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McCollough effect acquisition depends on duration of exposure to inducing stimuli, not number of stimulus presentations

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In a test of Murch's (1976) conditioning model of McCollough effects, we sought evidence that the acquisition of these effects was influenced by the number of color/contour pairings within inspection trials of various durations. Our results indicated that acquisition rate depended only on trial length; it was not affected by changes in the number of presentations within trials. We found these results to be inconsistent with predictions based on the characteristics of conditioned responses.

In 1965, McCollough first reported the existence of chromatic aftereffects contingent upon spatial characteristics of lined patterns. Now known as McCollough effects (MEs) or contingent aftereffects, these subjective colors may be produced by having subjects view chromatic grating patterns, for example, black vertical lines on a red background alternating with horizontal lines on a green background. Subsequently, achromatic vertical and horizontal patterns appear to have a weakly saturated hue approximately complementary to that previously associated with each orientation.

Attempts to provide a theoretical explanation for MEs have included a suggestion that MEs are classically conditioned responses. Murch (1976), the major advocate of this theory, proposed that the lined portion of the inspection stimulus functions as the conditioned stimulus, and that color serves as the unconditioned stimulus. Thus, "as the result of the pairing of the CS (lined grid) with the UCS (color), a conditioned response (CR) develops so that the adaptive response of the visual system to the color is evoked by the lined grid" (p. 615).[1]

Support for this model has been accrued from the apparent resemblance of various characteristics of MEs to those of classically conditioned responses. Murch (1976) claims, for example, that variations in the temporal relationship between inspection contour and color affect ME magnitude in a manner consistent with the conditioning hypothesis. Some attributes of conditioned responses are not shared by MEs, however. For example, Skowbo and Rich (1982) have reported that MEs are not more readily acquired with practice.

Like the investigators discussed above, we feel that the conditioning model is best evaluated by seeking evidence that MEs share fundamental properties of learned responses. One such property is the dependence of the acquisition of a CR on the number of pairings of CS and UCS. As Pavlov (1927/1960) described the conditioning process, sounds evoke salivation "after several repetitions of the combined stimulation" (p. 26) of food and metronome. Descriptions of experiments in Pavlov's laboratory clearly indicate the dependence of CR strength on the number of stimulus pairings. For example, in the case of one subject conditioned by Anrep (1920), 10 combinations of food and tone produced only 6 drops of saliva, but, after 30 combinations, the tone evoked 60 drops. The number of joint color/contour presentations used to induce MEs has varied in several studies, but these have been paradigms in which number of presentations covaried with such independent variables as inspection duration and the alternation rate of the two lined patterns. Riggs, White, and Eimas (1974), for example, showed that strength of MEs increases with the duration of exposure to the inducing patterns; since alternation rate was kept constant, number of exposures to each color/contour pair varied exactly with inspection duration.

In another study, White and Ellis (Note 1) kept inspection duration constant while varying the rate at which the patterns alternated; here, the total number of presentations of each pattern varied exactly with alternation rate. In their slowest rate, the stimuli alternated every 7½ min, giving one presentation

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of each pattern in the 15-min inspection period. The fastest rate was 18.2 presentations of each pattern per second, or a total of 16,400 presentations of each pattern during the inspection period. At the end of inspection, ME strength was assessed with a color-cancellation technique. Their results revealed the strength index to be moderate following the slowest alternation rate, and larger when somewhat faster rates were used. At even higher rates, however, the index declined again. White and Ellis concluded that pattern presentation rate had a small but measurable influence on the strength of MEs, in that a broad range of rates, from about 1 presentation/sec to about 1 presentation/min showed greater efficiency for buildup than did higher or lower rates.

If White and Ellis' (Note 1) results are viewed as attributable to number of presentations, rather than to alternation rate, the findings seem incompatible with a learning model in three respects: the small magnitude of changes in ME strength (a factor of about 3) as compared with the variation in number of presentations (a factor exceeding 16,000); the equivalence of the broad intermediate range of presentations; and the low assessments of ME strength following very large numbers of presentations. However, the confounding of number of presentations with alternation rate makes it difficult to evaluate the influence of number of presentations per se. The same difficulty applies to the interpretation of Riggs et al.'s (1974) results, in which number of presentations was confounded with inspection duration.

Since the number of stimulus presentations equals total inspection duration divided by the duration of each stimulus (or alternation rate), it is not possible to vary the number of presentations while keeping both other variables constant. In the present experiment, the conditions are various combinations of these three parameters, and we attempt to evaluate the role of number of presentations by comparing performance among the conditions in which it covaries with one or the other of the remaining parameters.

Our paradigm is analogous to that used to establish learning curves: we track ME acquisition by assessing it at intervals (or trials) throughout the inspection (or acquisition) period. If MEs were conditioned responses, we would expect their acquisition to depend in some way upon the number of paired presentations per acquisition trial.

METHOD

Subjects

Two females served as subjects. Both had color-discriminating ability in the superior range, as measured by the Farnsworth-Munsell 100-Hue Test, and both had had extensive previous practice matching MEs with the color-mixing device described below.

Apparatus

The subjects sat facing two adjacent circular fields, 11 deg in diameter, on a large black background. Grating patterns used to induce and test the effect were projected onto the left of these fields. The inducing patterns were vertical or horizontal green (Wratten No. 53) or magenta (Wratten No. 32) gratings; their space-average luminances were, respectively, 96 and 75 cd/m². The test pattern contained vertical lines in its upper half and horizontal lines on the bottom; its space-average luminance was 5 cd/m². The spatial frequency of the patterns was 2 cycles/deg.

A homogeneous field of variable chromaticity appeared on the right-hand field. Its luminance was 7 cd/m². The subjects adjusted this stimulus to match effects seen on the adjacent test pattern. The source of the field was a projection colorimeter which mixed light transmitted by two Wratten filters (CC30M and CC50G). All mixtures could be located in C.I.E. space along a straight line connecting two points with the coordinates $x = .407$, $y = .454$ and $x = .421$, $y = .350$.

Procedure

The subjects began each session by adapting for 3 min to the homogeneous field set at a previously established neutral point. Next, they made one match to the top and another to the bottom half of the test pattern. The subjects then proceeded through 20 trials, each consisting of a period of exposure to alternating chromatic gratings followed by a pair of matches to the test pattern.

Table 1 shows the parameters associated with each of the six conditions. In Condition 4, for example, each trial would present a vertical green or magenta grating for 10 sec, followed by a horizontal grating of the other color for 10 sec, followed by the test pattern. As soon as the matches to the test stimulus were completed, the vertical chromatic pattern reappeared and a new trial began.

Each subject participated in each condition twice. The color-orientation combination used to induce the effect was reversed in successive sessions and counterbalanced over conditions. The order of conditions was determined randomly. Three to 4 days elapsed between sessions, and no subject began a session if evidence of residual effects appeared in the initial matches to test patterns.

RESULTS

Each match was converted to C.I.E. coordinates, and an index of ME strength was taken to be the distance in C.I.E. space between the pair of matches obtained in each trial. Graphs of each individual session revealed that between-subject differences were comparable to within-subject differences for given conditions, so data from the two subjects were combined.

Figure 1 shows the strength index plotted against trials for the six conditions. Inspection of these func-

Table 1
Values for Stimulus Duration, Number of Stimulus Presentations, and Trial Length in the Six Conditions

Condition	Duration Stimulus	Number of Exposures	Trial Length
1	5	1	10
2	5	2	20
3	5	4	40
4	10	1	20
5	10	2	40
6	10	4	80

Note—Duration stimulus = duration of each stimulus (in seconds); number of exposures = number of exposures to each stimulus per trial. Trial length given in seconds.

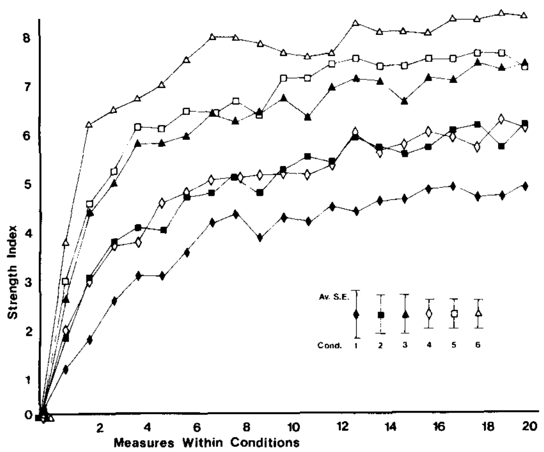

Figure 1. Strength index as a function of trials for six exposure conditions. Each symbol shows the mean of four sessions—two for each of two subjects. Inset shows the mean of the 21 standard errors calculated within each condition.

tions shows that the rate of acquisition depends upon duration of the trials, and not on the number of stimulus presentations per trial. The six functions fall into four groups according to trial length; the two functions for the 20-sec trials are indistinguishable, as are the two functions for 40-sec trials, despite the fact that one condition at each duration had twice the number of pairings as the other.

DISCUSSION

We have varied number of presentations, alternation rate, and trial duration in several combinations. Number of presentations per trial was 1, 2, or 4; trial duration was 10 or 20 sec; duration of each stimulus (i.e., alternation rate) was 5 or 10 sec. We observed no variation in acquisition rate with changes in alternation rate. This is consistent with White and Ellis's finding (Note 1) that rates varying from about 1/sec to about 1/min are equally efficient at producing MEs.

Our functions also did not show any variation with number of presentations. Had this variable been a major influence, we might have found our curves grouped into pairs with conditions having four presentations per trial rising most rapidly and conditions having one presentation per trial rising least rapidly. However, our functions fell into groups according to trial duration. A comparison of curves within conditions of same trial duration reveals no effect due to number of presentations.

Although we were unable to find, in the learning literature, a study that examined efficiency of number of paired presentations relative to duration of the joint presentation,[2] our speculation is that more information regarding the association of two stimuli is available when the pair is presented many, albeit relatively brief, times than when it appears a fewer number of times for longer durations. The former paradigm would thus seem to be the more efficient way to effect the learning of an associative response. However, we find no evidence of this in the acquisition of MEs. Like Skowbo and Rich (1982), we conclude that the ME has acquisition characteristics unlike those of classically conditioned responses.

REFERENCE NOTE

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NOTES

1. We are aware of discrepancies between this model and the traditional classical conditioning paradigm. However, since references to the model appear frequently in ME literature, we feel that empirical tests are appropriate. Therefore, for purposes of evaluation, we have assumed Murch's (1976) schematics.

2. A reason for this lack of information in the literature may be the following dilemma: The effect of variations in the duration of a CS-UCS pair could be established only in a simultaneous conditioning paradigm; however, the unreliability of simultaneous conditioning in producing learning (see, e.g., Hall, 1976) makes it less than ideal as a vehicle for a parametric investigation.

Rescorla and Holland (1982), in their recent review, did point out several examples of situations in which associations between two stimuli may be established very well by presenting them simultaneously. These included sensory preconditioning and other paradigms in which the associations are formed between neutral stimuli, such as compound CSs, prior to the introduction of a UCS. While it might be possible to establish the role, if any, played by duration of the stimulus pair in this context, it is sufficiently removed from the model proposed by Murch (1976) for us to question its relevance to our design.

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