there was ambiguity about the novelty of the percept reported.

The recording technique was slightly different for the auditory beeps. To indicate the patterns she heard, S wrote a sequence of long and short dashes on a piece of paper. *E* watched the writing, and noted the time of each on the pressure sensitive tape. The net result of this technique was the same as for the visual stimuli, in that a written record and a timed record were both available. The technique was not, however, as simple for S as was the verbal description, and it was found necessary to give a training task before presenting the beep pattern. This consisted of a sequence like the actual test beeps, except that there were pronounced changes in rhythm. S was required to listen to this practice tape and report the actual

changes, to ensure that she understood the method of reporting. The use of such a test tape is likely to bias the expectations of S regarding the type of changes to be heard, but, from the results of the verbal transformation experiment, such a bias should not affect the nature of the relation between the number of forms and the number of transitions.

Ss were forty paid housewives and teen-aged girls, thirty-five of whom had served some two months earlier in the verbal transformation study. The data from two other Ss were discarded, as later questioning ascertained that they had failed to understand the instructions.

Qualitative Results

Each stimulus usually gave rise to several percepts. Out of 120 trials with the visual patterns (40 subjects, three stimuli), only nine resulted in just one form (four with the binocular spikes, four with the binocular hexagon), and 17 in just two (seven with the binocular spikes). On the remaining 94 trials up to 22 different forms were reported during the ten minutes. It seems that for naïve observers, these "reversible" figures ordinarily result in a multitude of different percepts. All the visual patterns gave fewer forms and transitions with binocular than with monocular viewing.

There was often difficulty in interpreting the transcripts, in that the description of one form was like that of a different form, so that analysis in terms of the actual sequence of forms given was not possible. For several subjects changes came so fast that they were able only to report that the form was new or old. In most cases the occurrence of a new form was quite clear, because the subject specifically mentioned that the form was new, because of a gross difference in description, or because, in some questionable cases, the experimenter immediately asked her whether a particular description represented a new form. Hence it is unlikely that the estimate of the number of different forms is very much in error for any one trial. The main source of possible error appears to be in the assignment of descriptions involving slow changes in the percept. Not many such changes were reported. Most of the changes were abrupt.

The following extracts from some of the transcripts may give an idea of the sorts of changes seen. Some of these represent common forms, others idiosyncratic changes. As a group, they effectively counter Warren's objections to consideration of the verbal transformation effect as similar to the visual changes.

(*Necker Cube*) ". . . It's turned, but it seems like it's more sitting on an angle to the left than it just did—now it's back to a more normal position. . . ."

(*Necker Cube*) ". . . The centre is much smaller than it was originally—oh, the box is upside down. Tee-hee! It's on its side hanging as if suspended in mid-air . . . [later] . . . Now the box is shaping into an elongated cone shape, only square, of course, stretching out, on its side . . . the sides keep enlarging. . . ."

(*Hexagon*) ". . . Now it's trying to get back to that cube, but the side still remains up and outward, like a Christmas parcel if you are trying to wrap it up . . . [later] . . . the lines have disappeared, all but the two end lines. . . ."

(*Revolving spikes*) ". . . Now it's a fence and it's got little pieces of isinglass between each picket. . . . They are moving very fast and there's one that keeps sitting off by itself and it keeps getting bumped by the others. . . ." (This last observation was very common.)

(*Necker Cube*) ". . . The left hand corner seems to be shrinking a bit. Then goes back into its place. . . ."

(*Hexagon*) ". . . Now it looks like a box with the lid just a little bit open. [*E* asks "Is that new?"] Yes. Now it looks like—golly, the lid is coming way up, or there are 1½ boxes or something. . . . It looks as if the lid is opening right up on the box. . . ."

(*Revolving spikes*) ". . . One moving back and forth in front of me now, while the others continue in a circle. . . ."

Despite the great variability in the percepts and the fact that the "standard" percepts apparently did not predominate (this is only an impression gathered by reading the transcripts, since difficulty of interpretation makes it difficult to be sure exactly when a "standard" form is being seen), there was a great deal of obvious alternation behaviour. Some one percept would be followed by another and return to the original many times. Again, the records are not secure enough to give an accurate estimate of the proportion of the changes that returned to the immediately preceding percept, but it was of the order of 25-30 per cent. Furthermore, in the majority of trials with alternations, more than one pair of percepts exhibited the alternation behaviour.

It seems, then, that the behaviour of the percepts of naïve observers viewing these "reversible" figures shows qualitative affinity with Warren's verbal transformation effect, with the ordinary reversible figure effect, and with the continuous and discrete distortion effects of Marks and of Honisett and Oldfield.

Quantitative Results

The subjects were asked to indicate the occurrence of a novel form, and most of them did so. In some cases of doubt they were asked at the time whether the percept was new or not. Even in the cases when changes were too fast for the subject to describe, she noted the occurrence of novel forms. Accordingly, it was possible to analyse the relation between the number of forms and the number of transitions, to the degree that the subjects were able accurately to decide whether a form was new or not. The most likely bias resulting from errors on the part of the subject appears to be an excess of forms claimed to be new when there have been a large number of forms (for example, Shepard &

Teghtsoonian, 1961). Any such bias, or other measurement error, should tend to attenuate the expected relation.

The empirical relation found by Taylor and Henning (1963) between the number of transitions and the number of forms in any trial may be stated

$$T = kF\ (F\text{–}1) \qquad (1)$$

where T is the number of transitions at any sufficiently late stage, F the number of different forms reported up to the same stage, and k a constant ($k = 1$ for Taylor and Henning's data, $k = 0.7$ for Warren's).

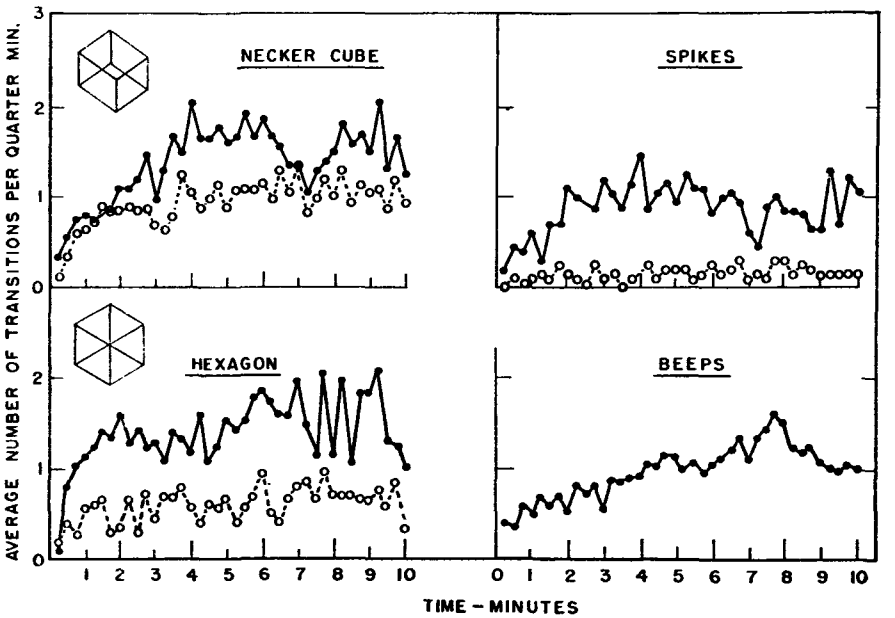


FIGURE 1. Average number of transitions in each quarter minute. For the visual figures, open circles represent binocular viewing, solid circles, monocular viewing. The inset figures represent the drawings used.

The average rates of transitions and of reports of new forms are shown for the seven inspection conditions in Figures 1 and 2 respectively. The relatively smooth increase in transition rate and decrease in rate of production of novel forms shown in Figures 1 and 2 are not characteristic of any typical trial. Ordinarily, transitions seem to occur in bursts, each burst followed by a pause in which few transitions are reported.

Figure 3 shows the relation between forms and transitions for each condition. The average curve for this relation is reasonably representative

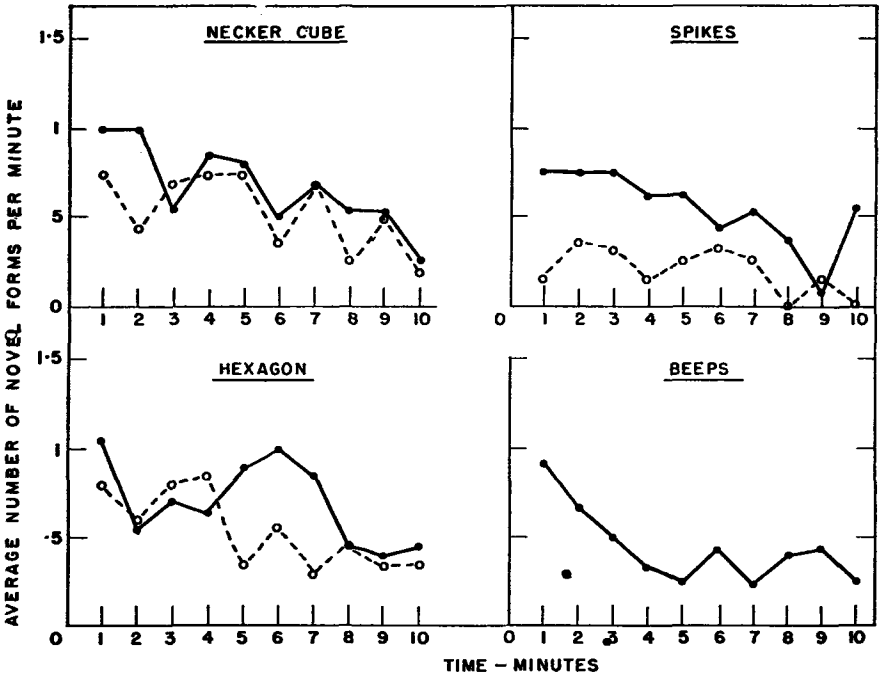
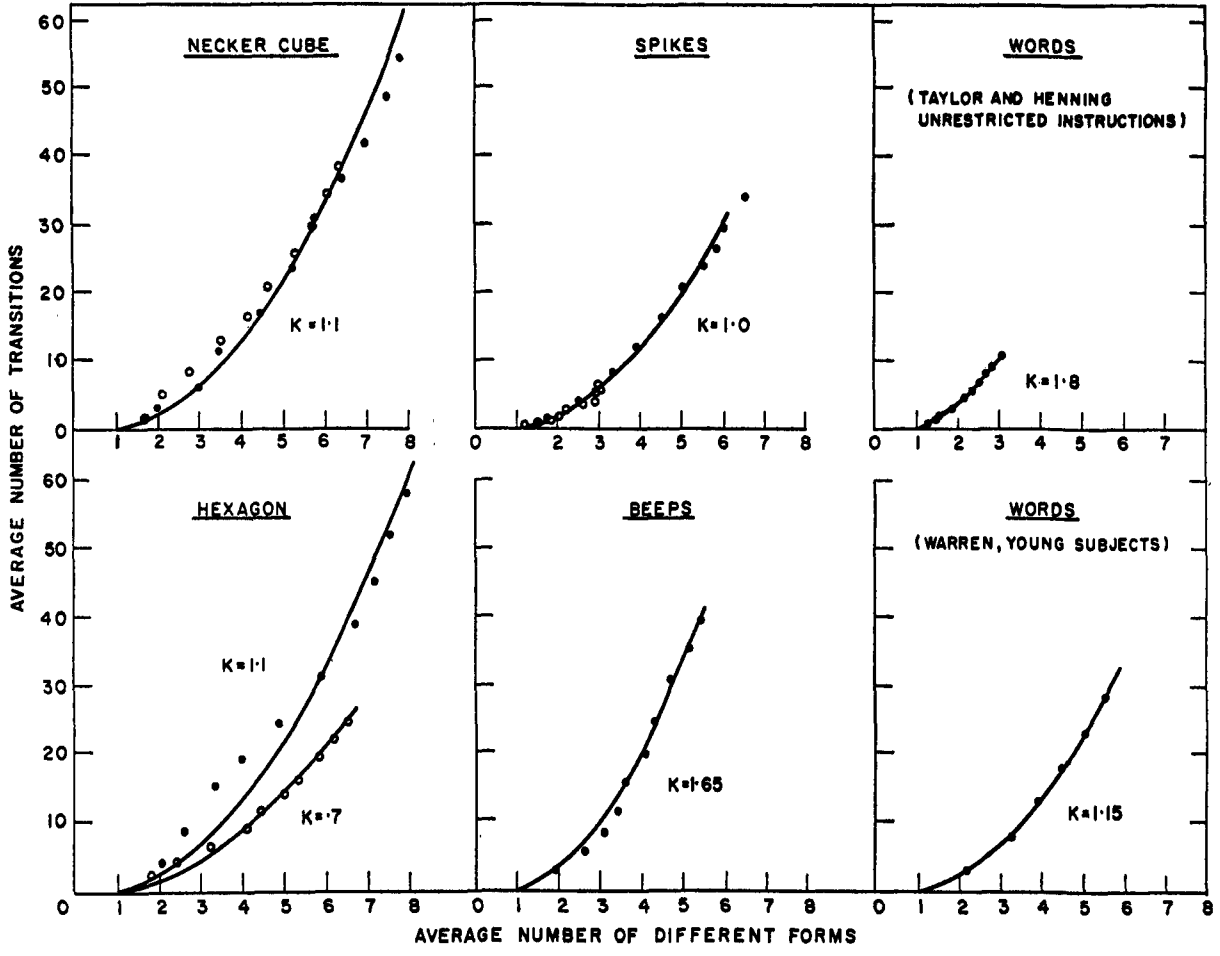


FIGURE 2. Average number of novel forms reported in each minute of observation. For the visual patterns, open circles represent binocular viewing, solid circles, monocular viewing.

of the curves obtained on single trials. A curve of the form of equation 1 is fitted by eye to the averaged data for each condition, and the value of k used in the fit is noted. Equation 1 provides a fit that ranges from good for the monocular spikes and binocular hexagon to poor for the monocular hexagon. This latter condition also appears anomalous in Figure 2 in that there seems to be a deficiency of new forms in the second to fourth minute and an excess in the fifth and sixth. This fluctuation is reflected in the monocular hexagon curve of Figure 3.

Although equation 1 gives a reasonable approximation to the average numbers of forms and transitions both in this experiment and in the earlier verbal transformation experiment, it is really supposed to apply

FIGURE 3. Relation between cumulative average number of transitions and cumulative average number of forms during the course of observation, for the stimulus patterns of this study, and for representative samples from two verbal transformation studies (Taylor & Henning, 1963; Warren, 1961a). The curves are given by the equation $T = kF\ (F-1)$. For the visual patterns, open circles represent binocular viewing, solid circles, monocular viewing.


NECKER CUBE
K=1·1
SPIKES
K=1·0
WORDS
(TAYLOR AND HENNING
UNRESTRICTED INSTRUCTIONS)
K=1·8
HEXAGON
K=1·1
K=·7
BEEPS
K=1·65
WORDS
(WARREN, YOUNG SUBJECTS)
K=1·15
AVERAGE NUMBER OF TRANSITIONS
AVERAGE NUMBER OF DIFFERENT FORMS

to individual runs. To test its applicability to the data from individual runs, the numbers of transitions reported were used to calculate the numbers of forms that should have been reported on the assumption that $k = 1$. The predicted numbers of forms were then correlated, for each condition separately, with the actual numbers of forms reported. The correlations are shown in Table I. They range from a non-significant low of 0.34 for the monocular spikes to a highly significant 0.955 for the beeps. Five of the seven are significant at the 1 per cent level or better. These correlations are attenuated by real differences in k that may occur among the subjects. Based on these individual runs, the average value of k is about 0.8, except that the beep gives k about 1.3, and the binocular hexagon about 0.5. These values are of the same order of magnitude as those found for the various experiments on the verbal transformation effect. The values are lower than those used in Figure 3, because of the averaging artifact discussed by Taylor and Henning (1963).

TABLE I

CORRELATIONS BETWEEN PREDICTED AND OBTAINED NUMBERS OF DIFFERENT FORMS ON SINGLE RUNS UNDER THE DIFFERENT INSPECTION CONDITIONS

Condition	N	r	P
Beeps	40	.995	.001
Binocular spikes	19	.876	.001
Monocular spikes	21	.343	$>.1$
Binocular hexagon	20	.905	.001
Monocular hexagon	20	.644	.005
Binocular Necker Cube	20	.549	.02
Monocular Necker Cube	20	.778	.001

It seems that the verbal and the visual transformation effects operate in the same way. According to Axelrod and Thompson (1962), the numbers of transitions do not correlate very highly when the same subject reports changes in the words, the Necker Cube, and the rotating spikes. This finding seems to indicate that the different configurations do not use the same mechanism for their changes. Changeability would be a characteristic not of the subject, but rather of the particular subsystem involved with the particular stimulus.

Table II shows the correlations both among the numbers of forms reported and among the numbers of transitions reported when the same subject observed different stimuli. Including the verbal transformation study, there are nine different inspection conditions, but not all possible combinations were used. In particular, no subject did the verbal transformation study both under "unrestricted" and under "English" in-

TABLE II

CORRELATIONS AMONG THE NUMBERS OF FORMS AND AMONG THE SQUARE ROOTS OF THE NUMBERS OF TRANSITIONS GIVEN BY THE SAME *S* FOR DIFFERENT STIMULI[1,2]

	B hex	B NC	U words	E words	Beeps	M hex	M NC	B sp	M sp
B hex	×	$.83^{0.1}$ (20)	.26 (11)	−.16 (8)	.09 (20)	×	×	−.11 (9)	−.29 (11)
B NC	$.98^{0.1}$	[.83]	.51 (11)	.01 (8)	.09 (20)	×	×	.04 (9)	−.40 (11)
U words	.20	.52 [.24]	[.88]	×	$.46^{5}$ (19)	.37 (8)	.40 (8)	.48 (10)	−.44 (9)
E words	.22	.18	×	×	$.62^{1}$ (16)	−.26 (8)	−.07 (8)	.00 (7)	.46 (9)
Beeps	.35	.38	.13	$.61^{5}$	×	$.58^{1}$ (20)	$.68^{1}$ (20)	.32 (19)	.18 (21)
M hex	×	×	.24	−.19	.42	×	$.73^{0.1}$ (20)	$.74^{2}$ (10)	$.74^{2}$ (10)
M NC	×	×	−.19	.25	$.62^{1}$	$.74^{0.1}$	×	$.77^{1}$ (10)	$.83^{1}$ (10)
B sp	.31	.04 [.06]	.37 [.38]	.28	$.60^{1}$	.56	$.81^{1}$	[.83]	×
M sp	.11	.56	$-.91^{0.1}$	.45	.18	.37	.40	×	×

[1]Above the main diagonal unbracketed numbers are correlations among forms, bracketed numbers are the numbers of *S*s represented. On or below the main diagonal, numbers represent correlations among the square roots of the transitions. Unbracketed numbers are results of the present study, numbers in square brackets the results of Axelrod and Thompson (1962).

[2]Significance levels in per cent are indicated by superscripts.

structions (Taylor & Henning, 1963), and no subject did either drawings or spikes under both monocular and binocular viewing conditions. The number of subjects involved in each of the other correlations is indicated in Table II in parentheses under the correlation concerned. To equalize variance, the square roots of the numbers of transitions were used rather than the actual numbers for the transformation correlations.

Table II shows a clear but unexpected pattern of correlations that is roughly the same between forms as between transitions. The inspection conditions have been roughly ordered so that neighbours are more highly correlated than separated conditions. The most striking point about Table II is that the binocular drawings are in a class by themselves. The number of forms and the number of transitions correlate very highly between them—about as highly as they could, according to Axelrod and Thompson's results (shown in parentheses)—while correlating insignificantly, and even negatively, with each of the other conditions.

As might be expected, the auditory stimuli yield generally significant correlations among themselves, though the correlations between the unrestricted (U) words and the beeps are low. The beeps correlate highly with the monocular drawings, and probably with the binocular spikes, but not with the monocular spikes, while the monocular drawings correlate with both binocular and monocular spikes. These groupings are indicated by the boxes in Table II.

TABLE III

NUMBER OF TIMES THE FIRST PERCEPT WAS OF A BOX AND OF A FLAT FORM FOR THE TWO DRAWINGS UNDER MONOCULAR AND BINOCULAR OBSERVATION

	Necker Cube		Hexagon	
	Flat	Box	Flat	Box
Monocular	0	20	12	8
Binocular	1	19	12	8

A pattern of correlations such as this is hard to interpret. Where direct comparison is possible, there is good agreement with the results of Axelrod and Thompson, if it is assumed that these authors used binocular vision throughout. The main surprise is the separate grouping of the binocularly viewed drawings. One plausible hypothesis to explain this might be based upon Klein, Gardner, and Schlesinger's (1962) factor of tolerance for percepts known not to represent the physical stimulus. Since, as shown in Table III, there is no tendency for the drawings initially to be seen more flat when viewed binocularly than when seen monocularly, this cognitive control factor seems not to be operative. We have no other hypothesis to put forward.

In connection with Table III, it is interesting to note that Hochberg and McAlister (1953) found that a Necker Cube like the one used in the present experiment was seen as flat about 1.3 per cent of the time, whereas the hexagon figure was seen as flat 60 per cent of the time. The relevant figures in the present experiment, based on the initial forms only, are 2.5 per cent (one out of 40) and 60 per cent. It is also interesting that there was no greater tendency to see the hexagon as a box when it was presented after the Necker Cube than when it was presented before.

Conclusion

The results of this study tend to support the conclusion that the verbal transformation effect and the changes in the visual reversing figures are aspects of the same phenomenon. They also support the view that the reversing figures represent only special cases of general transformations that occur with prolonged observation. These transformations may be manifested sometimes in continuous deformations of the percept and sometimes in abrupt changes to a different percept.

People who speak only one language, when exposed to the sounds of another, hear the vowels transformed into sounds that occur in their own language (for example, Sapir, 1921). Similarly, Taylor and Henning (1963) found that the percepts of changed forms in the verbal transformation effect were affected by the range of forms the subjects supposed possible. In general, it seems that incoming stimuli are coded in terms of a repertoire of possibilities.

When the stimulus material is verbal, the possible percepts (not considering changes of accent, pitch, etc.) are discretely different words. When it is pictorial, the possible percepts contain continuous ranges of variation around many discretely different objects. If continuing observation tends to be accompanied by random or non-random fluctuations of a continuous nature, then the verbal material should give rise only to abrupt discrete changes of percept, and the pictorial to either or both continuous and discrete changes, depending on the subject's expectations and on the stimulus material. In the cases where a given stimulus may equally plausibly be construed as representing two different objects, abrupt fluctuations between the two might be expected, especially when the subject is instructed to look for such alternations. When the stimulus most probably represents one particular object, however, or is an abstract configuration, then continuous deformation or random abrupt changes should be seen. The autokinetic movement may be the simplest example of such an effect. From this viewpoint, the apparent differences in character among the three transformation effects are seen as the result of differences in the character of the permissible or expected percepts, and not of differences in the mechanism of the transformation.

The suggested explanation for the differences among the transformation effects carries with it no implication regarding the form-transition relation found to be common to the abrupt transitions. The deduction of that relation requires the assumption of some properties of the perceptual spaces, and of the behaviour of possible satiation mechanisms.

Résumé

Une méthode d'analyse déjà appliquée à l'étude de l'effet de transformation verbale est ici appliquée à l'étude des changements intervenant dans la perception de la structure d'un pattern auditif et de trois patterns visuels. La plupart des sujets voient plusieurs formes différentes dans les patterns visuels et la relation existant entre le nombre de formes et le nombre de changements s'avère semblable à celle à laquelle l'effet de transformation verbale avait déjà donné lieu. Les résultats suggèrent que les effets de renversement figural sont des cas spéciaux d'un phénomène plus général de distorsion englobant l'effet de transformation verbale. Il existe toutefois un réseau complexe de correlations entre le nombre de formes ou de changements observés par un même sujet en des tâches différentes, ce qui semble indiquer que la sensibilité au changement n'est pas une caractéristique simple du sujet.

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(*First received April 29, 1963*)