DOCUMENT RESUME

ED 323 916 IR 014 539

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TITLE Cerebral Laterality in Color Information Processing.

PUB DATE Feb 90

NOTE 17p.; In: Proceedings of Selected Paper Presentations at the Convention of the Association for Educational Communications and Technology; see IR 014 535.

PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS Analysis of Variance; *Brain Hemisphere Functions; *Cognitive Processes; *Color; Graduate Students; Higher Education; *Intermode Differences; *Recognition (Psychology); Statistical Distributions; Visual Learning; *Visual Stimuli

ABSTRACT

This study investigated the interaction between hemispheric specialization and pictorial recognition memory for pictures presented in three different color modes: realistic color, non-realistic color, and monochrome (back and white). The study was also designed to confirm the efficacy of applying signal detection analysis to color recognition memory data to obtain a more accurate assessment of the role of color in visual information processing. The stimuli consisted of 120 stimulus slides and 60 distractor slides, all photographs of North American and Canadian geography scenery. Twenty-six graduate students were first shown the set of 120 stimulus slides. They were then instructed to perform a complex verbal masking task designed to localize processing to the right hemisphere while viewing either the first or second 60 slides; the alternate slides were viewed without the masking task. The subjects were then presented with a random distribution of the stimulus and distractor slides for five seconds each, and asked to indicate whether the slide was one they had seen before or a "new" one. It was found that under the right localized treatment, both the realistic color and black and white treatments scored significantly lower than the non-realistic color treatment, although the non-realistic group did not differ significantly from any of the treatment groups under the integrated treatment. It is concluded that color processing is bi-locational, with realistic/verbal image processing being done in the left hemisphere and pure color processing in the right hemisphere. It is further concluded that visual realism probably constitutes a combination of imaginal and verbal information. Three figures are appended. (49 references) (BBM)

Title:

Cerebral Laterality in Color Information Processing

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CEREBRAL LATERALITY
IN
COLOR INFORMATION PROCESSING

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During the past several years, extensive research has addressed the interaction between hemispheric specialization and the processing of visual information. Studies suggest that visual material may be stored in memory in different locations or forms depending upon how meaningful the visual cues are in relation to the information presented. Other researchers have explored the degree of processing of visual information in the right and left cerebral hemispheres. Little research however, has investigated the specific interaction between how color information is processed and the relationship of that processing to hemispheric specialization.

The purpose, therefore, of this study was to investigate the interaction between hemispheric specialization and pictorial recognition memory for pictures presented in three different color modes: realistic color, non-realistic color and monochrome (black and white). A secondary purpose was to further confirm the efficacy of applying signal detection analysis to color recognition memory data as a means of obtaining a more accurate assessment of the role of color in visual information processing.

BACKGROUND RESEARCH

Substantial research has focused on the role of color in visualized instruction (Dwyer, 1972, 1978; Berry, 1974; Winn, 1976; Chute, 1979; Lamberski, 1980). This research represents one aspect of the larger theoretical debate which continues regarding visual complexity and human information processing. It has long been contended that the mere addition of visual cues will increase the ability of the viewer to store and retrieve visual information.. This orientation, termed "realism theory" by Dwyer (1967), has strong theoretical foundations (Dale, 1946; Morris, 1946; Carpenter, 1953 and Gibson, 1954) and is indeed the major premise of cue summation theory (Severin, 1967). Other researchers (Broadbent, 1958, 1965; and Travers, 1964) have, however, taken strong opposition to this theoretic base on the grounds that the human information processing system is of limited capacity and that, in times of rapid information reception, irrelevant cues may block the processing of other, relevant information. Studies (Kanner, 1968; Katzman and Nyenhuis, 1972; Dwyer, 1972, 1979) have investigated this apparent contradiction with conflicting results.

The inclusion or absence of color information can be regarded as one dimension of visual complexity. Color can function in a dual role when used in visual displays. First, it can serve primarily a coding function, providing additional information but not providing any realistic description of the display. In this case, the effectiveness of color can be predicted by cue summation theory, but not by the realism hypothesis. Alternately, color can be used to present a more realistic version of the visual display. In this instance, in addition to providing a greater number of overall cues, it provides the viewer with more realistic attributes or "handles" with which to store and retrieve information. When color is used in this fashion, its value could be predicted by the realism theories as well as by cue summation theory.

Much past research investigating the differences between color and monochrome visuals failed to take into account the fact that realistic color visuals contain intrinsically more information and consequently require more time for processing. In an attempt to resolve this methodological inconsistency as well as to more accurately assess the role of color in human information processing, Berry (1974) compared realistic and non-realistic color versions of the instructional materials on the human heart developed by Dwyer (1967). Data suggested that, in those learning tasks where visual materials contributed significantly to the improvement of instruction, realistic color materials were most effective. Later research (Berry, 1977, 1982, 1983) which investigated the color realism/complexity question relative to pictorial recognition memory found both realistic and non-realistic color materials superior to monochrome visuals. These findings suggest that cue summation theory may provide an accurate description of how color functions in basic information processing tasks such as picture recognition.

Other research by Berry (1984), in which the role of the cognitive style of field dependence identified by Witkin et al (1971) was investigated in relation to color information processing, suggested that field dependent individuals experience greater processing and storage difficulties. In this study, it was concluded that such difficulties may represent less efficient organization of the material in memory.

Studies by Craik and Lockhart (1972) and Craik and Tulving (1975) strongly suggest that a continuum of levels of information processing exists and that more meaningful information is processed more deeply and thereby is more effectively stored in memory. Such a theory would imply that realistic color materials, due to their greater number of meaningful cues would be more deeply processed and therefore more effectively stored. Paivio (1971, 1975) hypothesized a dual coding theory in which one system, the imagery system processes information related to concrete objects and events, while the second, verbal system processes language-based information. This theory may imply that more realistic information which might be easily described verbally could be processed separately from that which has fewer verbal/realistic labels. Much of this research suggests that visual information may indeed be processed in a variety of ways or in more than one memory location.

Extensive research during the past thirty years has addressed the concept of cerebral laterality and hemispheric specialization as another means of explaining variations in the processing of information. In summarizing this mass of research findings, Hellige (1980) presents the common conclusion that the right hemisphere of the brain specializes primarily in visuospatial processing and the left hemisphere focuses on verbal/linguistic tasks. While it would be absurdly simplistic to attribute the processing of specific types of information to one or the other hemispheres of the brain, it would not be unreasonable to expect visual information to be processed somewhat differently in the different locations. Although it is generally held that visual information is processed first in the right hemisphere, it is not clear how or where color information is processed. Beauvois and Saillant (1985) however, found significant data which indicated that color is represented in two separate memory systems, one verbal and one visual When color is used in a realistic manner, it can supply additional, meaningful verbal or linguistic labels, while the use of color simply as a coding technique (non-realistic) may not be processed in the left hemisphere. Research by Meyer (1975), Daehler et al (1976) and Lamberski and Dwyer (1983) support the coding concept of color.

Research conducted on brain damaged subjects by De Renzi and Spinnler (1967) found that subjects with right hemisphere damage had significantly more problems in color naming and identification tasks while subjects with left hemisphere lesions did not demonstrate significant impairment. These results were further confirmed in studies by Scotti and Spinnler (1970), and Capitani, Scotti and Spinnler (1978). A study conducted by Davidoff (1976) with normally functioning subjects reported a right hemisphere advantage in sensitivity to perception of color stimuli. These findings were confirmed in a later study (Davidoff, 1977). Malone and Hannay (1978) however, investigated color memory relative to hemispheric asymmetry in normal subjects. Results indicated a significant main effect for color in the right visual field, implying a left hemisphere advantage. These results were, however, attributed to the use of verbalization in the performance task. Jorgenson,Davis, Opella & Angerstein (1980, 1981) found a right hemisphere advantage for color and a left hemisphere advantage for color/verbal responses.

From the preceding review, it is apparent that the means by which color information is processed is still, as Otto and Askov (1968) concluded, essentially unclear. It was the purpose therefore, of this study to investigate differences in the processing of color information within the two hemispheres of the brain. Since it is a well established fact that the two hemispheres do not function independently, it would be inappropriate to attribute specific modes of processing to one or the other discreet hemispheres. Consequently, in this study, comparisons were made between the processing attributable to the integrated functioning of both hemispheres as is normally the case, with processing accomplished by the right hemisphere independent of the left. To achieve this condition, it was necessary to occupy the left hemisphere with a complex verbal masking task, thereby effectively preventing it from effectively processing the presented visual information. Such a technique has become a commonly accepted means of localizing processing to the right hemisphere.

METHOD

The stimulus materials used in the study were similar to those used by Berry (1977, 1982, 1983, 1984) and El Gazzar (1984). These consisted of 120 stimulus slides and 60 distractor slides. All slides were obtained from a pool of geographic scenery slides taken by semi-professional and professional photographers in various locations of the United States and Canada. In selection of the materials, care was exercised to exclude all recognizable human figures, verbal materials or unique objects. The entire collection of materials was randomly divided into thirds. One third was retained as a realistic color group, a second third was recopied onto black and white slides and the remaining third was altered by photographic reversal to produce a non-realistic color group. By means of the photographic reversal process, the overall number of color cues could be held constant, while the degree of color realism could be manipulated.

The sample for the study consisted of twenty six graduate students drawn from academic areas of education, health professions and library science. All subjects were consenting volunteers.

The list learning procedure was employed, in which all subjects were first shown the set of 120 stimulus slides, individually for 500 ms each. On a random basis, subjects were instructed to perform a masking task while viewing either the first sixty slides or the second sixty slides. The remaining, alternate sixty slides were viewed without the performance of the masking task. The task employed required each subject to begin counting backward by threes from the number 488 as quickly as possible, while viewing the specified group of stimulus slides. In this way, right hemisphere processing could be localized by inhibiting left hemisphere processing. Subjects were subsequently presented with a random distribution of all slides (stimulus and distractor) for five seconds each. During that time, subjects responded on a checklist either "old" (stimulus slide - seen before) or "new" (distractor slide - never seen).

The design of the study was a two-way repeated measures type with three levels of the color factor (realistic, non-realistic, monochrome) and two levels of the cerebral localization factor (right specialized, integrated).

ANALYSIS

Analysis of the data obtained was conducted via the method of Signal Detection Analysis. This approach has been frequently applied to the analysis of recognition data in the past as a means whereby both recognition rate and error rate are taken into account.

Signal Detection Theory has been accepted as a reliable technique for assessing a subject's ability to describe the occurrence of discrete binary events. The basic model of SDT was described by Swets (1964) and has been used extensively to study the ability of individuals to distinguish the presence of a signal when that signal was mixed with noise. More recently, Grasha (1970) has suggested the use of SDT parameters in the study of memory processes. Signal Detection Theory has been applied specifically to recognition memory experiments involving pictorial material in research conducted by Snodgrass, Volvovitz and Walfish (1972), Loftus and Kallman (1979), Loftus, Greene and Smith (1980), Berry (1982, 1983, 1984) and El Gazzar (1984).

The mean probability of hits and the mean error rates for each treatment and level were calculated as well as the measure of sensitivity, d', which was determined from tables developed by Elliot (1964). To facilitate analysis, the d' statistic was uniformly transformed to eliminate negative values (d' adjusted). These data are presented in table 1.

TABLE 1
Means and standard deviations for hit and false alarm probabilities, error rates and d' by treatments and cerebral localization
(N = 26)

	P(H)		P(FA)		ERRORS		d' ADJUSTED	
TREATMENT	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Right localized								
Realistic Color	.480	.163	.519	.134	16.56	2.98	2.918	.431
Nonrealistic Color	.565	.193	.419	.176	13.07	3.34	3.427	.487
Black & White	.479	.184	.492	.136	14.12	3.32	2.909	.411
Integrated								
Realistic Color	.617	.174	.519	.134	13.87	3.24	3.283	.486
Nonrealistic Color	.533	.181	.419	.176	13.75	2.90	3.236	.555
Black & White	.546	..203	.492	.136	12.77	3.73	3.143	.579

Analysis of variance procedures for two factor repeated measures were conducted on the probability of hits (recognition scores), total error scores and on the adjusted SDT measure of sensitivity, d' adjusted.

With respect to the analysis of the hit probability data, a significant F value for the interaction, $F(2,50) = 5.90$, $p = .0050$ and a significant F value for the main effect of lateral localization, $F(1,25) = 8.95$, $p = .0062$ were obtained. The main effect for color was not significant $F(2,50) = .62$, $p = .5422$. Since a significant interaction was found, the Scheffe procedure for pairwise comparisons was applied. The results of that analysis is shown in table 2.

TABLE 2
Summary of pair-wise comparisons for hit probabilities, error rates and d' adjusted

HIT PROBABILITY	ERROR RATE	d' ADJUSTED
Real/Integrated > B &W/Right	Real/Right >Non-real/Right	Non-real/Right >Real/Right
Real/Integrated > Real/Right	Real/Right > Non-real/Integrated	Non-real/Right > B & W/Right
	Real/Right > B &W/Integrated	

Analysis of the error rates produced a significant interaction, F (2,50) = 5 84, p = 0053; a significant main effect for lateral localization, F (1,25) =8.51), p = .0074; and a significant main effect for color, F (2,50) = 3.80 p = .0291. Results of the pairwise comparisons are shown in table 2.

Analysis of the adjusted d' scores produced a significant interaction, F (2,50) = 8.18, p = .0008; a significant main effect for lateral localization, F (1,25) =4.55, p = .0428; and a significant main effect for color, F (2,50) =3.38, p = .0419. The results of the Scheffe procedure are summarized in table 2.

Since, in all cases, the interactions were significant, no further analyses of the main effects data were warranted. Each of the interactions is illustrated respectively in figures 1 through 3.

DISCUSSION

Examination of the hit probabilities indicate that under the right localized treatment, both the realistic and black & white treatments scored significantly lower than did the non-realistic color treatment. Additionally, the non-realistic group did not differ significantly from any of the treatment groups under the integrated treatment. This finding would suggest that the masking task inhibited recognition under the realistic and black & white treatments, but did not do so under the non-realistic treatment. An examination of the error rates confirms this, since both the realistic and black & white error rates are high, with the realistic color rate significantly so. It is because of this relationship between hit rates and error rates that the measure of recognition sensitivity, d' was derived. The statistic, d' accounts for both hit and false alarm rates and is therefore a more precise index of the true recognition rate.

Analysis of the d' scores also indicate that the non-realistic color group achieved significantly higher than did either of the other two color treatments under the right localized treatment. Additionally, the non-realistic color /right localized group did not differ significantly from any of the integrated treatments, although the mean d' value for the non-realistic/right localized group was somewhat higher (see figure 3).

Reasons for these findings can be drawn from the literature on cerebral asymmetry as well as from research on memory and information processing. The left cerebral hemisphere is generally attributed with processing verbal and linguistic information, while the right hemisphere tends to specialize in visuospatial processing. In the case of the images presented in this study, it could be concluded that the recognition process incorporates both types of processing, as research generally suggests. The right half processes the visuospatial component which includes color information, while the left hemisphere processes verbal or labeling information i.e. tree, lake, rocks etc. It is this combination which constitutes "realism", the visual image plus the verbal labels describing previously encountered concepts. In the case of the right localized groups, the verbal label component was inhibited by the verbal masking task, reducing the effectiveness of that form of processing. In the case of the non-realistic treatment, the additional color cues, which did not have any verbal or "realistic" associations were used purely as unique cues for storage and retrieval of the information. Since there were no realistic verbal cues, these were not used in the processing of the images. In the case of the integrated treatments, the findings of previous studies (Berry; 1977, 1982, 1983,1984) were upheld, in that realistic color materials are generally found to be superior to other color formats.

These conclusions are supported by the now classic work of Craik and Lockhart (1972) and Craik and Tulving (1975) which contends that more meaningful material is processed more deeply. In the case of visual material, the combination of imagery (color and structure) and semantic description (verbal labels) contribute to more complete or deeper processing. When part of this information is inhibited, the remaining information is processed less deeply. The lack of labels in the non-real group is replaced by more unique color codes which serve to process the information more deeply.

Research related to cerebral asymmetry also supports this finding. Beauvois and Saillant (1985) suggest that color information is stored separately, in both hemispheres. This would imply that if the left hemisphere processing of color information is inhibited, the processing would continue in the right. Research by Jorgenson, Davis, Opella and Angerstein (1980, 1981) also suggest left hemisphere color/verbal processing and right hemisphere color processing. This study inhibited the left hemisphere processing but permitted right hemisphere color processing to proceed. Realistic color, which is generally considered "color" in most research is the type of color information processed in the left half, since realism implies semantic or verbal labels. Right hemisphere color processing is non-verbal and thereby represents the type of processing done with non-realistic color.

The primary conclusion of this study, therefore, is that color processing is bi-locational, with realistic/verbal image processing being done in the left hemisphere and pure color processing being done in the right hemisphere. In terms of color realism, it can be concluded that visual realism probably constitutes a combination of information, some being imaginal and some being verbal in nature.

A word of caution should however be attached to the interpretation of these findings. This study utilized a verbal (arithmetic) masking task to occupy and therefore inhibit left hemisphere processing in the right localized treatment group. It cannot be completely assured that this task completely engaged the processing of the left half, but rather only interfered with such processing. It is the suggestion of this researcher that further research address these questions using perceptual rather than verbal means of localizing processing to either half of the brain to assure more complete localization of processing. Such presentation formats would present different stimulus materials, simultaneously to each individual visual field (left, right).

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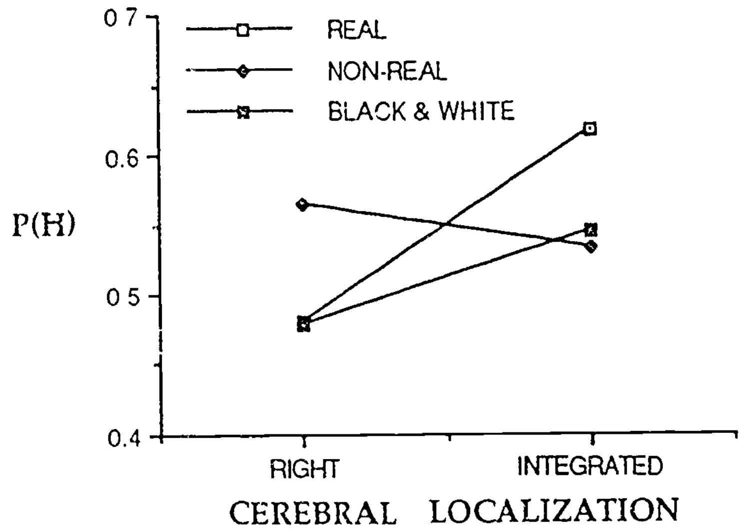

FIGURE 1
Hit probability - by - cerebral localization interaction for color treatments

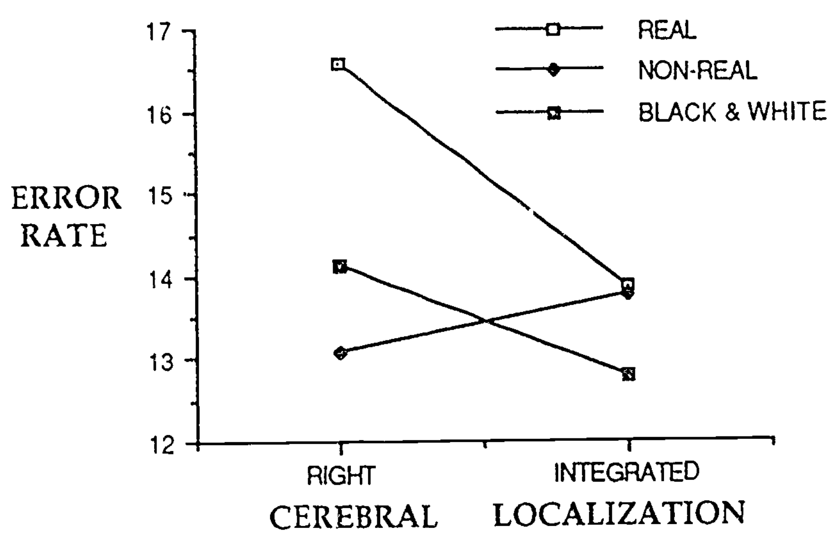

FIGURE 2.
Error rate - by - cerebral localization interaction for color treatments

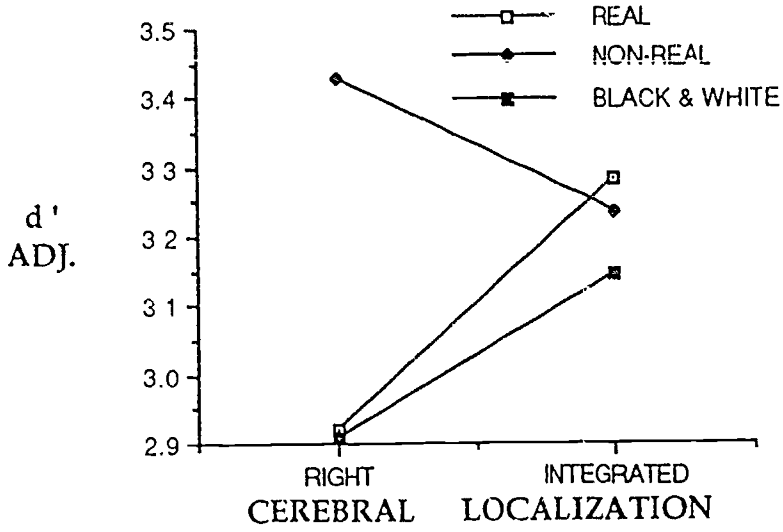

FIGURE 3.
d' adjusted - by - cerebral localization interaction for color treatments