of the foursome: $F(1,336) = 14.74$, $p < .005$]. Additionally, the doubles and triples were different from one another, $F(1,336) = 3.16$, $p < .05$.

Thus, an end effect was shown, but not quite the same as Anderson's. His Ss' ratings of likability of the hypothetical personality became *more extreme* when the entire set of six or nine adjectives was presented. Yet Ss in this study predicted the occurrence of the event light more often with all predictors present with all treatments. For $\pi < .50$ this is less extreme rather than more extreme behavior.

Anderson's task seems, intuitively, to be less ambiguous than the one in this study. A reasonable explanation for his end effect may be that Ss felt they were given all the information available about the personality when an entire adjective set was presented and could have felt more certain whether they liked or disliked the personality. Presentation of only a subset may have implied there was additional information on which the judgment should have been based, but the information was unavailable. In contrast, it seems there is no a priori reason to suppose that a greater number of predictor lights in this study provided Ss with greater surety that the event would occur.

The general numerosity effect seems to be of an unspecified method of averaging, as Schipper has suggested. The difference between the doubles and triples is not immediately explainable. Anderson suggests that Ss average the adjectives with some subjective impression (possibly analogous to some probabilistic response set), but this predicts that judgments would be a monotone increasing (or decreasing) function of the number of cues, which, in this study, is not the case.

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Redundant stimulus coding and keeping-track performance

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The effect of redundant color coding on keeping-track performance was investigated, using symbols as the primary cue. Ss were assigned to one of four coding conditions: symbol color (SC), color symbol (CS), symbol only (S), or color only (C). Performance was measured on a task requiring S to monitor eight information channels, which were being updated randomly. Results indicated that the addition of a redundant color code did not yield a significant improvement in performance, as compared to performance on the component codes (i.e., the S and C groups).

A keeping-track task is one in which S is required to remember the present state of each of a number of variables. The task is a continuous one in which the states of the variables are changed at random intervals. This experimental paradigm was introduced by Yntema & Mueser (1960) and has the advantage of enabling one to study a dynamic or a continuous memory process.

Kanarick & Petersen (in press) investigated the effect of redundant color coding, in which the stimulus was uniquely identified by both a primary dimension and a secondary color code, on keeping-track performance. They hypothesized that the use of color as a redundant cue would increase the effectiveness of keeping-track performance. Their study required S to keep track of information consisting of numbers, colors, or numbers on a colored background, the latter being the redundantly coded information. Their results did not support the hypothesis. Rather, the technique appeared to increase performance variability through the number of strategies Ss used. The authors suggested that the apparent inefficacy of the redundant cue may be a result of the ease with which numbers can be encoded and chunked. The present study was, therefore, an attempt to investigate the effect of redundant color coding on keeping-track performance, using additional task controls.

Symbols were chosen for one stimulus dimension because they are of a class that does not possess a natural order, as compared with numbers. Monty, Fisher, & Karsh (1967) suggest that use of a class of stimuli possessing sequential order (such as numbers or letters of the alphabet) as a coding dimension is likely to lead to greater proficiency in keeping-track performance than use of stimuli not possessing such an order.

To reduce variability of individual keeping-track strategies, paced overt rehearsal during update trials was introduced.

METHOD

The Ss were male and female students from the University of Minnesota and Hamline University. All Ss were pretested for color defectiveness by the Farnsworth D-15 test; two Ss were eliminated by this test. The remaining Ss were assigned randomly to one of four coding conditions, with eight Ss per group. The four coding conditions were: symbol color (SC), symbol being the cue S was instructed to attend to and color serving as the redundant cue; color symbol (CS), the cues being reversed; symbol only (S); and color only (C).

The apparatus consisted of eight IEE solid-state digital readouts controlled by a tape reader and interval timers. The readouts, each 2 in. square, were mounted horizontally on a rack approximately 40 in. from S's eye level. Each readout was programmed to display either a symbol (=, >, +, —, ÷, or ×), a color (yellow, blue, purple, green, red, or orange), or a unique symbol-color combination (=/yellow, >/blue, +/purple, —/green, ÷/red, or ×/orange). Small white lights to pace rehearsal and 1-in. capital identification letters (A through H) were mounted above the readouts or "channels."

Each S was given paired-associate training with the six unique combinations of colors and symbols to the criterion of two errorless trials. All Ss received equal training regardless of coding condition. The S was then told that his task would be to keep track of many pieces of information at one time. One new piece of information would be presented to him in one of the windows (readouts) at a time. The S was instructed that the information would be in the appropriate mode (i.e., symbol and color, color only, or symbol only) for his group. Following each presentation of new information in one of the channels (update trial), he would be asked to recall what information had most recently been stored in a channel (interrogation trial). These two types of trials would alternate.

The new updated information remained displayed throughout each

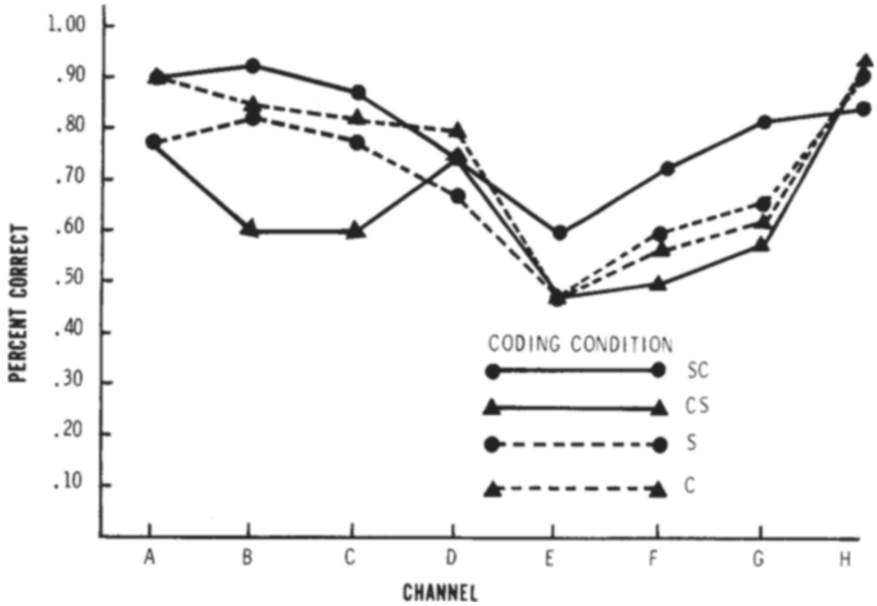

Fig. 1. Percent responses correct by channel and coding condition.

update trial and was the only information displayed. Each trial consisted of two complete overt rehearsals of all channels in sequential order, paced by the lights above the channels. Total rehearsal time per trial was 16.5 sec (1.06 sec/channel). Following each update, one channel was interrogated by means of the light above that channel. The S was allowed 6.6 sec to respond verbally, the appropriate response being what information had most recently been displayed in that channel. Each S was given two practice runs of 17 updates and 17 interrogations each (25 min of training) before the test run. The test consisted of 40 updates and 40 interrogations. Each channel was interrogated five times during the test run. Each run began with four trials, during which initial information stored in each channel was displayed simultaneously. These trials were run to increase the probability that all initial information was encoded and stored. The same sequences were presented to all Ss, the groups differing only in coding dimensions.

RESULTS AND DISCUSSION

The number of correct responses to interrogations was used as the measure of performance. Homogeneity of variance between the four coding groups was verified by Hartley's test (Winer, 1962, p. 93), $F_{max}(4,7) = 7.94$, $p < .05$. A two-way analysis of variance (Winer, 1962, p. 302) yielded statistical significance only for the main effects of coding condition, $F(3,28) = 3.13$, $p < .05$, and channel, $F(7,196) = 16.36$, $p < .001$. A subsequent Tukey (a) procedure for post hoc comparisons (Winer, 1962, p. 87) yielded a significant difference ($p < .05$) only between the SC and CS groups.

The anticipated serial position curve was found. As can be seen in Fig. 1, the greatest number of errors occurred at Channel E. McCrary & Hunter (1953) investigated the effect of conditions for verbal learning upon the serial position curve. They concluded that, with an efficient code, the greatest reduction of mean errors per serial position would occur in the middle or just past the middle of the series, i.e., at the most difficult positions. Channel E is just past the middle of the series. To determine if the performance of the SC group was significantly better than that of the CS, S, and C groups at Channel E (i.e., does redundant color coding represent a more efficient condition?), a simple main effects test for Channel E was performed. Nonsignificant results were obtained, $F(1,224) = 1.10$, $p > .10$. Therefore, we must conclude that redundant color coding, relative to unidimensional coding, is not an efficient aid to keeping track of performance.

The results of the present study are in agreement with those of Kanarick & Petersen (in press), in that the addition of a redundant color code did not yield a significant improvement in performance, as compared to performance on the component codes (i.e., the S and C groups). The poor performance of the CS group may be explained in terms of perceptual set. When a stimulus is color coded, color is typically the redundant rather than the primary cue. The Ss in the CS group were required to attend to the color dimension and apparently had difficulty doing so. A figure-ground problem existed for these Ss, as they reported that the symbols were "in the way" of the colored background and distracted from it. These subjective reports, supported by the results of the Tukey (a) procedure, suggest that, in multidimensional coding, color is most effective as the redundant rather than the primary cue.

This relative inefficiency of the redundant code in the present study was substantiated by subjective comments. The Ss in the SC group reported that they often ignored the redundant color code and used it only when adjacent channels contained the same color (e.g., two consecutive blues). The Ss in the CS group reported that they used the redundant symbol code only with colors especially difficult to differentiate (e.g., red-orange). Those reports suggest that the present task may not have been difficult or complex enough to require dependence upon a redundant code. Percent correct was above 90% on some channels without a redundant code (see Fig. 1). Increasing complexity through increasing the number of channels S has to keep track of may result in a change in keeping-track strategy. The S would now have to "chunk" information, and the redundant color code would provide an additional basis on which to "chunk." Conversely, an increase in rate of presentation might reduce the effectiveness of the redundant cue, since available processing time would be reduced. The S might tend to ignore the redundant cue to concentrate on the primary one. These, however, are questions for future investigation.

In summary, the hypothesis that performance on a keeping-track task would be superior when information was redundantly color coded, when compared with performance on the component unidimensional codes, was rejected. A suggestion was made for further investigation of redundancy effects.

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