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Cognitive Storage Modes for Color Memory

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COGNITIVE STORAGE MODES FOR COLOR MEMORY

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ABSTRACT

The roles of cognitive storage modes for color memory were investigated through their effects on response accuracy and response latency. Through the use of specific instructions, subjects were focused on one of five modes of storing color information (sensory, imagery, verbal, imagery with a verbal mask, or verbal with an imagery mask). After viewing a color stimulus, subjects were required to identify that stimulus from a group of six highly similar stimuli. Results of the study suggest that accuracy of memory for a color depends on both the color and the storage mode used. Differences in response accuracy and response latency were noted between the sexes; females generally responded more accurately and faster than males. This advantage for females appeared to result from their use of verbal encoding techniques for color information, although both verbal and imagery components were involved in the information processing. The roles of delay between stimulus viewing and recognition, and stimulus color in the storage mode were also investigated. The results of the study are discussed in terms of the apparent sex differences in color encoding and information processing, individual differences in this process, and possible effects of previous experience with color discrimination.

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INTRODUCTION

Memory for color concerns both the areas of cognition and color vision. Previous research, however, has not been able to determine by what mode a color memory leaves the realm of pure sensory store and becomes a cognitive image. This study attempts to determine the cognitive mechanisms which contribute to longer term memory for color.

Memory of Form

Early studies in the phenomenon of memory for non-verbal material were based on attempts to prove or disprove a Gestalt approach based on memory changes improving the symmetry and "goodness of form" (Allport, 1930; Perkins, 1932). From these studies it became apparent that several variables might affect the quality and duration of a memory. The effects of verbal labeling and interpretation (Brown, 1935; Carmichael, Hogan & Walter, 1932; Gibson, 1929) were noted as the reproduction of a remembered stimulus changed to fit associations presented and manipulated by the experimenter. The effects of multiple attempts to reproduce a stimulus, and the repeated errors made by the subject were noted in progressive deterioration of the memory (Hanawalt, 1937).

The detection of a distinct difference between reproduction and recognition came to light when the reproduction was found to have substantially deteriorated and yet the recognition abilities were left intact (Hanawalt, 1937). Further studies revealed that the reproduction of a memory could be influenced by verbal labeling while the recognition remained true to the original stimulus (Prentice, 1954). The Gestalt theory was temporarily laid to rest when studies of memory deterioration revealed no predictable patterns but rather a general deterioration of the memory (Hebb & Foord, 1945).

The study of memory then turned more to the effects of delays and the progressive, but not necessarily predictable changes, on recognition (Crumbaugh, 1954; Karlin & Brennan, 1957). It was found that while verbal labeling had an immediate influence on reproduction, the effect of labeling was also influenced by the attention given to the stimulus on exposure; the greater the exposure, the less the effects of labeling (Bruner, Busick & Minturn, 1952; Herman, Lawless & Marshall, 1957).

The approach to information processing now generally accepted identifies several stages of memory; acquistion, storage, retrieval and utilization of the information (Haber, 1969). The first phase of acquistion is achieved through the senses and results in a sensory store. This sensory store provides a very brief storage for information in its original sensory form (Reed, 1982).

Memory of Color

Studies in short-term memory of color with verbal labeling have been inconclusive in their results. Although one study has shown loss of color information after 0.8 seconds (Well & Green, 1972) other studies have produced no significant losses after 8.0 seconds (Kroll, Kellicut, Berrian & Kreisler, 1974; Eichengren, 1976; Judd, 1951). Tasks involving the recognition of a color when labelled with a name not best suited to that color do not indicate distortion of the color memory (Ridley, 1972). These studies suggest that the memory for color is relatively stable over time and is unaffected by language interference, providing the sensory representation is not masked by additional retinal stimulation (Ridley, 1972; Southall, 1937).

Studies in long term color memory have concentrated on the effects of distortion of the colors over time (Burnham & Clark, 1955; Hamwi & Landis, 1955; Nelson, Sinha & Olsen, 1977; Nillson & Nelson, 1981). The results suggest a variety of possible distortions in the memory. Drifts due to brightness and saturation occurred in tasks involving hue memory when compared to simultaneous matches (Newhall, Burnham & Clark, 1957). Other studies have indicated low distortions of memory for mid-spectrum colors and pronounced distortions in blue-green and red-purple hues. These distortions appear to have taken place following stimuli exposure periods of 105 seconds and response delays up to 15 minutes. Minor additional errors occurred following delays of 15 minutes to 65 hours (Hamwi & Landis, 1955).

Color Perception and Sensory Storage

The perception of color can be affected by manipulation of hue, brightness or saturation of the color. Manipulations in color hue result from changing the wavelength, thus changing the position within in the color spectrum. The brightness of a color changes with the amplitude of the wave. The saturation changes with the amount of white contributing to the perceived color.

After stimulation of the rods and cones of the retina, a sensation lingers for varying amounts of time depending on the nature and intensity of the original stimulus. A positive afterimage (a near exact imitation of the original stimulus) is most effectively developed by an intense, short-lived stimulus with the exclusion of light thereafter. In studies conducted tachistoscopically, thus preventing eye movement during stimulation, the afterimage lasted up to 3.00 seconds before deteriorating. Further studies of afterimages suggested their strength was related to the structural complexity and meaningfulness of the stimuli. Very complex stimuli, particularly those which were meaningful and nonabstract, increased the visibility and duration of the afterimage (Pritchard, Heron & Hebb, 1960; Pritchard, 1961).

Beyond Sensory Storage

Research based on a theory of visual information storage (VIS) suggested that the VIS maintained a visual image (an icon) from 1/20 of a second to several seconds, with the average life of 0.25 seconds, and may have contributed to the formation of the afterimage (Sperling, cited from Haber, 1969).

Visual input is stored in three ways: (1) sensory representation (iconic representation), (2) verbal description and (3) schematic representation (Kroll et al, 1970; Posner, cited in Haber, 1969). A short-term visual memory has been proposed following studies using visual input classified as too brief for sensory retention or of nonverbal information (Phillips & Baddeley, 1971). In these studies, loss of memory occurred after 0.90 seconds. Phillips (1974) has proposed distinct differences between sensory storage and the short-term visual memory. Phillips has suggested that sensory storage has a high capacity, a storage time of about 0.10 seconds and can compare two images only if they appear in the same position of the retina. In addition, it appears highly sensitive to masking effects. The description of the short-term visual memory, however, is one of very limited capacity, with a duration period in excess of 0.60 seconds, showing minor losses at 9.00 seconds. Short-term visual memory appears to be capable of comparing two images appearing in different places, and is not necessarily affected by masking.

Recently, Haber (1983) has questioned the importance of iconic representation. Haber argues that while the iconic memory may well exist, its contribution to visual information processing may be negligible except under specific conditions, primarily those of dark-adaptation and tachistoscopically viewed stimuli. In raising these questions regarding the impact of iconic representation on visual memory, the issue of cognitive storage modes for color memory becomes even more salient.

Cognitive Storage Modes of Color Memory

The studies of color memory have focused primarily on the effects of verbal labeling and on the distortions of the memory over time. They have not, however, determined the cognitive storage mode required for the long term retention of color information.

The present study was an attempt to identify the most efficient and interference-free storage mode for color memory by evoking sensory, imagery and verbal labeling effects on hue recognition. These modes were evoked through instructions which focused the attention of the subject on the use of imagery or verbal techniques by which to remember the color, and also by instructions which attempted to mask the use of alternate storage modes. It was predicted that the sensory storage mode would provide the least accurate hue matches over time, as research has indicated that under similar conditions, sensory modes decay within 3 seconds. Previous research had suggested no effect of verbal labeling on color recognition. Pilot studies by this author, however, suggested that while the verbal labeling may not change the hue perceived and remembered, it is an important component to the storage of information. It was predicted that neither imagery nor verbal labeling alone would be the most efficient mode for color memory and would be surpassed by modes combining imagery and verbal labeling. Within the modes using single components, that is, either imagery or verbal labeling alone, it was predicted that imagery would be the most efficient mode. The use of a single component was inferred in those conditions through the use of masking techniques to disrupt other possible storage mechanisms. That is, in the condition which paired imagery storage with a verbal mask, the verbal mask was expected to disrupt a verbal encoding mechanism, leaving the imagery as the single component responsible for storage of the color memory. In the condition of verbal encoding paired with an imagery mask, the single component was inferred to be verbal encoding, as the imagery mask was expected to disrupt imagery storage. This study was designed to test the accuracy of the recognition memory over time using specific storage modes and to determine any patterns of memory deterioration within these modes. Furthermore, factors which may interfere with the storage modes were examined. In order to detect the confounding of data through practice effects, fours colors and four delay periods were systematically randomized within a block; each subject was tested over four blocks. Delay selection was based on significant delay periods noted in the pilot studies.

METHOD

Subjects

The 96 subjects who participated in the study were volunteers from the College of William and Mary undergraduate psychology student pool, and received credit for their participation. Five subjects were unable to distinguish subtle differences in the recognition stimuli and did not complete the experiment. The remaining subjects, 47 males and 44 females, completed all of the trials in the study, with each subject randomly assigned to one of five instruction conditions (See Appendix A for cell breakdowns).

Materials

Nineteen original stimulus cards were used in the experiment; three for practice purposes and sixteen for testing purposes. The stimulus cards were constructed from white poster board, with one FulColor paint chip centered on each 8 x 8 card. Each stimulus card had a corresponding recognition card, of similar size and material, which displayed six FulColor paint chips arranged in a circle. Of the paint chips on the recognition card, only one exactly matched the original stimulus. The other five chips were selected as foils and differed from the original in hue and/or saturation. These foils had been previously tested and selected for being just noticably different from their corresponding stimuli cards. The arrangement of the six paint chips on a card alternated hue and saturation differences, to avoid presenting a distinct beginning or end to the array. (See Appendices B & C for stimuli codes and recognition card construction).

There were nineteen different color stimuli; subjects saw each stimulus card only once. For the practice cards, one yellow, one green and one pink stimulus were used. The sixteen testing cards covered six color groups: blue-green (4), blue (4), green (2), yellow (2), pink (2) and violet (2).

Procedure

Each subject was tested individually under identical lighting conditions. Each subject received one set of instructions to elicit the use of a specific storage mode. The subject was allowed to view the stimulus card for 5 seconds. After the viewing period, the subject closed his eyes until the end of the previously determined delay period. The delay periods used were: immediate (within 5 seconds), 25 seconds, 50 seconds and 75 seconds. The immediate delay period was expected to pick up vestiges of sensory storage. The subsequent delay periods were noted in a pilot study to cover 100% recognition at 25 seconds to 0% recognition at 75 seconds (Dunn, 1983). The delay periods were randomized, with each delay period occurring once in each of four blocks of trials. The subject was then shown the recognition card, and was to select the color chip that matched the original stimulus. The stimulus colors were also randomized within blocks (See Appendix B).

Each subject participated in three practice trials to facilitate his or her understanding of the instructions. In addition, following each practice trial the subject was required to match the stimulus to the recognition chip while both were viewed, to assure the subject's ability to discriminate and match hues. Three additional stimuli were matched in this manner during the sixteen trials, with the subject required to accurately match one set of hues from each color group.

Subjects in the _sensory condition (S)_ were presented with a stimulus and told they would have to match the color later. They were asked to hum songs to themselves while their eyes were closed. The subjects in the condition which focused on imagery (_imagery condition - I_) were presented with a stimulus and told to picture a t-shirt of the same color while their eyes were closed; they were to image the color in their mind's eye. The subjects in the condition which focused on verbal labeling (_verbal condition - V_) were shown a stimulus and told to describe the color as accurately as they could in the five second viewing period. They were told to remember their description of the color during the delay period when their eyes were closed. The _imagery/verbal-mask condition (I/V)_ required subjects to view a stimulus card for five seconds and then perform two tasks during the delay period. They were told to remember the color by imaging a t-shirt of that color in their mind's eye. In addition, they were told to list as many words beginning with a specific letter as they could during the delay period. These letters were selected from the Word Frequency Book, according to their frequency in the English language (Carrol, Davies & Richman, 1971). This verbal mask was expected to mask any covert labeling that might occur during the delay period. The verbal/imagery-mask condition (V/I) required the subjects to describe the stimulus color within the five second viewing period. They were told to remember their description while they performed an imagery task during the delay period. The imagery task required the subjects to imagine themselves painting a brick wall; each brick was to be painted a different color and they were told not to use the color they had been shown. The subjects were to tap their finger to indicate when they had finished each brick. This condition was expected to prevent the subjects from imaging the colors during the delay period.

Following the completion of the experiment, subjects were asked to describe what they had done to remember the colors. Although subjects reported varying degrees of difficulty in following the instructions, it was not necessary to eliminate any subject from the study because of his or her failure to follow the instructions.

The subject's responses were recorded in terms of their accuracy of stimulus matching and the time required to make the match. A response was operationally defined as an exact match (accurate), a saturation error or a hue error with regard to the original stimulus. The subjects were advised to make their matches as quickly as possible and were given a maximum of 10 seconds to do so. The response latency was measured to the nearest 1/10th second using a stopwatch.

RESULTS

Data were analyzed with regard to two dependent measures; level of accuracy and response latency. Three levels of response accuracy were considered: accurate (correct hue and saturation - no error), saturation error (correct hue but incorrect saturation) and hue error (incorrect hue). The data were analyzed in a series of repeated measures, mixed model factorial designs using the SPSS Manova Statistical Package.

The independent variables included sex, instruction, color, delay and block. As the delay periods were nested within color variables, these analyses were done independently. The conditions of instructions were; (1) sensory storage (S), (2) imagery (I), (3) verbal (V) encoding, (4) imagery with a verbal mask (I/V) and (5) verbal encoding with an imagery mask (V/I). Sixteen different colors were used as stimuli; 2 pink, 2 green, 2 violet, 2 yellow and 4 each of blue-green and blue stimuli. For each subject, the sixteen trials were arranged in four blocks, with four colors and four delay periods systematically randomized within each block. The four delay periods were "0" seconds (immediate), 25 seconds, 50 seconds and 75 seconds.

Accuracy

The data were first analysed in terms of response accuracy, with the independent variables of sex, instruction and color. A 2 x 5 (x 16) analysis of variance (ANOVA) for sex, instruction and color revealed a main effect for sex, with $F(1, 81) = 4.45$, $p < .05$. Females showed a more accurate memory for colors than males (see Table 1). The interaction between instruction and color, with $\underline{F}$ (60, 220) = 1.28, $\underline{p} < .10$, suggested that an interaction might be color specific, and that any significance might be masked due to heterogeneity of the color variables.

Insert Table 1 about here

Using a chi-square contingency test for homogeneity of data, five colors were found to show only extreme responses (See Appendix D). Cards 02, 09, and 16 were found to elicit extreme responses in terms of significantly high accuracy or high hue errors. These cards appeared to be either too easy or too difficult and were removed from the study. In addition, two cards were found to vary significantly from the other stimuli with regard to saturation errors. Cards 01 and 06 were found to have either significantly high or low rates of saturation errors, and were also removed from the study. The data were then re-analyzed, based on the remaining 11 cards.

The second analysis, a 2 x 5 (x 11) design for sex, instruction and color revealed an interaction between instruction and color with $\underline{F}$ (40, 220 = 1.53, $\underline{p} < .05$, as shown in Figure 1. When accuracy was strictly defined as absolute correctness, the blue-green stimuli were best recognized through imagery instructions. Pink stimuli were least likely to be recognized using imagery instructions. Other interactions of color and instructions were inconsistent throughout the remaining color stimulus groups. When the definition of correctness was expanded to include saturation errors, thus redefining accuracy as correct color versus a distortion of the hue, both the pink and green stimuli were better recognized through verbal instructions. Pink stimuli. again, were least likely to be recognized through imagery instructions. Blue stimuli were best recognized through imagery and least often recognized using sensory instructions. Violet stimuli were recognized most often using instructions which focused on imagery and were least often recognized following the use of verbal instructions.

Insert Figure 1 about here

A main effect for color (F (10, 220) = 3.96, $p < .01$) revealed that this effect could be seen for individual color stimuli only. Again, the effect was not consistent across or within color groups. The single factor of color did not affect the response accuracy for all colors, nor did it affect all colors within a specific color group. The effect on the response accuracy for individual colors is shown in Figure 2.

Insert Figure 2 about here

The analysis of sex, instruction and block, a 2 x 5 (x 4) design, revealed a near significant main effect between blocks, with F (3, 87) = 2.58, $p < .10$. The second block was found to contain the majority of the colors previously noted to be eliciting extreme responses, that is, colors 01, 02, 06, 09, and 16. When this block was removed from the analysis, the trend toward a significant difference between blocks was no longer found.

Analysis of a 2 x 5 (x 4) design for sex, instruction and delay revealed no significant differences between delay periods and the accuracy of the response. This suggests that these delay periods may not have been long enough to pick up deterioration of the color memory using recognition tasks.

Response Latency

The second series of analyses focused on response time, with the independent factors of sex, instruction, color and delay. As in the first series of analyses, color and delay were analyzed separately.

A 2 x 5 (x 16) analysis of sex, instruction and color revealed a significant main effect for sex, with F (1, 81) = 6.04), $p < .05$, with females responding more quickly (M = 5.86 secs) than males (M = 6.70 secs). A significant main effect for instructions, F (4, 81) = 3.48, $p < .05$) indicated the fastest response time occurred when using imagery instructions. The most inefficient (slowest) instruction condition was the imagery with mask condition, as shown in Figure 3. This suggests that when using imagery, a subtle but important level of verbal encoding may occur. The verbal mask appeared to impede this verbal encoding, thus requiring more time to recognize the color based on imagery alone.

Insert Figure 3 about here

The interaction between sex and instruction neared significance, F (4, 81) = 2.21, $p < .10$. This suggests that females using imagery with verbal masking take longer to respond than males using the same encoding technique; the females appeared faster to respond than males, however, when using a verbal encoding technique with an imagery mask. The interaction between sex and instruction was also found to be significant in an analysis across blocks, and will be discussed in more detail below.

An interaction of instructions and color, with F (20, 220) = 1.53, $p < .01$, indicated that over most colors, the fastest response time resulted from imagery encoding and the longest response time resulted from using imagery with verbal masking. As shown in Figure 4, the longest response times for the color yellow were elicited by verbal encoding. Other color differences appeared to be inconsistent.

Insert Figure 4 about here

The main effect for color, F (15, 220) = 7.82, $p < .01$, indicated that some colors required significantly less time to be recognized than others. The effect, however, did not appear to be consistent within color groups. This suggests that differences in the time required for recognition were the result of individual differences in the colors rather than differences in color-group characteristics.

Analysis of response time in a 2 x 5 (x 4) design of sex, instruction and delay revealed a significant main effect for instructions, with F (4, 81) = 3.07, $p < .05$. Imagery with verbal masking again required the longest response time and the use of imagery evoked the shortest response time.

A main effect for sex approached significance, with F (1, 81) = 3.80, $p < .10$, suggested that females responded faster than males for all conditions. This affect, however, would be qualified by the significant interactions noted above. A main effect for delay was significant, F (3, 87) = 7.90, $p < .01$; the shortest delay (0 secs) evoked the shortest response time. The longest delay (75 secs) resulted in the longest response time, regardless of any other factors in the experiment, as shown in Figure 5.

Insert Figure 5 about here

Analysis of sex, instruction and block, a 2 x 5 (x 4) design revealed an interaction of sex and instruction, F (4, 81) = 2.51, $p < .05$. As seen in Figure 6, females responded faster than males under imagery, verbal, and verbal/imagery-mask conditions. There were no significant differences between the sexes for either sensory or imagery/verbal-mask conditions. Response times for males under the sensory condition or the imagery condition were virtually identical, and males were the slowest to respond under the verbal/imagery-mask condition. Females were fastest to respond under the verbal/imagery-mask condition and slowest to respond under the imagery/verbal-mask condition.

Insert Figure 6 about here

This analysis also revealed a significant main effect for sex, F (1, 81) = 8.50, $p < .01$, indicated females again were faster than males overall. The main effect for instructions, F (4, 81) = 3.03, $p < .05$, again indicated that the fastest response occurred using imagery, and the longest response time was evoked using imagery/verbal-mask conditions. Once again, it should be noted that these interpretions must be qualified by the significant interaction already discussed.

A significant main effect for block, F (3, 87) = 3.54, $p < .05$, indicated that response time decreased from the presentation of block one to block four, as shown in Figure 7.

Insert Figure 7 about here

This may be a result of increased familiarity with the task; a practice effect for task performance in terms of response time only.

DISCUSSION

This study focused on identifying the mechanisms of storage and the most efficient storage mode of color memory. In addition to the specific types of storage modes, such as imagery and verbal encoding, the factors of stimuli color, subjects' sex, delay periods and practice were also examined, with regard to their roles in color memory.

Accuracy

In terms of accuracy, the data suggest that neither instruction nor color alone can account for the accuracy of a color memory. In other words, the particular mode of information storage is not wholly responsible for determining the quality of the color memory. Instead, an interaction between instruction and color might provide a better explanation.

The five instruction conditions (sensory, imagery, verbal, imagery with a verbal mask, and verbal with an imagery mask) did not show significantly different levels of response accuracy. Trends in the data, however, suggest that the masking tasks did have some effect on the storage of color information. It appears that the masking tasks used were effective in blocking certain modes of information storage, as suggested by differences in response accuracy when comparing related instruction conditions, such as imagery compared to imagery/verbal-mask conditions and verbal compared to verbal/imagery-mask conditions. The verbal masks did appear to block the use of verbal storage and increased the subjects' reliance on imagery storage modes. Imagery masks appeared to block the use of imagery, thus increasing subjects'reliance on verbal encoding techniques. Trends in the data also suggested that the subjects were able to focus on the intended storage modes sufficiently enough to suggest differences without their having to rely on masking techniques. The conditions which focus on imagery, either with or without the use of a verbal mask, appear to be distinct from those conditions which focus on verbal encoding, with or without an imagery mask.

When an accurate response was defined as one which matched the original stimulus in both hue and saturation, the results were inconsistent within and across color groups. When an accurate response was defined as matching the original only in terms of hue, the interaction between instruction and color was found to be consistent within some color groups, but not necessarily across color groups.

Color and Instruction Interactions

The least effective storage mode for the blue-green stimuli appeared to be imagery, with most errors in accuracy occurring in both conditions requiring imagery encoding. The blue-greens did not show any particular mode to be the most effective for color information storage. The blue stimuli were shown to be most accurately remembered using imagery conditions, primarily the imagery condition which was affected by verbal masking. The blue stimuli were least often recognized when subjects used sensory storage. The memory for green stimuli appeared best stored using the instruction condition which focused the subjects on verbal encoding (but did not prevent imagery storage); the errors for green stimuli occurred most frequently in those conditions which actively masked one storage mode or another. This suggests that for green, both verbal and imagery modes are necessary for efficient storage of the color memory. The violet stimuli were best remembered in those conditions which focused on imagery, with or without the use of a verbal mask. They were least often remembered through the use of instructions which focused on verbal encoding or the verbal condition which prevented the use of imagery.

These results suggest that while the memory of color information is not distinct across colors, there are distinct differences between how different colors are stored. It is possible that the storage of color is affected by its associativeness, that is, whether the color can be associated with a remembered object or experience. If an individual is familiar with the color through experience, the encoding process may be very different from that for a color not frequently encountered. For example, a familiar color may be encoded through an imagery comparison to other similar colors remembered. An unfamiliar color, however, may be verbally encoded, where the verbal cues provide an intermediate level of detail which can then be related to familiar colors.

Another possible explanation lies in the purity of the color. Colors which are closer to color "standards" (i.e. blue) may be more readily recognized through imagery, whereas half-tones (i.e. blue-greens) may be more readily encoded verbally. The colors selected for this study were classified according to their placement on the spectrum, however, with no classifications made according to their relative distance from a "standard".

The use of multidimensional scaling techniques might be useful in the study of color memory and individual encoding processes. Following an individual's scaling of colors in terms of their perceived distance from the standard, the use of recognition tasks based on evoked storage modes might provide additional information regarding the initial encoding process for color information and subsequent changes occurring as the colors become more complex. The multidimensional scaling technique results in an arrangement of colors in terms of spatial relationships, making it possible to determine what encoding techniques are most efficient as the color moves away from the stimulus standard.

Sex Differences and Response Accuracy

The results of the current study indicate that females are more accurate than males for both response categories; those comprised of both hue and saturation accuracy, and those which focused purely on hue differences. The significant differences in the ability to accurately encode color information between males and females may lie in the differences in role expectations and socialization. Females may demonstrate superior recognition of colors as a result of their experience in color matching. This skill has become significant for females through expectations of color-coordinated fashions and home decor, and is continually reinforced through advertising. Similar expectations of males are primarily oriented to professional needs, and would presumably become reinforced through professional training. Studies by Cohen, Welch & Fisichelli, and by Woods (cited in Burnham & Clark, 1955) on the effects of training in color memory suggested those individuals with a great deal of training (e.g. an extensive art background or professional training) would perform better on memory tasks than those individuals without training. Burnham & Clark (1955) found no such training effects. The lack of significant differences between blocks in this study also suggests that practice over the sixteen trials did not improve or hinder the storage of color information. This suggests that the experience received over the sixteen trials is not sufficient to be considered training, supporting idea that "color memory training" comes as a result of extended practice, as in professional training and/or prolonged exposure to tasks which demand color matching. It should be noted, however, that prior color training (e.g. artistic backgrounds) was not used as a covariate. When questioned about their experience with colors only five subjects acknowledged having any formal art training or specific artistic interests which might have provided prior experience with color discrimination or memory.

Experience_vs_Encoding_Process

The degree of training may be of less importance than the timing of the training, with early training having the greatest effect as an individual first begins to distinguish the colors. The success of training for color memory may be related to the use of a specific encoding technique first used to discern the colors; those individuals who made finer distinctions between colors when learning to identify them may improve more dramatically with training. If the colors were initially discerned using verbal cues, then the success of subsequent training may depend on the continued use of that storage cue. This also implies that individuals may have a specific encoding technique they use to process color information. Further research, which first distinguishes the most efficient storage mode for an individual, might provide more information as to how color information is stored and retrieved. Observations of the interactions between children and adults as the children are taught to identify colors might provide useful information regarding how the colors are presented; whether the child is taught to verbally encode color differences as they vary from a standard, or whether the child learns to associate the colors with experiences. For example. is the color red first related to a fire engine or is it considered a "bright red" which implies a variation on a standard of "red"?

Response Latency

The second focus of the study pertained to response latency. The first analysis revealed a significant difference between males and females, with females responding faster overall. This result may be related to differences in task familiarity; if females have more experience in identifying colors they may be more adept at making distinctions between colors, not only in accuracy but also in terms of response latency. The interaction between sex and instructions, however, suggests there may be an additional factor involved. The data indicate that the greatest difference between the response times of males and females occurred in those instructions which required a verbal component. Females were able to respond faster than males using instructions which focused on verbal encoding as well as through verbal encoding instructions which masked imagery.

Differences in Encoding Processes

Comparisons of response latency for the verbal and verbal with imagery mask conditions reveal that while the prevention of imagery increased the response times for males, it did not significantly affect the response times for females. Comparisons of the two imagery conditions, on the other hand, showed only a modest difference (0.5 seconds) between male and female response times. In addition, this 0.5 second advantage for females remained consistent across instructions which focused on imagery and those which masked verbal encoding. That is, as the verbal component was masked, both males and females required more time to make their response, and females were again only slightly faster than the males. Thus, it appears that while color memory is stored with both verbal and imagery components, females are more dependent on the verbal component than males for retrieval of the information, and the verbal component appears to aid them in accurately identifying a color. While the previous studies on color memory have not focused on information encoding techniques or the differences seen between the sexes in terms of accuracy and response times, the results of this data appear to support other research on sex differences regarding verbal or spatial functioning abilities (McGlone, 1980; Burstein, Bank & Jarvik, 1980). It has not yet been determined whether the differences result from innate differences between the sexes or from differential training techniques.

In addition, the results of this study may be limited to the specific population tested, the student population of the College of William and Mary. This population may differ from other student populations not only in the degree of previous exposure to color training and art backgrounds, but also in terms of their level of verbal skills. The results of this study may also reflect differences in the internal composition of students; the differences in response accuracy and response latency may arise from general sex differences in the population rather than differences specifically related to color memory.

<u>Summary</u>

This study has demonstrated that the quality of color memory is affected by the encoding process in interaction with individual color. Females are generally more accurate in their color memory and faster in their ability to recognize a color match; they appear to gain this advantage through their use of verbal encoding techniques. Males on the other hand, appeared to use an imagery encoding process. It must be noted that although females appeared to use different encoding techniques than males, both verbal and imagery components were involved in the information processing.

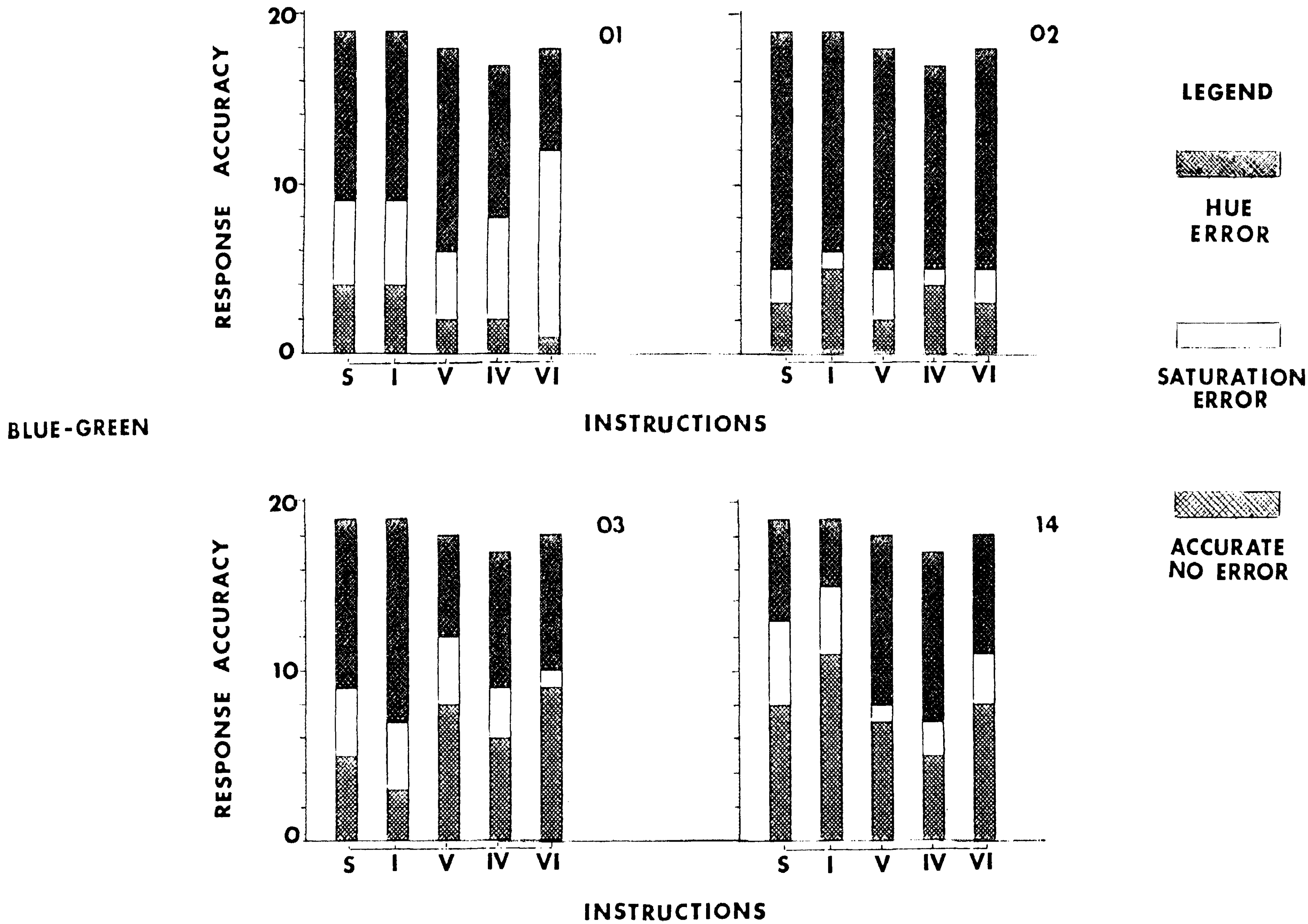
While the interactions between encoding techniques and colors were not always consistent across or between color groups, there was some suggestion that the hue complexity of a color and perhaps its distance from a standard might affect the quality of the memory, and thus the specific choice of stimuli matches. In addition, the familiarity of the color might also affect its memorability. This familiarity might, in turn, be affected by differences in training, experience or socialization expectations. For both training and experience, the salient factor might be the type of encoding process first used to discern and identify colors. Further research should investigate not only these individual differences, determining the individual's preferred and/or most efficient technique for the storage of color information, but also the development of the these techniques, in terms of individual differences and differences between the sexes.

TABLE 1

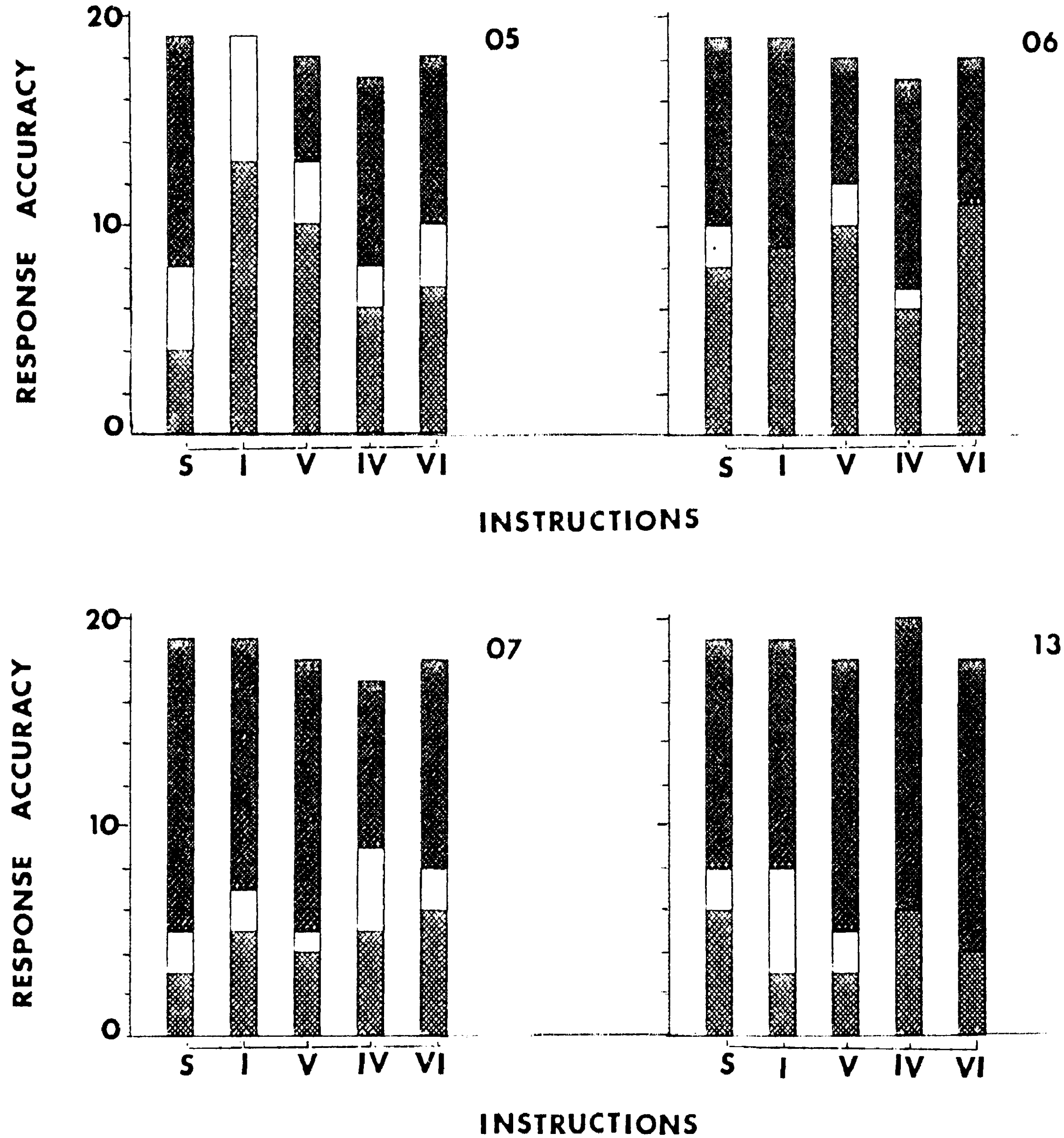
Differences in Percent of Response Accuracy by Sex

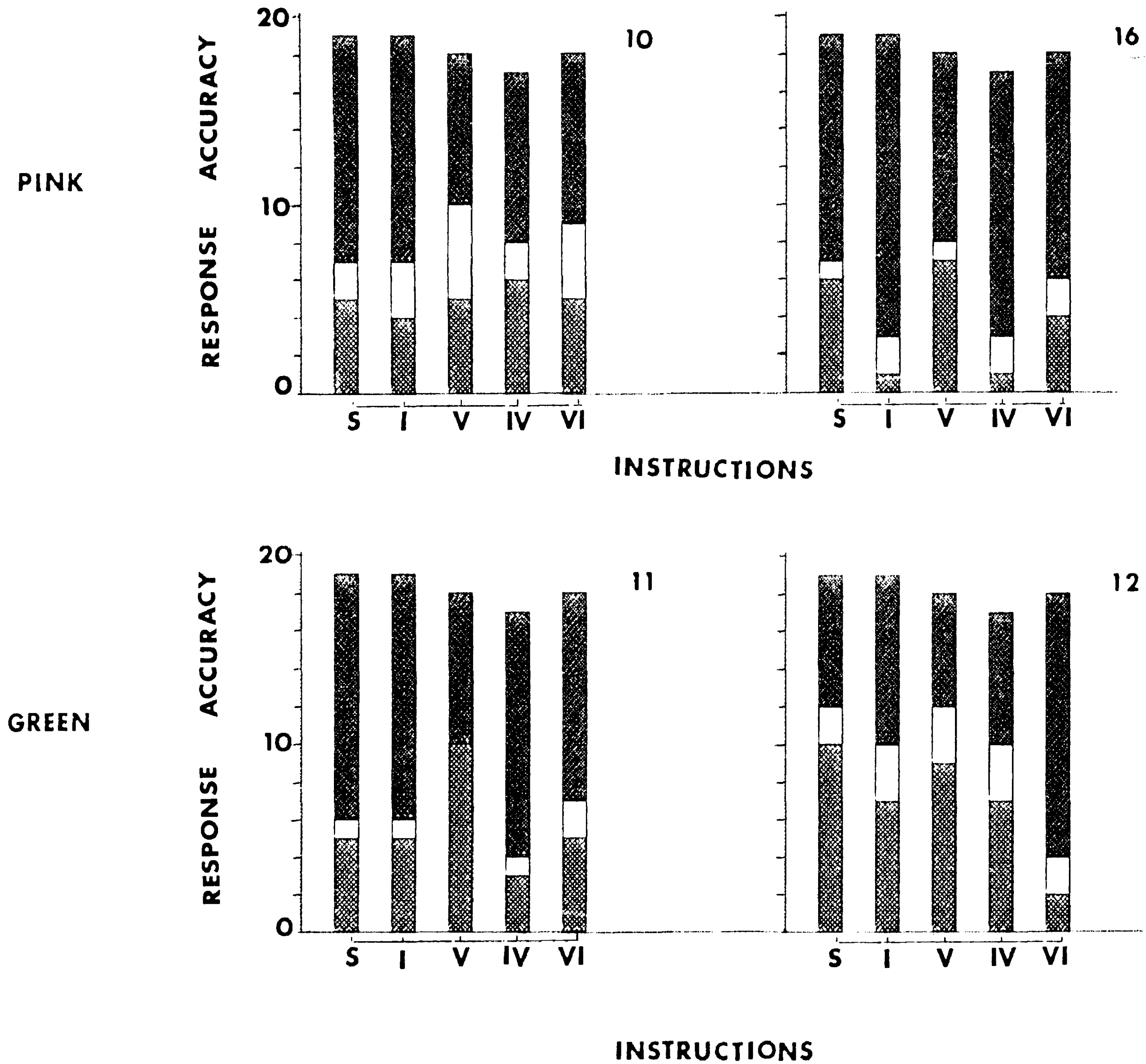
		Response Accuracy			
		Accurate	Saturation	Hue	Total
Sex	n	(No Error)	Error	Error	Response
Males	47	.32	.15	.53	1.00
Females	44	.38	.13	.49	1.00

FIGURE 1. Response accuracy (in percentages) resulting from the interaction of color (shown by groups) and instructions (Sensory, Imagery, Verbal, Imagery/Verbal-mask, Verbal/Imagery-mask.


BLUE-GREEN
RESPONSE ACCURACY
20
10
0
01
02
03
14
S
I
V
IV
VI
INSTRUCTIONS
LEGEND
HUE ERROR
SATURATION ERROR
ACCURATE NO ERROR

BLUE




PINK
GREEN
RESPONSE ACCURACY
20
10
0
10
16
11
12
S
I
V
IV
VI
INSTRUCTIONS

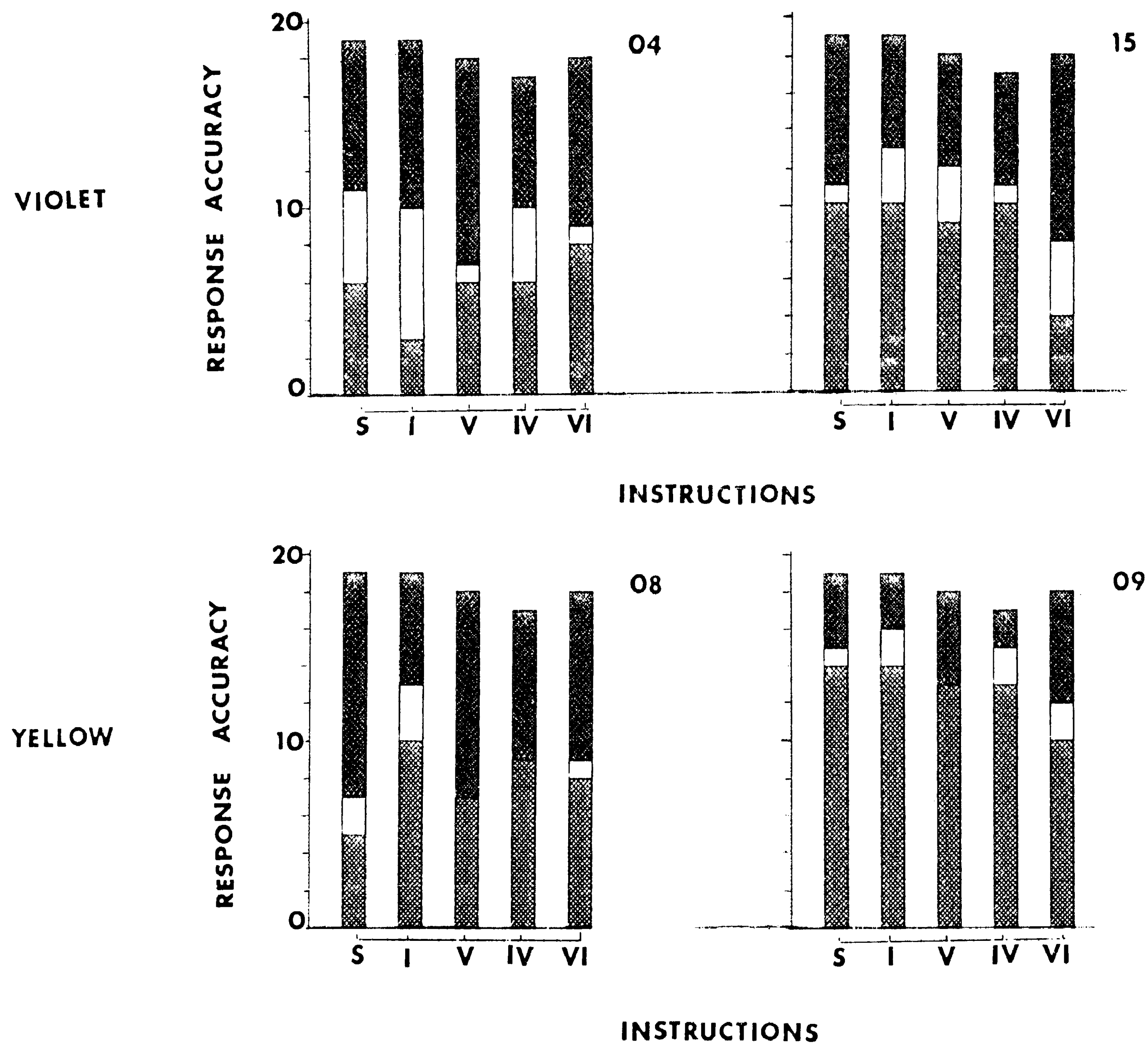
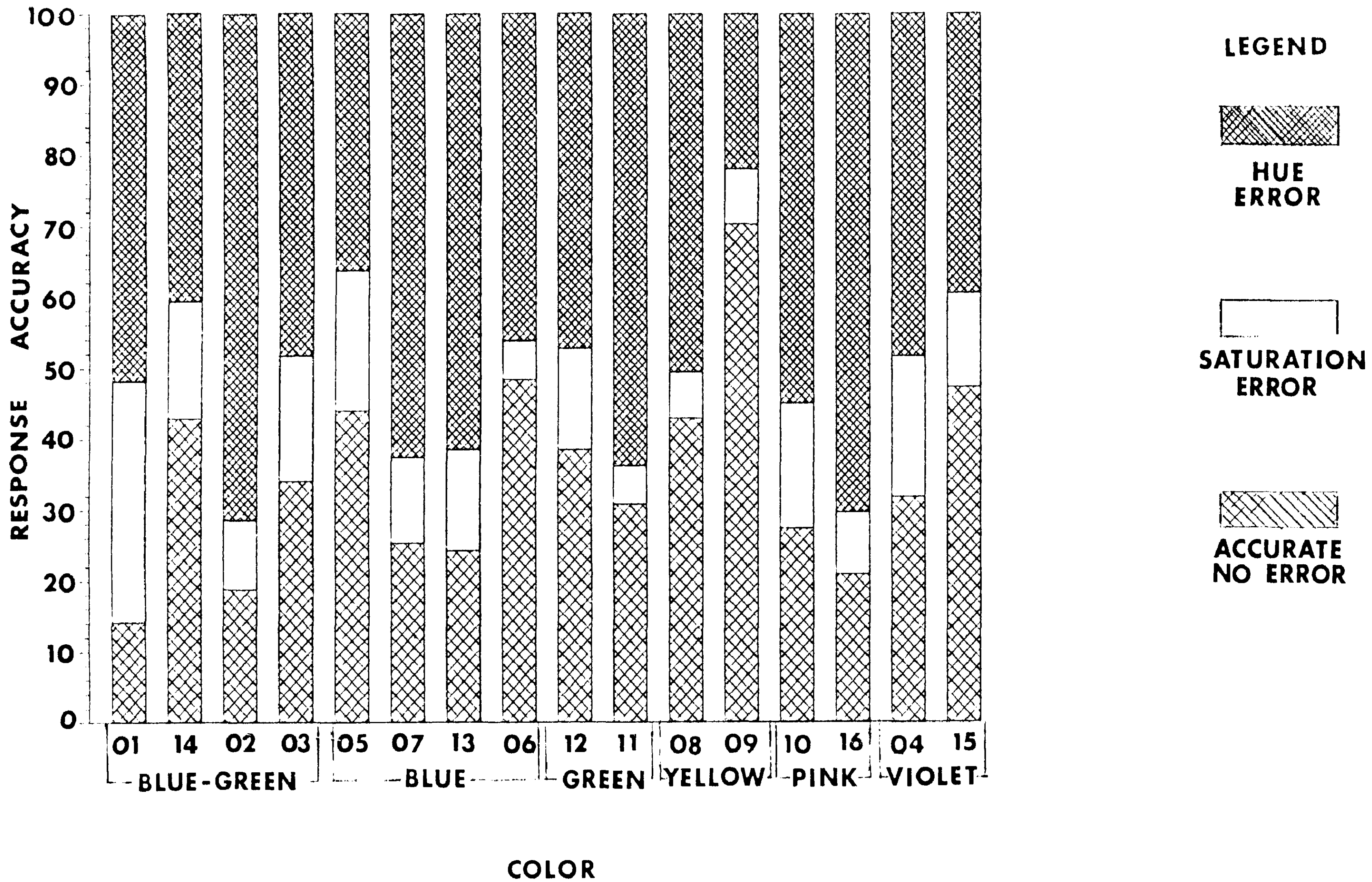

VIOLET
YELLOW
RESPONSE ACCURACY
20
10
0
04
15
08
09
S
I
V
IV
VI
INSTRUCTIONS

FIGURE 2. Response accuracy (in percentages) as a function of color.



RESPONSE ACCURACY
100
90
80
70
60
50
40
30
20
10
0
01 14 02 03
BLUE-GREEN
05 07 13 06
BLUE
12 11
GREEN
08 09
YELLOW
10 16
PINK
04 15
VIOLET
COLOR
LEGEND
HUE ERROR
SATURATION ERROR
ACCURATE NO ERROR

FIGURE 3. Response latency (shown in seconds) as a function of instructions (Sensory, Imagery, Verbal, Imagery/Verbal-mask, Verbal/Imagery-mask).

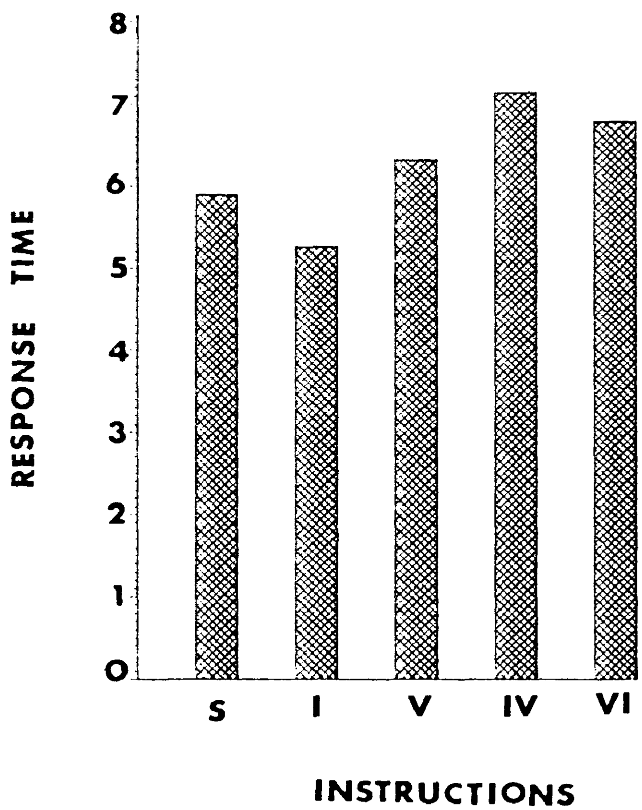
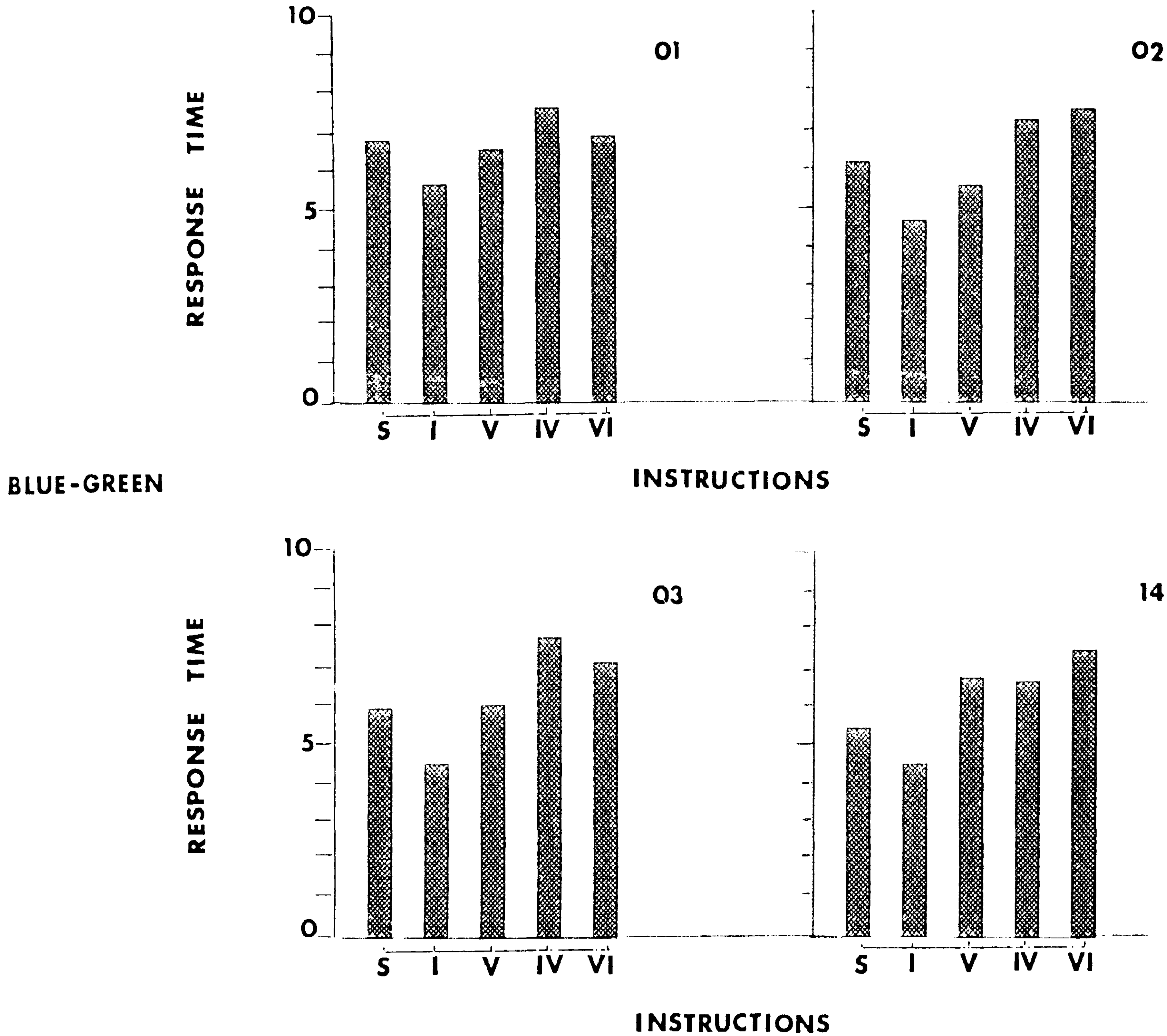
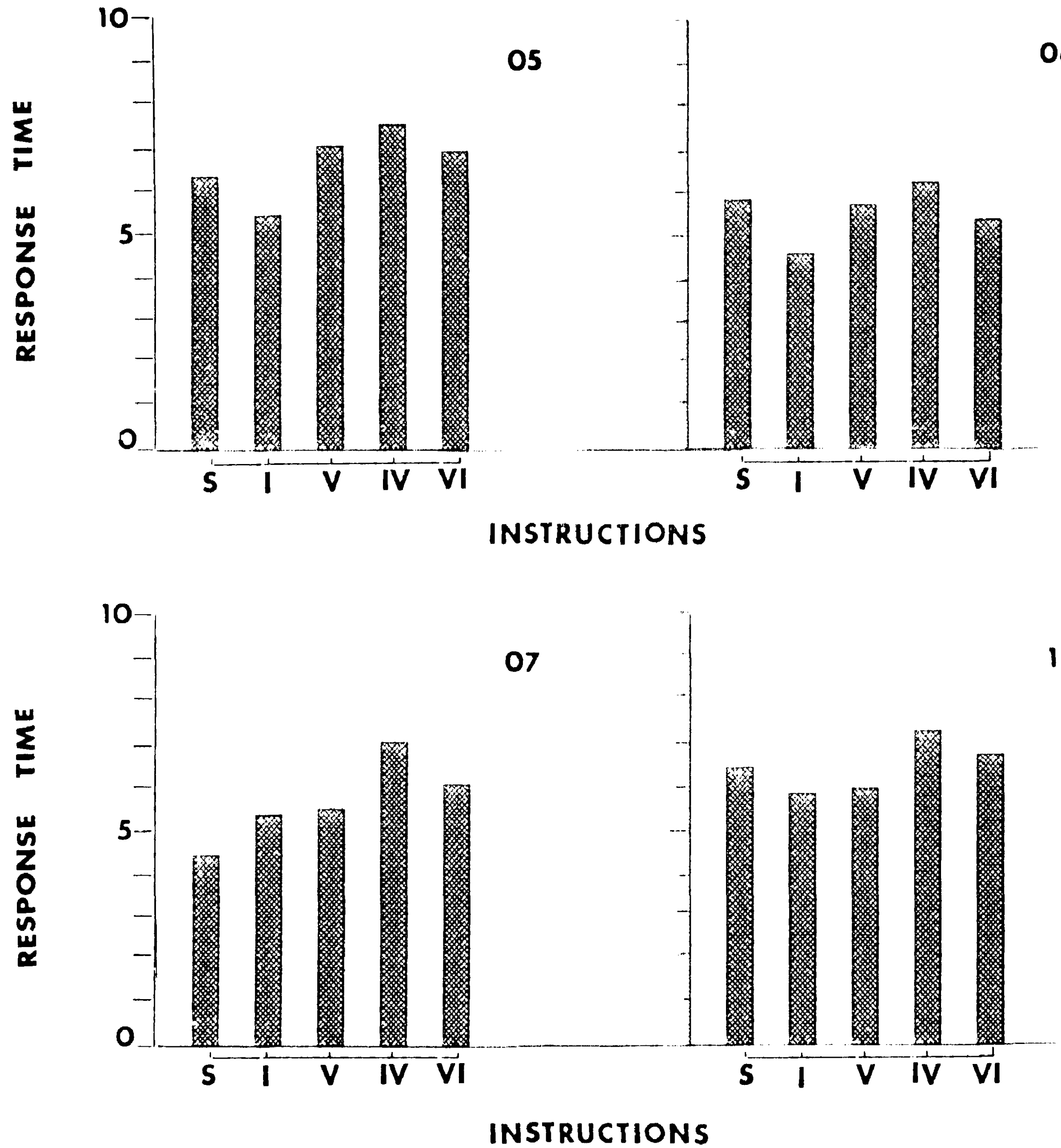
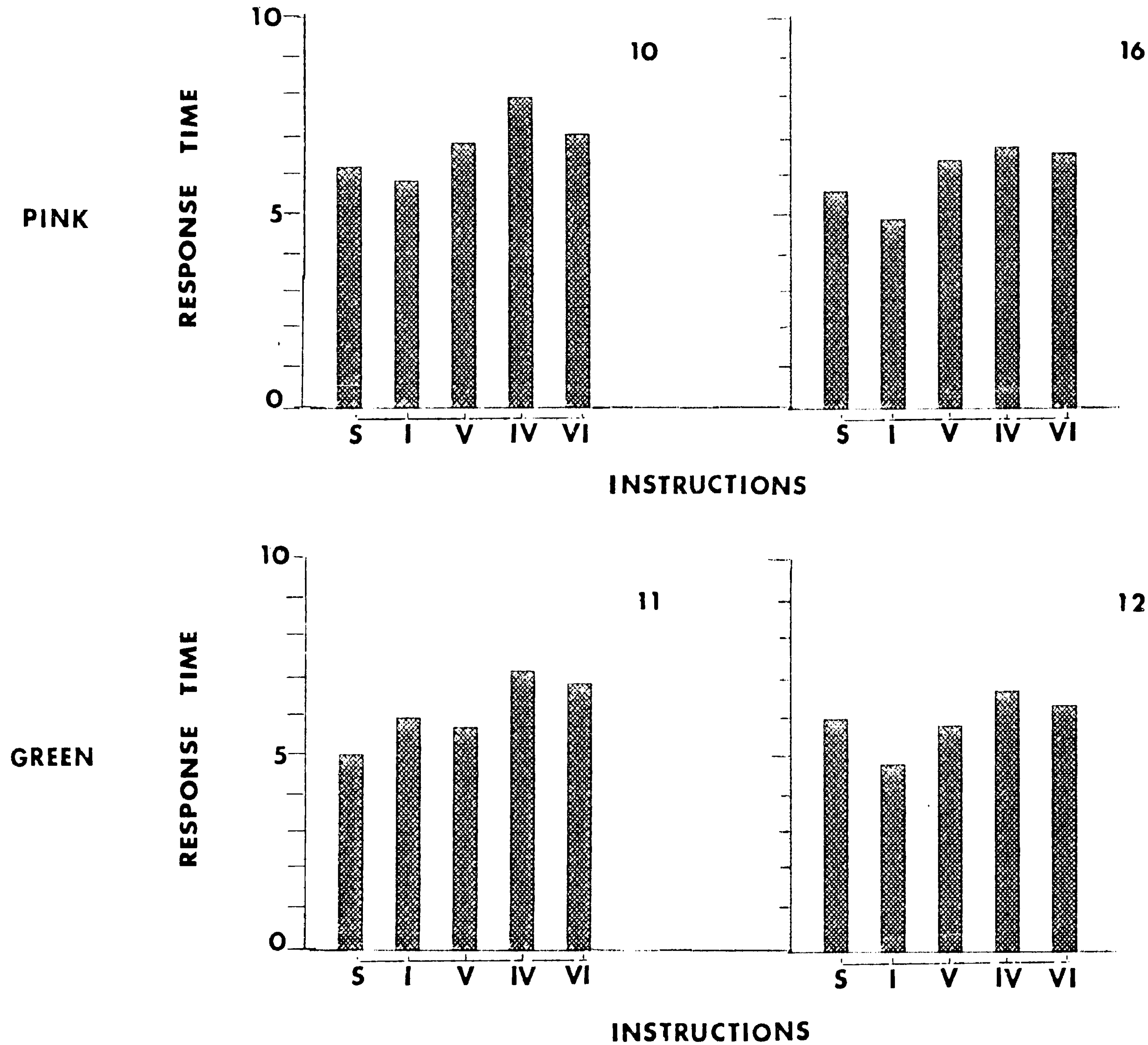

RESPONSE TIME
8
7
6
5
4
3
2
1
0
S
I
V
IV
VI
INSTRUCTIONS

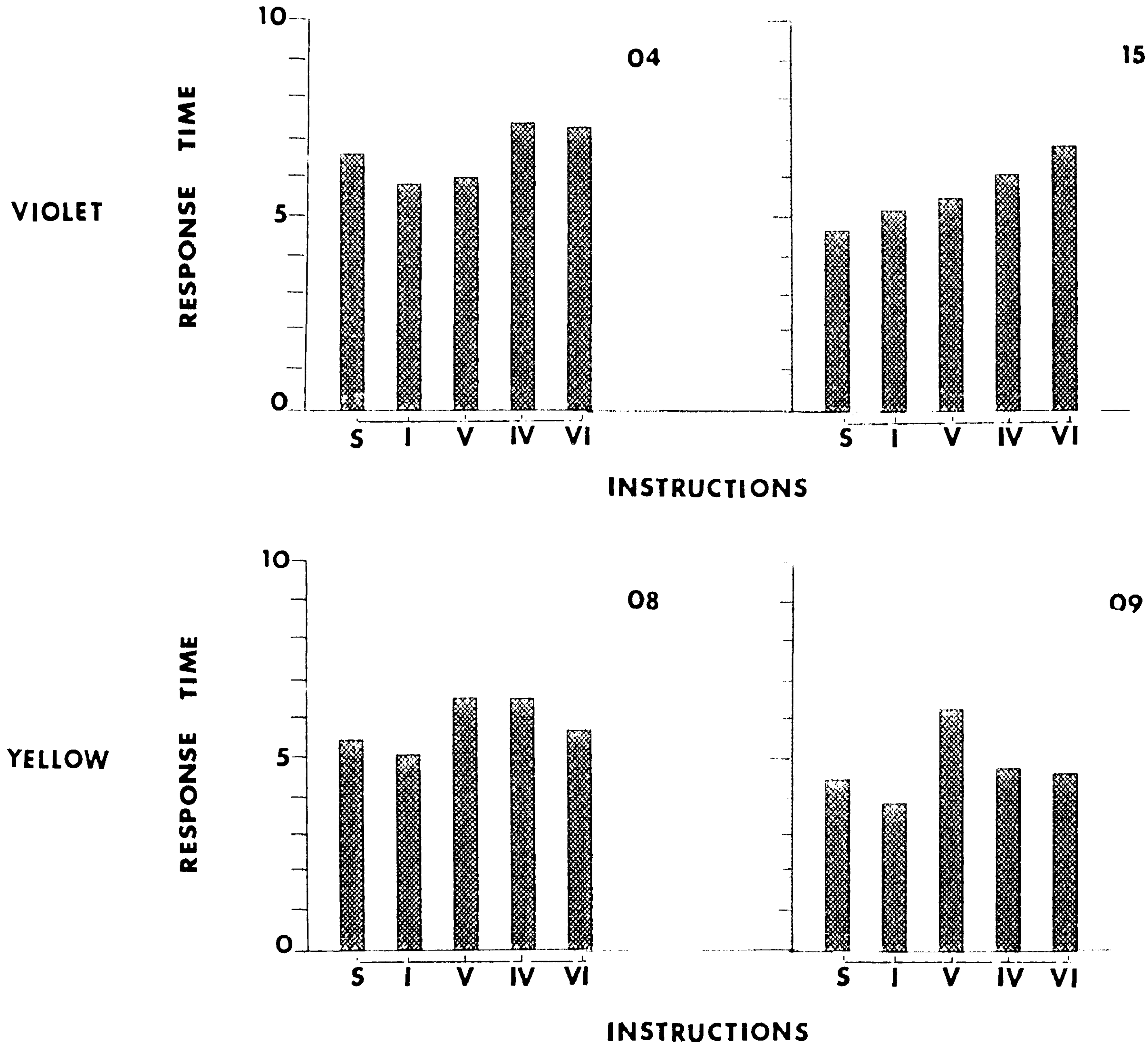
FIGURE 4. Response latency (shown in seconds) as a result of the interaction between color and instruction (Sensory, Imagery, Verbal, Imagery/Verbal-mask, Verbal/Imagery-mask).


BLUE-GREEN
RESPONSE TIME
10
5
0
01
02
03
14
S I V IV VI
INSTRUCTIONS

BLUE




PINK
GREEN
RESPONSE TIME
10
5
0
10
16
11
12
S I V IV VI
INSTRUCTIONS



VIOLET
YELLOW
RESPONSE TIME
10
5
0
04
15
08
09
S
I
V
IV
VI
INSTRUCTIONS

FIGURE 5. Response latency (shown in seconds) as a function of delay (shown in seconds).

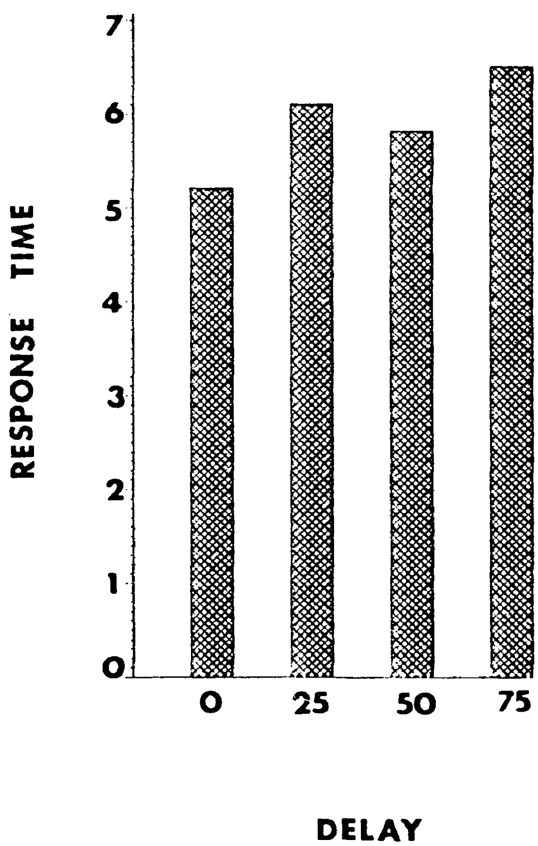
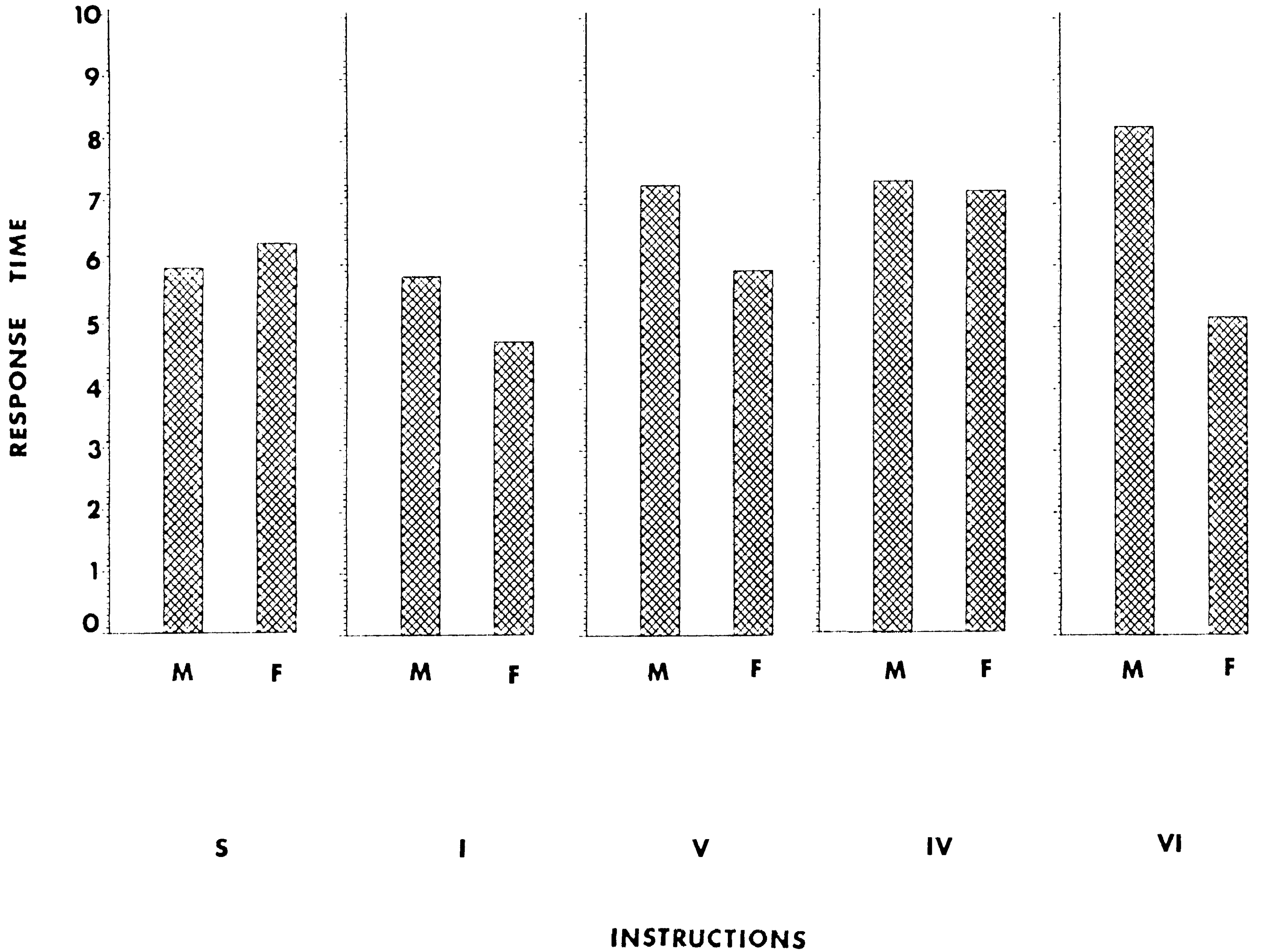
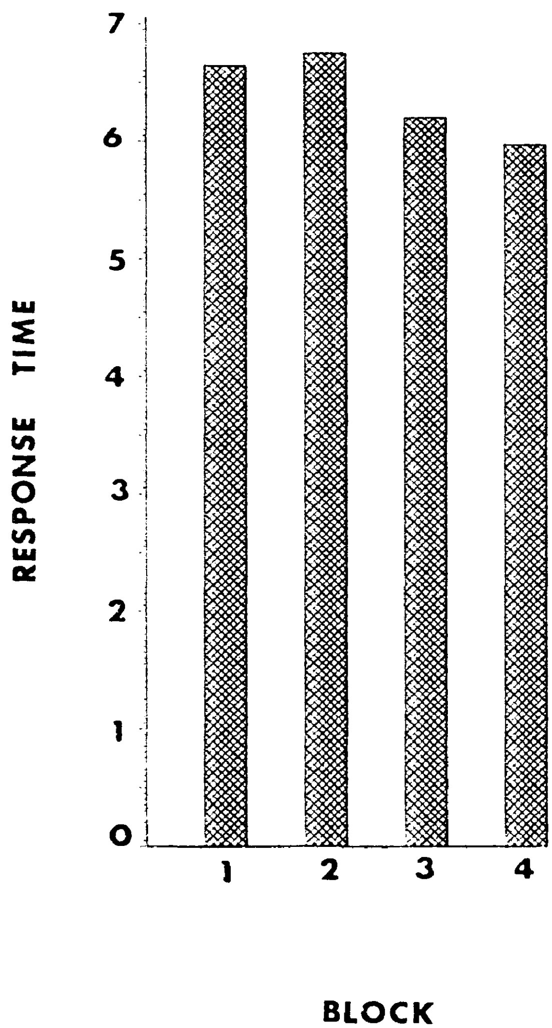

RESPONSE TIME
7
6
5
4
3
2
1
0
0
25
50
75
DELAY

FIGURE 6. Response latency (shown in seconds) as a resulting from the interaction of sex and instruction (Sensory, Imagery, Verbal, Imagery/Verbal-mask, Verbal/Imagery-mask).


RESPONSE TIME
10
9
8
7
6
5
4
3
2
1
0
M
F
S
I
V
IV
VI
INSTRUCTIONS

<u>FIGURE 7</u>. Response latency (shown in seconds) as a function of block.



RESPONSE TIME
7
6
5
4
3
2
1
0
1
2
3
4
BLOCK

APPENDIX A

Breakdown of Instruction Cells by Sex

Instruction		Males	Females
Sensory		10	9
Imagery		9	10
Verbal		10	8
Imagery with Verbal Mask		9	8
Verbal with Imagery Mask		9	9
	Total	47	44

APPENDIX B

Stimulus Colors Randomized within Blocks

Block	Color Group	Code # Stimuli	Code # Fulcolor
1	Blue-green	01	E29E
	Violet	04	C68C
	Blue	05	D88D
	Yellow	08	A82A
2	Blue-green	02	E40E
	Pink	10	B24B
	Green	11	E78E
	Blue	13	D86D
3	Blue	06	D91D
	Green	12	F36F
	Blue-green	14	E26E
	Violet	15	C68C
4	Blue-green	03	E43E
	Blue	07	E104E
	Yellow	09	A45A
	Pink	16	C33C

APPENDIX C

Recognition Card Construction

Stimuli #	Code # Response	Code # FulColor	Relationship to Stimuli Color
01	1	E40E	Hue
	2	E44E	Hue
	3	E43E	Hue
	4	E39E	Hue
	5	E29E	Match
	6	E28E	Saturation
02	1	E40E	Match
	2	E44E	Hue
	3	E43E	Hue
	4	E39E	Saturation
	5	E29E	Hue
	6	E28E	Hue
03	1	E40E	Hue
	2	E44E	Saturation
	3	E43E	Match
	4	E39E	Hue
	5	E29E	Hue
	6	E28E	Hue

Appendix C (cont.)

Recognition Card Construction

Stimulus #	Code # Response	Code # FulColor	Relationship to Stimulus Color
04	1	C69C	Saturation
	2	C68C	Match
	3	C64C	Hue
	4	C62C	Hue
	5	C63C	Hue
	6	C67C	Saturation
05	1	D89D	Saturation
	2	E105E	Hue
	3	E104E	Hue
	4	D91D	Hue
	5	D88D	Match
	6	D92D	Saturation
06	1	D89D	Hue
	2	E105E	Hue
	3	E104E	Hue
	4	D91D	Match
	5	D88D	Hue
	6	D92D	Saturation

Appendix C (cont.)

Recognition Card Construction

Stimulus #	Code # Response	Code # FulColor	Relationship to Stimulus Color
07	1	D89D	Hue
	2	E105E	Saturation
	3	E104E	Match
	4	D91D	Hue
	5	D88D	Hue
	6	D92D	Hue
08	1	A45A	Hue
	2	A80A	Hue
	3	A25A	Hue
	4	A82A	Match
	5	A85A	Saturation
	6	A41A	Hue
09	1	A45A	Match
	2	A80A	Hue
	3	A25A	Hue
	4	A82A	Hue
	5	A85A	Hue
	6	A41A	Saturation

Appendix C (cont.)

Recognition Card Construction

Stimulus #	Code # Response	Code # FulColor	Relationship to Stimulus Color
10	1	B17B	Hue
	2	B21B	Hue
	3	B24B	Match
	4	B32B	Hue
	5	B29B	Hue
	6	B25B	Saturation
11	1	E86E	Hue
	2	E83E	Hue
	3	E82E	Hue
	4	E79E	Saturation
	5	E76E	Hue
	6	E78E	Match
12	1	F86F	Hue
	2	F91F	Hue
	3	F87F	Hue
	4	F82F	Hue
	5	F36F	Match
	6	F37F	Saturation

Appendix C (cont.)

Recognition Card Construction

Stimulus #	Code # Response	Code # FulColor	Relationship to Stimulus Color
13	1	D103D	Hue
	2	D90D	Hue
	3	D86D	Match
	4	D82D	Hue
	5	D78D	Hue
	6	D87D	Saturation
14	1	E26E	Match
	2	E56E	Hue
	3	E38E	Hue
	4	E60E	Hue
	5	E42E	Hue
	6	E27E	Saturation
15	1	C71C	Saturation
	2	C66C	Hue
	3	C72C	Match
	4	C74C	Hue
	5	C14C	Hue
	6	C18C	Hue

Appendix C (cont.)

Recognition Card Construction

Stimulus #	Code # Response	Code # FulColor	Relationship to Stimulus Color
16	1	C32C	Saturation
	2	C83C	Hue
	3	C72C	Hue
	4	C74C	Hue
	5	C33C	Match
	6	C78C	Hue

APPENDIX D

Chi-square Test for Homogeneity of Data

Chi-Square Values for

Card #	Type of Error: Accurate	Saturation	Hue	Sum by Card
01	11.23	26.42	0.03	37.68*
02	6.98	1.07	7.48	15.53*
03	0.03	0.86	0.12	1.01
04	0.27	2.22	0.12	2.61
05	2.03	2.22	3.86	8.11*
06	4.55	4.62	0.41	9.58*
07	2.50	0.23	2.44	5.17
08	1.56	3.53	0.002	5.092
09	32.18	2.55	15.00	49.73*
10	1.51	0.86	0.28	2.65
11	0.49	4.62	2.92	8.03*
12	0.22	0.01	0.24	0.47
13	3.09	0.01	2.00	5.10
14	1.56	0.42	1.89	3.87
15	3.83	0.04	2.32	6.19
16	5.24	1.73	6.70	13.67*
Total:	77.27	51.41	45.812	174.492

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VITA

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