Contingency and the McCollough effect

SHEPARD SIEGEL and LORRAINE G. ALLAN
McMaster University, Hamilton, Ontario, Canada

According to a Pavlovian conditioning analysis of the orientation-contingent color aftereffect (the McCollough effect), orientation stimuli become associated with simultaneously presented chromatic stimuli. This account suggests that decreasing the contingency between the putative conditional stimulus (grid orientation) and the unconditional stimulus (color) should decrease the strength of the aftereffect. In the present experiment, the effect of presentations of achromatic grids and/or homogeneous chromatic stimuli between presentations of chromatic grids was evaluated. Although interpolated achromatic grid presentations did decrease the magnitude of the McCollough effect, interpolated chromatic stimuli had no effect on the magnitude of the phenomenon. The results are discussed in terms of current research concerning the selective associability of certain categories of conditional and unconditional stimuli, and differences in the development of associations between simultaneously (compared with successively) presented conditional and unconditional stimuli.

Orientation-contingent color aftereffects, originally reported by McCollough (1965), are readily demonstrated. During a training period of several minutes, an observer inspects two patterns that alternate every few seconds. For example, one pattern could consist of black horizontal bars on a green background and the other pattern could consist of black vertical bars on a magenta background. Following such training, complementary color aftereffects contingent on bar orientation are noted. In the above example, the achromatic background of horizontal bars would appear pinkish and the achromatic background of vertical bars would appear greenish.

A number of investigators (e.g., Allan & Siegel, 1986; Bonnet, 1975; Bonnett, LeGall, & Lorenceau, 1984; Murch, 1976; Schmidt, Pinette, & Finke, 1978; Siegel & Allan, 1985; Skowbo, Timney, Gentry, & Morant, 1975; Westbrook & Harrison, 1984) have suggested that the McCollough effect (ME) is a phenomenon of classical conditioning. According to Murch (1976),

The lined grid in inspection functions as a conditioned stimulus (CS) while color functions as the unconditioned stimulus (UCS). As a 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)

There is considerable controversy as to the associative status of the ME (Allan & Siegel, 1986; Skowbo, 1984, 1986). One finding that has been seen as contrary to an associative analysis of the phenomenon is the failure to demonstrate that it is decremented by reducing the con-

tingency between the putative CS and UCS. Skowbo and Forster (1983) reported that the addition of homogeneous chromatic stimuli (presumably equivalent to UCS-alone presentations) to the sequence of usual grid-plus-color McCollough patterns did not have a significant influence on the size of the ME. Inasmuch as interpolated UCS-alone presentations often decrement the strength of conditioning (see Rescorla & Wagner, 1972), Skowbo and Forster suggested that their results were contrary to an associative model of the ME. This argument was elaborated in Skowbo's (1984) review of the literature relevant to the role of conditioning in the ME.

Allan and Siegel (1986) noted that although Skowbo and Forster's (1983) result may be taken as evidence against an associative interpretation of the ME, there may be other bases for such a finding. As suggested by Rescorla and Wagner (1972), the detrimental effect of interpolated UCS-alone presentations on the strength of the CS-UCS association may not be apparent early in acquisition. In Skowbo and Forster's (1983) study, a training session lasted for 10 min, and of the 10 min the colored grids were present for a maximum of 5 min.¹ It is possible that a training period more extensive than that used by Skowbo and Forster may be necessary to evidence the effects of degraded contingency. One purpose of the present experiment was to evaluate the effect of contingency manipulations on the strength of the ME in subjects given more extensive ME training.

In Skowbo and Forster's (1983) experiment, the contingency between the CS and UCS was decremented by interpolating UCS-alone presentations between paired CS-UCS presentations. The contingency between a CS and UCS can be decremented in other ways, too, and another purpose of the present experiment was to evaluate the effects of other contingency-reduction procedures on the magnitude of the ME. Presentation of the CS alone between paired CS-UCS trials is a procedure for decreasing the contingency between the CS and UCS (Rescorla

This research was supported by grants from the Natural Sciences and Engineering Research Council of Canada and the McMaster University Science and Engineering Research Board. The assistance of Khris Morine, Shannon Radigan, and Carla Garbos is gratefully acknowledged. Requests for reprints should be sent to either author at the Department of Psychology, McMaster University, Hamilton, Ontario L8S 4K1, Canada.

& Wagner, 1972). In the present experiment, the effect of this procedure, as well as the combined effects of both interpolated CS-alone and UCS-alone presentations, was assessed.

Evaluation of various operations that reduce CS-UCS contingency is of special interest, since there are findings in the conditioning literature that suggest that interpolated UCS-alone presentations may not always reduce the strength of conditioning. As pointed out by Allan and Siegel (1986), Wasserman, Deich, Hunter, and Nagamaisu (1977) found no evidence that UCS-alone presentations, interpolated between CS-UCS pairings, decreased the strength of the keypeck CS, much as Skowbo and Forster (1983) found that unpaired chromatic stimuli, interpolated between grid-color pairings, did not decrease the strength of the ME. Similar findings have been obtained in other conditioning preparations (e.g., the conditioned fear situation; Keller, Ayres, & Mahoney, 1977, Experiments 2 and 3).

METHOD

Subjects

The subjects were 142 male and female students with no previous experience in contingent-aftereffect tasks. They were enrolled in introductory psychology courses at McMaster University and received course credit for their participation.

Design

Each daily session was divided into 3-sec segments. Alternate segments were designated "trials" and "intertrial intervals." All intertrial intervals consisted of presentation of a dark gray square. One third of the trial segments (McCollough trials) consisted of presentations of chromatic grids; half of these consisted of black horizontal bars on a green background, and half consisted of black vertical bars on a magenta background. The content of the remaining two thirds of the trial segments (interpolated trials) depended on group assignment, and consisted of achromatic grids (i.e., putative CS-alone presentations), nonpatterned chromatic squares (i.e., putative UCS-alone presentations), and/or blank trials (i.e., presentation of a light gray square).

Group abbreviations indicate the stimuli presented during interpolated trial segments. For subjects in Group N ("nothing"), all interpolated trials consisted of blank trials (i.e., the light gray square). Group N provided a measure of the contingent aftereffect in subjects who were presented with the chromatic grids intermittently, and who received no exposure to the components of these chromatic stimuli between McCollough trials.

Subjects in Group CS were treated like subjects in Group N, except that half of the interpolated trials consisted of presentations of an achromatic grid. Achromatic horizontal and vertical grids were presented equally often. The remaining interpolated trials consisted of presentations of the light gray square.

Subjects in Group UCS were treated like subjects in Group N, except that half of the interpolated trials consisted of presentation of a chromatic square. Green and magenta squares were presented equally often. The remaining interpolated trials consisted of presentations of the light gray square.

Subjects in Group CS/UCS received interpolated presentations of both the grids and the colors. Half of the interpolated trials consisted of presentation of achromatic grids (the two orientations were

presented equally often), and the remaining interpolated trials consisted of presentation of chromatic squares (the two colors were presented equally often).

Group assignment (N, CS, UCS, CS/UCS) was combined factorially with duration of training (30 min, 60 min, 84 min), yielding 12 independent groups. During training, subjects assigned to the 30-min, 60-min, and 84-min training durations received either 100, 200, or 280 McCollough trials. Subjects in Groups CS, UCS, and CS/UCS additionally received the same number of interpolated exposures to achromatic grids, chromatic squares, or both, respectively.

Subjects assigned to 30-min training groups participated in the experiment in a single session. In order to maintain a reasonable session duration, subjects assigned to 60- and 84-min training groups participated in the experiment in two sessions of equal length, with an intersession interval of approximately 24 h.

For each group, the duration of training is indicated by a subscript following the abbreviation of the training condition. This subscript indicates the total number of McCollough trials experienced by subjects in that group (e.g., Groups CS/UCS₁₀₀, CS/UCS₂₀₀, and CS/UCS₂₈₀ received, respectively, 100, 200, and 280 McCollough trials, and an equal number of interpolated presentations of achromatic grids and chromatic squares).

In addition to the 12 groups described above, the design of the experiment included a 13th group, Group Mc₁₀₀, which received the traditional training for the McCollough effect. Subjects in Group Mc₁₀₀ received 100 3-sec alternating presentations of chromatic grids (i.e., the horizontal-green grid and vertical-magenta grid were each presented 50 times, with no interpolated stimuli and no intertrial intervals); thus, the training phase of the experiment for subjects in Group Mc₁₀₀ lasted 5 min. Comparison of the magnitude of the orientation-contingent color aftereffects in Groups Mc₁₀₀ and N₁₀₀ provides an indication of the extent to which the aftereffect is affected by intertrial intervals and interpolated blank trials.

Ten to 12 subjects were assigned to each of the 13 experimental groups (see Table 1).

Apparatus

The stimuli were presented on an Electrohome RGB color monitor (Model ECM 1301) driven by a Vectrix color graphics computer (Model VX384). The monitor was located 125 cm from the subject. The stimuli were 11.7 cm square, subtending 5.36° of visual angle. Temporal parameters, stimulus presentation, and recording of responses were controlled by a Commodore 64 computer.

The color on the monitor is the result of a combination of red, green, and blue (R, G, B). When each input is at its maximum value (R=G=B=255), the result is white. Decreasing all three values by equal amounts produces various shades of gray, from light to dark. When each input is at its minimum value (R=G=B=0), the result is black. Changing the relative proportions of R, G, and B produces various hues at different saturations.

Stimuli

Grids. The grids were composed of 31 bars, either horizontal or vertical, each bar subtending .17° of visual angle. Fifteen of the bars were black (R=G=B=0). For the chromatic grids, the horizontal black bars alternated with horizontal green (R=0, G=255, B=0) bars and the vertical black bars alternated with vertical magenta (R=255, G=0, B=160) bars. For the achromatic grids used as CS-alone presentations, the space between the bars was white (R=G=B=255).

Nonpatterned squares. Chromatic squares used as UCS-alone presentations were a homogeneous green (R=0, G=255, B=0) or magenta (R=255, G=0, B=160). The achromatic square used on

blank trials was a homogeneous light gray ($R=G=B=230$). The achromatic square used during intertrial intervals was a homogeneous dark gray ($R=G=B=190$).

Aftereffect Measurement

The magnitude of the orientation-contingent color aftereffect was determined with a computer colorimeter, which provided a measure of the amount of color necessary to counterbalance or nullify a color aftereffect. Assessment of the aftereffect was conducted in the same manner for all subjects. The subject was presented with a test pattern consisting of an 11.7-cm square divided into quadrants. Horizontal and vertical grids, of the same spatial frequency as the grids used during training, appeared in diagonally opposite quadrants of the test pattern. The relative amounts of green and magenta provided to each diagonally opposite pair of quadrants could be adjusted by the operation of a joystick connected to the Commodore 64 computer. At the outset of a determination of the magnitude of the aftereffect, two diagonally opposite quadrants were clearly greenish ($R=221$, $G=255$, $B=221$) and two were clearly pinkish ($R=255$, $G=221$, $B=255$). The subject was instructed to adjust the display so that the figure appeared achromatic.

To make the test pattern appear achromatic, the subject adjusted the display so that red and blue were added to the greenish quadrants while green was simultaneously added to the pinkish quadrants. In the absence of a color aftereffect, a subject should adjust the pattern so that, in all four quadrants, $R=G=B=255$. This setting, however, would appear as a mismatch if a color aftereffect were present. Specifically, for an achromatic test figure to be seen following training with the magenta vertical and green horizontal stimuli used in this experiment, relatively less green would be added to the vertical quadrants and relatively less red and blue would be added to the horizontal quadrants. The difference between the true achromatic setting and the subject's setting of subjective achromaticity provided an index of the color aftereffect.

Procedure

The subjects were tested individually in a darkened room, with the experimenter present in the room throughout the session. There were three phases: baseline measurement of the ME, training, and posttraining measurement of the ME.

Baseline measurement of the ME. Prior to presentation of any training trials, the subjects were presented with the test pattern on four occasions. On two of the baseline determinations, the upper left and lower right quadrants were initially pinkish, and the other diagonally opposite quadrants were greenish. These initial colors were reversed on the other two baseline determinations. For each determination, the subject was instructed to manipulate the joystick until the pattern appeared colorless. The mean of the four settings provided the baseline measure.

Training. Following baseline determination, subjects were trained in accordance with their group assignment. In the case of subjects participating in the experiment for one session, training was followed by 2 min in normal room illumination prior to posttraining determination of the ME. If the subject was participating for two sessions, he/she left the lab at the end of training, returning the next day at approximately the same time for additional training. The second training period was followed by 2 min under normal room illumination, followed by posttraining determination of the ME.

Posttraining measurement and calculation of the ME. The post-training determination was conducted in the same manner as the baseline determination. The mean of the four posttraining determinations provided the posttraining measure of the ME. The difference between the baseline measure and the posttraining measure constituted the magnitude of the ME.

Consider the following example of a calculation of the ME magnitude for a given subject: During baseline determination, the mean

Table 1
Mean Magnitude of the McCollough Effect, Standard Error of the Mean (*SEM*), and Number of Subjects (*n*) in Each Group

	Condition					Row Mean
	Mc	N	UCS	CS	CS/UCS	
100 Trials Experienced						
<i>M</i>	5.43	5.71	7.63	3.56	4.85	5.44*
<i>SEM</i>	.64	.55	.85	.54	.65	
<i>n</i>	10	12	12	12	12	
200 Trials Experienced						
<i>M</i>		6.90	6.32	3.97	3.70	5.22
<i>SEM</i>		1.21	1.03	.68	.94	
<i>n</i>		10	10	10	10	
280 Trials Experienced						
<i>M</i>		6.89	7.85	4.84	4.63	6.05
<i>SEM</i>		.69	.94	.65	1.17	
<i>n</i>		11	11	11	11	

*This row mean excludes Group Mc_{100} .

setting of the colorimeter would be near the ideal of $R=G=B=255$ (e.g., the settings for the vertical quadrants might be $R=255$, $G=253$, $B=255$; hence the mean setting for the horizontal quadrants would be $R=253$, $G=255$, $B=253$). If an ME was induced during training, one would expect a decrease in the amount of green for the verticals (e.g., a mean setting of $R=255$, $G=245$, $B=255$), and a corresponding decrease in the amount of red and blue on the horizontals (a mean setting of $R=245$, $G=255$, $B=245$). The size of the ME in this example would be 8 (the difference between the G input on the vertical, or between the R or B input on the horizontal).

RESULTS

The mean magnitude of the ME and the *SEM* for each condition/frequency combination are shown in Table 1. A comparison of Groups N_{100} and Mc_{100} reveals similar performance [$t(20) = .33$, $p > .05$].

The data from four training conditions (CS/UCS, CS, UCS, N) under three presentation frequencies (100, 200, 280) were subjected to a between-subjects, two-factor ANOVA. Only the main effect of condition was significant [$F(3,120) = 10.26$, $p < .001$]. This result is shown in Figure 1. The Tukey HSD test indicates that Groups

Figure 1. Mean McCollough effect (ME) magnitude for Groups N, UCS, CS, and CS/UCS, collapsed across presentation frequency.

CS/UCS and CS both differed significantly from Groups UCS and N (all p s < .05). No other differences were significant.

DISCUSSION

Similar contingent color aftereffects were displayed by subjects in Groups N₁₀₀ and Mc₁₀₀. This suggests that the magnitude of the ME is not affected by the random presentation of McCollough trials (rather than alternating presentation) or by the insertion of a gray square during intervals between McCollough trials (rather than having no interpolated intervals).

There was no main effect of presentation frequency; that is, the strength of the ME did not increase significantly as the number of McCollough trials was increased. In order to maintain a reasonable session duration, presentation frequencies of 200 and 280 were distributed over two sessions. The absence of a main effect of presentation frequency suggests that either the ME was asymptotic after 100 trials or there was little savings between sessions. Given the long-lasting nature of the ME (e.g., Jones & Holding, 1975), the finding that additional training on a second day did not significantly strengthen the aftereffect is somewhat surprising. This finding, however, is similar to others in the ME literature (White, 1977).

Our data indicate that the interpolation of chromatic stimuli among McCollough trials did not affect the magnitude of the contingent color aftereffect. This replicates Skowbo and Forster's (1983) report that the interpolation of UCS-alone trials had no influence on the size of the ME. Using an autoshaping preparation, Wasserman et al. (1977) similarly reported that response strength was not affected by interpolated UCS-alone presentations. In Wasserman et al.'s experiment, interpolated CS-alone presentations also did not affect responding, but interpolation of both CSs and UCSs did decrease the strength of the keypeck CR. In the present experiment, interpolation of CS-alone trials did reduce the magnitude of the color aftereffect. This decremental effect of interpolated CS presentations was not augmented by the addition of interpolated UCS presentations (i.e., the CS/UCS condition did not differ significantly from the CS condition). Thus, the present pattern of results is not consistent with those obtained in a similarly designed conditioning experiment.

There are several interpretations for the results of the present experiment. One interpretation is that of Skowbo (1984), who concluded that the ME is not due to classical conditioning. There is a considerable amount of evidence, however, that is consistent with an associative account of the phenomenon (Allan & Siegel, 1986). One intriguing possibility is that the ME represents an instance of selective CS-UCS associability that may not be modifiable by interpolated UCS presentations.

The selective associability of certain CSs with certain UCSs has been well documented in the animal learning

literature and is characteristic of several learning situations (e.g. flavor stimuli, but not exteroceptive stimuli, are readily associated with gastrointestinal distress; see Barker, Best, & Domjan, 1977, and Domjan, 1983). Such constraints have usually been interpreted as evidence for biological predispositions to learn certain CS-UCS relationships (Barker et al., 1977). It has been suggested that the ME is yet another manifestation of this selective associability (Allan & Siegel, 1986; Harris, 1980; Siegel & Allan, 1985; Westbrook & Harrison, 1984), since only a limited range of stimulus characteristics, following pairing with color, can contingently elicit complementary aftereffects. For example, Foreit and Ambler (1978) reported a green aftereffect when subjects had been adapted to a magenta outline square, but no aftereffect when the magenta outline square had been alternated with a green cross during adaptation. That is, there was no evidence for a color aftereffect contingent on form (square vs. cross) when the two forms shared the same line orientations and differed only in the rearrangement of their constituent lines. A number of investigators (e.g., Harris, 1980; White & Riggs, 1974) have noted that there have been no reports of color aftereffects contingent on forms "such as letters of the alphabet, people's faces or makes of automobiles" (White & Riggs, 1974, p. 1153), or of color aftereffects contingent on nonvisual stimuli.

On the basis of an influential interpretation of contingency manipulations, the Rescorla-Wagner model, such constraints on CS-UCS associability should affect the ability of interpolated UCS presentations to decrementally affect learning (Rescorla & Wagner, 1972). According to this model, associations between the experimental context and interpolated UCSs develop in parallel with CS-UCS associations. Given the difficulty, noted above, of establishing a color aftereffect contingent on form, it would be anticipated that interpolated chromatic stimuli would not affect the strength of the orientation-color association, since the inability of the experimental context cues to become associated with chromatic stimuli would render the contingency manipulation ineffective.

Another analysis of the ME that may be relevant to the failure of interpolated presentations of chromatic stimuli to decrement the effect emphasizes the fact that the putative CS (grid) and UCS (color) are presented simultaneously during training. In most conditioning preparations, the CS and UCS are presented sequentially, and prevalent views of conditioning emphasize the role of the CS as a signal for the UCS—a relationship that is best described as "informative" or "predictive" (see Rescorla, 1981). Some investigators have suggested that an alternative view of the learning process may be appropriate for simultaneously presented events (Asch, Ceraso, & Heimer, 1960; Domjan & Burkhard, 1986; Rescorla, 1981), especially if the events are motivationally neutral: "Associations between two biologically weak stimuli (two visual cues, for example) appear to be learned somewhat differently than associations between a weak and a strong

stimulus (a tone and food, for example)" (Domjan & Burkhard, 1986, p. 81). In the case of simultaneously presented sensory events, subjects may form a unitary representation of the elements that form the compound perceptual stimulus, rather than form separate representations that are then associated (i.e., "coherence within units," rather than "coherence between units"; Asch et al., 1960). Based on results of experiments concerning the role of perceptual characteristics of the stimulus in the formation of associations, Asch et al. (1960) considered it likely that different processes may mediate the acquisition of simultaneous and sequential associations. More recently, on the basis of the results of animal experiments involving the acquisition of simultaneous associations, Rescorla (1981) reached a similar conclusion: "The results reported here suggest that substantial, important, and perhaps qualitatively different, learning occurs when stimuli are presented simultaneously" (p. 78).

In summary, the present results provide no evidence that decreasing the contingency between the grid and color decreases the magnitude of the ME. This procedure is analogous to decreasing the contingency between the CS and UCS in Pavlovian conditioning, which is known to decrementally affect conditioning in a variety of situations (Rescorla & Wagner, 1972). These results, then, provide no evidence for the conditioning analysis of the ME, and are consistent with Skowbo's (1984, 1986) conclusion that conditioning is irrelevant to the phenomenon. This conclusion, however, is in marked contrast to abundant evidence indicating parallels between the ME and learning (Allan & Siegel, 1986). There are several ways in which the present data may be compatible with an associative analysis of the ME. It is possible that the ME represents an instance of selective associability of certain CSs and UCSs. On the basis of this selective associability perspective, the contingency manipulation would not be expected to be effective. Alternatively, the ME may best be understood as a result of processes unique to simultaneous associations between biologically weak stimuli. From this perspective, some phenomena of sequential associations, such as those revealed by contingency manipulations, may not be relevant to elucidating the associative status of the ME.

REFERENCES

- ALLAN, L. G., & SIEGEL, S. (1986). McCollough effects as conditioned responses: Reply to Skowbo. *Psychological Bulletin*, **100**, 388-393.
- ASCH, S. E., CERASO, J., & HEIMER, W. (1960). Perceptual conditions of association. *Psychological Monographs*, **74**(490), 1-48.
- BARKER, L. M., BEST, M. R., & DOMJAN, M. (Eds.). (1977). *Learning mechanisms in food selection*. Waco, TX: Baylor University Press.
- BONNET, C. (1975). Le conditionnement sensori-sensoriel dan les analyseurs visuels d'attributs. *Psychologie Française*, **20**, 34-43.
- BONNET, C., LEGALL, M., & LORENCEAU, J. (1984). Visual motion aftereffects: Adaptation and conditioned processes. In L. Spillmann & B. R. Wooten (Eds.), *Sensory experience, adaptation, and perception* (pp. 561-582). Hillsdale, NJ: Erlbaum.
- DOMJAN, M. (1983). Biological constraints on instrumental and classical conditioning: Implications for general process theory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 17, pp. 215-277). New York: Academic Press.
- DOMJAN, M., & BURKHARD, B. (1986). *The principles of learning and behavior* (2nd ed.). Monterey, CA: Brooks/Cole.
- FOREIT, K. G., & AMBLER, B. A. (1978). Induction of the McCollough effect I: Figural variables. *Perception & Psychophysics*, **24**, 295-302.
- HARRIS, C. S. (1980). Insight or out of sight? Two examples of perceptual plasticity in the human adult. In C. S. Harris (Ed.), *visual coding and adaptability* (pp. 95-149). Hillsdale, NJ: Erlbaum.
- JONES, P. D., & HOLDING, D. (1975). Extremely long-term persistence of the McCollough effect. *Journal of Experimental Psychology: Human Perception & Performance*, **1**, 323-327.
- KELLER, B. J., AYRES, J. J., & MAHONEY, W. J. (1977). Brief versus extended exposure to truly random control procedures. *Journal of Experimental Psychology: Animal Behavior Processes*, **3**, 53-65.
- MCCOLLOUGH, C. (1965). Color adaptation of edge-detectors in the human visual system. *Science*, **149**, 1115-1116.
- MURCH, G. M. (1976). Classical conditioning of the McCollough effect: Temporal parameters. *Vision Research*, **16**, 615-619.
- RESCORLA, R. A. (1981). Simultaneous associations. In P. Harzem & M. D. Zeiler (Eds.), *Predictability, correlation, and contiguity* (pp. 47-80). New York: Wiley.
- RESCORLA, R. A., & WAGNER, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and non-reinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current theory and research* (pp. 64-99). New York: Appleton-Century-Crofts.
- SCHMIDT, M. J., PINETTE, P. R., & FINKE, R. A. (1978). Further evidence for conditioning processes in the McCollough effect. *Journal of General Psychology*, **99**, 117-132.
- SIEGEL, S., & ALLAN, L. G. (1985). Overshadowing and blocking of the orientation-contingent color aftereffect: Evidence for a conditioning mechanism. *Learning & Motivation*, **16**, 125-138.
- SKOWBO, D. (1984). Are McCollough effects conditioned responses? *Psychological Bulletin*, **96**, 215-226.
- SKOWBO, D. (1986). McCollough effects as conditioned responses? Reply to Allan and Siegel. *Psychological Bulletin*, **100**, 394-397.
- SKOWBO, D., & FORSTER, T. (1983). Further evidence against the classical conditioning model of McCollough effects. *Perception & Psychophysics*, **34**, 552-554.
- SKOWBO, D., TIMNEY, B. N., GENTRY, T. A., & MORANT, R. B. (1975). McCollough effects: Experimental findings and theoretical accounts. *Psychological Bulletin*, **82**, 497-510.
- WASSERMAN, E. A., DEICH, J. D., HUNTER, N. B., & NAGAMASU, L. D. (1977). Analyzing the random control procedure: Effects of paired and unpaired CSs and USs on autoshaping the chick's key peck with heat reinforcement. *Learning & Motivation*, **8**, 467-487.
- WESTBROOK, R. F., & HARRISON, W. (1984). Associative blocking of the McCollough effect. *Quarterly Journal of Experimental Psychology*, **36A**, 309-318.
- WHITE, K. D. (1977). Summation of successively established orientation-contingent color aftereffects. *Perception & Psychophysics*, **22**, 123-136.
- WHITE, K. D., & RIGGS, L. A. (1974). Angle-contingent color aftereffects. *Vision Research*, **14**, 1147-1154.

NOTE

1. Each subject participated in a number of training sessions; however, extinction occurred between sessions.

(Manuscript received July 7, 1986;
revision accepted for publication March 26, 1987.)