A visual illusion of succession¹

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The sides of a contour square appear successively when context lines are presented one before and one after the square. As the interstimulus interval (ISI) between lines and square is increased to 140 msec, reports of succession increase. If the sides of the square are presented successively and interpart interval (IPI) varied by a single staircase method in order to determine a succession threshold, the average magnitude of this threshold varies as a function of ISI, decreasing up to 140 msec ISI. Each S, however, shows a maximum decrease in threshold between 80 and 120 msec. Reports of this illusion are not dependent on beta movement of either context lines or square.

Considerable attention has been directed to the issue of whether parallel or sequential processing of information occurs in the central nervous system during performance of pattern recognition tasks (Neisser, 1967). The experimental question is whether the operations of matching a present stimulus with memory traces of past stimulation occur simultaneously, or successively, viz., in parallel or sequentially. Concurrently there has been renewed interest in the issue of whether or not time is unitized in the central nervous system (Kristofferson, 1967; White, 1963). The experimental questions are: what is the magnitude of the unit, and what is the psychophysiological mechanism underlying production of the unit.

Other recent work relates to both of these issues (McFarland, 1965a, b, 1967). This work deals with the questions of whether there is parallel or sequential processing within the psychophysiological unit of time, and whether or not there is a constant unit of time. The procedure used in this work consists of presenting parts of a contour visual form in succession, varying interpart intervals (IPI), and asking Ss to judge whether the parts of the form appear simultaneously or successively. The IPIs at which the response of simultaneous drops to 50% (the succession threshold) is added to the duration of the parts and taken as the index of the unit of time. For example, when line parts X Y Z of an equilateral triangle are presented for 10 msec each at an IPI of 27 msec, the report of simultaneous drops to 50%, and the unit is calculated as $3(10 \text{ msec}) + 2(27 \text{ msec}) = 84 \text{ msec}$. Using this procedure, the unit of time has been

found to vary as a function of parameters of this procedure. The unit varies as a function of whether line (84 msec) or angle (71 msec) parts of a triangle are presented in succession, and as a function of whether the line parts are presented in a clockwise (61 msec) or counterclockwise (70 msec) sequence. The fact that parts of a form and the sequence of presenting the parts affects this index of the unit of time has been interpreted as providing some support for the proposition that within the unit there is a sequence of responses to particular portions of a presented form (McFarland, 1965a, b, 1967).

This report includes four experiments that deal with an illusion of succession. The results are interpreted as providing further support for the proposition that there is a sequence of responses to parts of a form within the psychophysiological unit of time.

EXPERIMENT 1

The experimental procedure consists of presenting a contour square between two vertical lines (context lines); the one on the left of the square is flashed 100 msec before the square, and the one on the right is flashed 100 msec after the square.

This procedure is based on the following

Fig. 1. A. Stimulus square and context lines. B. Pulse diagram when left and right context lines are presented, respectively, before and after the square; interstimulus intervals (ISI) are maintained equal when ISI is varied. C. Pulse diagram when line parts of the square are presented in succession; interpart intervals (IPI) are maintained equal when IPI is varied to index the succession threshold.

speculative reasoning. If there is a sequence of responses to parts of the square, and if the unit of psychophysiological time is 100 msec, then some of the part responses will fall in the first unit of time; the remainder will fall in the second unit of time; and Ss will report an apparent succession between parts of the square.

Procedure

The line stimuli are presented parallel to left and right sides of the square stimulus at a distance of 28 min of visual angle (Fig. 1A). In one condition, the left line, A, is presented first for 5 msec; 100 msec later, the square, BCDE, is presented for 5 msec; 100 msec later, the right line, F, is presented for 5 msec (Fig. 1B). In a second condition, the sequence is reversed. In both conditions, the series of stimuli is recycled at a rate of 1 cps for 1 min.

Five Ss are asked to report whether portions of the square appear successively or simultaneously. Ss are instructed, "If one or more sides either come on or go off before the others, press the right key. If all sides both come on and go off together, press the left key."

Stimuli are formed by transilluminating 35-mm slides in separate projectors with Sylvania R1131C tubes and rear-projecting on a Pola-coat screen. Pulsing of the tubes, control of pulse duration, control of interpulse duration, and control of sequence of pulses is accomplished with Iconix equipment.

Subjects fixate a red dot in the center of the circular screen when stimuli are presented; they are seated 23 in. from the screen in a dental chair with headrest. A 15-W red bulb, to the rear and above the S's head, illuminates the rear-projection screen and the room. Prior to testing, Ss are dark adapted for 10 min.

Results

After the first few cycles of the series of stimuli, all Ss report the sides of the square

appear successively. Typically, Ss report the left side of the square appears first, followed by the top, bottom, and right sides together. (When the sequence is reversed, right line-square-left line, this illusion of succession is also reported.) Sometimes the square appears to "flow" on (McFarland, 1966). According to one S, "the square looks like slits of brightness with someone moving a bright light behind it from left to right or from right to left."

EXPERIMENT 2

Although the illusion of succession reported in Experiment 1 is most striking when the stimulus series, line-square-line, is recycled, the illusion is frequently, though variably, reported with single presentations. This experiment considers the effect of the context lines on single presentations of the square at different interstimulus intervals (ISI) between lines and square. This variation in ISI will provide a stronger test of the reasoning behind the experimental procedure. The expectation is that reports of succession will reach a maximum when ISI equals the unit of time that is assumed to be 100 msec.

Procedure

Details of procedure are identical to those of Experiment 1 except as follows. Each of two Ss receives 10 single presentations of line-square-line at ISI of 1, 20, 40, 60, 80, 100, 120, 140 msec for both left-right and right-left sequences of line-square-line. Order of presentation is randomized for each S across presentations and ISI.

Results

As ISI increases from 1 to 140 msec, there is an increase in reports that parts of the square appear successively (Fig. 2A). The expected maximum does not occur at an ISI of 100 msec.

EXPERIMENT 3

As might be expected, Ss in Experiments

1 and 2 spontaneously report apparent movement of the context lines and the square. This experiment considers whether the reports of illusory succession are dependent on reports of apparent movement of the context lines or of the square. In addition, ISI is extended to 280 msec with the expectation that the maximum in succession reports at 100 msec will be more evident with a greater range of ISI.

Procedure

The details of procedure are the same as those of Experiment 2 except as follows. Each of 10 Ss receives one presentation of line-square-line at ISI of 1, 40, 80, 120, 160, 200, 240, 280 msec for both left-right and right-left sequences of line-square-line. Order of presentation is randomized for each S across sequence and ISI.

Results

The reports of succession and beta movement as a function of ISI are not similar on visual inspection (Fig. 2B). Collapsing the ISI variable for both types of reports permits computation of the statistic developed by McNemar for correlated proportions; it is 0.75, $p > .05$. A more powerful test of the dependency of these two types of reports is possible with the Spearman rank-order correlation. The correlation between reports of movement and succession for the left-right sequence of presenting the line-square-line is 0.12, $t = 0.34$, $p > .05$. For the right-left sequence, the correlation is 0.09, $t = 0.25$, $p > .05$. Considering these statistics, there is no support for a dependency between reports of beta movement and succession in this test situation.

On visual inspection, these data do not provide support for the expectation that a maximum in succession reports occurs at an ISI of 100 msec.

EXPERIMENT 4

Using a single staircase method to determine a succession threshold for the sides of the square, the expectation tested in Experiments 2 and 3 is retested. Here the expectation is that succession threshold will decrease to a minimum when ISI = 100 msec, the assumed unit of psychophysiological time.

Procedure

Details of procedure are identical to those

Fig. 2. A. Effect of ISI on report that parts of the square appear successively. B. Effect of ISI on reports that parts of the square appear successively, and that the context lines or the square appear to undergo beta movement.

Fig. 3. Effect of ISI on succession threshold. Horizontal line indicates control measure without presentation of the context lines.

in Experiment 2 except as follows. Line parts of the square are presented successively (BCDE) and interpart intervals (IPI) are varied (Fig. 1C); a single staircase method is used (Cornsweet, 1962). On the first trial, the IPI between the parts of the square is set at 50 msec and decreased on succeeding trials until a report of successive is obtained. This procedure is continued until a total of 10 crossovers in report occurs. The mean IPI (equivalent 50% IPI) at these crossovers is taken as the threshold. Results comparable to those reported below have also been obtained using a double staircase method (Nachmias & Steinman, 1965).

A threshold is determined for each ISI, which are presented in a random order to each of four Ss. Prior to these threshold determinations, a control threshold is obtained for each S without the context lines.

Results

At a 1-msec ISI, the threshold does not differ significantly from the control determined without the context lines (Fig. 3). As a function of ISI, the threshold decreases ($F = 3.36$, $p < .025$). These data show a significant linear trend ($F = 11.88$, $p < .005$), and there are no significant deviations from linearity.

Although there is no significant nonlinear component, the maximum effect of the context lines appears at an ISI of 100 msec, suggesting that 100 msec is the magnitude of the time unit in this situation. However, inspection of each S's data shows that the

maximum decrease in threshold occurs between 80 and 120 msec ISI.

DISCUSSION

The results of Experiment 1 were a surprise. Although the experiment was planned with some confidence, the reasoning behind the experimental procedure was rather "far out"; and total unanimity of the Ss in their reports that the square's parts appeared successively was not expected. The results of Experiments 2 and 3, planned to provide a stronger test of the reasoning, do not provide the expected maximum in succession reports when the square is presented between two units of time assumed to be demarcated by the two context lines presented 200 msec apart (100-msec ISI). The results of Experiment 3 do provide evidence that reports of apparent succession between the square's parts are not dependent on reports of apparent movement of context lines or square.

The results of Experiment 4 provide some support for the stronger test of the reasoning behind the experimental procedure. The average maximum decrease in succession threshold for the square's line parts occurs at 100 msec ISI. However, each S shows a maximum decrease in succession threshold between 80 and 120 msec ISI. This latter feature of the data suggests that the maximum decrease in succession threshold occurs at an ISI that matches an individual S's alpha period. This is in accord with data that the psychophysiological unit of time is correlated with the alpha period (Kristofferson, 1967; Murphree, 1954).

These data also provide another indication that the psychophysiological unit of time, when indexed by a succession threshold for parts of a form, is not a constant magnitude. Other studies have shown that such a succession threshold varies with type of part and type of part sequence presented (McFarland, 1965a, b, 1967). The data of Experiment 4 indicate that this succession threshold also depends on the temporal context in which the form is located. The tentative interpretation of this dependency is as follows. When two context lines are presented one before and one after a form, the first context line starts a timing sequence and, two units of psychological time later ($2 \times 80 - 120$ msec), the second context line terminates the timing sequence. Placing a form at the junction between these two psychophysiological units of time maximizes the probability that some of the sequential responses to the form's parts fall in one unit and the remainder fall in the other unit. When the part responses occur in different units of time, there is an apparent succession between parts of the form.

Three questions need to be raised and discussed relative to this interpretation of

the data. First, what is the effect on this succession threshold over a greater range of ISI than that used in Experiment 4? Other experiments (McFarland & Prete, in press) show that mean succession threshold for the sides of the square decreases to a minimum at 100 msec ISI and returns to control when ISI reaches 240 msec.

Second, since the procedure used to demonstrate this effect on succession threshold is similar to that used to study metacontrast, may the results of these experiments be mediated by mechanisms that lead to metacontrast? A contour stimulus (A) presented at appropriate ISI before or after another stimulus (B) has been shown to have an effect on the brightness, the reaction time, and the detection of B (Raab, 1963; Schiller & Smith, 1966). When the two stimuli are in the fovea and do not share or overlap contours, the effect of the A stimulus, presented after the B stimulus, on the brightness and detection of B decreases to practically zero at a separation of 10-15 min of visual angle (Alpern, 1953; Streicher & Pollack, 1967). However, in the periphery, the effect on brightness of the B stimulus does not decrease to zero until the separation between stimuli increases to 2 deg (Alpern, 1953). Since the separation between context lines and square used in the experiments reported here is 28 min of visual angle, and since the lines are 2 deg in length, thereby extending into the periphery, it may be argued that the effect on succession threshold is mediated by the mechanism leading to a metacontrast effect. Other experiments (McFarland & Prete, in press) show that this argument cannot be maintained. As the distance between lines and square is varied from 0.12 to 2.00 deg of visual angle, succession threshold for the square's sides is lowered over all distances; and the largest decreases occur at distances of 0.25 and 2.00 deg between lines and square when no metacontrast effect has been reported to occur.

The third question concerns the dependency of this illusion on figural relations between the context stimuli and the square. If these relations are to be considered in an explanation of this illusion, then the interpretation advanced above may require modification or rejection depending on the data from experiments in progress.

REFERENCES

- ALPERN, M. Metacontrast. *Journal of the Optical Society of America*, 1953, 43, 648-657.
- CORNSWEEET, T. N. The staircase-method in psychophysics. *American Journal of Psychology*, 1962, 75, 485-491.
- KRISTOFFERSON, A. B. Successiveness discrimination as a two-state, quantal process. *Science*, 1967, 158, 1337-1339.
- McFARLAND, J. H. Sequential part presentation: A method of studying visual form perception. *British Journal of Psychology*, 1965a, 56, 439-446.

- McFARLAND, J. H. The effect of different sequences of part presentation on perception of a form's parts as simultaneous. Proceedings of the 73rd Annual Convention of the American Psychological Association, 1965b, 43-44.
- McFARLAND, J. H. The influence of eye movements on a new type of apparent visual movement. *Psychonomic Science*, 1966, 4, 51-52.
- McFARLAND, J. H. Some evidence bearing on operations of "analysis" and "integration" in visual form perception by humans. In W. Wathen-Dunn (Ed.), *Models for the perception of speech and visual form*. Boston: M.I.T. Press, 1967.
- McFARLAND, J. H., & PRETE, M. The effect of visual context on perception of a form's parts as successive. *Vision Research*, in press.
- MURPHREE, O. D. Maximum rates of form perception and the alpha rhythm: An investigation and test of current nerve net theory. *Journal of Experimental Psychology*, 1954, 43, 57-61.
- NACHMIAS, J., & STEINMAN, R. M. An experimental comparison of the method of limits and the double staircase method. *American Journal of Psychology*, 1965, 78, 112-115.
- NEISSER, U. *Cognitive psychology*. New York: Appleton-Century-Crofts, 1967.
- RAAB, D. H. Backward masking. *Psychological Bulletin*, 1963, 60, 118-129.
- SCHILLER, P. H., & SMITH, M. C. Detection in metacontrast. *Journal of Experimental Psychology*, 1966, 71, 32-39.
- STREICHER, H. W., & POLLACK, R. H. Backward figural masking as a function of intercontour distance. *Psychonomic Science*, 1967, 7, 69-70.
- WHITE, C. T. Temporal numerosity and the psychological unit of duration. *Psychological Monographs*, 1963, 77, Whole No. 575.

NOTES

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