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AUTHOR Isaacs, Dan Lee
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ABSTRACT

The present study was designed to evaluate the effect of color coding on reducing the time required to reach a criterion in a paired associate learning task. This study consisted of two experiments using bones which were color coded. Data were collected on four dependent variables: (1) number of trials required to reach a criterion of two correct trials on non-color-coded stimuli; (2) number of correct responses on a paper and pencil test on which all eight bones which S had learned were pointed out at one time; (3) the number of correct responses made by S when he was shown pictures of the bones and asked to respond with the color name associated with it; and (4) the number of correct responses made by S when he was shown a color and asked to respond with the name of a bone associated with it. It was concluded from the results of the two experiments that color coding, even when instructions alerting S to the color are added, was not beneficial in reducing the number of trials required to learn the type of material presented in this study. (Author)

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Dan Lee Isaacs, Project Director
Audio-Visual Research Department
Indiana University
Bloomington, Indiana 47401

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U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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D.L.I.

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CHAPTER I

INTRODUCTION

The behavioral effects of the use of color in visual displays has been a much discussed topic in the audio-visual field. However, studies in which the instructional effectiveness of materials having color cues has been compared with the effectiveness of materials having only black and white cues have generally produced inconsistent results. Several reviewers of the literature (Hoban and Van Ormer, 1950; Hoban, 1960; and Travers, 1964) have concluded that the results of many studies are difficult to interpret because of a failure by investigators to analyze the role of color in the learning process. Therefore, in spite of considerable research concerning color, the present situation seems adequately summed up dy Dale's (1955) observation that the educator "has precious little to draw on" in guiding his utilization of color in the design of educational messages. Although people generally express a preference for color when both a black and white version and a color version of a message are available to them, there is little evidence to support the generalization that more learning occurs when color cues are available to them.

However, several authors have suggested some situations in which color might be useful. Miller (1957) conjectured that the use of color should be advantageous if it is one of the most relevant cues or if it can be used to emphasize relevant cues; it should be disadvantageous if it distracts or complicates. McGeoch and Irion (1952) found that color can, indeed, be useful in helping one to discriminate between relevant cues, and Hoban and Van Ormer (1950) concluded that color must not draw the learner's attention away from the important cues.

In light of the above generalizations, the present study was designed to obtain further information about the use of color in discrimination learning. Specifically, the purpose of the study was to examine the effect of an early use of color coding to facilitate learning and a later removal of it, such as ultimately the correct response is associated with the primary cue, shape. It seemed that if such a procedure did facilitate learning, it might be adapted to the preparation of instructional materials. There are many learning situations in which a temporary enhancement of the critical cues might very well serve to draw attention to these cues.

In the present experiment each subject (S) was presented with a paired associate task in which he was required to learn the names of each of several parts ("shapes") of a visual configuration. In an attempt to facilitate discrimination, a color-coding technique was used. There are two types of studies that are relevant to the task in the present study. The first type of study can be labeled as "searching" tasks. In one study, Green and Anderson (1956) determined the effectiveness of a color code as a function of the number of symbols shown in each color. They required Ss to locate numbers in a 10 x 6 matrix. They found that when Ss knew the color of the number they were searching for, time and errors were reduced. They concluded that added color, when S is alerted to its use, can act as a beneficial cue. Secondly, in a series of studies concerned with searching behavior (Smith, 1963; Smith and Thomas, 1964; Smith, Thomas, and Farquhar, 1965), Ss were presented with tabular matrices and asked (1) to search for objects and (2) to count them. In all of these studies, color-coding markedly reduced search time, counting time, and number of errors. In addition, the use of color was as much as three times as effective as the use of symbol codes. These investigators expressed the view that color was superior because it provided a visual separability among the objects. It seems plausible, then, that some means of providing visual separability may facilitate learning in many instructional situations. Such situations often involve visual configurations made up of white shapes outlined in black. Parts of the configuration that are contiguous often have parts of their outlines in common. As a result, they may tend to "run into each other." For this reason the parts may be difficult to find or separate out, and hence the separability provided by added color may promote discrimination. It seemed possible, then, that in the present study the addition of color might act as a beneficial cue, helping Ss to identify the various parts of the configuration whose names were to be learned.

The results of a second type of study that is relevant to the present study have shown that contextual color cues, i. e., cues not specifically a part of the primary stimuli, can facilitate learning. Weiss and Margolius (1954) instructed Ss to learn paired associates presented on variously colored backgrounds. In addition, they had a control condition in which Ss learned the paired associates on homogeneous gray backgrounds. They found that the number of trials to learn was significantly less for those Ss who learned with colored backgrounds. Though they said that the actual process by which the colored background, or context stimuli, facilitated learning was not evident, they suggested two possible explanations. These explanations might be summarized by saying that the probability of correct responses increased due to the increased number of cues available. It seems likely, based on these two groups of studies, that color cues might facilitate learning in other instructional tasks, including that of the present study. The particular type of procedure used in the present study has been anticipated in a study by Saltz (1963). In a 2 x 2 factorial design, color context cues were either present or absent during learning and either present or absent during transfer in a paired-associate task. Learning was facilitated more when color was used during training but not during transfer than when color was absent in both phases. These results suggest that the presence of color cues during learning can facilitate transfer to a task where color cues are no longer present.

In the experiment just described, the color cues were withdrawn abruptly once S reached a certain criterion. A second method of withdrawing the color cues involves a procedure called "fading." As described by Taber and Glaser (1964), this is a process in which some aspect of a stimulus complex is faded in intensity, saturation, or some other physical quality while all the other parts of the stimulus complex remain the same. This procedure may be described as one in which the discrimination task is initially an easy one and is gradually made more difficult. Several studies of this sort have been performed. Schlosberg and Solomon (1943), training rats on a Lashley jumping stand, found that rats could learn a simultaneous discrimination between two certain narrowly-separated grays if, and only if, the discriminative stimuli were gradually changed from a white card and a black card to the narrowly separated gray ones. Later, Lawrence (1952) trained four groups of animals on simultaneous brightness discriminations. All groups received the same number of reinforced training trials on a given discrimination and then were transferred to a test discrimination involving two middle grays. One group was trained throughout on the test discrimination; a second group was trained on a slightly easier discrimination and then shifted abruptly to the test discrimination; and the last group was trained similarly to the third group but approached the test discrimination through a series of graduated steps. Lawrence found that learning was more efficient when animals were first trained on an easy discrimination and then shifted to the test discrimination, than if all training were given directly on the latter. In addition, learning was most efficient when the animals approached the test discrimination through a series of graduated discriminations. Moore and Goldiamond (1964) attempted an errorless establishment of a visual discrimination using fading procedures. In a matching-to-sample task, they had children face a panel with one sample window above three response windows. After seeing a triangle in the sample window, the children were to choose the triangle in one of the three response windows that was most like the sample and then they were to respond by pushing a key under that window. In the condition labelled "full presentation" all of the triangles were always presented at full intensity or brightness. However, in another condition only the sample triangle and its "match" in a response window were presented at full intensity while the other triangles were gradually brought to full intensity over a number of trials. Moore and Goldiamond found that fading improved performance regardless of when it was made a part of the procedure, but that it was most effective when introduced on the first trial.

It seemed likely, then, on the basis of the results of prior studies that color coding, especially when color cues were "faded" over trials, would result in Ss' learning the required task in less time than would its similar, uncoded counterpart. In addition, in view of the results of Weiss and Margolius (1954) and those of Saltz (1963), it appeared likely that the removal of color would result in little or no decrement in the probability of correct responses. However, for a coding system to be valuable it must result in a reduced learning time. In other words, the duration of initial training (with color coding) added to the duration of final training (without color coding) must be less than for similar training that does not include a coding system. In the present study it appeared that the procedure that would be most likely to accomplish this would be one including color-coded stimuli in which color was gradually faded away. It seemed that this should not only help Ss to discriminate the shapes but also decrease the probability of their becoming dependent upon the color cues rather than upon the shape cues.

The present study consisted of two successive experiments. The second experiment was designed following the outcome of the first experiment, and its purpose will be described later. The purpose of the first experiment was to obtain answers to the following questions:

1. Does the temporary addition of color cues reduce the learning time in a paired-associate task requiring Ss to discriminate on the basis of shape alone?
2. Does the gradual elimination of color cues reduce learning time more than an abrupt elimination of them?

CHAPTER II

METHOD--EXPERIMENT 1

Subjects

There were 54 Ss in this experiment. They were enrolled in graduate level audio-visual courses at Indiana University and participated in this experiment in order to fulfill a course requirement. Four additional individuals were discarded, two because they performed the paired-associate task perfectly on the first trial and two because they did not reach the criterion of learning in the 45 minutes allowed for each S.

Stimuli

The visual configuration whose parts were stimulus terms in a paired-associate task was a segment of the human skeletal system (see Figure 1). The visuals were presented via rear projected slides. Though there are many bones in the human body, only 24 were used for this study, and of these only eight were used for any one subject. In other words, the bones, as stimulus terms, formed three groups each consisting of eight bones. The purpose of using three separate groups of bones was to establish whether experimental effects were similar for various natural formations of groups and thereby broaden the scope of the experiment. In the present study, the bones were grouped according to the following natural divisions: bones of the hand; bones of the head; and bones of the torso, arms, and legs. Table 1 contains a complete listing of the scientific names of the bones and indicates the bones' locations.

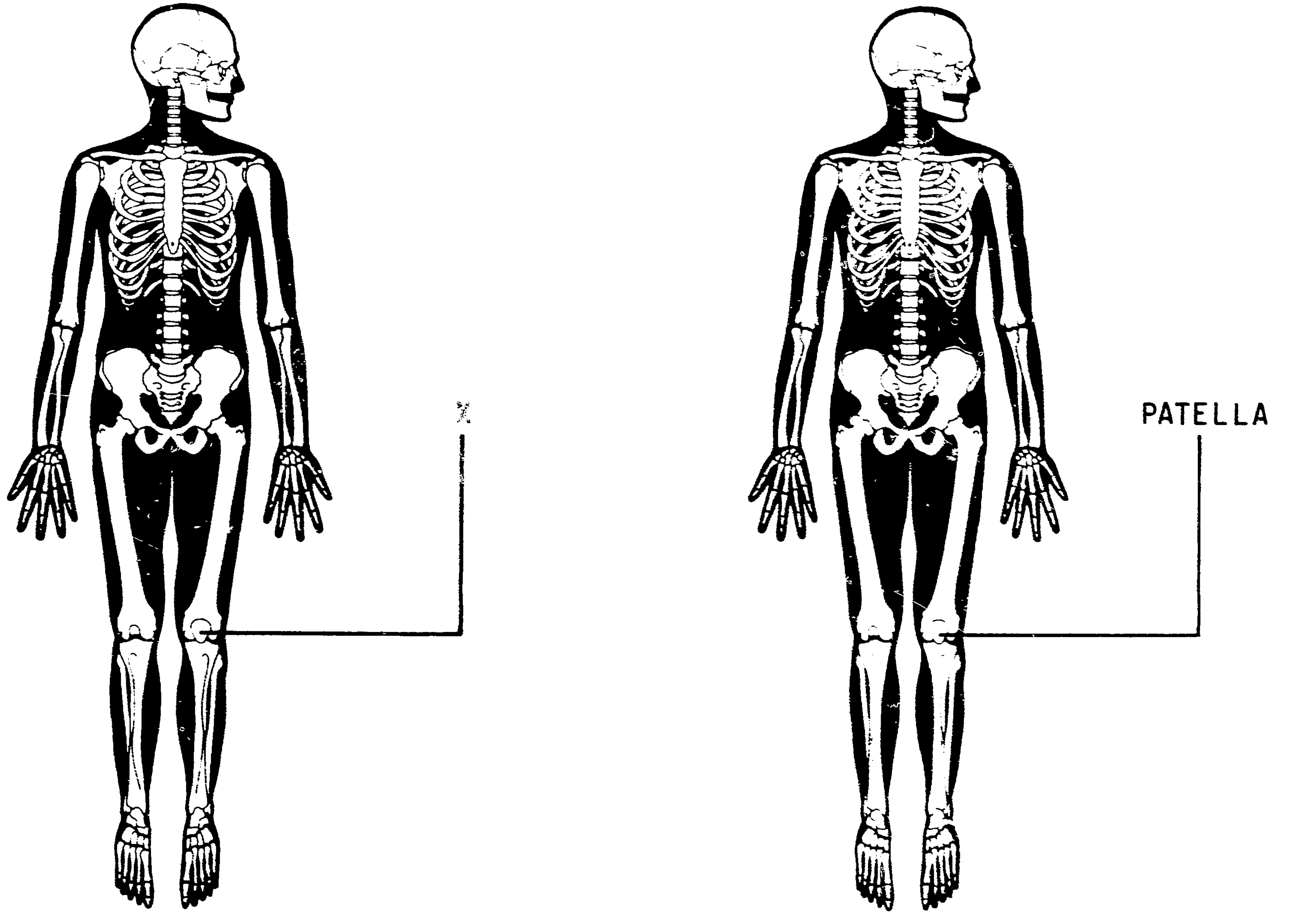
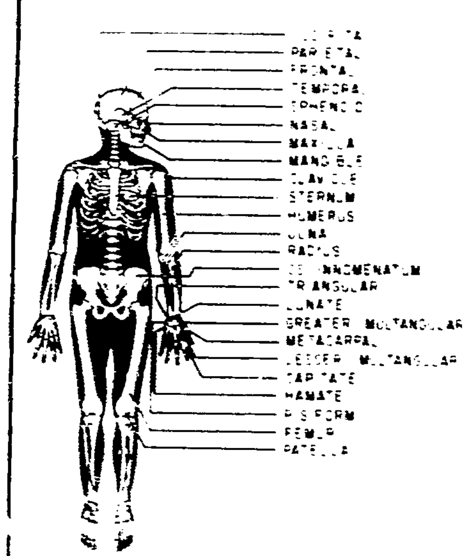


Fig. 1. Example of stimulus material. A skeleton labelled like the one on the left was presented first and was then immediately followed by one labelled like the one on the right.

TABLE 1

SCIENTIFIC NAMES OF THE BONES IN EACH GROUP, THEIR LOCATION IN THE HUMAN SKELETON, AND THE COLOR ASSOCIATED WITH EACH



HAND	HEAD	TORSO	COLOR
TRIANGULAR	PARIETAL	HUMERUS	COBALT BLUE
LUNATE	MAXILLA	ULNA	BURNT UMBER
METACARPAL	TEMPORAL	PATELLA	MAGENTA
LESSER MULTANGULAR	MANDIBLE	OS INNOMENATUM	MISTLETOE GREEN
GREATER MULTANGULAR	OCCIPITAL	FEMUR	CADMIUM PRIMROSE
CAPITATE	NASAL	STERNUM	CADMIUM YELLOW DEEP
HAMATE	FRONTAL	CLAVICLE	SPECTRUM RED
PISIFORM	SPHENOID	RADIUS	BURNT SIENNA

Each slide included all of the major bones of the body even though S was required to learn the correct label for only eight of them. There were two slides for each bone. The first slide showed the skeleton with an X denoting the particular bone that S was to name. The second slide was the same except that either the scientific name of the bone, for some Ss, or a trigram name of the bone, for other Ss, appeared in place of the X (see Figure 1). In other words, there were sixteen slides for each group of eight bones and a particular type of name, scientific or trigram.

For each of these three groups of bones there were three different sets of slides which differed on the basis of the use of color. The first set of slides was prepared with no color, i.e., there were eight white shapes, each defined by a black outline. A second set of slides was prepared using eight colors, i.e., there were eight differently-colored shapes, each defined both by the color and a black outline (see Table 1 for the color associated with each bone). These colors were Windsor and Newton's Designer Gouache (see Appendix A). The third set of slides was prepared in part like the second set. However, additional slides, varying in saturation of the colors, were prepared so that the colors could be made to "fade in" or "fade out." Including zero saturation (white), there were eight values of saturation of each color for this treatment. Variation in saturation of the colors was achieved by adding various amounts of white pigment to the original colors. An attempt was made to establish equal appearing changes in saturation from one value to the next through simple visual inspection.

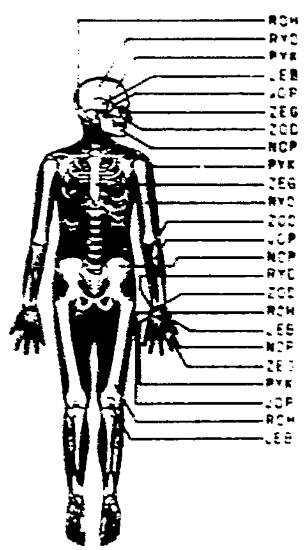
In order to determine more explicitly the origin of any differences in learning time when different groups of bones were used, nine control conditions were introduced. These control conditions were identical to the above experimental conditions except that they required Ss to respond with trigram names rather than scientific names. The trigram names were drawn randomly from a list by Archer (1960), with the exception that no word that seemed unpronounceable was included. The same eight trigrams were used for each group of bones. Within groups, the trigrams were assigned randomly to the bones. Thus, it was possible to determine whether any differences in learning times occurring as a function of which group of bones was used could be attributed unambiguously to differences between the bones and not to differences between the scientific names of the bones. Table 2 contains a complete listing of the trigram names of the bones, indicates the bones' locations, and indicates the color associated with those bones during the experiment. It can be seen from Tables 1 and 2 that the color of each bone was the same whether a scientific name or a trigram name was associated with it.

Apparatus

Two rooms, each about eight feet square, were utilized for this experiment (see Figure 2). S sat in one room facing a rear projection screen on the wall between the two rooms. S sat about three feet from the wall. The center of the 18" high x 15" wide rear projection screen was 45" above the floor and was approximately at eye level for most Ss. S communicated with the experimenter (E) by means of an inter-com. E and an assistant and all of the projection equipment were in the adjoining room.

TABLE 2

TRIGRAM NAMES OF THE BONES IN EACH GROUP, THEIR LOCATION IN THE HUMAN SKELETON, AND THE COLOR ASSOCIATED WITH EACH



HAND	HEAD	TORSO	COLOR
RYD	RYD	RYD	COBALT BLUE
ZOD	ZOD	ZOD	BURNT UMBER
LEB	LEB	LEB	MAGENTA
NOP	NOP	NOP	MISTLETOE GREEN
ROH	ROH	ROH	CADMIUM PRIMROSE
ZEG	ZEG	ZEG	CADMIUM YELLOW DEEP
PYK	PYK	PYK	SPECTRUM RED
JOP	JOP	JOP	BURNT SIENNA

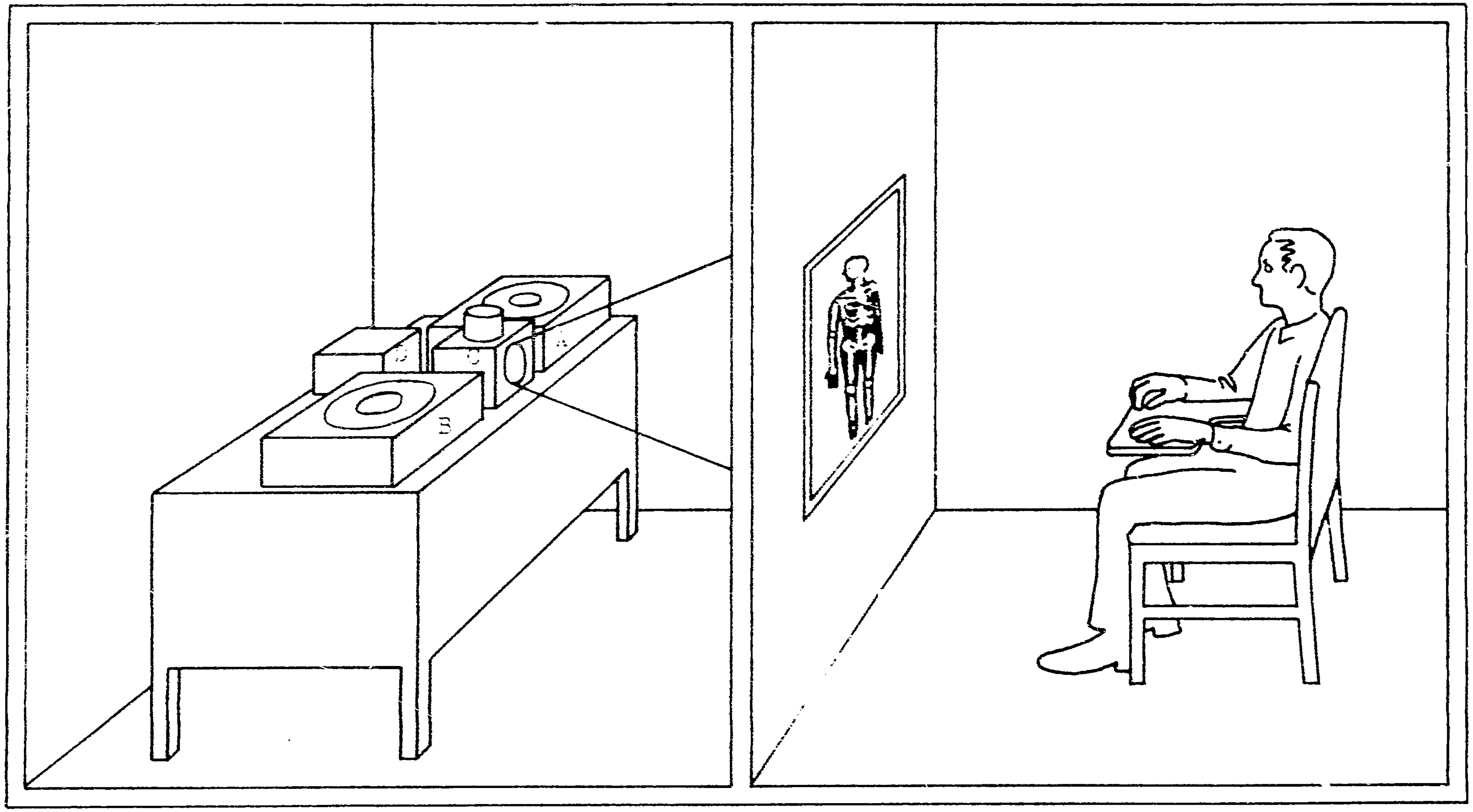


Fig. 2. The physical arrangements for the experiment. There were two rooms, with S in one room and E and the equipment in the other. There were two projectors (A and B) and a mirror (C) whose position was controlled by an electromechanical timing device (D).

Slides with stimulus materials were presented by means of two Anscorama slide projectors. The use of two projectors permitted the positioning of the next scheduled slide while a slide was being projected. The image from each of the two projectors nearly filled the screen and the respective images were made to appear at the same place on the screen through the use of a rotating mirror arrangement (see Figure 2). The mirror rotated 45 degrees to either side and thereby aimed the image from each projector onto the screen. The duration of the mirror's being positioned to either side and to a central position was determined automatically by an electromechanical device.

Procedure

Ss were assigned arbitrarily, by the order of their arrival, to one of the eighteen experimental conditions resulting from combinations of the values of the three variables, namely, manner of color coding, group of bones, and type of names to be learned. The order of experimental conditions was random with the restriction that each condition occurred three times. S was seated in front of the rear projection screen and instructions were read to him by the experimenter. It is important to note at this point that no mention was made about color in any of these instructions (see Appendix B for the instructions for Experiment 1).

Each S was given pre-training designed to familiarize him with the response names that he would later be required to associate with each of the bones. All eight names were shown on the screen at one time, and each S was asked to read all of the names aloud at his own pace. After

S had read all of the names, the screen went blank, and then S was asked to recall as many of the eight names as he could. This sequence was repeated two additional times for a total of three pre-training trials. The order in which the bone names were listed was different for the three trials, and the sequencing of these orders was the same for all Ss (see Appendix C).

Immediately following pre-training, the learning period began. Ss were shown one slide at a time. Every slide contained the human skeletal system. For each bone, the first of two slides, in which an arrow was shown pointing to one bone and which was labelled with an "X," was presented for 5 seconds. The second slide, which was projected a fraction of a second after the termination of the first slide, was similar to the first except that the "X" was replaced with the scientific (or trigram) name of the bone. This slide was also presented for 5 seconds and was followed by an interval of 2 1/2 seconds during which the projection screen was blank and dark. S was instructed to respond while the "X" slide was being projected. This 12 1/2-second sequence was repeated for each of the eight bones for which S was to learn a name. This entire eight-bone (sixteen-slide) sequence, called a trial, was repeated until S reached the criterion described below. For each trial, a separate, randomly-oriented presentation of the pairs of slides was used. The order was the same for all Ss.

The criterion in all conditions was two consecutive trials on the non-color-coded materials (white shapes with black outlines) without S's making an incorrect response. In the case of the non-color-coded (NC) conditions, Ss were presented the same, unchanging stimulus terms throughout the learning period. In the case of the two color-coded conditions, however, Ss were initially presented color-coded shapes; but eventually the color was withdrawn so that they were required to respond to non-color-coded stimuli and to reach a criterion of two consecutive correct trials on the non-color-coded material. In one of the color-coded conditions (CC), S was presented color-coded materials until he could correctly name all eight bones on a single trial before he was shifted to the black and white shapes. In the second color-coded treatment (CCF), the colors of all of the bones "faded in" or "faded out" on each new trial, depending on the total number of errors the subject had made on the preceding trial. It was expected, however, that, over trials, the colors would fade out completely. In fact, this was the case for all Ss under this treatment. On the trial following each trial on which S made n more correct responses than on the previous trial, the color faded n steps; while on the trial following each trial on which S made n less correct responses than on the previous trial, the saturation increased n steps. The color-coding disappeared completely beginning with the trial following the one on which S made no more than one error. At that point the stimuli became identical with those in the NC treatment. However, if S again made more than one error, the coding would return and would fade in or out as it had previously. As in the other conditions, the criterion was two correct consecutive trials on black and white shapes.

It seemed of interest to test for transfer of what had been learned to a situation similar to common academic tests. Therefore, after reaching the criterion, each S was asked to perform a paper and pencil task. Each S was handed a single sheet of paper with a mimeographed drawing of a skeleton on it (see Appendix D). This presentation was similar to the non-color-coded slide presentation except that there were eight arrows present at one time, each pointing to one of the eight bones previously learned by S. S was asked to write down the correct name for each bone opposite the arrow pointing to that bone. The number of correct responses was recorded.

Following his performance on this paper and pencil test, each S was asked to perform two additional tasks. In one of these S was asked to respond with the name of a color when shown a slide of a skeleton on which one bone was pointed out; in the other, S was asked to respond with the name of a bone when presented with a color which filled most of the projection screen. In each case, the number of correct responses was recorded. The order of occurrence of these two tests was random for each S. In addition, the order of presentation of stimuli on the former test was arbitrary, and the order of presentation of the stimuli on the latter test was random. These orders were the same for all Ss. These two tests were administered in order to gain some insight into the process underlying any reduction in learning time accomplished by the use of color coding. If the test requiring S to respond with a bone name to a presentation of a color resulted in significantly more correct responses in the color-coded treatment it might be concluded that a prompting effect had taken place. In other words, it would suggest that the color cues had acted as prompts. However, if the test requiring S to respond with a color name to a presentation of a picture of a bone, or if both tests resulted in significantly more correct responses in the color-coded treatment it would suggest that the learning process had involved what is called chaining.

Experimental Design

The design of the experiment was a 3 x 2 x 2 factorial one in which there were three treatments with respect to color coding--non-color-coded (NC), color-coded (CC), and color-coded-with-fading (CCF); three groups of bones, determined by natural location--bones of the hand, bones of the head, and bones of the torso, arms, and legs; and two types of response terms--scientific names and trigram names (see Table 3). A separate analysis of variance was carried out on each of the following four dependent variables: (1) the number of trials to criterion, including the trial on which criterion was reached, (2) the number of correct responses on the paper and pencil test, (3) the number of correct responses where color names corresponding to the bones were required, and (4) the number of correct responses where bone names corresponding to the colors were required.

TABLE 3

EXPERIMENTAL DESIGN FOR EXPERIMENT 1

Type of Response Term		Color-Coding Treatment	Group of Bones: Hand	Head	Torso, Arms and Legs
Type of Response Term	Scientific	Non-Color-Coded (NC)			
		Color-Coded (CC)			
		Color-Coded-With-Fading (CCF)			
	Trigram	(NC)			
		(CC)			
		(CCF)			

Note: There were three subjects per cell.

CHAPTER III

RESULTS--EXPERIMENT 1

It will be recalled that the independent variables in this experiment consisted of (1) which group of bones' names were learned (3 levels), (2) kind of color coding (3 levels), and (3) type of names learned (2 levels). There were four dependent variables, as described at the conclusion of Chapter II. The dependent variable values for each S are presented in Appendix E.

Table 4 shows the mean number of trials required to reach criterion by Ss in each of the eighteen experimental conditions. The statistical significance of the experimental effects was determined via a three-way analysis of variance. The results of this analysis appear in Appendix F. The critical region adopted for statistical significance corresponded to 5% level.

The mean numbers of trials to criterion for the color-coding conditions were 10.27, 10.44, and 10.00 for the non-color-coded, color-coded, and color-coded-with-fading conditions, respectively. The analysis of variance showed that the differences between these means were not significant. Thus, there was no evidence that the manner of color coding affected learning. The mean numbers of trials required by Ss to learn the names of the bones of the hand, head, and torso, arms, and legs were 15.94, 8.38, and 6.38 trials, respectively. The differences between these means was significant, F (2, 36) = 58.69. The mean numbers of trials required by Ss who learned nonsense syllable names and those who learned scientific names were 11.70 and 8.77, respectively. The

TABLE 4

MEAN NUMBER OF TRIALS REQUIRED TO REACH CRITERION IN EACH

OF EIGHTEEN TRAINING CONDITIONS IN EXPERIMENT 1

Type of Response Term		Color-Coding Treatment	Group of Bones		
			Hand	Head	Torso, Arms, and Legs
Scientific		Non-Color-Coded (NC)	17.00	5.67	4.67
		Color-Coded (CC)	14.67	5.00	5.00
		Color-Coded-With-Fading (CCF)	14.33	8.33	4.00
Trigram		(NC)	16.33	9.66	8.00
		(CC)	18.00	10.33	9.67
		(CCF)	15.00	11.33	7.00

difference between these means was significant, F (1, 36) = 14.69. None of the interactions was significant.

The mean numbers of correct responses on the paper and pencil test are shown in Table 5. The results of the three-way analysis of variance of number of correct responses on the paper and pencil test are shown in Appendix G. Since this data did not satisfy the assumption of homogeneity of variance, McNemar's (1957) suggestion of requiring the .01 level in order to report the .05 level of significance was followed. Ss in the color-coded conditions made significantly more correct responses than those in the non-color-coded conditions, F (2, 36) = 6.72. The mean numbers of correct responses were 6.38, 7.16, and 7.66 for NC, CC, and CCF conditions, respectively. Thus, it appears that although color coding did not affect the rate of learning the names of the bones, it did affect performance on the paper and pencil test. Ss required to learn the bones of the hand made a smaller mean number of correct responses (5.38) than those required to learn the bones of the head (7.83), and these Ss, in turn, made a smaller mean number of correct responses than those required to learn the bones of the torso, arms, and legs (8.00). These differences were similar to those occurring during learning and were statistically significant, F (2, 36) = 34.62.

The nature of the interaction is such as to suggest that the effect of color coding was confined to the conditions involving the bones of the hand. In the case of the bones of the hand, the NC, CC, and CCF means were, respectively, 3.50, 5.50, and 7.16. The rank order of these three means was the same as that of the corresponding three means for the main effect of the color-coding variable. On the other

TABLE 5

MEAN NUMBER OF CORRECT RESPONSES IN EACH OF EIGHTEEN TRAINING CONDITIONS ON PAPER AND PENCIL TEST IN EXPERIMENT 1

Type of Response Term		Color-Coding Treatment	Group of Bones		
			Hand	Head	Torso, Arms, and Legs
Scientific		Non-Color-Coded (NC)	1.67	7.67	8.00
		Color-Coded (CC)	6.00	8.00	8.00
		Color-Coded-With-Fading (CCF)	8.00	7.67	8.00
Trigram		(NC)	5.33	7.67	8.00
		(CC)	5.00	8.00	8.00
		(CCF)	6.33	8.00	8.00

hand, the rank orders of these three means (NC, CC, and CCF) were not the same as the main effect rank order in the case of the other two groups of bones. In fact, for each of these two latter groups of bones, there was little or no difference in their order of magnitude. The means for the group of bones of the head were 7.67, 8.00, and 7.84 for the NC, CC, and CCF conditions, respectively, and for the group of bones of the torso, arms, and legs were 8.00, 8.00, and 8.00 for NC, CC, and CCF conditions, respectively. Further, their order of magnitude did not correspond to that of the main effect. This interaction was significant, $\underline{F}$ (4, 36) = 5.82. Thus, though there was no interaction apparent in the rate of learning the names of the bones, it does appear that there was an interaction effect on the paper and pencil test. The interaction between the color-coding conditions and the types of response was also significant, $\underline{F}$ (2, 36) = 3.52. This interaction was of little importance for the present study and hence will not be described in detail. In addition, the three-way interaction was significant, $\underline{F}$ (4, 36) = 3.97. However, its complexity precludes a very meaningful interpretation.

Finally, the results with respect to the mean numbers of correct responses when $\underline{S}$ was (1) presented with the picture of a bone and asked to respond with the name of a color, and (2) presented with a color and asked to respond with the name of a bone will be considered. The analysis of variance for the former is presented in Appendix H, and the analysis of variance for the latter is presented in Appendix I. The mean number of correct responses for each of the eighteen conditions in the case of these procedures is presented in Tables 6 and 7, respectively. A

TABLE 6

MEAN NUMBER OF CORRECT RESPONSES IN EACH OF EIGHTEEN TRAINING CONDITIONS ON A TASK REQUIRING *Ss* TO RESPOND TO A PICTURE OF A BONE WITH A COLOR NAME IN EXPERIMENT 1

Type of Response Term		Color-Coding Treatment	Group of Bones		
			Hand	Head	Torso, Arms, and Legs
Scientific		Non-Color-Coded (NC)	1.00	1.67	1.00
		Color-Coded (CC)	2.00	1.33	2.67
		Color-Coded-With-Fading (CCF)	2.00	2.00	2.67
Trigram		(NC)	1.00	1.33	1.00
		(CC)	2.33	2.33	3.67
		(CCF)	2.00	3.33	4.67

TABLE 7

MEAN NUMBER OF CORRECT RESPONSES IN EACH OF EIGHTEEN TRAINING CONDITIONS ON A TASK REQUIRING *Ss* TO RESPOND TO A COLOR WITH A BONE NAME IN EXPERIMENT 1

Type of Response Term		Color-Coding Treatment	Group of Bones: Hand	Head	Torso, Arms, and Legs
Scientific		Non-Color-Coded (NC)	1.33	2.00	.67
		Color-Coded (CC)	1.33	1.00	2.33
		Color-Coded-With-Fading (CCF)	2.33	1.00	2.00
Trigram		(NC)	1.67	1.33	1.00
		(CC)	1.33	1.33	2.67
		(CCF)	2.00	1.00	2.67

comparison of the means of the color-coded treatments in the test in which Ss were required to respond with a color name to a presentation or a picture of a bone shows that Ss in the CCF conditions made a greater number of correct responses (2.77) than those in the CC conditions (2.36) and that those Ss in the NC conditions made the fewest number of correct responses (1.16). The differences between these means were statistically significant, $F(2, 36) = 9.41$. None of the other differences was significant.

CHAPTER IV

DISCUSSION--EXPERIMENT 1

The results of this experiment were not similar to those of previous studies utilizing color coding. Whereas Weiss and Margolius (1954) and Saltz (1963) found that the use of colored background cues reduced learning time, there was no evidence that the integration of colors with pictorial stimuli in the present experiment resulted in such reduction. One might conjecture that this lack of reduction in learning time was due to the fact that color was integrated with the shape cues in the present study. Of course, it is the case that when color is used as a background for words, as it was in the previously-cited experiments, its size, or area is much greater than when the color is integrated with the stimulus shape, as it was in the present experiment. In fact, since the colored areas were often very small, the colors may not have been the most discriminable cues. Perhaps, then, color was not beneficial in this experiment because other cues were more easily discriminated than the colors. In other words, it is quite possible that shape cues or even the locations of shapes in relation to other shapes were the cues with respect to which Ss formed discriminations.

It had also been anticipated, based on speculations and extrapolations of Miller (1957) and Hoban and Van Ormer (1950), that color coding would be most effective when cues other than the coding ones were most difficult. If this were true, color coding should have been most effective in reducing learning times in the case of that group of bones that made the task most difficult. It will be recalled that learning the names of the bones of the hand was more difficult than learning the names of the other two groups of bones. Therefore, an interaction between color-coding treatment and group of bones learned might have been expected. However, this was not the case. Of course, the fact that there was no evidence that the manner of color coding affected learning makes this result less relevant as a test of the predictions of Miller (1957) and Hoban and Van Ormer (1950).

The question arises as to whether Ss in the color-coded conditions were even aware of the color. It will be recalled that color was not mentioned in the instructions. As would be expected if they were, indeed, aware of the colors, Ss in the color-coded conditions did make more correct responses on the two color tests (Ss responding with a color name when presented with a picture of a bone and responding with a bone name when presented with a color). To some extent this might also be anticipated merely because Ss in the CC and the CCF conditions had been exposed to the colors.

It will be recalled that the reason for the test in which Ss responded to colors with the names of bones and to pictures of bones with names of colors was to gain some insight into the learning process occurring. Since Ss in the color-coded conditions made more correct responses than did Ss in the non-color-coded condition on only the test requiring them to respond with a color name to a presentation or a picture of a bone it might be concluded that the learning process was one of chaining. This effect may, in fact, be underestimated since these tests occurred after interpolated trials without color coding. If these tests had occurred immediately after criterion on color-coded trials had been reached, perhaps more correct responses would have occurred.

It is interesting to note that although mean differences in learning time from one color-coded condition to another were not significant, the mean differences in the case of the number of correct responses on the paper and pencil test were significant. It should be noted at this time that it seems unlikely that the difference in mean number of correct responses on the paper and pencil test could be due to a difference in learning times. This is so in view of the fact that the differences between mean learning times as a function of color-coding conditions were small and not significant. The fact that the number of errors on this test was less for the color-coded conditions than for the non-color-coded conditions might, however, be considered consistent with earlier findings of beneficial effects of color coding. For example, in the Weiss and Margolius (1954) study there were significantly fewer errors in a recall test where the stimuli had colored backgrounds than where they did not have colored backgrounds.

As pointed out previously, at least one possible reason that color was ineffective in reducing learning trials was that Ss had not been instructed to use color. Hence, their performance might have been poorer than it would have been otherwise. In fact, in an earlier study Isaacs (1966) used shapes defined by color to provide a stimulus made up of apparently inseparable shape-color cues in the manner of the present study and found that learning took place on the basis of both color cues and shape cues. (Unlike the present study, however, the shapes were presented one at a time.) He concluded that this was due to interspersed tests on both color and shape cues which alerted Ss to the fact that he would be tested on both cues. Further, it might be remembered from Chapter I that

Green and Anderson (1956) concluded that added color can act as a beneficial cue when S is alerted to it. Consequently, a second study was designed in which Ss were specifically instructed to make use of the color. Included in these instructions was the information that color would be present initially but that later it would be withdrawn (see Appendix J). Only one set of response terms--trigram names--was used in the second experiment. Also, since the bones of the torso, arms, and legs had required so few trials in the first experiment, bordering on the minimum limit imposed by the design, this group of bones was eliminated from the design of the second experiment. The second experiment was designed to answer the following questions:

1. Does the temporary addition of color cues reduce the learning time in a paired-associate task requiring S to discriminate on the basis of shape alone when he has been instructed as to how color cues might help him as well as when they will be available?
2. Does the gradual elimination of color cues reduce learning time more than an abrupt elimination of them when S has been instructed as to how color cues might help him as well as when they will be available?

CHAPTER V

METHOD--EXPERIMENT 2

Subjects

Forty-two Ss participated in this experiment. They were drawn from the same population and in the same manner as those of the first experiment. None was discarded.

Stimuli

The stimuli were the same as in the first experiment, except that the bones of the torso, arms, and legs were not used and only trigram response terms were used.

Apparatus

The apparatus was exactly the same as that used in the first experiment.

Procedure

The procedure was the same as that of the first experiment except for the change in instructions. Ss in the color-coded conditions were told that color had been found to be helpful in a previous study and that each of the shapes whose names they were to learn had a separate color. They were told further that eventually they would have to respond to the non-color-coded shapes (see Appendix J). Ss in the non-color-coded conditions were instructed that the type of arrow being used had been found to be the most effective way of pointing out the bones. This was done in an attempt to limit any biasing of the results by the portion of the instructions given to the color coded groups in which color coding was said to be helpful (see Appendix K).

Experimental Design

The design of the experiment was a 3 x 2 factorial one in which there were three treatments with respect to color coding--non-color-coded (NC), color-coded (CC), and color-coded-with-fading (CCF); and two groups of bones, determined by natural location--those of the hand and those of the head (see Table 8). As in the first study, a separate analysis of variance was carried out on each of the following four dependent variables: (1) the number of trials to criterion, (2) the number of correct responses on the paper and pencil test, (3) the number of correct responses where color names corresponding to the bones were required, and (4) the number of correct responses where bone names corresponding to the colors were required.

TABLE 8

EXPERIMENTAL DESIGN FOR EXPERIMENT 2

		Group of Bones	
	Color-Coding Treatment	Hand	Head
Color-Coding Treatment	Non-Color-Coded (NC)		
	Color-Coded (CC)		
	Color-Coded-With-Fading (CCF)		

Note: There were seven subjects per cell.

CHAPTER VI

RESULTS--EXPERIMENT 2

It will be recalled that the independent variables in this experiment consisted of (1) which group of bones' names were learned (2 levels), and (2) kind of color-coding (3 levels). There were four dependent variables, as described at the conclusion of Chapter V. The dependent variable values for each S are presented in Appendix L.

Table 9 shows the mer numbers of trials required to reach criterion by Ss in each of the six experimental conditions. The statistical significance of the experimental effects was determined via a two-way analysis of variance. The results of this analysis appear in Appendix M. As in the first experiment, the critical region adopted for statistical significance corresponded to the 5% level.

The mean numbers of trials to criterion for the color-coding conditions were 11.07, 19.93, and 11.64 for the non-color-coded, color-coded, and color-coded-with-fading treatments, respectively. The analysis of variance showed that the differences between these means were not significant. Thus, as in experiment 1, there was no evidence that the manner of color-coding affected learning. The mean numbers of trials required by Ss to learn the bones of the hand and the bones of the head were 15.04 and 8.71, respectively. The difference between these means was significant, F (1, 36) = 40.70. The interaction between these two variables was not significant.

The results of the analysis of variance of number of correct responses on the paper and pencil test are shown in Appendix N. As in

TABLE 9

MEAN NUMBER OF TRIALS REQUIRED TO REACH CRITERION IN EACH OF SIX TRAINING CONDITIONS IN EXPERIMENT 2

		Group of Bones	
	Color-Coding Treatment	Hand	Head
Color-Coding Treatment	Non-Color-Coded (NC)	14.43	7.71
	Color-Coded (CC)	16.14	9.71
	Color-Coded-With-Fading (CCF)	14.57	8.71

experiment 1, because of heterogeneity of variance, the .01 level of significance was required for establishing significance at the .05 level. Table 10 shows the mean number of correct responses in each condition. _Ss_ in all three color-coding treatments made nearly the same number of correct responses, namely, 6.64, 7.14, and 7.00 for the non-color-coded, color-coded, and color-coded-with-fading conditions, respectively. These differences were not statistically significant. A comparison of the mean number of correct responses for the two groups of bones does reveal that fewer correct responses (6.14) were made by _Ss_ learning the bones of the hand than for those learning the bones of the head (7.71). The analysis showed this difference to be significant, F (1, 36) = 10.30. The interaction of these two variables was not significant.

Finally, the results of the last two dependent variables will be described. These are the tests on which _S_ was (1) presented with the picture of a bone and asked to respond with the name of a color, and (2) presented with a color and asked to respond with the name of a bone. The analysis of variance for the former is presented in Appendix O, and the analysis of variance for the latter is presented in Appendix P. The mean number of correct responses for each of the six conditions in the case of each of these procedures is presented in Tables 11 and 12, respectively.

The differences between the means of the color-coding conditions were not significant in either test. On the test on which _Ss_ were to respond with a color name when presented with a picture of a bone, _Ss_ learning the bones of the hand made fewer correct responses (1.05) than

TABLE 10

MEAN NUMBER OF CORRECT RESPONSES ON PAPER AND PENCIL TEST IN EACH OF SIX TRAINING CONDITIONS IN EXPERIMENT 2

		Group of Bones	
	Color-Coding Treatment	Hand	Head
Color-Coding Treatment	Non-Color-Coded (NC)	5.71	7.57
	Color-Coded (CC)	6.43	7.86
	Color-Coded-With-Fading (CCF)	6.29	7.71

TABLE 11

MEAN NUMBER OF CORRECT RESPONSES ON TEST REQUIRING Ss TO RESPOND TO A PICTURE OF A BONE WITH A COLOR NAME IN EACH OF SIX TRAINING CONDITIONS IN EXPERIMENT 2

		Group of Bones	
	Color-Coding Treatment	Hand	Head
Color-Coding Treatment	Non-Color-Coded (NC)	0.86	1.00
	Color-Coded (CC)	1.22	2.11
	Color-Coded-With-Fading (CCF)	0.55	2.22

TABLE 12

MEAN NUMBER OF CORRECT RESPONSES ON A TEST REQUIRING

Ss TO RESPOND TO A COLOR WITH A BONE NAME

IN EACH OF SIX TRAINING CONDITIONS

IN EXPERIMENT 2

	Color-Coding Treatment	Group of Bones: Hand	Group of Bones: Head
Color-Coding Treatment	Non-Color-Coded (NC)	0.44	1.22
	Color-Coded (CC)	1.00	2.44
	Color-Coded-With-Fading (CCF)	0.78	2.11

those learning the bones of the head (2.05). This was significant, F (1, 36) = 7.60. On the test requiring *S*s to respond with the name of a bone when presented with a color, *S*s learning the names of bones of the hand also made fewer correct responses (0.95) than those learning the names of bones of the head (2.47). This was significant, F (1,36) = 14.36. The interaction of these two variables was not significant in either test.

CHAPTER VII

DISCUSSION--EXPERIMENT 2

Despite the addition of specific instructions to use color coding, the major results of the second experiment were similar to those of the first experiment--i.e., color coding did not significantly reduce the time required by Ss to learn the material in this experiment. In an earlier experiment, Green and Anderson (1956) had concluded that color could facilitate learning when S was alerted to its use. In addition, Isaacs (1966) concluded that interpolated tasks, tasks alerting S to test cues during paired-associate learning, had increased the probability of Ss' sampling color cues. Therefore, it had been anticipated that instructions as to how S was to use the color, as well as instructions as to how color would be eliminated, would have an effect similar to that of the interpolated task in the earlier Isaacs' study, that is, would increase the probability that Ss would sample the color cues. However, this was not the case. In fact, in the case of the test in which S was required to respond with a color name when presented with a picture of a bone the analyses revealed a significant difference in the first experiment but not a significant difference in the second experiment. Thus, it might be concluded that instructions telling that color was available as well as how it might be useful actually reduced the probability that Ss would sample the color cues.

Another possible conclusion, one based on the results of both experiments, might be that the availability and discriminability of cues of shape and location far overshadowed that of the cues provided by the added and temporary color cues, particularly when S knew that they were only temporary. This might seem further strengthened by the results of the tests on which Ss responded (1) to pictures of bones with color names and (2) to colors with bone names. It will be recalled that Ss learning the bones of the head (those shown to be easiest to learn) made significantly more correct responses on these two tests than Ss learning other groups of bones. Thus, it is possible that when the stimuli were easiest to learn, the probability was greater that color cues would be sampled on a given stimulus presentation. This possibility is plausible if we assume that S is spending less time observing shape and hence has more time for observing color.

In both experiments Ss in the groups learning the names of the bones of the head performed better on the paper and pencil test than those in groups learning the names of other bones. This may have been the case because of technical limitations of the test. Since the test was mimeographed, the maximum available format was 8 1/2" x 11" and, therefore, the bones of the hand were quite small and somewhat indistinguishable when lines were drawn to each of the eight bones S was to respond to. Thus, though all Ss had learned to the same criterion, the paper and pencil test may have been biased in favor of the bones of the head. It was reported earlier that in the first experiment Ss in the color-coded treatments performed better on the paper and pencil test than those in the non-color-coded treatments. The results of the second experiment, however, were not the same--there were no significant differences between the color-coding treatments on the paper and pencil test. Thus, it is possible, based on the previously stated conclusion that instructions actually reduced the probability that Ss would sample the color cues, that the instructions also reduced or eliminated any previously found differences between color-coding conditions on the paper and pencil test.

In the present study there was no evidence that color-coding facilitated learning. However, it is possible that other manners of using colors as well as other types of tasks might find this type of coding beneficial. First, as for the type of coding, two procedures now appear plausible to the author. (1) Color coding of the entire group of bones over all trials; that is, coding each bone to be learned with a different color and then pointing out the bone that is to be responded to. This procedure has the advantage of more adequately separating out all of the shapes all of the time than did the procedure used in the present study. (2) Using the color rather than an arrow or some such device to "point out" the bone to be responded to. This procedure has the advantage of not confounding the effects of the color and those of the arrow. Secondly, as for types of task, one suggestion seems evident. It is likely that color-coding can be most useful (1) when the color is in a large enough area to be easily recognized as to what color it is and (2) when locations and shapes are not as easily discriminated as are colors.

CHAPTER VIII

SUMMARY

A number of studies has shown color coding to be beneficial in searching tasks (Smith, *et al.* 1963, 1964, 1965) as well as in reducing the learning times in paired associate tasks (Weiss and Margolius, 1954; Saltz, 1963). The present study was designed to evaluate further the effect of color coding on reducing the time required to reach a criterion in a paired associate learning task.

This study consisted of two experiments. In the first experiment 52 *Ss* were required to learn the names of bones. There were three color-coding treatments--non-color-coded; color-coded; and color-coded-with-fading, and three groups of bones--bones of the hand; bones of the head; and bones of the torso, arms and legs. In order to establish whether any of the effects found were due to differences in the scientific names themselves, two types of responses were used--scientific names and trigram names. Thus a 3 x 3 x 2 factorial design resulted. The slides were presented one at a time via a rear projection screen to one *S* at a time. Data were collected on four dependent variables: (1) number of trials required to reach a criterion of two correct trials on non-color-coded stimuli; (2) number of correct responses on a paper and pencil test on which all eight bones which *S* had learned were pointed out at one time; (3) the number of correct responses made by *S* when he was shown pictures of the bones and asked to respond with the color name associated with it; and (4) the number of correct responses made by *S* when he was shown a color and asked to respond with the name of a bone associated with it. The last two tests were included in order to gain some insight into the process underlying any reduction in learning time accomplished by the use of color coding. An examination of the results revealed that the difference between the mean numbers of trials required to reach criterion by Ss in the three color-coding conditions were not significant. However, Ss in the color-coded conditions made significantly more correct responses on the paper and pencil test and on the test requiring them to respond to a picture of a bone with the name of a color than did Ss in the non-color-coded conditions.

The second experiment was similar to the first one. There were 42 subjects. The design was a 3 x 2 factorial one utilizing the same color-coding treatments and two of the groups of bones (hand and head). All Ss learned trigram names. The main difference between the two experiments was that instructions telling Ss in the color-coded conditions when color would be present and how it could be used were added to the second experiment. Data were collected on the same four dependent variables as in the first experiment. An examination of the results of the second experiment revealed that the differences between the color-coding conditions were not significant in the case of any of the dependent variables.

Thus, it was concluded from the results of the two experiments that color coding, even when instructions alerting S to the color are added, was not beneficial in reducing the number of trials required to learn the type of material presented in this study.

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APPENDIX

Appendix A

Colors Used in Preparing Color-Coded Slides

The color coding was accomplished through the use of Windsor and Newton's Designer Gouache. The colors used were as follows:

Mistletoe Green	(Series 2)	#366
Spectrum Red	(Series 1)	#327
Magenta	(Series 2)	#341
Cobalt Blue	(Series 3)	*
Burnt Umber	(Series 1)	#387
Burnt Sienna	(Series 1)	*
Cadmium Yellow Deep	(Series 4)	#311
Cadmium Primrose	(Series 4)	#305
Zinc White	(Series 1)	#301

*There was no identification number listed for this color.

Appendix B

Instructions to Subjects--Experiment 1

I'm going to show you a series of slides on the screen in front of you. You will notice that each slide contains the picture of a human skeleton and that there is an arrow pointing to one bone. There are two slides for each of eight different bones. One is labelled with an X and the other with a unique name for that bone. Your task will be to learn the name of each of the eight bones that will be presented.

There are eight different bones as well as eight unique names. Each bone will be shown first labelled with an X and then labelled with its own correct name.

Beginning with the very first slide that has a bone labelled with an X, I'd like you to respond aloud with the name you think is associated with that bone. Please respond while the slide with an X is on the screen. The slide with the correct name will then be presented so that you can check your answer.

Before we begin the experiment, however, I would like you to become familiar with the names that you will have to associate with the eight bones during the experiment. You will be shown all eight names at one time and you should read each one of these names carefully. Then while the screen is blank you should attempt to recall as many of them as you can. There will be three presentations like this, then the experiment itself will begin.

(Note: There was a pause here.)

Are there any questions? (At this point, and all others where questions are invited, the instructions were paraphrased in answering any that did arise.)

(Note: There was a pause here.)

OK, now remember, after the three slides containing the names alone, I will show you eight bones and you should associate one of the names with each bone. Please be sure to respond aloud while the slide labelled with an X is still on the screen.

(Note: There was a pause here.)

Do you have any questions?

(Note: At this point the experiment began. After S reached criterion, the following instructions were read.)

You have now learned the names of all the bones but I'd like you to do just a couple of other things. First, I would like you to label each of the bones on this sheet of paper.

(Note: At this point the subject was handed a pencil and a piece of paper on which a skeleton had been mimeographed. He was given as much time as he needed to label all eight bones. Then the two following instructions were given [in an order randomly assigned to each subject]. Following each instruction the appropriate test was given.)

(1) Now I'm going to show you the bones again, one at a time, and I'd like you to tell me in each case what color you think was associated with that bone.

(2) Finally I'm going to show you one at a time, the eight colors that were associated with the bones, and I'd like you to tell me in each case the name that you think was associated with that color.

Appendix C

Order of Response Names for Each of Three Trials During Pre-Training

Trial 1

	Bones of the Hand		Bones of the Head		Bones of the Torso, Arms, and Legs	
	Scientific	Trigram	Scientific	Trigram	Scientific	Trigram
1	Triangular	Ryd	Nasal	Ryd	Humerus	Ryd
2	Lunate	Zod	Frontal	Zod	Ulna	Zod
3	Pisiform	Jop	Parietal	Jop	Radius	Jop
4	Greater Multangular	Roh	Sphenoid	Roh	Femur	Roh
5	Metacarpal	Leb	Mandible	Leb	Patella	Leb
6	Hamate	Pyk	Maxilla	Pyk	Clavicle	Pyk
7	Lesser Multangular	Nop	Temporal	Nop	Os innomenatum	Nop
8	Capitate	Zeg	Occipital	Zeg	Sternum	Zeg

Appendix C (cont'd.)

Trial 2

	Bones of the Hand		Bones of the Head		Bones of the Torso, Arms, and Legs	
	Scientific	Trigram	Scientific	Trigram	Scientific	Trigram
1	Capitate	Zeg	Frontal	Zeg	Sternum	Zeg
2	Hamate	Pyk	Maxilla	Pyk	Clavicle	Pyk
3	Triangular	Ryd	Occipital	Ryd	Humerus	Ryd
4	Pisiform	Jop	Parietal	Jop	Radius	Jop
5	Lesser Multangular	Nop	Temporal	Nop	Os innomenatum	Nop
6	Lunate	Zod	Sphenoid	Zod	Ulna	Zod
7	Metacarpal	Leb	Nasal	Leb	Patella	Leb
8	Greater Multangular	Roh	Mandible	Roh	Femur	Roh

Appendix C (cont'd.)

Trial 3

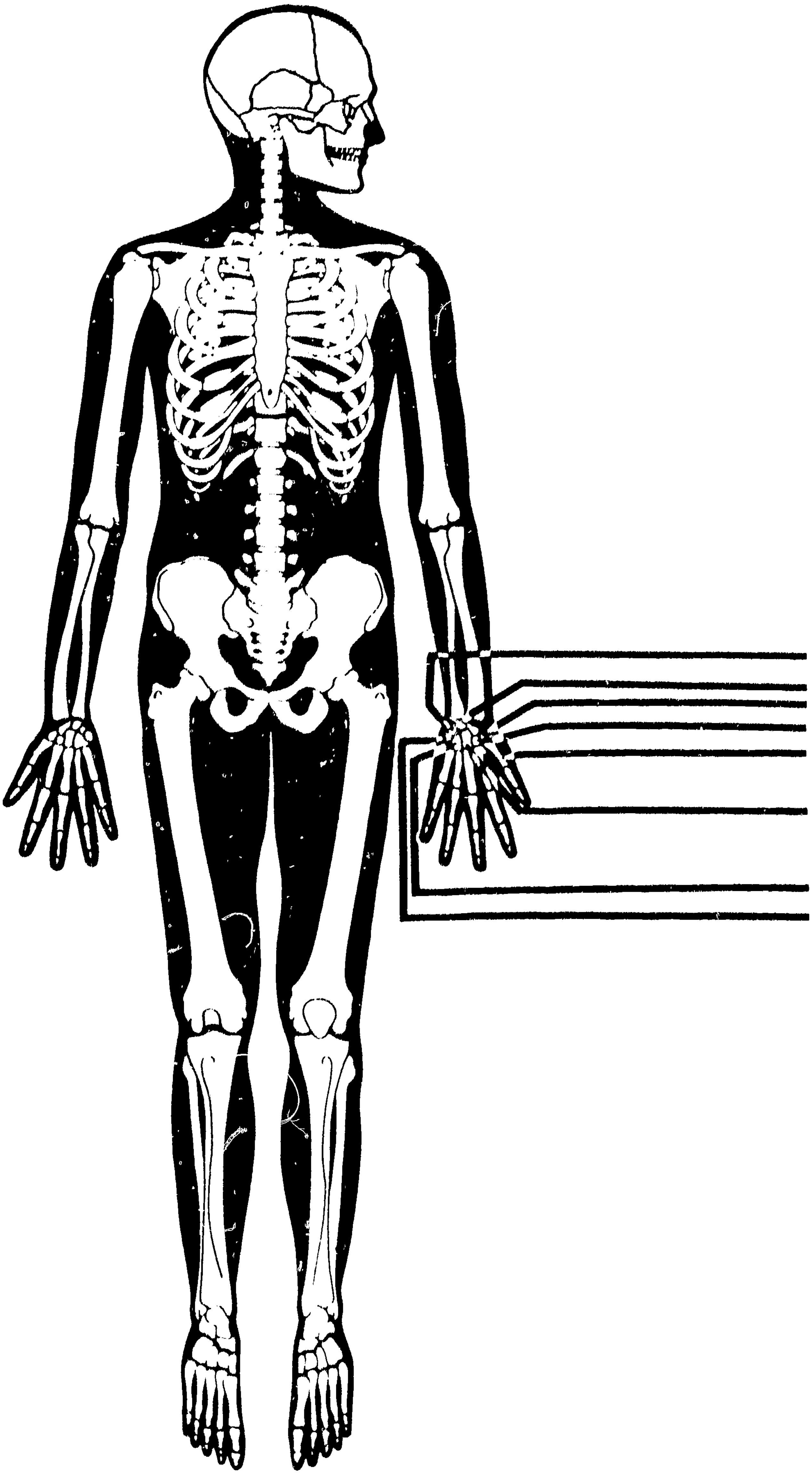
	Bones of the Hand		Bones of the Head		Bones of the Torso, Arms, and Legs	
	Scientific	Trigram	Scientific	Trigram	Scientific	Trigram
1	Hamate	Pyk	Parietal	Pyk	Clavicle	Pyk
2	Lunate	Zod	Maxilla	Zod	Ulna	Zod
3	Greater Multangular	Roh	Sphenoid	Roh	Femur	Roh
4	Triangular	Ryd	Occipital	Ryd	Humerus	Ryd
5	Metacarpal	Leb	Temporal	Leb	Patella	Leb
6	Pisiform	Jop	Frontal	Jop	Radius	Jop
7	Capitate	Nop	Mandible	Nop	Sternum	Nop
8	Lesser Multangular	Zeg	Nasal	Zeg	Os innomenatum	Zeg

Appendix D

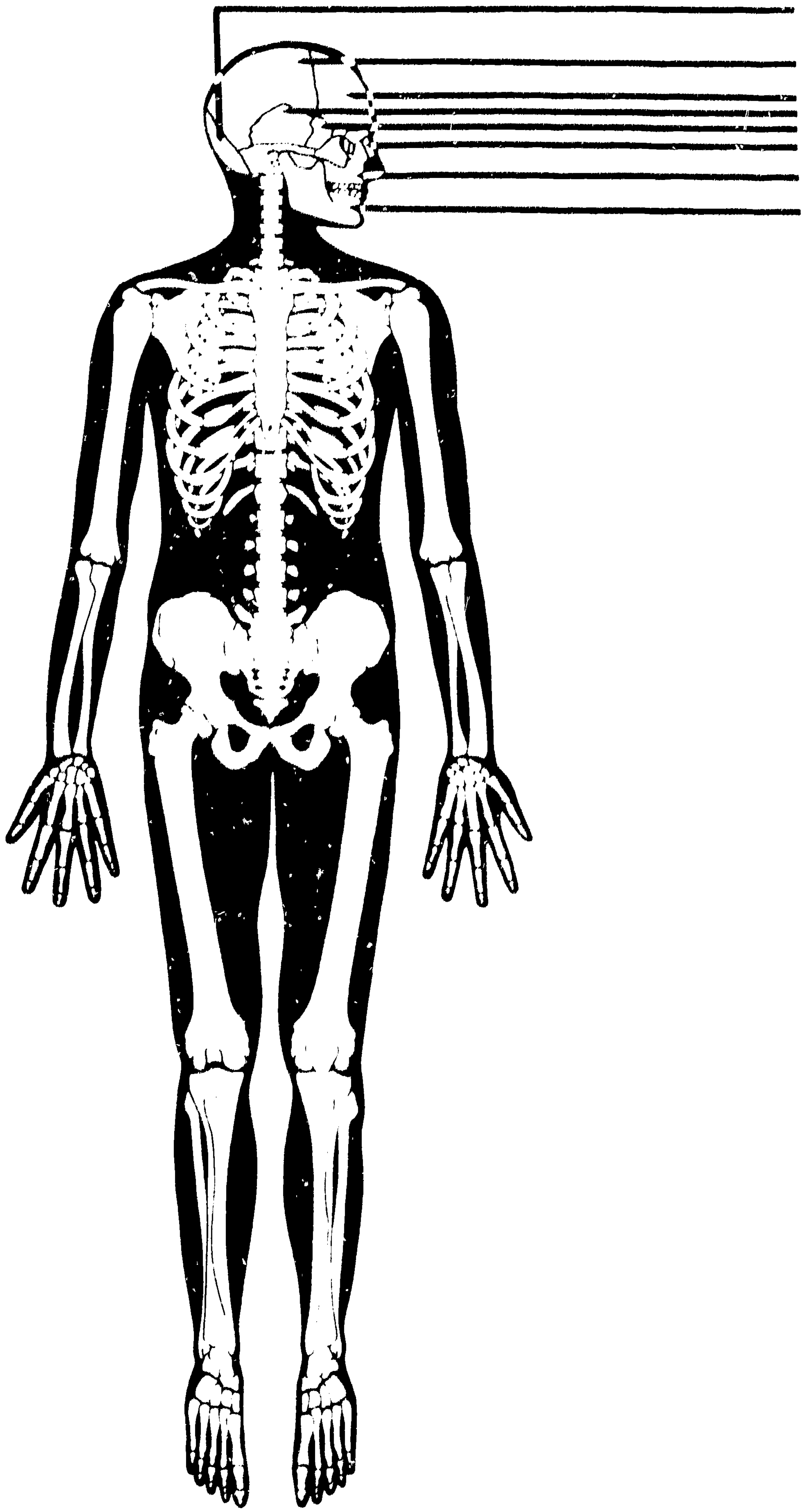
Paper and Pencil Tests

1. Bones of the Hand
2. Bones of the Head
3. Bones of the Torso, Arms, and Legs

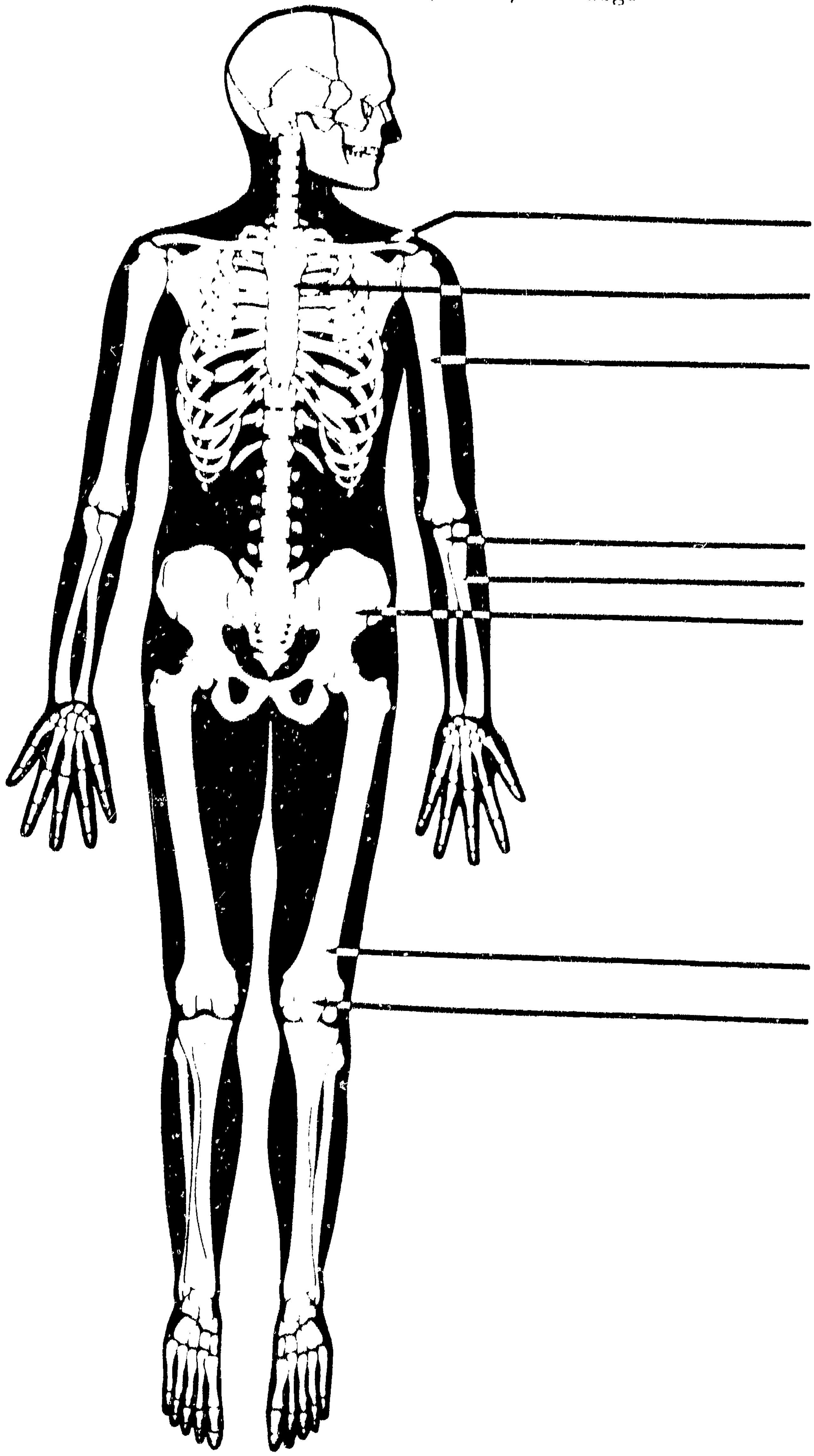
Bones of the Hand



Bones of the Head



Bones of the Torso, Arms, and Legs



Appendix E

Four Dependent Variable Values for Each S--Experiment 1

Subject	Condition (See Note, this Appendix)	Number of Trials to Criterion	Number Correct on Paper and Pencil Test	Number Correct on Color-Name Test	Number Correct on Bone-Color Test
1	7	12	8	3	3
2	1	10	3	4	0
3	2	4	7	0	1
4	3	4	8	2	2
5	9	4	8	0	1
6	17	9	8	2	4
7	11	9	8	1	1
8	5	5	8	1	1
9	12	9	8	1	1
10	13	17	8	2	1
11	18	6	8	0	3
12	6	4	8	1	1
13	10	20	6	1	0
14	15	9	8	0	1
15	16	16	6	3	3
16	4	15	7	1	1
17	8	12	7	3	2
18	14	12	8	3	4
19	11	9	7	2	1
20	17	17	8	4	4
21	1	20	1	0	0
22	16	18	7	1	2
23	18	8	8	1	3
24	14	8	8	4	5
25	10	17	4	2	2
26	2	9	8	1	0
27	15	13	8	2	4
28	5	5	8	2	2
29	13	18	2	1	1
30	9	4	8	4	3
31	8	5	8	2	4
32	12	7	8	1	1
33	6	6	8	1	1
34	7	14	8	2	1
35	3	5	8	3	3
36	4	15	3	1	2

Appendix E (cont'd.)

Subject	Condition (See Note, this Appendix)	Number of Trials to Criterion	Number Correct on Paper and Pencil Test	Number Correct on Color-Name Test	Number Correct on Bone-Color Test
37	17	8	8	2	6
38	3	4	8	1	1
39	5	5	8	4	5
40	10	12	6	2	1
41	4	14	8	2	3
42	9	4	8	1	2
43	12	8	8	2	2
44	14	11	8	1	2
45	8	8	8	1	2
46	18	7	8	2	4
47	11	11	8	0	1
48	13	19	5	0	3
49	16	11	6	2	1
50	1	22	1	0	3
51	15	7	8	2	2
52	6	5	8	1	2
53	2	4	8	1	2
54	7	17	8	2	2

Appendix E (cont'd.)

Note: The numbers listed in the column labelled condition refer to the eighteen experimental conditions, as shown below.

		Color-Coding Treatment	Group of Bones		
			Hand	Head	Torso, Arms, and Legs
Type of Response Term	Scientific	Non-Color-Coded (NC)	1	2	3
		Color-Coded (CC)	4	5	6
		Color-Coded-With-Fading (CCF)	7	8	9
	Trigram	(NC)	10	11	12
		(CC)	13	14	15
		(CCF)	16	17	18

Appendix F

Analysis of Variance of Number of Trials to Reach Criterion as a Function of Color-Coding Treatment (C), Group of Bones (G), and Type of Response Term (R)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	1.815	2	.907	3.23	<1
Group of Bones (G)	914.370	2	457.185	3.23	58.090*
Type of Response Term (R)	115.574	1	115.574	4.08	14.685*
C X G	42.519	4	10.630	2.61	1.351
C X R	15.593	2	7.796	3.23	<1
G X R	25.482	2	12.741	3.23	1.619
C X G X R	5.185	4	1.296	2.61	<1
error	283.333	36	7.870		

*Statistically significant.

Appendix G

Analysis of Variance of Number of Correct Responses on Paper and Pencil Test as a Function of Color-Coding Treatment (C), Group of Bones (G), and Type of Response Term (R)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	14.926	2	7.463	3.323	6.717*
Group of Bones (G)	76.926	2	38.463	3.23	34.617*
Type of Response Term (R)	.296	1	.296	4.08	<1
C X G	25.852	4	6.463	2.61	5.817*
C X R	7.815	2	3.907	3.23	3.517*
G X R	.259	2	.128	3.23	<1
C X G X R	17.630	4	4.407	2.61	3.967*
error	40.000	36	1.111		

*Statistically significant.

Appendix H

Analysis of Variance of the Number of Correct Responses on the Bone-Color Test as a Function of Color-Coding Treatment (C), Group of Bones (G), and Type of Response Term (R)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	25.444	2	12.722	3.23	9.411*
Group of Bones (G)	7.445	2	3.722	3.23	2.753
Type of Response Term (R)	4.741	1	4.740	4.08	3.507
C X G	7.556	4	1.889	2.61	1.397
C X R	3.593	2	1.796	3.23	1.329
G X R	1.815	2	.907	3.23	<1
C X G X R	1.852	4	.463	2.61	<1
error	48.667	36	1.352		

*Statistically significant.

Appendix I

Analysis of Variance of the Number of Correct Responses on the Color-Name Test as a Function of Color-Coding Treatment (C), Group of Bones (G), and Type of Response Term (R)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	3.370	2	1.685	3.23	1.167
Group of Bones (G)	2.259	2	1.129	3.23	<1
Type of Response Term (R)	.019	1	.019	4.08	<1
C X G	9.852	4	2.463	2.61	1.705
C X R	.260	2	.130	3.23	<1
G X R	1.370	2	.685	3.23	<1
C X G X R	1.185	4	.296	2.61	<1
error	52.000	36	1.444		

*Statistically significant.

Appendix J

Instructions to Subjects--Experiment 2: Color-Coded Conditions

I'm going to show you a series of slides on the screen in front of you. You will notice that each slide contains the picture of a human skeleton and that there is an arrow pointing to one bone. There are two slides for each of eight different bones. One is labelled with an X and the other with a unique name for that bone. Your task will be to learn the name of each of the eight bones that will be presented.

There are eight different bones as well as eight unique names. Each bone will be shown first labelled with an X and then labelled with its own correct name.

Beginning with the very first slide that has a bone labelled with an X, I'd like you to respond aloud with the name you think is associated with that bone. Please respond while the slide with an X is on the screen. The slide with the correct name will then be presented so that you can check your answer.

We have found in a past experiment that color coding can help reduce the number of trials required to learn this type of material. The color can help you separate out the bones. Therefore, please note that each of the shapes has been given a unique color. You should use these colors to help you learn the eight bones in this experiment. However, I want to caution you that

(Note: The following was read only to Ss in the color-coded [CC] conditions.)

the color will disappear after you have responded correctly to all of the bones on one trial.

(Note: The following was read only to Ss in the color-coded-with-fading [CCF] conditions.)

the color will disappear, a little at a time, as you begin making fewer and fewer errors. In fact, it will disappear after you respond correctly to 7 or more bones on a single trial.

(Note: The following was read to Ss in both of the color-coded conditions.)

Thus, though color will be present at the beginning you must eventually respond correctly to all eight bones without the presence of the color-coding.

Before we begin the experiment, however, I would like you to become familiar with the names that you will have to associate with the eight bones during the experiment. You will be shown all eight names at one time and should read each of these names carefully. Then while the screen is blank you should attempt to recall as many of them as you can. There will be three presentations like this, then the experiment itself will begin.

(Note: There was a pause here.)

Are there any questions?

(Note: There was a pause here.)

OK, now remember, after the three slides containing the names alone, I will show you eight bones one at a time, and you should associate one of the names with each bone. Please be sure to respond aloud while the slide labelled with an X is still on the screen.

(Note: There was a pause here.)

Do you have any questions?

(Note: At this point the experiment began. After S reached criterion the following instructions were read.)

You have now learned the names of all the bones but I'd like you to do just a couple of other things. First, I would like you to label each of the bones on this sheet of paper.

(Note: At this point the subject was handed a pencil and piece of paper on which a skeleton had been mimeographed. He was given as much time as he needed to label all eight bones. Then the two following instructions were given [in an order randomly assigned to each subject]. Following each instruction the appropriate test was given.)

(1) Now I'm going to show you the bones again, one at a time, and I'd like you to tell me in each case what color you think might be associated with that bone.

(2) Finally, I'm going to show you, one at a time, eight colors that might be associated with the eight bones, and I'd like you to tell me in each case the name of the bones that you think go with each color that you see.

Appendix K

Instructions to Subjects--Experiment 2: Non-Color-Coded Conditions

I'm going to show you a series of slides on the screen in front of you. You will notice that each slide contains the picture of a human skeleton and that there is an arrow pointing to one bone. There are two slides for each of eight different bones. One is labelled with an X and the other with a unique name for that bone. Your task will be to learn the name of each of the eight bones that will be presented.

There are eight different bones as well as eight unique names. Each bone will be shown first labelled with an X and then labelled with its own correct name.

Beginning with the very first slide that has a bone labelled with an X, I'd like you to respond with the name you think is associated with that bone. Please respond while the slide with an X is on the screen. The slide with the correct name will then be presented so that you can check your answer.

In past experiments we have tried several ways of indicating to the subject each time as a slide is shown which bone he is to name. We have found that the type of arrow that we are using today can help to reduce the number of trials required to learn this type of material.

Before we begin the experiment, however, I would like you to become familiar with the names that you will have to associate with the eight bones during the experiment. You will be shown all eight names at one time and you should read each one of these names carefully. Then while the screen is blank you should attempt to recall as many of them as you can. There will be three presentations like this, then the experiment itself will begin.

(Note: There was a pause here.)

Are there any questions?

(Note: There was a pause here.)

OK, now remember, after the three slides containing the names alone, I will show you eight bones one at a time, and you should associate one of the names with each bone. Please be sure to respond aloud while the slide labelled with an X is still on the screen.

(Note: There was a pause here.)

Do you have any questions?

(Note: At this point the experiment began. After S reached criterion, the following instructions were read.)

You have now learned the names of all the bones but I'd like you to do just a couple of other things. First, I would like you to label each of the bones on this sheet of paper.

(Note: At this point the subject was handed a pencil and a piece of paper on which a skeleton had been mimeographed. He was given as much time as he needed to label all eight bones. Then the two following instructions were given [in an order randomly assigned to each subject]. Following each instruction the appropriate test was given.)

(1) Now, I'm going to show you the bones again, one at a time, and I'd like you to tell me in each case what color you think might be associated with the bone.

(2) Finally, I'm going to show you, one at a time, eight colors that might be associated with the eight bones, and I'd like you to tell me in each case the name of the bones that you think go with each color that you see.

Appendix L

Four Dependent Variable Values for Each S--Experiment 2

Subject	Condition (See Note, this Appendix)	Number of Trials to Criterion	Number Correct on Paper and Pencil Test	Number Correct on Color-Name Test	Number Correct on Bone-Color Test
1	2	10	7	1	3
2	5	23	8	1	1
3	3	19	2	1	1
4	6	11	8	3	2
5	4	8	8	4	4
6	1	18	8	1	0
7	4	8	8	5	4
8	2	13	8	1	1
9	1	20	4	0	1
10	6	8	6	1	2
11	3	17	7	0	1
12	5	11	8	0	0
13	2	6	8	2	1
14	5	14	3	1	2
15	3	13	8	3	1
16	1	16	3	3	1
17	4	10	8	1	2
18	6	7	8	3	1
19	3	17	6	0	3
20	5	15	6	1	0
21	6	9	8	2	1
22	1	12	8	0	0
23	4	7	8	1	1
24	2	5	8	1	0
25	1	12	7	0	0
26	3	16	8	1	0
27	6	6	8	3	3
28	5	9	3	1	0
29	2	7	7	1	2
30	4	11	8	4	2

Appendix L (cont'd.)

Subject	Condition (See Note, this Appendix)	Number of Trials to Criterion	Number Correct on Paper and Pencil Test	Number Correct on Color-Name Test	Number Correct on Bone-Color Test
31	4	17	7	4	4
32	2	5	8	2	2
33	3	17	6	0	4
34	6	9	8	6	5
35	5	17	8	2	1
36	1	12	5	0	2
37	2	8	7	3	0
38	5	13	8	1	1
39	4	7	8	3	2
40	3	14	8	4	1
41	1	11	5	0	2
42	6	11	8	1	1

Appendix L (cont'd.)

Note: The numbers listed in the column labelled <u>condition</u> refer to the six experimental conditions, as shown below.

<table>
<tr><td colspan="2"></td><td colspan="2">Group of Bones</td></tr>
<tr><td></td><td>Color-Coding Treatment</td><td>Hand</td><td>Head</td></tr>
<tr><td rowspan="3">Color-Coding Treatment</td><td>Non-Color-Coded (NC)</td><td>1</td><td>2</td></tr>
<tr><td>Color-Coded (CC)</td><td>3</td><td>4</td></tr>
<tr><td>Color-Coded-With-Fading (CCF)</td><td>5</td><td>6</td></tr>
</table>

Appendix M

Analysis of Variance of Number of Trials to Reach Criterion as a Function of Color-Coding Treatment (C), and Group of Bones (G)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	25.339	2	12.669	3.23	1.224
Group of Bones (G)	421.172	1	421.172	4.08	40.696*
C X G	1.328	2	.664	3.23	<1
error	372.571	36	10.349		

*Statistically significant.

Appendix N

Analysis of Variance of Number of Errors on the Paper and Pencil Test as a Function of Color-Coding Treatment (C), and Group of Bones (G)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	1.857	2	.929	3.23	<1
Group of Bones (G)	25.929	1	25.929	4.08	10.306*
C X G	.429	2	.214	3.23	<1
error	90.572	36	2.516		

*Statistically significant.

Appendix O

Analysis of Variance of the Number of Correct Responses on the Bone-Color Test as a Function of Color-Coding Treatment (C), and Group of Bones (G)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	8.333	2	4.167	3.23	3.017
Group of Bones (G)	10.500	1	10.500	4.08	7.604*
C X G	1.857	2	.929	3.23	<1
error	49.714	36	1.381		

*Statistically significant.

Appendix P

Analysis of Variance of the Number of Correct Responses on the Color-Name Test as a Function of Color-Coding Treatment (C) and Group of Bones (G)

Source	SS	df	MS	$F_{req.}$ .05	$F_{obt.}$
Color-Coding Treatment (C)	9.572	2	4.786	3.23	2.818
Group of Bones (G)	24.381	1	24.381	4.08	14.355*
C X G	1.476	2	.738	3.23	<1
error	61.143	36	1.699		

*Statistically significant.