Determinants of Performance in Color Anomia

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It is generally accepted that color anomia results from the visuo-verbal disconnection created by a lesion of the splenium of the corpus callosum, or of its outflow, in a patient in whom the left cortical visual system has also been damaged. A similar explanation is applied to pure alexia, a deficit which often is associated with color anomia. However, that established neuroanatomical basis does not fully account for some seeming paradoxes of patients presenting those signs, such as the disparity between preserved object naming and markedly impaired color naming. Nor does it clearly indicate why some tasks related to color perception, such as coloring pictures, should be impaired to the extent they generally are, suggesting the presence of a stimulus-specific agnosia rather than a more naming defect.

It is our hypothesis that the paradoxical performances of these patients may be determined by additional contributing factors, such as: (a) the nature of stimuli used in testing; (b) the demands of the task and, consequently, the perceptual and problem-solving strategy required for each specific testing procedure; and (c) the neuroanatomic and neurophysiologic specifications of the human brain which determine the form of processing of different types of stimulus. This amounts to proposing that different stimuli and different testing circumstances engender forms of neural activity which are anatomically and physiologically distinct. A study focusing on the role of these determinant factors is described below.

MATERIAL

The study was undertaken in two patients with stable syndromes of color anomia and pure alexia conforming to the standard description of the condition (Geschwind and Fusillo, 1966). In both instances the syndrome resulted from infarction in the territory of the left posterior cerebral artery, sustained several months prior to the beginning of the study. Age and medical history were very similar. Cerebral status was evaluated by means of neurologi-

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cal examination, electrophysiological study, radiographic procedures, and neuropsychological assessment.

Patient 1

D.C. is a 66-year-old woman, right-handed, with a history of poorly controlled adult onset diabetes. For the past 4 years, she has been hypertensive. On March 18, 1976, the patient was admitted to our care after an episode of nausea and vomiting, during which she noted weakness and pain in the right arm and leg and a staggering gait, and after which she could not "see to her right side" and was unable to read.

On admission, major findings included mild right hemiparesis with minimal increase of stretch reflexes on the right side of the body, right hypesthesia and dysesthesia, and right homonymous hemianopia. The fundi showed signs of retinopathy compatible with hypertension and diabetes. The cranial nerves were otherwise unremarkable. The patient's gait was hemiparetic and moderately ataxic. Motor coordination was mildly impaired on the right on tests such as finger-to-nose and heel-to-shin and in addition, visuomotor control was impaired, producing a significant degree of "optic" ataxia. Speech was fluent, melodic, and well articulated. Oral comprehension was normal. The patient was able to spell words presented orally and to produce words given to her in orally spelled form. Spontaneous word finding and lexical choice were normal. Naming of tactile and auditory nonverbal stimuli was normal. She had a severe alexia for all written material, as well as a severe color-naming defect, but could write well spontaneously and to dictation though she could not read what she had just written. Tactile reading of numbers and letters with the left and right hands was normal. There was no history, personal or familial, or color blindness. Tactile double simultaneous stimulation was intact. Oral calculation was normal, but written calculation could not be carried out. Radiologic studies of the chest and skull were normal, and an EKG showed nonspecific ST changes. An EEG was moderately abnormal, with slowing of the left hemisphere activity, particularly over the left posterior quadrant. A radionuclide scan showed increased uptake in the left posterior regions. The results of computerized tomography (CT scan) of the head were compatible with the diagnosis of infarction in the territory of the left posterior cerebral artery. On the basis of that CT scan and of another one obtained 3 months later (Fig. 1) it was inferred that the patient had a lesion involving the left occipital lobe, both in its white matter axis and in its cortical surface. The lesion severed cortical connections related to the cuneus and to the lingual and fusiform gyri. It also interrupted optic radiations. In addition there were lesions in the splenium of the corpus callosum and in the geniculate bodies on the left (Fig. 2).

While the patient was in the hospital, the hemiparesis, hemisensory defect, and ataxia improved remarkably through not completely. The reading and color-naming defects as well as the right homonymous hemianopia remained unchanged. The patient was discharged 2 weeks later. The patient was followed in our clinic in June and August 1976 and again in July 1977. The special study reported below was carried out during those follow-up visits. No further improvement has been noted.

Patient 2

E.F.P. is a right-handed 63-year-old physician who became ill in January 1973; he complained of an intense headache accompanied by sudden and maintained visual loss in his right visual field. Later he reported that he was unable to read, and his relatives noticed what they described as a period of incoherent but fluent and well-articulated language. He was then hospitalized under the care of a neurologist. The language problem cleared, but the reading and visual difficulties remained. The patient had a mild right-sided hemiparesis involving proximal and distal segments to equal degrees and a marked right hemihypesthesia for superficial forms of sensibility. An EEG revealed a left occipital focus of slow activity.

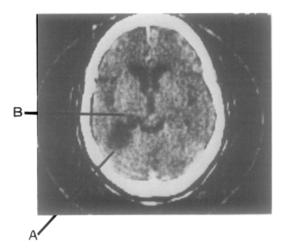


FIG. 1. Large low-density area indicative of infarction deep in the white matter of the occipito-temporal junction on the left (A). Small low-density area (B) in the region of geniculate bodies on the left.

Previous history showed that the patient suffered from diabetes and hypertension, neither of which had ever been carefully managed. Therapy was aimed at controlling both disorders. In the following weeks, the patient made a good recovery, and both the hemiparesis and sensory loss improved. Gradually he started walking by himself. Six months later his only complaints concerned the visual field loss and the reading impairment, which remained unaltered.

When first studied in October 1973 the patient was alert, cooperative, and attentive. He noticed many of his mistakes, which he tended to minimize, stating that "most people would

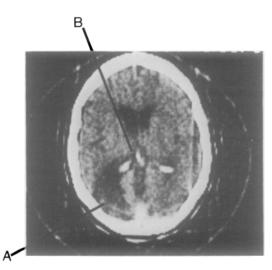


FIG. 2. Large low-density area indicative of infarction involving cuneus and fusiform and lingual gyri, as well as underlying white matter (A). Additional low-density areas in the region of the splenium of the corpus callosum and cerebellum (B).

probably perform similarly." The errors related to the visual sphere were blamed either on lack of "visual acuity" or on "lack of patience." There was a right-sided homonymous hemianopia. The fundi showed signs of long-standing moderate hypertension but were otherwise unremarkable. Examination of the remaining cranial nerves was normal. Tone was slightly augmented in the right upper limb. Power was slightly diminished on the right. Stretch reflexes were brisker on the right. Sensory examination was normal. Double tactile stimulation was correctly perceived. The finger-nose test was abnormal on the right, with mild dysmetria and intentional tremor. The patient walked without assistance.

Speech was fluent, with normal articulation, melody, and syntax. Spontaneous word finding and lexical choice were intact. Naming performance in the auditory and tactile modes was normal. However, as described below, naming to visual confrontation was more or less impaired according to the nature of the stimulus. Color naming was markedly defective, though there was no history of personal or familial color blindness. Verbal auditory comprehension was normal even for material of considerable lexical and syntactic complexity. He showed complete alexia for material presented visually, including the reading of letters, words, phrases, figures, and numbers (Arabic and Roman). Reading in the tactile modality was intact with both the right and left hands. Oral spelling was correct. Spontaneous writing and writing to dictation were intact. However, he was unable to read what he had just written, and his copy of several varieties of written material was poor, in script or print. Right-left orientation and finger recognition were normal. He was given three different tasks requiring the naming and identification of body parts on the examiner, on himself, and on a chart. He made occasional naming errors on himself and the examiner but could not name a single item on the chart. Identification of body parts with the names supplied by the examiner was similarly impaired. Oral calculation was normal but written calculation was clearly defective. The patient could give an adequate account of movies seen on television and apparently followed a football game with understanding. He was also able to carry a complex conversation on the telephone and did so with the examiner. The diagnosis was infarction in the territory of the left posterior cerebral artery.

In both cases, remarkably similar in terms of age, medical antecedents, and presentation, clinical localization of neural damage was based on the presence of signs suggesting impairment in structures supplied by major branches of the posterior cerebral artery. The hemiparesis and the right-sided disturbance of sensibility were viewed as resulting from dysfunction at midbrain and thalamic levels, the motor incoordination as consequent to cerebellar involvement, the hemianopia was due to a lesion of the left visual cortex and of some of its afferents, and the alexia as related to the combined lesions of the left visual system and of visual connections from the right visual cortex. On the other hand, the absence of agraphia and of aphasia and the remarkably preserved spelling and aural naming abilities tended to exclude involvement of structures supplied by the middle cerebral artery.

METHOD AND RESULTS

A set of tasks designed to assess the profile of visually dependent performance was given to both patients. The tasks were simple, and all would be performed correctly by a population of normal individuals of the same age group, educational level, and cultural background. In an attempt to minimize the effects of fatigue, observations were carried out in several sessions. To evaluate consistency of response, each task was given on at least two different occasions, after an interval of at least 1 month, and the results were compared. The order of presentation of problems varied in each session.

1. Comparative Naming of Three-Dimensional Objects and Two-Dimensional Graphic Representations of Objects

The Visual Naming Test of the Multilingual Aphasia Examination (Benton, 1969) was the source of the two-dimensional stimuli. In the test, twenty-seven 20×25 -cm plates with

black-ink drawings of common objects (e.g., telephone, television set, fork) were used. Confronted with the picture, the subject was required to name the whole or some of the parts.

The set of three-dimensional stimuli also numbered 27. They were real objects (e.g., electric iron, typewriter, spoon), all different from those represented in the two-dimensional set, although size and meaning were comparable.

The performances of the two patients on these tests are shown in Table 1. As will be seen, both patients performed adequately for three-dimensional object naming but showed severe defect in the naming of two-dimensional representations.

The poor performance in the naming of two-dimensional representations was characterized either by inability to produce any response, or, more commonly, by *conduites d' approche*, which on a third or fourth attempt might or might not produce the specific correct response.

2. Color-Related Performance in Nonverbal Tasks

(a) Ishihara test (1971 edition). The subjects were required to trace the hidden figures with their fingers in 10 plates

(b) Color matching. The subjects were required to match 10 cards of different colors to 10 corresponding color stripes in another card.

(c) Sorting and grouping of colored cards. The subjects were required to sort out, from a large set of differently colored cards, three groups of cards with the same color.

(d) Hue grading. The subjects were required to grade stripes of different hues of blue, green, and red (three stripes for each).

3. Use of Color Names in Verbal Tasks

(a) Naming of the color of objects. The subjects were required to state the name of the color of an orally named object. There were two different tasks:

- Phrase completion (e.g., blood is —; grass is—). Both patients performed all items correctly.
- (2) Specific questions (e.g., what color is the sky?). Both patients performed all items correctly.

(b) Naming of items of a given color. The subjects were required to name series of items, given their colors (e.g., name two blue objects). Five different colors were used. Both patients performed correctly but slowly.

(c) Association of color names. The subjects were asked to indicate as many names of colors as they could remember within the time limit of 1 min. Patient 1 produced seven names. Patient 2 produced eight names.

4. Naming and Identification of Colors

The patients performed poorly in both the naming and the identification of colors. In the first task, the patients were asked to name 20 consecutively presented colored cards. Black,

Naming of	Patient	
	1	2
Two-dimensional graphic representations (%) ^a	37	39
Three-dimensional objects (%)	92	100

TABLE 1 Visual Naming of Two-and Three-Dimensional Stimuli

^a Figures indicate percentage of correct responses.

white, and gray were used as colors. The patients were not told whether or not they were performing correctly. In the second task, the patients had to point to a colored card within a wide array, given the name of a specific color.

Performance conformed to the classic pattern. Both patients produced entirely wrong names or no name at all. The wrong names were always names of other colors, and in no instance were other verbal categories brought into play. Often there were approaches to naming prefixed by "a kind of" (e.g., "a kind of blue"). Occasionally there was perseveration of a given name across two or three stimuli presentations. In the identification task the patients sometimes performed correctly, but always in a hesitating and even labored fashion. We were unable to identify a color which was more often named incorrectly than others. However, blue was the name most frequently used in misnaming other colors. Misnaming of white (often referred to as "blue" or "gray") and black ("dark blue") and the naming of white and black did not seem less impaired than the naming of hues. Patient 1 produced 54% correct responses and Patient 2 produced 46% correct responses.

5. Naming and Identification of Colors According to Nonspecific Verbal Criteria

The subjects were asked to select from an array of colored cards those which they judged to be (1) "sad," (2) "light," (3) "joyful," and (4) "dark," respectively.

In a very quick and determined way, patients performed what we considered to be correct choices (Table 2).

The patients were then asked to name colored cards according to those criteria; e.g., given a card, the patient would have to say whether it was "sad" or "joyful." Both patients performed normally, but at a slower pace than on the previous task.

6. Coloring of Pictures

The subjects were given the task of coloring colorless pictures. The procedure attempted to evaluate each subject's ability to (1) identify the stimulus, and (2) identify the color that

Sad and joyful		
Patient 1		
Sad	Black	
Joyful	Yellow, red, bright blue, purple	
Patient 2		
Sad	Black, grey, violet	
Joyful	Yellow, green, red	
	Light and dark	
Patient 1		
Light	Light yellow, orange, light blue, white	
Dark	Brown, dark blue, dark green, black	
Patient 2		
Light	White, yellow	
Dark	Black, dark blue, brown	

TABLE 2 NAMING AND IDENTIFICATION OF COLORS ACCORDING TO GENERIC ATRRIBUTES

should go with the stimulus without using verbal mediation. Two examples of method and results are indicated:

(a) Patient 1 was presented with the colorless line drawing of banana. Asked what it was, she could not name it but correctly identified it, saying she "enjoyed them, would gladly peel one and eat it." She was then requested to pick up a pencil of the appropriate color from a set of colored pencils, without saying its name. She picked up a correct yellow pencil and said it was the right one. We then asked her to color the drawing. At this point she stated the color of the pencil looked right but really could not be used as it was "red" and that object was not really "red." Asked again to name the object, she did not. Nor could she name its color on request but insisted that it could not be red.

(b) She was presented with a colorless representation of a frog. Asked what it was, she did not name it but said that she knew it quite well (e.g., "it stands up and ribbits"). When asked to pick up a pencil of the appropriate color, she picked up a green pencil, proceeded to examine it carefully, and said it was probably wrong as the pencil was "pink" and the object should be "a kind of green." When asked to color the drawing, she put the green pencil down, picked up a blue one, called it "green," then started to color.

Patient 2 performed similarly but less consistently. In practically all instances, the patient verbalized the color first, even when specifically requested not to do so. He then behaved in the same fashion as Patient 1 and made inappropriate choices from the set of pencils. Both patients looked more and more puzzled as the experiment continued and manifested dissatisfaction with the results, in a manner reminiscent of that described in commissurotomy patients after failing tests of interhemispheric transfer.

7. Criticism of Wrongly Colored Pictures

A series of wrongly colored line drawings was presented to the patients (e.g., a blue baby, a purple elephant, a green woman's face). The patients were asked what the pictures represented. If no comment was made on the color, the patients were specifically requested to judge it as right or wrong. Examples from Patient 1 are as follows: (a) A green dog: The patient identified but did not name the picture, nor did she name the color. She stated that it was not the right one. Later she was able to name the dog and said the color was definitely wrong because "dogs are generally white, black or brown." Asked to comment again about the color, she hesitated and stated she felt it was wrong. (b) A purple elephant: She identified the stimulus but die not name it. "It should not be quite that color . . . this one looks blue . . . they are not blue in the circus." (c) A green woman's face: "The skin isn't the right color . . . it should be skin color . . . this one is a funny color."

Patient 2 only noted the wrong color after specifically being requested to comment on it and did so with hesitation. When given the name of the color, such as blue applied to the picture of a baby, he immediately rejected it, adding that "of course, babies are not blue."

DISCUSSION

We will start by considering the results of performance in the visual naming tasks, as they are of particular relevance to the discussion on color naming. As noted there was a marked difference between naming of three and two-dimensional stimuli. The nature of the impaired performance in the latter is indicative of adequate identification of the object and of appropriate but incompletely evoked verbal matrix. Dissociation of the ability to name two- and three-dimensional stimuli, e.g., the fact that one class of stimuli (two-dimensional) produces "optic aphasia" while the other one does not, is generally not reported in studies on color-naming defect and pure alexia; but it is our impression that this is possibly the rule rather than the exception. In a condition in which the dominant half of the cortical visual system is destroyed or severely limited in function and adequate interhemispheric transfer of visual information is precluded, this dissociation suggests that only certain stimuli are able to engender the type of neural activity capable of circumventing those anatomic limitations. Our interpretation is that the different nature of the stimuli produces different visual processing, carried out by diverse neural structures. As a result, the ability to build a name matrix is different in each case. Several features may contribute to the diverse processing, such as the third dimension; which calls for depth perception and the activation of a form of vision different from the one used to perceive surfaces. Possibly the different familiarity with the real objects and the fact that some of them were experientially "somatosensory" as well as visual entities also contributed to different processing and, ultimately, determined a better naming ability. The issue here is not the singling out of the major factor contributing to different performance, but simply that seemingly comparable visual stimuli often have different physical features and that a different performance will correspond to those differences. This, in turn, means that seemingly comparable stimuli are often not truly comparable. If the physical difference between three-dimensional objects and their twodimensional representations is a relevant one, significant dissociations should also be expected from the use of color as visual stimulus, since the physical properties of color are distinct.

Performance related to color conformed to classic descriptions. The use of names of colors in strictly verbal tasks which did not involve the simultaneous perception of color was intact, indicating the ability of the subjects to draw upon their knowledge of the verbal attributes of common objects. We suggest that these tasks were correctly solved in the absence of a concomitant inner visualization of the color and that, furthermore, if such a visualization occurred during performance, it was probably not appropriate to the verbal information being used. Also conforming to classic description were the results of specific naming and identification of colors. However, when verbal attributes of colors were used, such as "sad" or "light," instead of their specific names, the performance was strikingly normal. The dissociation is particularly striking in view of the fact that children are able to master the use of specific color names long before they acquire the ability to use names of their attributes (Gardner, 1977).¹

We would describe the behavior of our patients in that task as the overcoming of the component of color-naming defect which seems to be confined to the specific name of the color. The patients can still establish an

¹ Gardner, H. 1977. (Personal communication.)

appropriate relation between a *color stimulus* and a *verbal tag* provided the semantic field is large enough. We also think that this finding goes against the current notion that these patients are color agnosic.

Analysis of the patient's behavior in the task of coloring pictures indicates how the design of a task can crucially influence the outcome of the procedure. Although that was not the original aim of the experiment, it strengthened the view that we were not dealing with a true agnosia for color. Our interpretation of the results, as exemplified for Patient 1, is that she did have proper knowledge of the object, as shown by correct conduites d'approche, even if she did not name it from the two-dimensional drawing in accordance with previous performance in visual naming. She also had appropriate visual recall of the object (on the basis of the nonverbal stimulus) and thus knew its color and was able to match her visual nonverbal experience of "vellow" with the yellow pencil in the display. All of this knowledge was, however, dissociated from the adequate verbal tags, which were only faintly aroused. Up to this point her performance was indeed normal, and her failure started only when she was asked to color the object. We presume that her actions then became verbally directed and she began operating on a level that was "disrelated" from that of visual experience. She initiated her action by naming the pencil she held in her hand, and she misnamed it "red," something that jarred with the remainder of her poorly evoked verbal matrix of "banana." This form of behavior was consistent for other presentations of colorless pictures.

A similar analysis applies to the task of recognition of wrongly colored pictures. It is clear that the patient's behavior is not normal and that, just as in the previous task, the strategy of approach determined success or failure. The results underscore the role of the verbal component in the formation and integrity of the concept of color, which is, in essence, a strictly visuoverbal one. We suggest that when the specific verbal label is dissociated, the concept is considerably weakened though not necessarily lost and that certain forms of testing may elicit a seemingly agnostic behavior.

The different results obtained in naming and identifying colors are examples of the importance of task specification. Although the subjects performed defectively in both tasks, identification was less impaired. Possibly, an important factor accounting for this better performance is that in the identification condition the matching takes place between a verbal matrix determined by the given name and several visual matrices evoked by the colors confronting the subject simultaneously, that is, a matching between one matrix on the one hand and a finite number of matrices on the other, all determined by actual and simultaneous nervous processes. On the contrary, in the naming situation, the patient has to produce, among a considerable number of possibilities not offered simultaneously, the appropriate verbal matrix corresponding to the specific visual stimulus confronting him.

In short, elementary color stimuli, or three-dimensional objects, or their two-dimensional representations, are physically different. That concept formation, storage, and operation based on each of them should also be different in psychological terms, and hence different in terms of neurophysiologic substrate, is a distinct possibility. The same applies to the contention that words differ in their semantic field, and that the sphere of meaningfulness of a specific color name or of, say, the attribute "joyful," are not one and the same thing. The importance of task specification and problem-solving strategy also needs no further emphasis.

Hence, the results of the study support the proposal that the type of stimuli, the demands of the task, and the strategy of problem solving are contributory factors in either enhancing or minimizing the visuoverbal dissociation which is indicative of disconnection. This dissociation appears maximal (1) when at the perceptive end, stimuli are more "purely" visual, such as color, or structurally less "rich," such as two-dimensional in comparison with three-dimensional; or (2) when at the verbal end, a specific name rather than the name of a broad category is involved. Complex visual stimuli, on the one hand, or names representing large semantic fields, on the other, seem to foster the kind of neural activity necessary to reduce or cancel visuoverbal dissociation, that is, activity capable of circumventing disconnection and matching right hemisphere visual information with left hemisphere verbal processing.

One may hypothesize that some visual information is made available to the left hemisphere of these patients, proceeding from the right hemisphere via whatever is left of the splenium of the corpus callosum or through the anterior commissure. But regardless of the amount and type of information transferred, it is not processed in a form that can be utilized for specific naming of certain classes of stimuli, such as letters or colors or physically simple representations of objects. On the contrary, the same visual information can be utilized for generic naming and identification of attributes of some of those stimuli or else of physically complex visual stimuli. It is also possible that the latter depends on the transfer of visually evoked "extravisual" information elicited by the perception of such complex stimuli, for instance, in a cross-modal visuotactile transfer. The final product of such transfer could possibly be relayed interhemispherically by the intact anterior two-thirds of the corpus callosum, or by the anterior commissure. In essence, this mechanism would correspond to the "tactile arousal" explanation proposed by Meyer (1905) and revived by Geschwind (1965). An alternative explanation would be that certain types of verbal information are coprocessed in (or transferred to) the right hemisphere and that the visuoverbal interweaving process would take place

there rather than in the left hemisphere. There is no doubt the right hemisphere is capable of some language processing, but the evidence from commissurotomy and left hemispherectomy studies underscores how limited that ability is. We tend not to favor this hypothesis, although the present data do not help us decide one way or the other.

The results of the study are also compatible with the hypothesis that the neuroanatomic and neurophysiologic system underlying perception and naming performance varies with the object being perceived and named and that, in addition, such a diversification in processing enhances the possibility of a specific lesion involving a certain system while sparing another. It may be noted that there is support for this view in animal research. Work such as that of Hubel and Wiesel (1970, 1972), Cragg (1969), and Mishkin (1972) indicates that visual information is processed in a cascade of interconnected operators and that different features of visual features are appreciated by different sectors of the central nervous system (CNS). The recent findings of Zeki (1973, 1974a, 1974b, 1975, 1976, 1977) and Baizer, Robinson, and Dow (1977) in relation to color vision further strengthens the point. Their results suggest that some operators which process color do not process features such as line orientation, movement, angles, or depth, implying that analysis of color and of form are separated in the brain-in short, that different regions of the visual cortex share the load of feature analysis, and that the processing associated with seeing a color or a three-dimensional object is different. As for example, area 17 in the rhesus monkey has a limited amount of color-coded cells, that is, cells which respond to color stimuli presented to the animal in single cell recordings. In what corresponds to areas 18 and 19 (areas V_2 and V_3) few cells respond to color (0% in V_2 , approximately 10% in V₃). Moving into the prestriate region located in the lunate sulcus, and into what has been designated the fourth visual area (V_4) , a region has been identified that responds almost solely to color but does so with a marked partitioning of which subregion responds to which color. Since all visual input of that hemisphere has arrived in area 17 to start with, a pathway has had to transfer visual information to this area V_4 , a pathway that most probably traveled beneath parts of areas 18 and 19. Further forward, out of the lunate sulcus and already in the most posterior region of the superior temporal sulcus, cells will respond to color but in a different fashion, with columns responding to more than one color and to other visual features associated with color. As might have been expected, the nervous system has an alternative means of processing different features of stimuli, and the cortical units and subserving pathways which take care of the complex lines making up a letter are not the same ones which handle the changes in wave length that distinguish colors.

In classic terms, the disconnection model stresses the transfer of visual information in single channels and single steps. The model may be

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amplified by adding that there are several alternative channels and that each links a chain of processors. But the issue still is that damage at some point in one of the chains interferes with the mechanism of transfer and modification of information and produces a "disconnection" or "disrelation" of the ongoing visual processing from the pertinent and simultaneous verbal processing that is normally interwoven with it. Such a split is more or less complete according to the nature of stimuli and task specification, that is, according to the capacity of the CNS to reroute processing and achieve a compensatory coincidence of the visual and verbal processings related to a given stimulus.

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