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I SEES 'EM AS I CALLS 'EM--HUE DISCRIMINATION AND HUE NAMING ACROSS CULTURES.

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IN AN ATTEMPT TO BRIDGE THE GAP BETWEEN PSYCHOPHYSICAL STUDIES OF HUE DISCRIMINATION AND ETHNOLINGUISTIC STUDIES OF HUE LABELING, AN EXPERIMENT WAS CONDUCTED COMPARING LABELING AND DISCRIMINATION FUNCTIONS FOR SPEAKERS OF INDO-EUROPEAN (AMERICAN ENGLISH) AND NON-INDO-EUROPEAN (MEXICAN INDIAN) LANGUAGES. IT WAS FOUND THAT HUE LABELING PATTERNS OF THE TWO GROUPS DIFFERED AND THAT EACH LABELING PATTERN WAS ACCOMPANIED BY ITS OWN CORRELATED PATTERN OF HUE DISCRIMINATION. DISCRIMINATION TENDED TO BE POOR WITHIN LABELING CATEGORIES AND GOOD BETWEEN LABELING CATEGORIES IN BOTH LANGUAGE COMMUNITIES, A FINDING WHICH PARALLELS RESULTS OBTAINED FROM STUDIES OF CATEGORIZING IN THE PERCEPTION OF SPEECH. THIS SUGGESTS THAT CATEGORICAL PERCEPTION ALSO CHARACTERIZES THE VISIBLE SPECTRUM. THE OBSERVED INTERRELATION BETWEEN DISCRIMINATIONS AND LANGUAGE HABITS LENDS SUPPORT TO THE PRINCIPLE OF LINGUISTIC RELATIVITY--THE WHORFIAN HYPOTHESIS. THIS THESIS APPEARS IN "SUPPLEMENT TO STUDIES IN LANGUAGE AND LANGUAGE BEHAVIOR, PROGRESS REPORT V," SEPTEMBER 1, 1967, PUBLISHED BY THE CENTER FOR RESEARCH ON LANGUAGE AND LANGUAGE BEHAVIOR, UNIVERSITY OF MICHIGAN, 220 EAST HURON STREET, ANN ARBOR, MICHIGAN 48108. (AUTHOR/AMM)

THE UNIVERSITY OF MICHIGAN

Studies in Language and Language Behavior

I Sees 'Em As I Calls 'Em: Hue Discrimination and Hue Naming Across Cultures

James L. Kopp

CENTER FOR RESEARCH ON LANGUAGE AND LANGUAGE BEHAVIOR

I Sees 'Em As I Calls 'Em: Hue Discrimination and Hue Naming Across Cultures[1]

James L. Kopp

In an attempt to bridge the gap between psychophysical studies of hue discrimination and ethnolinguistic studies of hue labeling, an experiment was conducted comparing labeling and discrimination functions for speakers of Indo-European (American English) and non-Indo-European (Mexican Indian) languages. It was found that hue labeling patterns of the two groups differed and that each labeling pattern was accompanied by its own correlated pattern of hue discrimination. Discrimination tended to be poor within labeling categories and good between labeling categories in both language communities, a finding which parallels results obtained from studies of categorizing in the perception of speech. This suggests that categorical perception also characterizes the visible spectrum. The observed interrelation between discriminations and language habits lends support to the principle of linguistic relativity--the Whorfian hypothesis.

Footnote

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INTRODUCTION

Two substantial collections of studies in the behavioral literature deal with the phenomenon of color perception but have had strikingly little to do with one another in the hundred odd years that date modern psychology. The first of these collections comprises the work done by psychophysicists on hue discrimination; the second, the work of anthropologists and ethnolinguists on hue labelling in languages of diverse cultures.

Thresholds of Hue Discrimination

Starting with the work of Lamansky in 1871, and dating to the present (e.g., Siegel, 1964), many investigators have charted and examined the properties of the hue discrimination function--a complex curve showing the size of the difference threshold ($\Delta\lambda$) for hue at various wavelengths (λ) along the visible spectrum.[1]

The form of this function has been the subject of much debate, especially with regard to the exact number of discontinuities which give the curve its characteristic wave-like form. It is generally conceded that the curve approaches a minimum (discrimination is better) at several points along the spectrum, but the exact number and location of these "dips" is unsettled. Many investigators have found four such minima; others report only three (Wright, 1946; Ekman, 1963).

of the differential sensitivity of the retina to spectral stimuli.

Graham quotes Wright as saying that,

> The [discrimination] curves as a whole have the characteristics that might be expected from a qualitative examination of the spectrum. The part of the spectrum where a minimum exists must obviously occur where there is a rapid change of hue; thus in the yellow where the color turns redder on one side and greener on the other, in the blue-green where it turns bluer on one side and greener on the other, in the violet where it becomes redder or bluer, minimum steps would be expected. But beyond 0.61μ the color changes steadily to a deeper and deeper red, and in the green where there is only a gradual change to either a blue-green or yellow-green, the discrimination is poorer and the step consequently greater. (1959, p. 155).

The suggestion is that hue labels follow patterns determined by differential hue discriminability. Where discrimination is good, there will be a transition from one labelling category to another. Where discrimination is poor a common label will be applied. Areas of enhanced discrimination will be associated with boundaries between hue categories. But a boundary need not occur at each area of discrimination enhancement. Graham, noting that hue labelling systems have been reported to vary across cultures, suggests that not all potential areas for the formation of color boundaries need be utilized in a given language system. The observation of differences in hue labelling across cultures,

> ....probably means no more than that few color responses were ever reinforced in the early lives of....individual subjects. As Myers (1908) says: 'Language affords no safe clue to sensibility. A color name occurs when it is needful. When it is needless it will not be formed, be the sensitivity ever so great.' A manifestation of this principle is shown by the fact that Eskimos have many more verbal responses for snow than we do. (Graham, 1959, p. 154).

Hue Labelling

Although psychophysicists have conjectured about the relation between hue discrimination and hue labelling, they have historically confined themselves to studying the former. There have been some attempts at collecting hue labelling data for spectral stimuli among Indo-European Ss, but the data are seldom in a form which allows detailed comparisons to be made with hue discrimination data. For instance, Laurens and Hamilton (1923) examined the locus of twelve color labels by plotting the longest wavelength assigned a given label when discrete values were presented sequentially across the spectrum. Dimmick and Hubbard (1939) present data from twenty-one separate studies in which Ss selected wavelengths corresponding to "unitary" red, yellow, green, and blue. These data, like the Laurens and Hamilton data, are point estimates; they show what wavelengths would be assigned a given label 100% of the time. As such, they do not allow us to say what the probability of each color label is at any given spectral locus and therefore do not allow us to examine questions such as Wright's speculation that "A minimum exists [in the discrimination function] where there is a rapid change of hue [in the labelling function]."

The first continuous plot of hue labelling probabilities along the visible spectrum was presented by Beare (1963) for the English labels red, orange, yellow, green, blue, and violet. The distributions of labelling probabilities are orderly, each label being associated with a rather broad region of the spectrum. Transitions between distributions are remarkably sudden (Fig. 1). Beare attempted to relate her data to

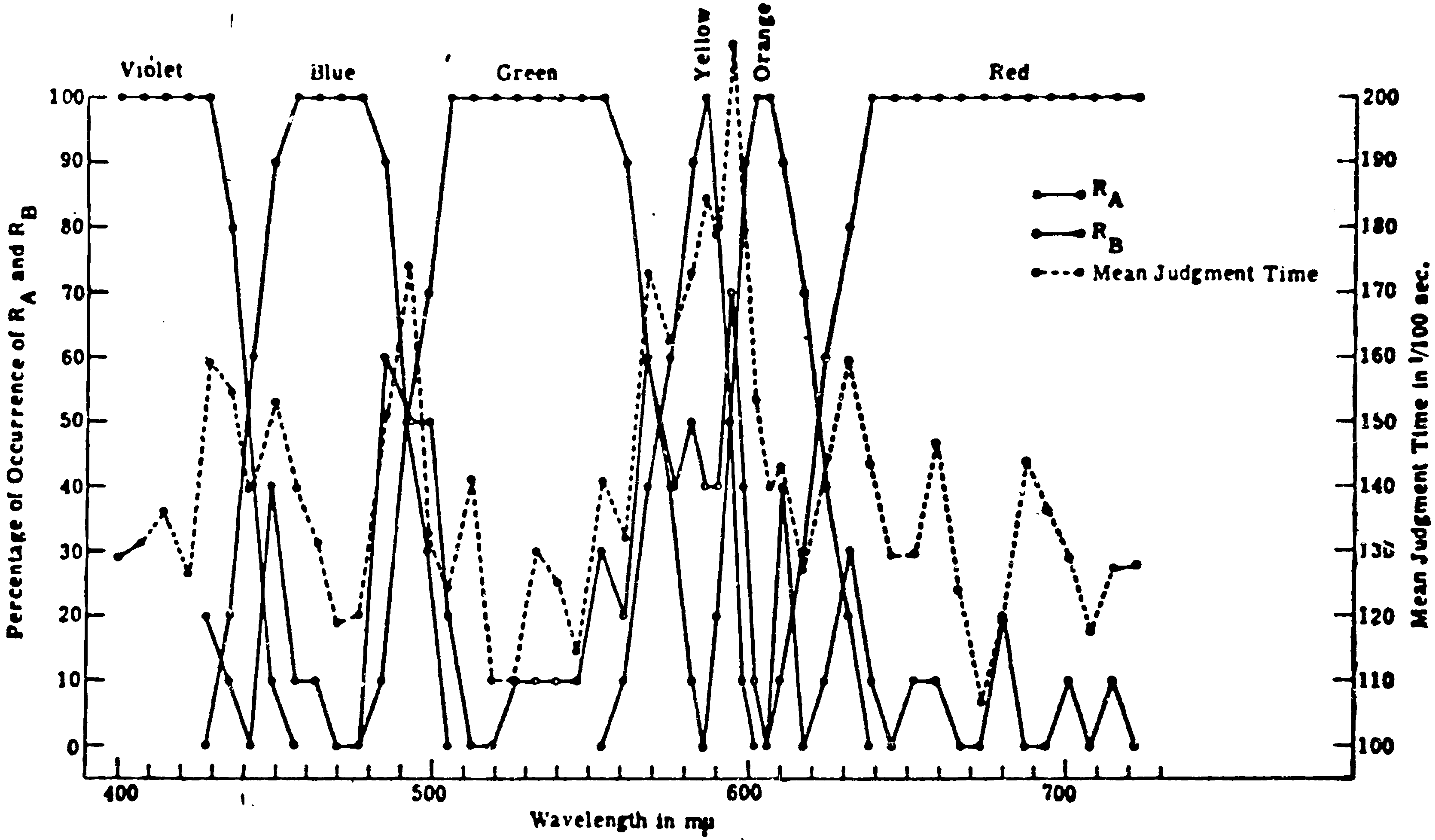

Fig. 1. Frequency distributions for six color names (R_A), distribution of qualifying responses (R_B) and mean judgment time for low intensities (105 db re: 10^{-10} L). From Beare (1963).

the composite discrimination function presented by Judd but could see no apparent correlation. Recently Boynton, Schaeffer, and Neun (1964) have charted the frequencies of the labels red, yellow, green, and blue by having Ss estimate the proportion of each hue in a given spectral sample. These data are quite similar to the Beare data when the boundaries between labelling distributions are compared.

By and large, the problem of hue labelling has been left to individuals interested in the various patterns of language behavior across cultures (Rivers, 1905; Ray, 1953; Conklin, 1955; Lenneberg & Roberts, 1956; Landar, et al., 1960; Lenneberg, 1961, Collier; 1963). Judging from these studies there is great variety in labelling systems from one cultural group to another. Ray, for example, has charted no less than nine different systems among Northwest American Indian groups, all substantially different; none identical to the American English pattern.

The data in this set of studies are more often descriptive than quantitative and the methodology lacks the precise control which characterizes psychophysical work. None of the cross-cultural studies, for instance, has been performed using projected monochromatic light. Prepared stimulus materials, when used, have consisted of various types of hand-painted or color-printed heterochromatic surfaces. These omissions are, of course, quite understandable given the difficulty of duplicating laboratory conditions in the field and given the fact that hue labelling is only one aspect of a host of behaviors to which the field investigator addresses himself. Nonetheless, the lack of stimulus specification and controlled testing conditions makes generalizations across studies difficult. It certainly precludes statements about the relationship of hue labelling to hue discrimination since discrimination data have only been collected among Indo-Europeans under controlled conditions and with monochromatic stimuli.

There is, then, a distinct gap in the array of studies dealing with hue perception. There is a lack of hue labelling data collected from Indo-European subjects and a corresponding lack of hue discrimination data collected from subjects in non-Indo-European cultural groups. The need for work in this area is rendered more salient by the fact that there has recently been a great deal of research relating discrimination and labelling in another field of perception with important implications for the perception of hue.

Categorical Perception

It has been demonstrated repeatedly by researchers in speech perception laboratories in recent years that stimuli along certain continua are associated with behavior in a discontinuous fashion (Liberman, Harris, Hoffman, & Griffith, 1957; Liberman, Harris, Eimas, Lisker, & Bastian, 1961; Bastian, Eimas, & Liberman, 1961; Liberman, Harris, Kinney, & Lane, 1961; reviewed by Lane, 1965). In these experiments Ss are asked to assign two or more labels to synthetic speech stimuli, or to label stimuli along some non-speech continuum, with responses which they have previously associated with the two extreme stimuli on the continuum. The distributions of labelling frequencies thus obtained resemble complementary step functions. The continuum is divided, as it were, by the intersections of these functions, into discrete sets, or categories, each set characterized by a broad range of stimuli which exercise a high degree of control over one labelling response to the exclusion of all others.

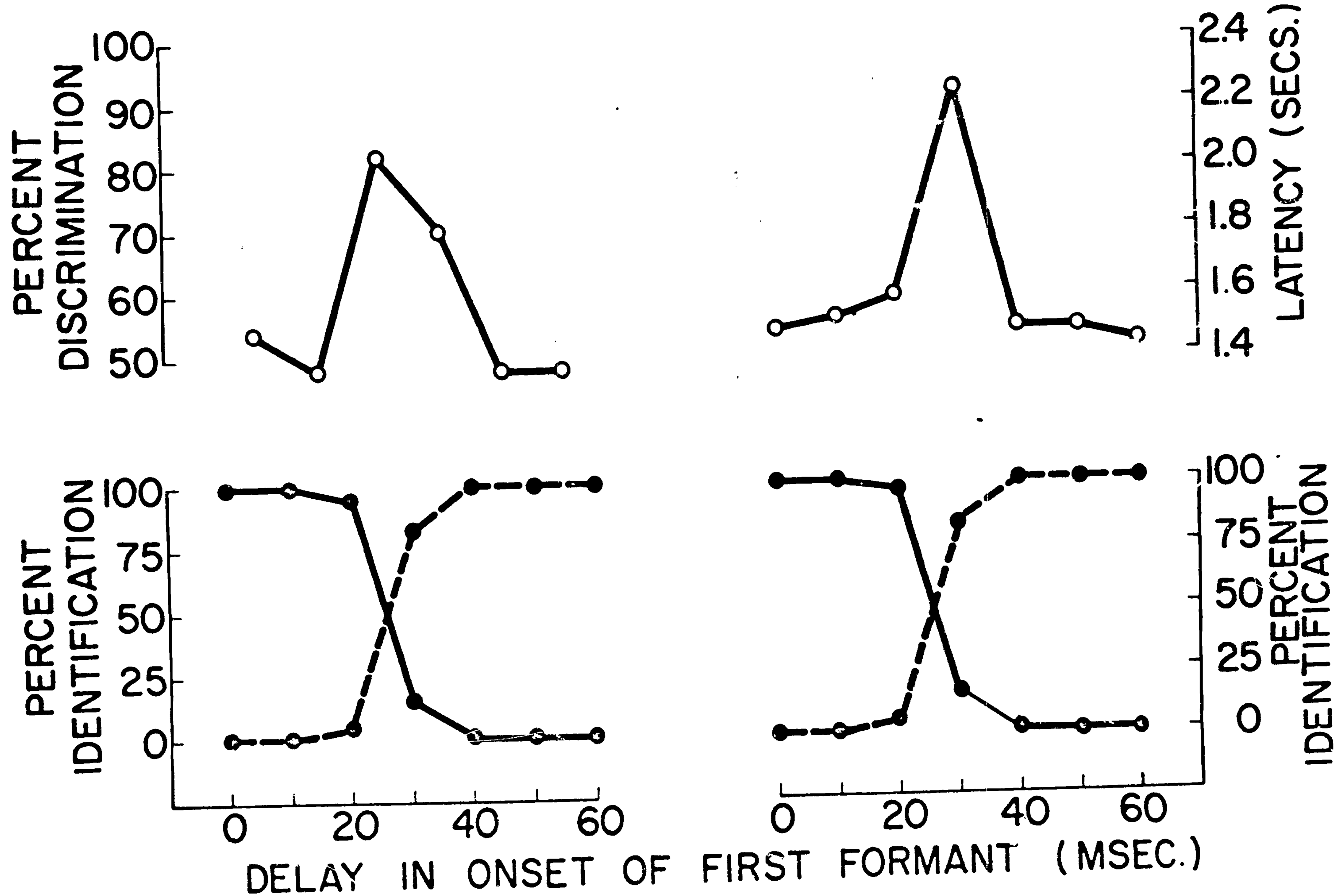

Fig. 2. Observed distributions of discrimination accuracy, identification probability and latency for a series of synthetic speech stimuli.

After the labelling data have been collected, Ss are tested for discrimination between pairs of adjacent stimuli along the continuum. It is then found that the accuracy of discriminating between two stimuli is systematically related to the probability that the two stimuli are categorized differently--i.e., stimuli that are named the same are not discriminated very well. Discrimination is better (percent correct same-different judgments) between stimuli which are associated with different labelling probabilities. In the transition region between two labelling responses, the region where labelling probabilities are most disparate, discrimination increases and peaks, returning to its original low level on the other side of the transition zone. In other words, discrimination between labelling categories is better than discrimination within categories. Typical labelling and discrimination functions for a synthetic speech continuum ranging between the English phonemes /do/ and /to/ are presented in Fig. 2. Also included is a function showing the average latency of the labelling responses. A peak in the latency function at the category boundary is characteristic of categorical perception (Cross & Lane, 1962; Studdert-Kennedy, Liberman, & Stevens, 1963; Cross, Lane, & Sheppard, 1965).

Categorical perception is most easily observed with speech stimuli (vowels and consonants) but has been demonstrated in the laboratory for non-speech continua as well (Cross & Lane, 1962; Lane & Schneider, 1963; Lane & Kopp, 1964; Cross & Lane, 1964; Kopp & Cross, 1964; Cross, Lane, & Sheppard, 1965). The method for establishing categorical perception with non-speech stimuli involves disjunctively conditioning two incompatible responses to two stimuli on a continuum. Generalization of labelling responses and discrimination between adjacent stimuli may then be measured at discrete points along the continuum. Since categorical perception can be not only conditioned by the language community but also, by these means, induced artificially in the laboratory for a variety of non-linguistic continua, the phenomenon is seen to result from a history of reinforcement with respect to labelling behavior and not from the discrete nature of the responses involved in the production of speech sounds, as was originally thought (e.g., Liberman, 1957).

It was recently observed (Lane, 1967) that the step-like nature of the labelling functions in the typical categorical perception experiment bear a marked resemblance to the color labelling data collected by Beare. In addition to the form of the labelling gradients, Lane notes that labelling responses in the Beare experiment are associated with long latencies at category boundaries and short latencies within individual categories (cf. Fig. 1). Lane points out that the Laurens and Hamilton hue discrimination function shows areas of enhanced discrimination (smaller thresholds) at those wavelengths at which the boundaries between hue labelling categories occur in the Beare data (Fig. 3).[2] Whereas Beare failed to find a correlation between hue labelling and hue discrimination, Lane's observation is that, at least in the case of the Laurens and Hamilton data, there is a very definite relationship-- one that would be expected from what we know of the interaction between labelling and discrimination in categorical perception experiments.

The speculation is, according to Lane, that categorical perception may be operative along the wavelength continuum as well as other

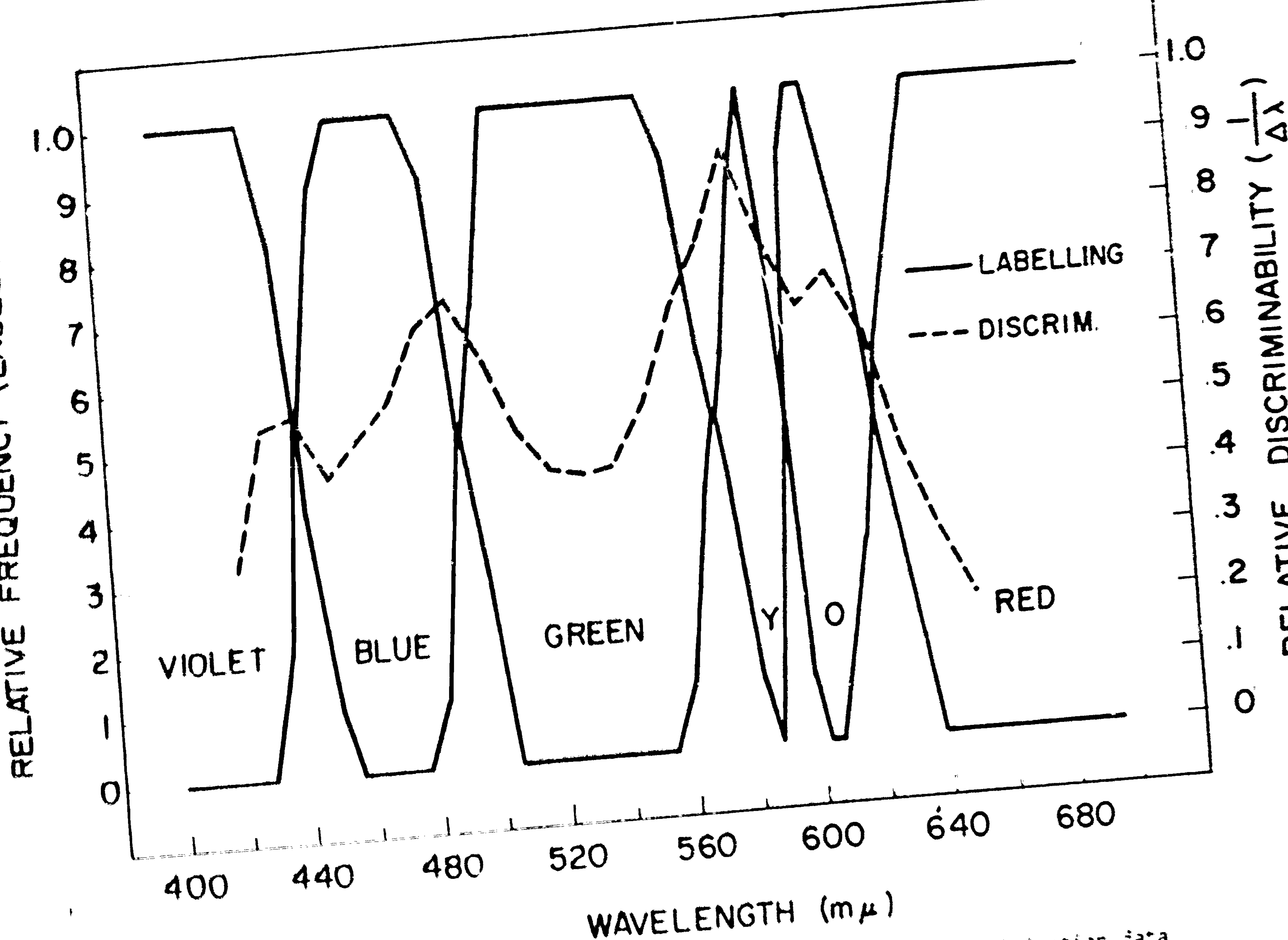

Fig. 1. Comparison of hue labelling and discrimination data obtained by independent investigators. Adapted from Beare (1963) and Laurens and Hamilton (1923). From Lane (1966).

continua; that perhaps labelling habits lead to differential discrimination among hues as they do among speech sounds, other acoustic stimuli, visual areas, etc.

If one desires, however, to extend the categorical perception notion to include the relationship between labelling and discrimination along the visible spectrum, a theoretical problem arises. By the categorical perception paradigm, discrimination enhancement at category boundaries is taken to result from the individual's extensive history of differential reinforcement with respect to language labels. This is normally accomplished in the language community but can be induced artificially in the laboratory. Differential discrimination along the visible spectrum, however, has historically been taken to reflect the summated activity of several subtypes of wavelength receptors in the retina. In other words, by the categorical perception interpretation, differential discrimination would be said to follow as a result of verbal conditioning with respect to color labels. But according to the classic view (e.g., Graham, 1959), differential discrimination is given physiologically and provides markers in the form of relatively homogeneous hue regions which then may or may not come to be labelled differently depending upon the needs of the language community. By the categorical perception formulation, labelling patterns determine discrimination patterns. By the classic psychophysical view, discrimination patterns determine labelling patterns (if there is any relation at all).

This apposition of viewpoints is related to a third body of literature--that concerning the "Whorfian hypothesis." This proposition, put forth most vigorously by Benjamin Lee Whorf in the late 1930's, has as its central tenet the notion of perceptual relativity, the idea that man sees the world in terms of the language he uses to describe it. In the oft-quoted words of Whorf (1940),

> We are thus introduced to a new principle of relativity which holds that all observers are not led by the same physical evidence to the same picture of the universe unless their linguistic backgrounds are similar or can in some way be calibrated.

How this proposition relates to behaviors such as labelling and discrimination of hues is discussed by Fishman (1960) at what he calls the "second level of analysis" in his recent discussion of the Whorfian view.

Fishman deals at this level with "linguistic codability and behavioral concomitants"; the Whorfian hypothesis interpreted in terms of the relationship between language and non-language behaviors. The basic notion is that the Whorfian hypothesis gains credence if learning to label stimuli can be shown to affect other aspects of behavior that are associated with these stimuli either within or across cultures. Within cultures, labelling has in fact been shown to influence such non-linguistic behaviors as discrimination (Lehmann, 1889); problem solving (Maier, 1930); recall (Carmichael, Hogan & Walter, 1932); latency (Brown & Lenneberg, 1954); recognition (Lenneberg, 19[illegible] Van de Geer, 1960; Van de Geer & Frijda, 1960; Lantz, 1963; Lantz & Stefflre, 1964; Stefflre, Castillo & Morley, 1966); learning speed (Lenneberg, 1957); and sorting behavior (Carroll & Casagrande, 1958). The data from both the Carroll et al., Stefflre et al., and Brown & Lenneberg studies also indicate (but do not confirm) that there are differences across cultures on several of these variables.

Fishman goes on to suggest that color stimuli may be especially convenient for further investigations directed at the influence of language on perception.

> The color continuum seems to be a particularly fortunate area in which to study (these) phenomena precisely because it is a real continuum. As such, no 'objective' breaks occur in it and it is a matter of cultural or sub-cultural consensus as to just which breaks are recognized, just where on the spectrum they are located, and how much of a range they include (1960, p. 330).

At this level of analysis, the Whorfian argument would extend to the perception of hue as follows. If we take hue discrimination to be the "picture of the universe," certain regions being perceptually homogeneous and others not, and if we take the repertoire of hue labels to be the "linguistic background," then the Whorfian hypothesis might predict, as the categorical perception argument does, that individuals will perceive colors as they label them, i.e., discrimination patterns will follow labelling patterns. The expectation would be that two cultures having different hue labelling habits would evidence different patterns of hue discrimination.

The demonstration of differences in hue labelling patterns across cultures, with corresponding differences in hue discrimination patterns, would constitute evidence in favor of the categorical perception proposition and, by analogy, support for the Whorfian hypothesis. The finding of identical hue discrimination functions across cultural groups, even if labelling patterns differ, would be a finding negative to the categorical perception prediction and its Whorfian corollary.

The following sections outline and summarize the results of an investigation comparing the hue discrimination and hue labelling patterns of Indo-European and non-Indo-European speakers. These questions guided the design and execution of the study:

1) Are hue labelling and discrimination related in the manner suggested by the comparison of the data of Beare with those of Laurens and Hamilton? That is, will enhanced discrimination be

associated with boundaries between labelling categories? Will it be the case for Indo-European speakers, for non-Indo-European speakers, or both?

2) Will purported differences in hue labelling patterns between two cultures obtain under controlled testing conditions and for monochromatic stimuli?

If discrimination and labelling are directly related, and labelling patterns differ across the two cultures, it would follow that discrimination patterns differ. This result would lend weight to the proposition, common to both the categorical perception argument and the Whorfian view, that language influences perception.

METHOD

Non-Indo-European Subjects. The major requisite for the experiment was the location of a group of Ss who:

1) speak a language which involves a hue labelling system different from Indo-European,
2) speak only that language (are monolingual),
3) are located near adequate electrical power, making it possible to use modern optical devices and experimental programming equipment.

A group fulfilling these requirements was located in the highlands of Chiapas, Mexico, in the vicinity of San Cristobal de las Casas. The Ss were from the village of Nevenchauk in the municipio of Zinancantan and spoke a language known as Tzotzil. Descendants of the Maya, the Zinancantecos are mostly monolingual (up to 90% in some areas) having retained an amazing degree of autonomy from Spanish influence in the five hundred or so years of the post-Colombian era.

Access to Ss was through a Zinancanteco informant who also served as a Spanish-Tzotzil interpreter during the actual experiment. Three Ss, one male and two females, participated. The male (Mariano) was 21 years of age and the females (Petrona and Gatarina) were 10 and 30 years old respectively. One additional Tzotzil male (age 35) was tested but his data had to be discarded as unreliable when it was found, after four hours of discrimination testing and several repeats of the instructions, that his responding consisted of simple alternation between the two response buttons. All subjects were monolingual in Tzotzil.

Data on the Zinancantan hue-labelling system, established for stimuli from the Farnsworth-Munsell 100 hue discrimination test, were provided by an earlier investigation in the Zinancantan region (Collier, 1963). This study showed that the Tzotzil have only four "primary" hue labels phonemically transcribed as /¢oh/, /k'on/, /yox/, and /ik'loan/. These labels are characterized by high peak probabilities of occurrence (¢oh, 40%; /k'on/, 65%; /yox/, 85%; /ik'loan/, 40%) and unimodal distribution over broad ranges of the Farnsworth-Munsell array. The peak frequencies of the other names ranged from 20% to 30%. Three of the labels are Tzotzil color morphemes. The fourth (/ik'loan/) is an inflected form of the morpheme for black used exclusively to label stimuli in the short wavelength region of the spectrum. According to Collier, the Tzotzil have no true morpheme for violet or purple.

The four labels refer to the attribute of color rather than an object in the Zinancantan world. The primacy of these four constructions as color names, in addition to the high probabilities and broad ranges of their distributions on the Farnsworth-Munsell continuum, is given by the fact that Collier found none of them to increase and some in fact to decrease in probability in what Conklin calls the "contrastive" situation, i.e., a situation in which two colors are presented simultaneously to be differentiated by description. Under these conditions, Collier found complex inflected forms of the four original terms to increase in frequency along with occasional "loan" words derived from the Spanish, words such as "rosado" and "celeste." In the contrastive situation, the S is forced to be increasingly specific in his description of hues. Increases in the grammatical complexity of color names, as well as increases in the frequency of derived or borrowed terms, are the means by which specificity is provided. /ȼoh/, /k'on/, /yox/, and /ik'loan/ correspond, by these criteria, to primary color terms, what Conklin calls "Level I" terms, terms to which, "all color terms can be reduced....but none of (which) is reducible" (1955, p. 342).

Indo-European Subjects. Two groups of American English Ss were also run, one before (English Group I) and one after (English Group II) the field investigation. The first English group was comprised of two females (MR and AA) and one male (SF). The second English group consisted of one female (PS) and two males (SN and JL). All were students at the University of Michigan and therefore relatively homogeneous with respect to age.

Primary or Level I color names in English are usually given as red, orange, yellow, green, blue, and violet. In the present experiment orange was eliminated for two reasons:

1) Ekman's analysis of similarity judgments for spectral stimuli and his examination of the number of minima in the typical hue discrimination function lead to the conclusion

that there are five factors operating in the perception of hue by Indo-Europeans. This suggests five primary color names.

2) Recent analysis of labelling probabilities derived by direct scaling techniques for spectral stimuli reveals that orange is reducible to yellow or red and therefore should not be considered primary (Sternheim & Boynton, 1966).

Apparatus. Monochromatic stimuli were generated by passing "white" (3200° K.) incandescent light through a continuous interference filter and thence through a 1mm vertical slit. This procedure produces relatively intense spectral stimuli with a half-band width of approximately 12 mμ over the entire range of visible wavelengths. Wavelength changes are produced by traversing the filter horizontally across the slit, the peak wavelength value in mμ being linear with the traverse distance in inches. In the case of English Group I, the filter was provided by Optics Technology Inc. (Palo Alto, Calif.). This filter necessitated the use of an auxiliary high-pass filter (Kodak Wratten No. 16) at wavelengths about 560 mμ and was therefore unwieldy. For the Tzotzil and the English Group II, a filter (Schott-Veril S-60) provided by Fish-Schurman Corp. (New Rochelle, N. Y.) was used. This device does not require additional filters. The Optics Technology filter yields a change of 5.5 mμ, and the Schott-Veril filter yields a change of 7 mμ, per mm of linear traverse. Stimulus intensities were measured at the location of the S's head by means of a spot photometer. Intensities ranged from 62 db (re:10^{-10} Lambert) at the least bright wavelength (421 mμ) to 86 db (re:10^{-10} Lambert) at the brightest (589 mμ). All of these intensities are well above the photopic threshold. Ss were seated in a totally darkened room 2.5 feet from a ground glass screen. The stimuli were projected upon the obverse side of the glass through the lens system of a standard classroom slide projector. The resultant stimulus image consisted of a vertical rectangle, the dimensions of which were 2 1/2" x 1/2" for the first English group and 3/4" x 5/16" for the Tzotzil and second English group. The stimulus surround was rendered completely black by masking the screen with flat black posterboard. All stimulus events and concomitant responses were recorded on an 8-channel event recorder. Labelling response latencies were recorded when the stimulus onset gated a multivibrator (Grason-Stadler) which led into a print-out counter (Sodeco). The multivibrator was then deactivated by a response which activated successively the print and reset mechanisms of the counter. By this procedure latencies could be measured with a temporal resolution of less than .064 sec.

Sweep Discrimination Pre-test. In the first part of the experiment, the S was provided with a telegraph key and instructed to report all hue changes, however slight, in the patch of light on the screen. The experimenter then actuated a motor which moved the filter slowly across the slit at a continuous fixed rate (2 mμ/sec. for the first English group; 5 mμ/sec. for the others) from the shorter to the longer wavelengths and back again. This yielded continually alternating ascending and descending "sweeps" of the usable spectrum (423 mμ to 643 mμ for the first English group; 421 to 645 mμ for the others).

Hue Labelling. In this phase discrete wavelength values were presented tachistoscopically at 7.5 sec. intervals (stimulus duration =

.75 sec.). For the first English group these values ranged from 423 to 643 mμ in 11 mμ steps. For the Tzotzil and second English group they ranged from 421 to 645 mμ in 14 mμ steps.

The appropriate wavelengths were set manually by the experimenter, according to a random protocol, by means of a dial micrometer rigidly affixed to the filter carrier. It was possible in this way to make hand settings quickly and accurately to within one or two thousandths of an inch. This corresponds to a wavelength error of less than one-half of one mμ. The S was instructed to press one of several dimly illuminated white plastic buttons on a panel in front of him, each button corresponding to a given color label. Labelling judgments were collected in two successive repetitions of the same random protocol. There were 10 stimulus presentations at each wavelength in each repetition of the protocol.

ABX Discrimination. In the third phase adjacent stimuli from the naming task were presented sequentially in "ABX" triads. By the ABX procedure, each pair of adjacent stimuli on the continuum is made into a triad in which the third stimulus is always a replication of one of the first two. There are four such triads possible; ABA, ABB, BAA, and BAB. The S is instructed to press one of two buttons to indicate whether the third stimulus is identical to the first or to the second stimulus. Each of the possible triads was presented six times, according to a random protocol, yielding a total of 24 comparisons of each stimulus pair. The stimulus duration during this phase was again .75 sec. Stimulus onsets occurred at 3 sec. intervals within triads. Triad onsets occurred at 19.5 sec. intervals.

Sweep Discrimination Post-test. The final phase consisted of a replication of the first phase in which the S depressed a telegraph key to report the slightest hue change as the wavelength values were gradually altered from the shorter to the longer wavelengths and back again.

The temporal sequencing of the various phases was as follows: Sweep Discrimination I -- $Break_1$ -- Labelling -- $Break_2$ -- ABX Discrimination (1st 1/2) -- $Break_3$ -- ABX Discrimination (2nd 1/2) -- $Break_4$ -- Sweep Discrimination II. The times for each phase were as follows: Sweep Discrimination I - 15 min.; Labelling - 1 hr.; ABX Discrimination - 2 hrs. each half; Sweep Discrimination II - 15 min. Breaks were 15 min. in length except for $Break_2$ and $Break_3$ for English Ss which were 24 hr. in length.

RESULTS

The test-retest procedure of collecting labelling judgments provided a check on the reliability of labelling category boundaries. It was found (Table I) that among English Ss the differences between boundaries from Test 1 to Test 2 were bidirectional and averaged 2 to 4 mμ, much less than the standard deviation of boundaries within each test. In English Group I there were 50% plus changes and 50% minus changes. In English Group II there were 42% plus changes, 25% minus changes, and 33% zero changes. Tzotzil Ss, however, evidenced shifts consistently in a negative direction with an average magnitude of 10 mμ - much larger than the standard deviations of boundaries within tests. There seems to

Table I

Individual Labelling Category Boundaries, Group Means, and Standard Deviations for Labelling Tests 1 and 2

English I	Labelling 1					Labelling 2				
Boundary	MR	AA	SF	$\overline{X}$	σ	MR	AA	SF	$\overline{X}$	σ
Violet-Blue	433	445	443	449	5.3	430	440	441	437	5.0
Blue-Green	489	493	506	496	7.3	491	484	505	493	9.4
Green-Yellow	555	570	562	562	6.1	560	571	559	563	5.4
Yellow-Red	607	606	599	604	3.6	594	608	604	602	5.8
Tzotzil	**Labelling 1**					**Labelling 2**				
Boundary	Mar.	Gat.	Pet.	$\overline{X}$	σ	Mar.	Gat.	Pet.	$\overline{X}$	σ
/ik'loan/-/yox/	457	457	468	461	5.2	453	455	459	456	2.5
/yox/-/k'on/	527	524	539	530	6.5	507	510	522	513	6.5
/k'on-/ȼoh/	613	600	601	605	5.9	601	595	597	598	2.5
English II	**Labelling 1**					**Labelling 2**				
Boundary	SN	PS	JL	$\overline{X}$	σ	SN	PS	JL	$\overline{X}$	σ
Violet-Blue	449	443	430	441	7.9	447	446	429	441	8.3
Blue-Green	495	489	498	494	3.7	496	489	498	494	3.9
Green-Yellow	551	559	571	560	8.2	554	561	568	561	5.7
Yellow-Red	608	593	610	604	7.6	608	596	610	605	6.2

be no ready explanation for this obvious tendency for category boundaries to shift toward shorter wavelengths among Tzotzil Ss. It is true that dark adaptation during testing was not controlled, but dark adaptation would not explain the shift adequately.[3]

It is probable that the shift toward shorter wavelengths among Tzotzil Ss represents a trend toward a steady state and that, with extended testing, the Tzotzil data would stabilize, shifts in category boundaries then occurring according only to the vagaries of sampling. Because of the settling trend in the Tzotzil data, examination of labelling patterns and comparisons between labelling and discrimination were undertaken exclusively with the data from labelling Test 2 for both English and Tzotzil Ss.

Individual data are presented for all Ss in Figs. 4 - 12. It can be seen that labelling gradients are orderly for all Ss and tend to be associated with longer latencies in the region of their intersections. This is commensurate with previous findings in categorical perception experiments and replicates Beare's finding of a similar relationship between latency and labelling probability for spectral hues.

Gradient intersections for English speaking Ss divide the spectrum at approximately 440, 495, 560, and 605 mμ. These data compare very well with Beare's data and the data of Boynton and Schaefer for the same hue label boundaries. The intersections in the Tzotzil data divide the spectrum at about 455, 510 and 600 mμ putting one boundary in the middle of the English blue category, the second well into the green, and the third at the English red-yellow boundary. If we treat gradient

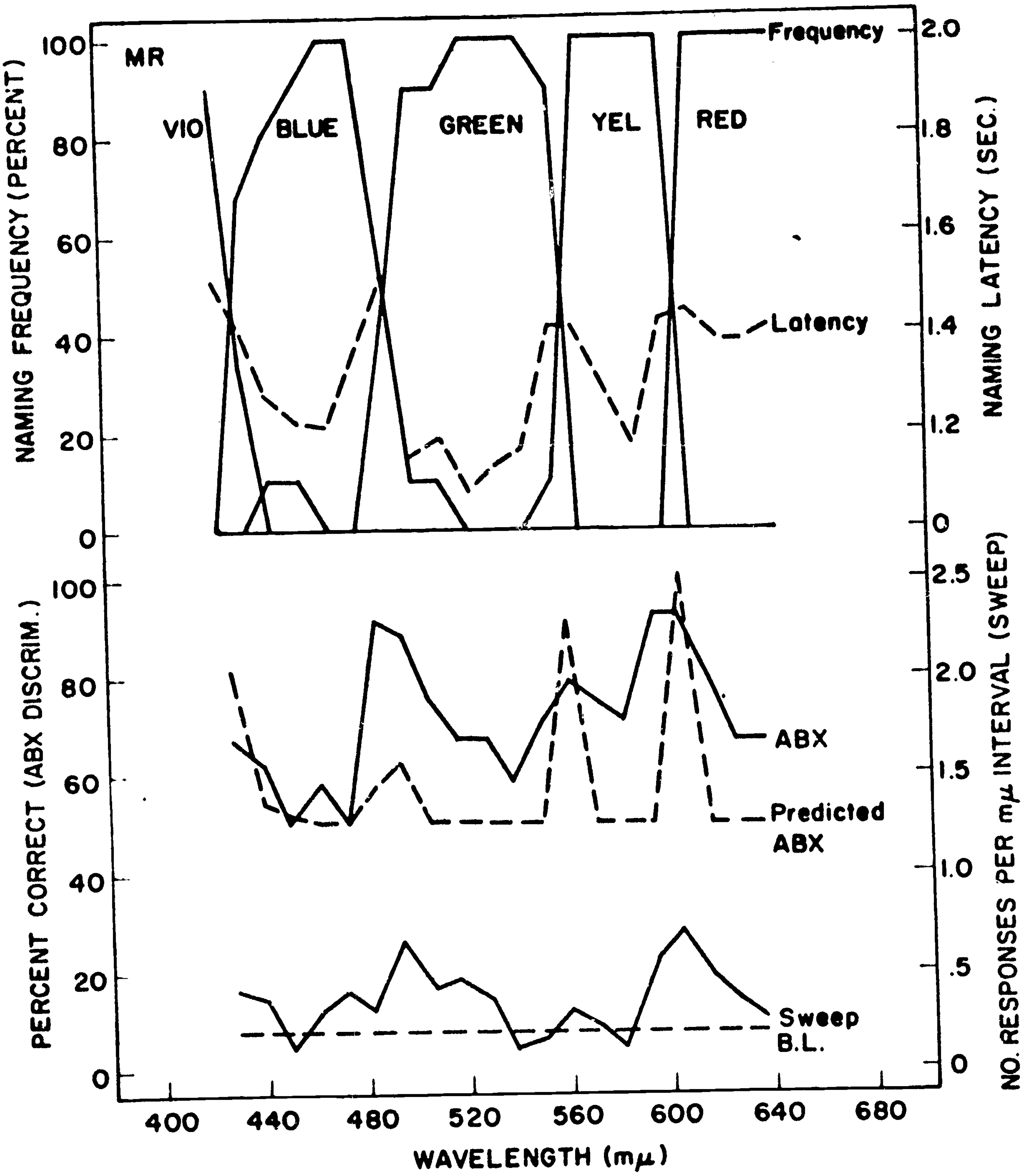

Fig. 4. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for MR, English Group I.

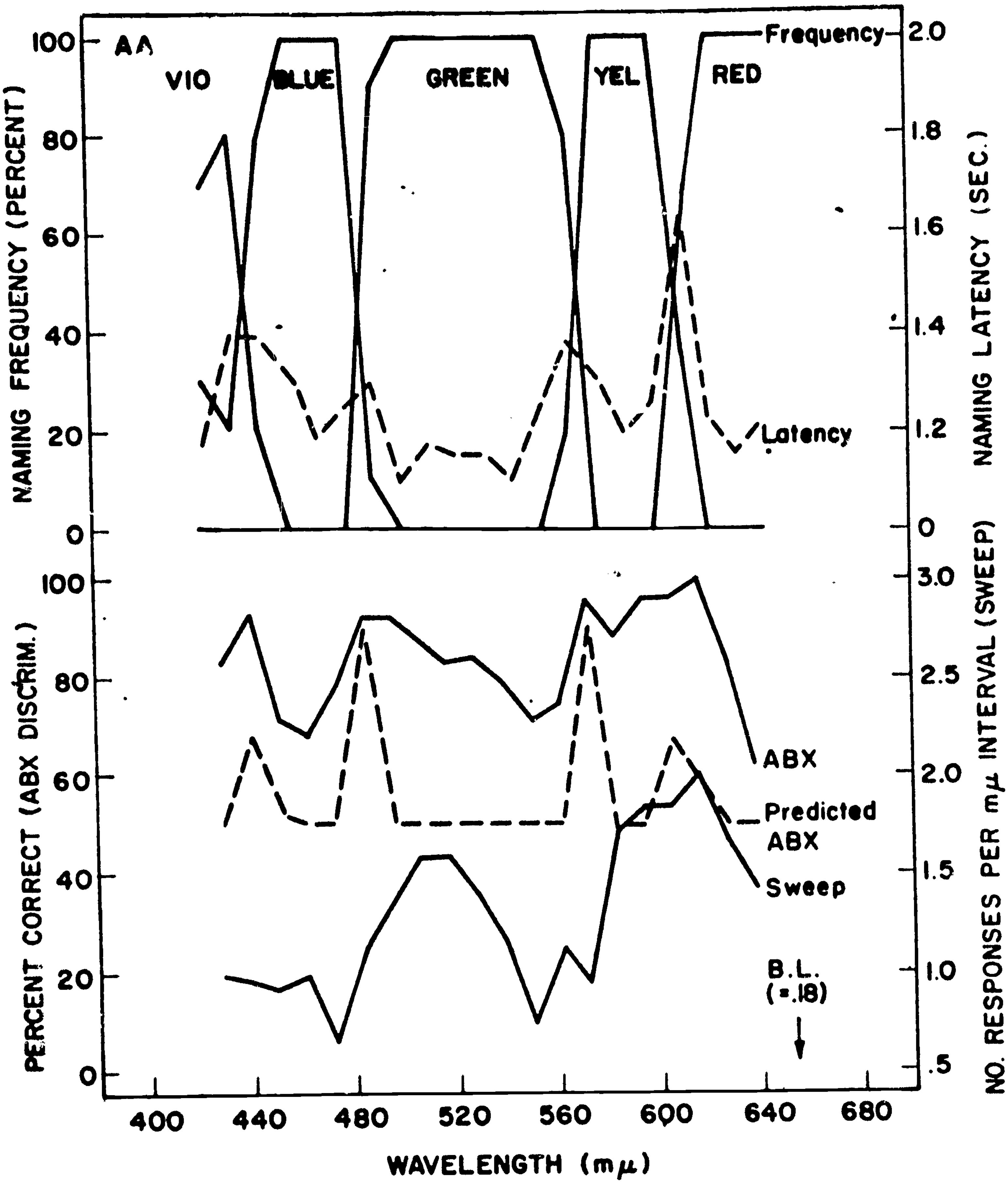

Fig. 5. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for AA, English Group I.

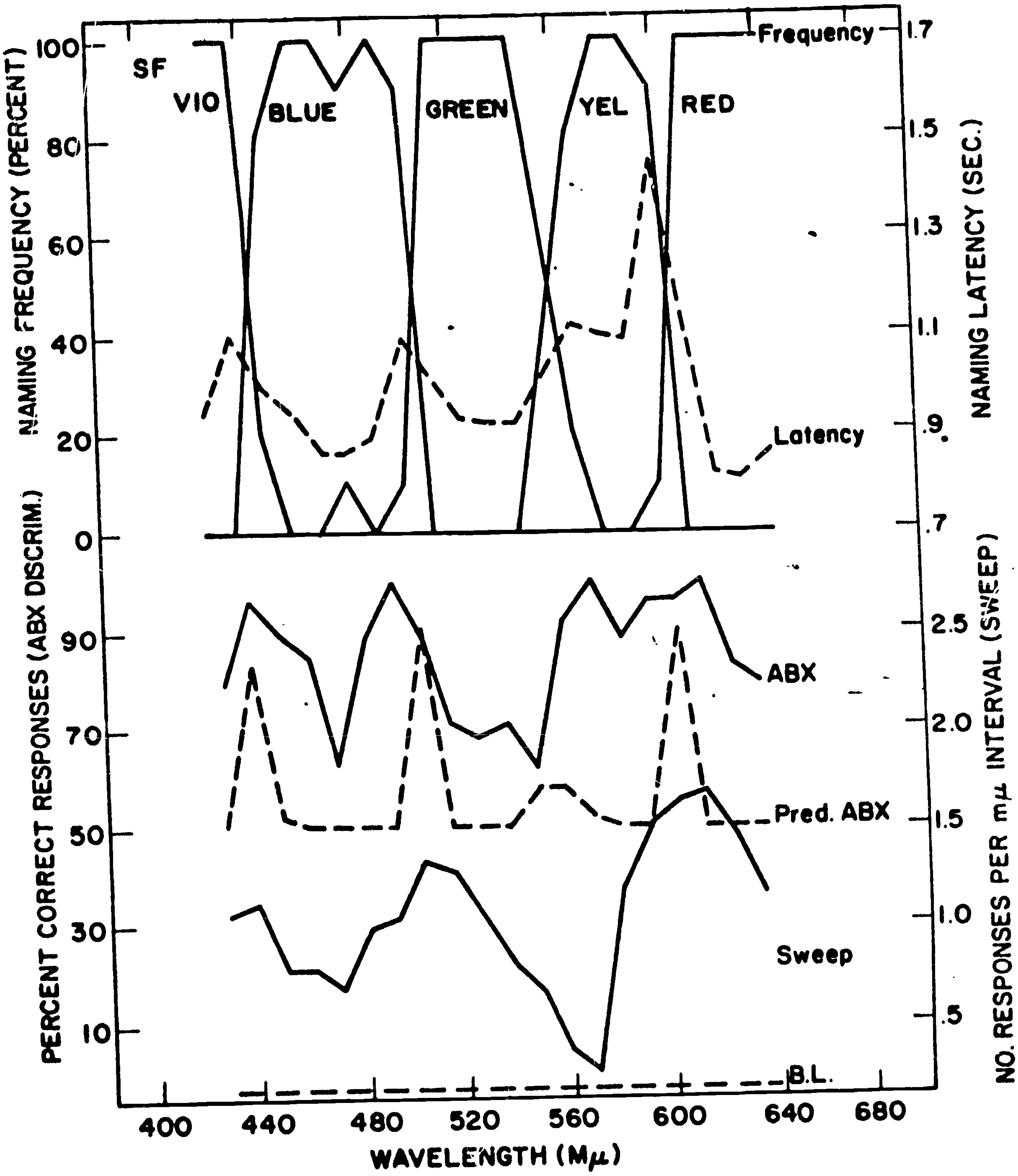

Fig. 6. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for SF, English Group I.

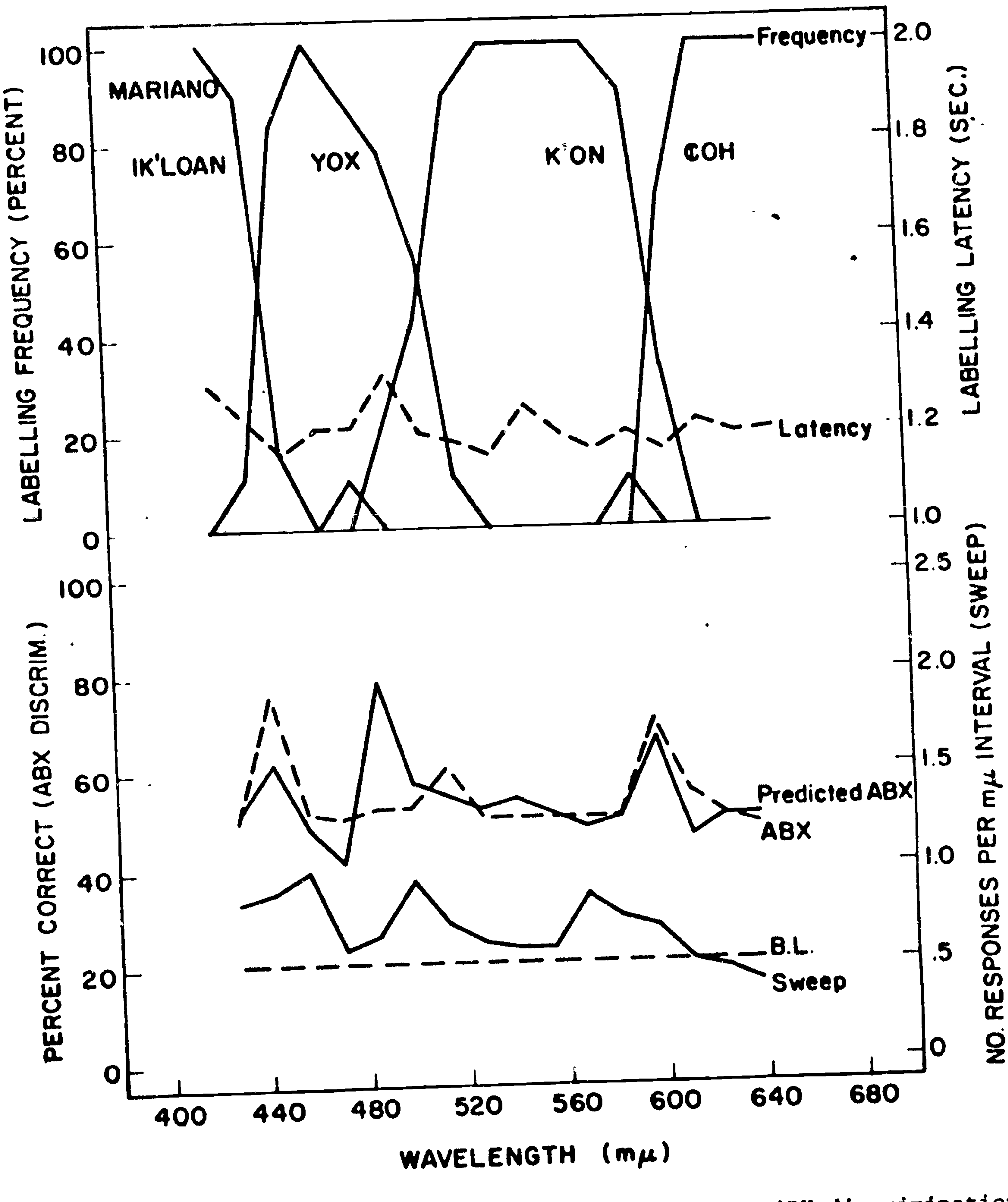

Fig. 7. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for Mariano, Tzotzil Group.

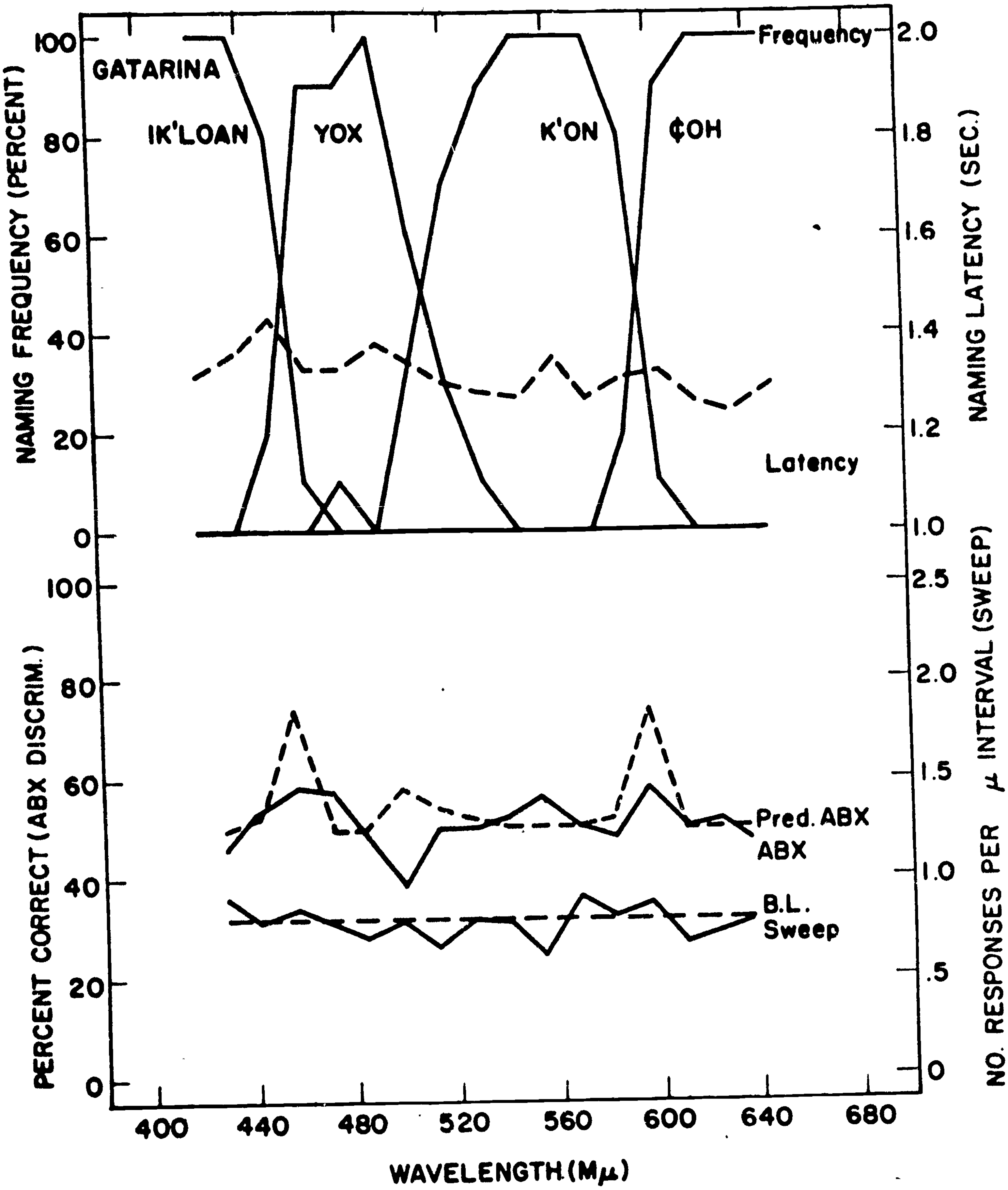

Fig. 8. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for Gatarina, Tzotzil Group.

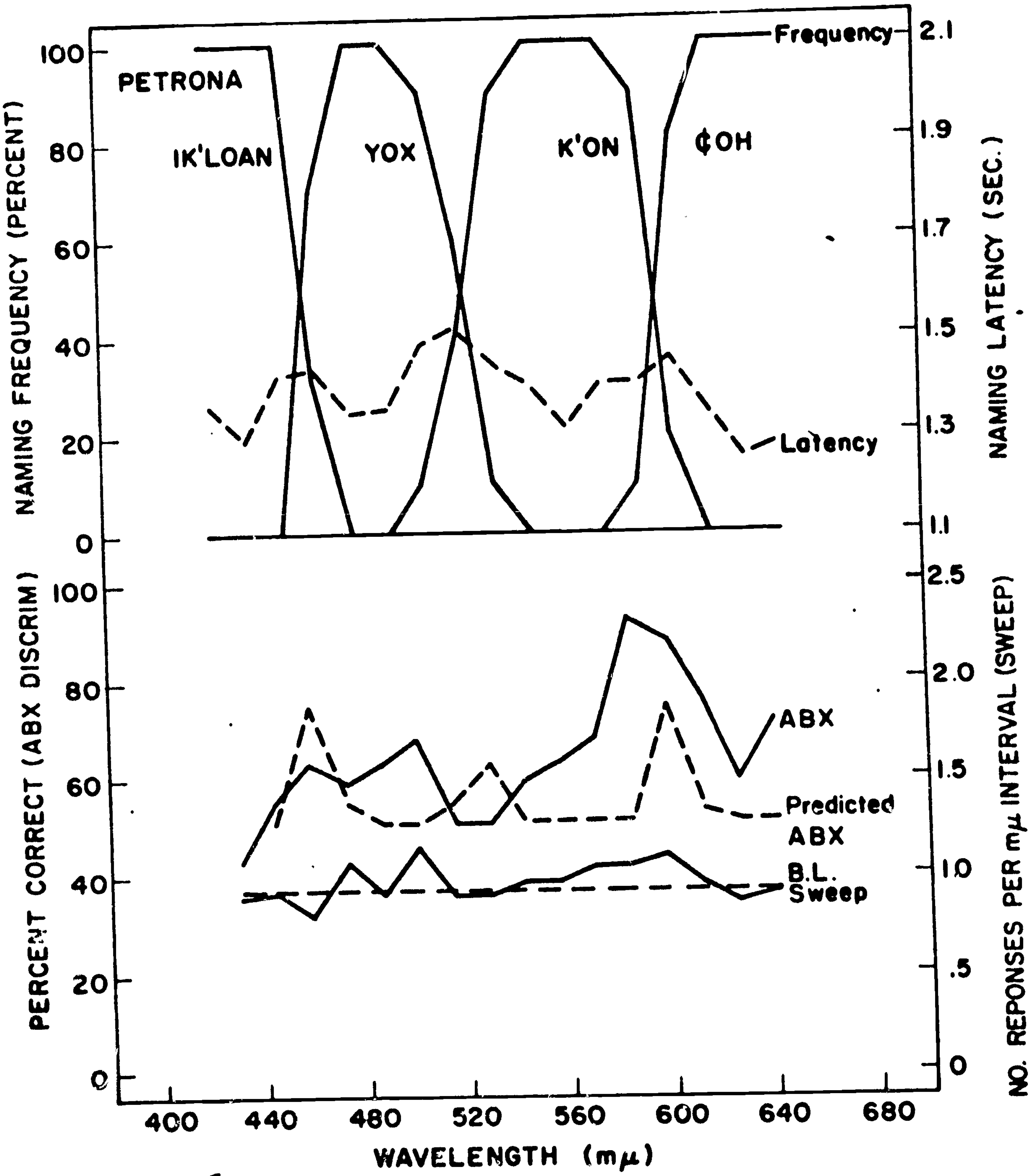

Fig. 9. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for Petrona, Tzotzil Group.

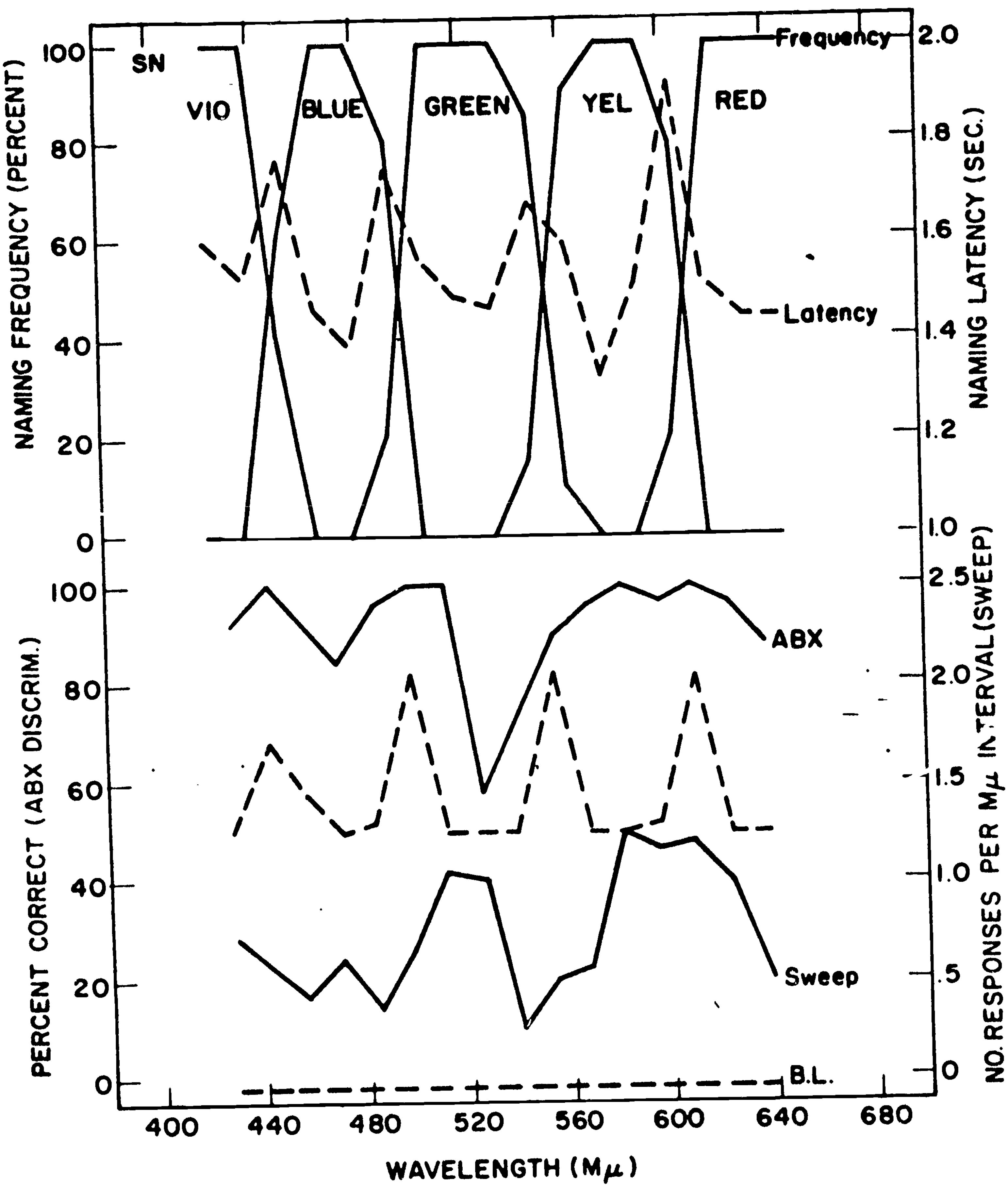

Fig. 10. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for SN, English Group II.

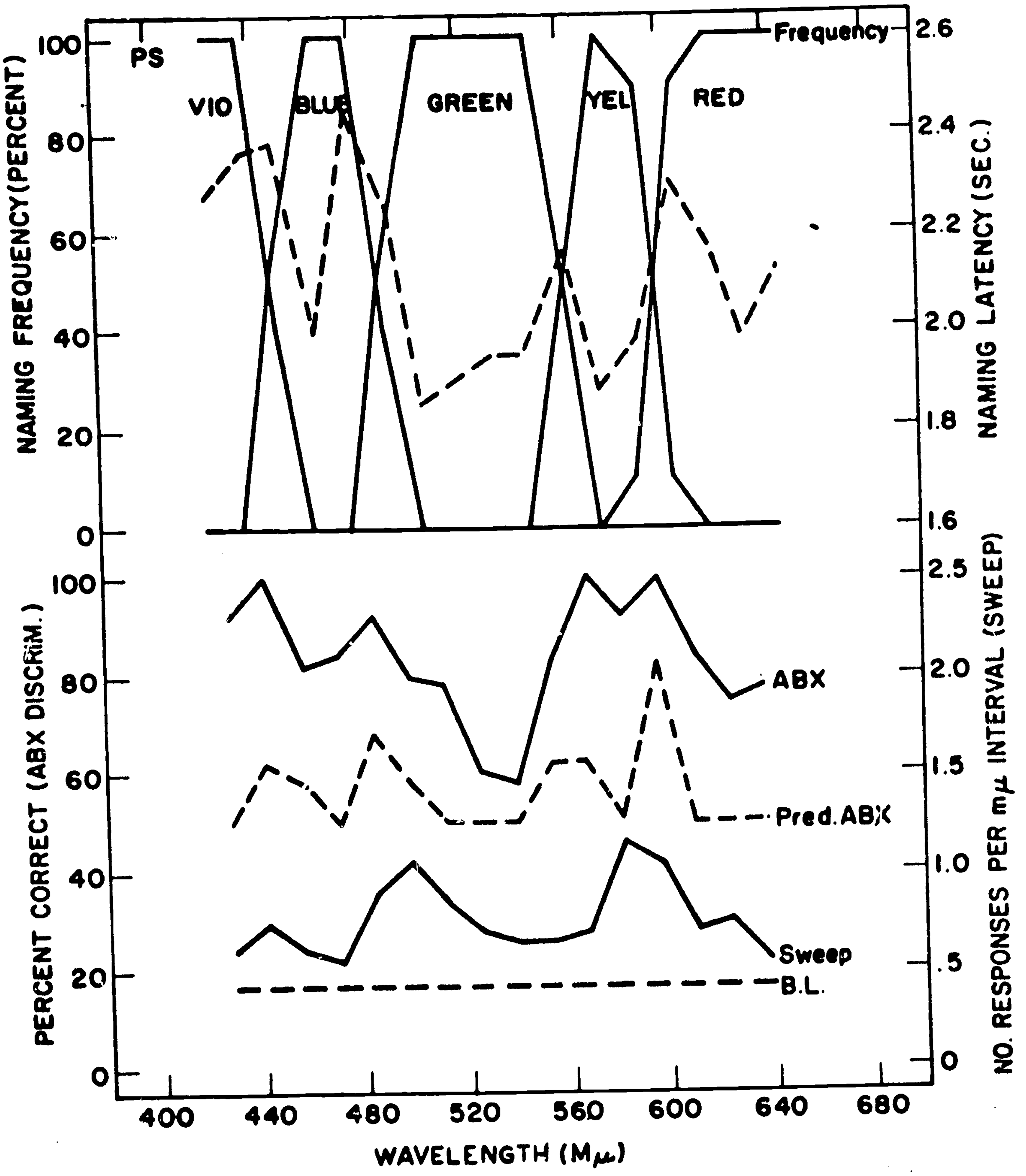

Fig. 11. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for PS, English Group II.

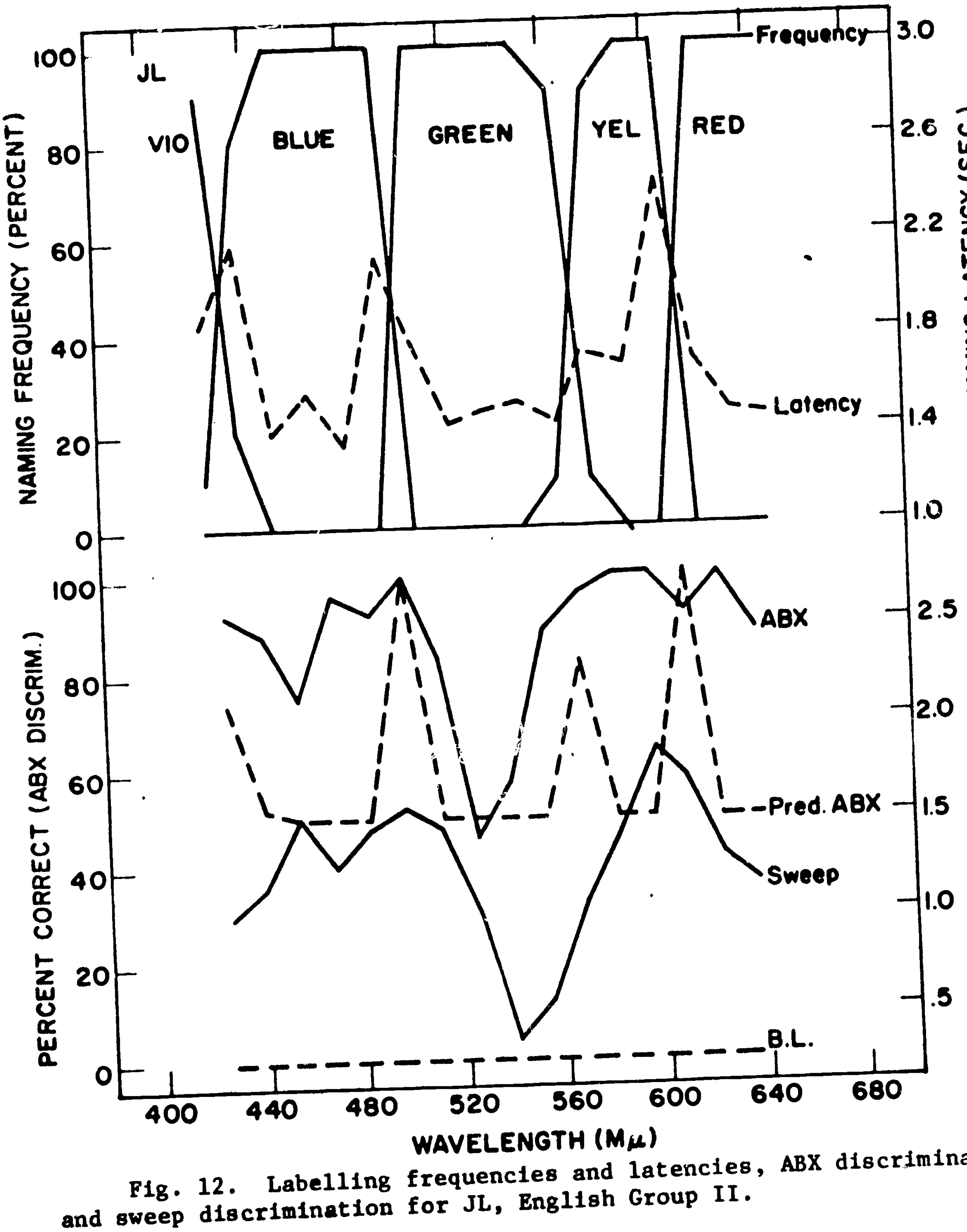

Fig. 12. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination for JL, English Group II.

intersection points for individual Ss as scores, a t-test for significance of difference between group means puts the probability that the two divergent Tzotzil means are chance deviations from their nearest neighbor among the English means at less than 5 in 100 (t = 2.71 and 2.40 with seven degrees of freedom for the first and second respectively).

Boundaries in both sets of data are matched by peaks in the ABX discrimination functions. English Ss exhibit four areas of enhanced ABX discrimination at points within a few mμ of category boundaries. Tzotzil Ss evidence three peaks, each of which is also closely associated with a category boundary.

In order to check on the reliability of the hue discrimination functions, it would be advantageous to compare the overall discrimination values to some baseline value. This value would indicate at what level the discrimination measures would be irrespective of whether the discrimination behavior was actually under the control of wavelength changes. For the ABX task this baseline is easily determined; it is 50%, the number of correct discriminations an S might be expected to make if he were simply guessing after each stimulus comparison. In the sweep discrimination situation, a similar baseline may be derived by counting the number of responses emitted during the brief "dead" periods at the end of each sweep, at which time the filter was motionless while the drive mechanism was reversed. The number of responses during this period, divided by the mμ change which would have occurred had the wedge actually been moving, constitutes a "false positive" score representing the rate of responding which would have occurred had the key press behavior not been under stimulus control.

Obtained overall discrimination values are compared to baseline values for both the ABX and sweep tasks in Table II (sweep baselines are also plotted in Figs. 4 - 12 as horizontal dashed lines labelled B.L.). It can be seen that in all cases but one the overall discrimination values are well above baseline values for both the ABX and sweep tasks. The exception is Gatarina, the oldest Tzotzil S, whose discrimination functions resemble neither the other two Tzotzil, nor the English functions. The eccentric form of the discrimination functions for this S and the near baseline level of her overall discrimination performance in both tasks suggest that these discrimination data are probably under the control of task variables, such as instructions, attention, etc., and do not reflect some unique pattern of differential discrimination.

For reliable Ss in both groups, the sweep discrimination function is less orderly but tends to replicate the ABX function. In the case of two English Ss (SF in English Group I and PS in English Group II) the yellow - green peak is missing in the sweep discrimination function. There seems to be no ready explanation for this except to note that the English "yellow" category is quite narrow and that perhaps the free response pattern inherent in the sweep task leads to an "overflow" of responses from one area of enhancement to another essentially fusing into one peak what, in the ABX data, is obviously two peaks.

Subsets of individual sweep discrimination data are too irregular to allow graphic comparison of sweep discrimination data before and after the labelling and ABX phases or comparison of the ascending and descending sweep sequences. Therefore, pre-test versus post-test and ascending versus descending differences are compared statistically by means of rank-difference correlations. Table III shows that these

Table II

Mean Overall Obtained and Baseline Discrimination

Values for Individual Subjects

		ENGLISH I			ENGLISH II			TZOTZIL		
		MR	AA	SF	SN	PS	JL	MAR.	GAT.	PET.
ABX (% correct)	Obt.	.71	.84	.84	.92	.84	.87	.54	.51	.63
	B.L.	.50	.50	.50	.50	.50	.50	.50	.50	.50
Sweep (No.responses)	Obt.	.34	1.04	1.03	1.45	.76	1.22	.63	.77	.94
	B.L.	.20	.18	.22	.70	.42	.25	.50	.80	.92

Table III

Rank Difference Correlation Coefficients for Subsets

of the Sweep Discrimination Data

	ENGLISH I			ENGLISH II			TZOTZIL		
	MR[1]	AA	SF	SN	PS	JL	MAR.	GAT.	PET.
Pretest vs. Post-test	-	.84*	.84*	.75*	.47	.73*	.73*	.80*	.85*
Ascending vs. Descending	.03	.54	.56	.53	.55	.49	-.22	-.10	-.40

[1]This subject had already been tested for labelling and ABX discrimination at the time the sweep discrimination technique was added to the experiment. Pretest data are therefore not available.

* $P < .005$

correlations are high and positive for pre-test and post-test sweep discriminations indicating that the effects of interpolating labelling and ABX discrimination tasks between sweep discrimination sessions is negligible. Ascending and descending sweeps tend not to be so highly correlated. This is to be expected since differences of this sort are characteristically observed whenever sequential presentation methods are used in psychophysical experiments. It is evidently necessary in the sweep discrimination task, as it is in threshold and equisection experiments, that both ascending and descending sequences be presented and the data then averaged in order to eliminate effects due to perseveration, adaptation level, etc.

A comparison of obtained and predicted ABX values is presented for individual Ss in Figs. 4 - 12. The rationale for predicting ABX discriminations from labelling probabilities is given by Liberman, et al. (1957). Predicted ABX values can be calculated from labelling probabilities on the assumption that Ss label stimuli in the ABX situation just as they do on the labelling task. When two stimuli (A, B) have identical labelling probabilities, the prediction is that they will only be discriminated by chance ($p\ corr_{AB} = .50$). When two stimuli are always labelled differently the prediction is that they will always be discriminated ($p\ corr_{AB} = 1.0$). The general expression for predicting ABX probabilities is:

$$p\ corr_{AB} = .5 + \frac{[(p\ R_1 - p'R_1) + (p\ R_2 - p'R_2) + (p\ R_3 - p'R_3) + \dots + (p\ R_n - p'R_n]}{4}$$

Where p corr$_{AB}$ = The predicted relative frequency of correct discriminations between stimuli A and B.

p R_n = The relative frequency with which a given labelling resp 'se (R_n) is assigned to stimulus A.

$p'R_n$ = The relative frequency with which a given labelling response (R_n) is assigned to stimulus B.

From Figs. 4 - 12 it can be seen that the form of the predicted ABX functions tends to follow the form of the obtained functions. In general the predicted ABX values are somewhat less than the obtained ABX probabilities. This is in line with the findings from most categorical perception experiments (Liberman, et al., 1957; Liberman, Harris, Eimas, Lisker, & Bastian, 1961; Cross & Lane, 1964; discussed in detail by Lane, 1965).

DISCUSSION

From the above data these facts emerge.

There is a direct relationship between hue labelling and hue discrimination for Indo-European <u>Ss</u>. Discrimination is not as good between stimuli that are labelled the same as it is between stimuli that are labelled differently and boundaries between hue label regions are associated with areas of enhanced hue discrimination. This confirms the relationship, noted by Lane, between Beare's data and the typical Indo-European hue discrimination function. It also confirms Ekman's observation that there are four areas of enhanced discrimination in the Indo-European function and that this is what would be expected on the basis of what we know about the similarity relations among hues.

American English Ss and Zinancantan Tzotzil Ss have dramatically different hue labelling patterns. The Tzotzil system divides the spectrum at a point in the middle of the English blue region, at a point somewhat short of the middle of the English green region, and at a point close to the English red-yellow boundary. The label /¢oh/ corresponds essentially to the English "red"; /k'on/ includes yellow and much of the green; /yox/ includes the shorter wavelength green and the longer wavelength blue; /ik'loan/ covers the shorter wavelength blue and all of the violet. This differs slightly from Collier's suggested translations of the Tzotzil labels in which /¢oh/ corresponds to red; /k'on/ to orange and yellow, /yox/ to blue and green; and /ik'loan/ to violet. The precision with which Ss in both groups assign color labels to spectral stimuli is astonishing (Table I). Within each of the two English groups the standard deviations of labelling boundaries range from about 4 to 9 mμ. Within the Tzotzil group they range from only 2 to 6 mμ. If the stimuli were musical tones instead of hues this might be analogous to finding entire populations with perfect pitch.

The relation between hue labelling and discrimination is not as well defined for the Tzotzil as it is for the English but the tendency is for there to be three peaks in the Tzotzil discrimination functions corresponding to three category boundaries in the labelling distributions. But, while the form of the discrimination functions between the two groups is obviously different, indicating that they are probably not based on a common physiological mechanism, the absolute relationships between category boundaries and correlated discrimination peaks is not as clear-cut as one might wish. There are observable disparities between category boundaries and points of discrimination enhancement in the discrimination functions for both groups. This is especially true for the Tzotzil Ss in the case of the /yox-k'on/ boundary, where the discrimination peak tends to be displaced on the order of 20 mμ towards the shorter wavelengths.

It is difficult to reconcile these displacements within the structure of the categorical perception paradigm since there is no provision in theory for the occurrence of peaks where there are no labelling boundaries and, conversely, for the existence of boundaries for which no peak exists. However, disparities between the locations of peaks and boundaries is not uncommon in categorical perception data especially in the case of individual Ss (see, for example, Liberman et al., 1957, p. 361; Liberman, et al., 1961, p. 384). Such deviations from perfect congruence are not usually troublesome as long as it can be shown that a peak in fact occurs.

For purposes of the present study, such deviations may be more troublesome than in the simple categorical perception experiment since a "renegade" peak could locate in the vicinity of a category boundary which is delineated by the labelling functions from the other language group. This tends, in fact, to be the case with the middle peak in the Tzotzil discrimination function which is located in the general vicinity of the English blue-green boundary.

In order to judge the extent to which disparities between discrimination peaks and labelling boundaries might be somewhat more than just occasional, it would be desirable to have a quantitative measure of the extent to which the apparent correspondences between category boundaries and discrimination peaks across groups characterizes the data as a whole. One such measure may be obtained by counting the number of instances in which category boundaries are associated with areas of discrimination enhancement (and non-enhancement) and comparing these frequencies within and across groups. The frequency with which matches between discrimination enhancement and category boundaries occur should be good within each group and poor between groups.

The results of such an analysis applied to the present data are shown in Table IV. It can be seen that for both ABX and sweep discrimination within groups there are consistently more instances of enhancement than non-enhancement at category boundaries. Across groups, at least as far as ABX discrimination is concerned, in all cases there are fewer instances of enhancement and more of non-enhancement. These results lend validity to the conclusion based on visual comparison, that hue discrimination is different across the two language groups in line with the observed differences in labelling behavior. On the other hand, in the case of sweep discrimination across groups, a rather disquieting effect is observed. The English sweep discrimination function is as good if not slightly better a match to the Tzotzil labelling boundaries than is the Tzotzil sweep discrimination function. The probabilities of enhancement and non-enhancement for sweep discrimination when the English function is compared to Tzotzil boundaries (.70 and .30 respectively) are almost the exact reverse of the ABX values for the same comparison (.33 and .67 respectively). Upon closer examination, it can be seen that this reversal is due almost entirely to the increased frequencies of enhancement in the English function near the Tzotzil /yox-k'on/ boundary (513 mμ). Inspection of individual English sweep discrimination function reveals that this increase results from the fact that in all but one case there is a shift in the English blue-green discrimination peak toward slightly longer wavelengths during the sweep discrimination task.

The exact cause of the shift as well as the contrary displacement of the middle Tzotzil peak away from its associated category boundary cannot be determined on the basis of the present data. It could be that the shifts represent random or systematic perturbations which are

Table IV

Relative Frequency of Discrimination Enhancement and Non-Enhancement for Individual Hue Discrimination Functions at Group Labelling Boundaries[1]

	Bdry.	Average (mμ)	ENGLISH ABX Enhan.	ENGLISH ABX Non-Enhan.	ENGLISH Sweep Enhan.	ENGLISH Sweep Non-Enhan.	TZOTZIL ABX Enhan.	TZOTZIL ABX Non-Enhan.	TZOTZIL Sweep Enhan.	TZOTZIL Sweep Non-Enhan.
English	V-B	439	6	0	5	1	1	1	1	1
	B-G	494	6	0	4	2	2	0	2	0
	G-Y	562	6	0	3	3	1	1	1	1
	Y-R	605	5	1	5	1	0	2	1	1
	f		23	1	17	7	4	4	5	3
	p		.96	.04	.70	.30	.50	.50	.62	.38
Tzotzil	I-Y	456	2	4	2.5	3.5	1.5	.5	1	1
	Y-K	513	1	5	6	0	0	2	1	1
	K-₵	598	3	3	4	2	2	0	2	0
	f		6	12	12.5	5.5	3.5	2.5	4	2
	p		.33	.67	.70	.30	.58	.42	.67	.33

[1]A change in a negative direction both ways from a data point is taken as an instance of enhancement. A change in a positive direction both ways is taken as an instance of non-enhancement. Entries indicate the frequencies with which labelling boundaries occur closest to a point of enhancement or non-enhancement. Fractional frequencies result from the occurrence of occasional ties.

due to a fundamental flaw in the methodology of the experiment and which could subsequently be eliminated. Perhaps, on the other hand, there is some other factor operating in the discrimination of hue in the region of 500 mμ and discrimination peaks in both English and Tzotzil at this point represent the results of language history confounded with the effects of some other variable. It could be, in fact, that in this one region of the spectrum retinal physiology competes somehow with categorical perception as the controlling variable in hue discrimination.

Another question which cannot be ignored in the light of the observed differences between English and Tzotzil Ss is that of color blindness. Why couldn't it be that the Tzotzil are clinically defective rather than culturally different with respect to the labelling and discrimination of hues?

The Tzotzil are certainly not color blind in the sense that there are gross retinal defects of the sort operating in the cases of the three most common clinical diagnostic categories: deuteranopia, protanopia, and tritanopia. These defects, known to be physiological in origin from studies of individuals color blind in one eye only--(Sloan and Wollach, 1948; Graham & Hsia, 1958), are characterized by gross confusions at points widely separated on the visible spectrum. Discrimination enhancement in these cases is observed at only one spectral locus (approx. 500 mμ), a region in which a grey or neutral zone occurs and in which the discrimination is, thus, between hue and no hue. The Tzotzil evidence discrimination enhancement at three regions, regions where it is impossible for the clinically diagnosed color blind individual to discriminate differentially. In addition, Collier, administering the Farnsworth - Munsell 100 hue test, found no difference between Tzotzil and normal English in their ability to order color stimuli along the spectrum. This is a finding clearly at odds with a color-blindness interpretation of Tzotzil discrimination patterns.

Could it be that the Tzotzil are partially color blind, or to use the clinical term, color anamalous? Again the data suggest not. The three Tzotzil are quite unanimous in their placing of category boundaries; and the two reliable discrimination functions are identical. This implies that, if a defect exists, all three Ss are similarly afflicted. Now, in a random sample of Indo-Europeans, the most common color defect (deuteranomoly or incomplete deuteronopia) occurs in about 40 out of 1000 males and 3 out of 1000 females (von Planta, 1928; Wieland, 1933). The probability of sampling three individuals all with this most common defect in a random selection of one male and two female Indo-Europeans is .040 x .003 x .002 = .00000024 or a little better than 2 chances in 10 million. The probability would be even smaller given some other color defect and smaller yet given that the Ss are not Indo-European. Studies of non-Indo-European Ss have consistently reported incidences of color defects to be very much below that among Indo-Europeans (Garth, 1933; Geddes, 1946; Chan & Mao, 1950; Applemans, Weyts & Vankan, 1953).

Taking into account the fact that there is some overlap between language groups with respect to both labelling and discrimination but that there is no consistent correlation between them, we may aspire to parsimony and answer our original queries as follows:

1) Hue labelling and hue discrimination do seem to be related in the manner suggested by the Beare and Laurens & Hamilton data for both English and Tzotzil Ss.

2) The claim that there are differences in the hue labelling patterns of English and Tzotil is confirmed.

3) It may then be deduced, and seems to be empirically the case, that hue discrimination patterns are different for English and Tzotzil.

These results may be taken as evidence in favor of the suggestion that categorical perception operates along the visible spectrum. There are certain inconsistencies with regard to the relation between labelling and discrimination for both groups and because of this we may not be absolutely certain that there is not some effect on hue discrimination at certain spectral locations which is due to factors other than language history. Nonetheless it seems safe to say that categorical perception is in evidence and that there are differences across groups with respect to hue naming and the discrimination of hues. These observations lend validity to the Whorfian hypothesis as it is rendered in this report. The suggestion is that individuals whose language community dictates a specific pattern for the naming of hues will discriminate well only between color stimuli for which there exist different names. This means that when hue labelling patterns differ from culture to culture, hue discrimination patterns will differ and individuals in the two groups will perceive hues differently. In such an instance the old tag-line is reversed to read "I sees 'em the way I calls 'em."

Of special pertinence to the Whorfian hypothesis is the fact that, in the present study, differential discriminability obtains in the continuous sweep discrimination as well as the pair-comparison (ABX) situation. In the ABX task, it could be said that discrimination enhancement is the result of coding; stimuli are labelled when they are presented and once labelled can be "forgotten" by the S. Discrimination is subsequently made between stimulus labels. When the labels are the same, correct discriminations are generally left to chance. It is only when a S can label stimuli differently that he begins to discriminate them. It follows from this that, in the ABX task, points along a continuum where there is some probability of different stimulus labels being used will be associated with enhanced discrimination.

In the sweep discrimination situation, however, opportunities for coding are minimized; stimulus changes are continuous and instantaneous; there is no occasion for the stimulus to be forgotten. And yet the same patterns of differential discrimination develop. The sweep discrimination function is pretty much the same as the ABX function. This result is much more dramatic in the Whorfian context than the simple observation of covariation between discrimination and labelling. It suggests that perceptual patterns, initially shaped by language habits, are not at all times directly mediated by language and that they will be maintained when language responses are minimized or eliminated from the perceptual situation. The finding of permanent patterns of perception, generated through a specific linguistic history, and therefore variable across cultures, is more in the spirit of the Whorfian dictum than the simple finding that perception is influenced by coding.

Notes

1. For a review of the early work see papers by Laurens and Hamilton, 1923; Judd, 1932.

2. Lane could have just as easily used other hue discrimination data since, as Ekman (1963) notes, most hue discrimination functions show four minima at about the same location on the spectrum.

3. Cone vision is obviously involved at the stimulus intensities used in this experiment. Since cone adaptation is complete in about 5 minutes and the length of the labelling task is on the order of one hour, the proportion of judgments which could be influenced by dark adaptation should be very small. Also, during dark adaptation, according to the properties of the Purkinje effect, category boundaries would be expected to move toward longer, not shorter, wavelengths. By the Purkinje phenomenon, the eye becomes differentially more sensitive to shorter wavelengths during dark adaptation and more instances of labels associated with the blue end of the spectrum would have to be emitted. This should have the effect of "swelling" the labelling categories forcing category boundaries toward the <u>long</u> end of the wavelength continuum--just the reverse of what occurs with the Tzotzil <u>S</u>s.

APPENDIX - Explanation of Figures

Fig. 1. Frequency distributions for six color names (R_A), distribution of qualifying responses (R_B) and mean judgment time for low intensities (105 db re: 10^{-10}L). From Beare (1963).

Fig. 2. Observed distributions of discrimination accuracy, identification probability and latency for a series of synthetic speech stimuli constructed by varying the temporal relations of formant frequencies. The dark dots represent naming frequencies, solid lines = /do/, dashed lines = /to/. The light dots represent ABX discrimination (upper left) and labelling latencies (upper right). The naming distributions are shown twice for ease of comparison. From Lane (1966).

Fig. 3. Comparison of hue labelling and discrimination data obtained by independent investigators. Adapted from Beare (1963) and Laurens and Hamilton (1923). From Lane (1966).

Figs. 4 - 6. English Group I. Labelling frequencies and latencies, ABX discrimination, and sweep discrimination functions for individual Ss. The number of observations per point are 10, 10, 24 and 40 (20 for MR for which there was no Sweep I phase) for each function respectively. Included also are ABX discrimination values predicted from labelling values as well as baseline (B.L.) sweep discrimination values based on the number of responses emitted between swe ps. (See text.)

Figs. 7 - 9. Tzotzil. Labelling frequencies and latencies, ABX discrimination and sweep discrimination functions for individual Ss. The number of observations per point are 10, 10, 24, and 40 for each function respectively. Included also are ABX discrimination values predicted from labelling values as well as baseline (B .) sweep discrimination values based on the number of responses emitted between sweeps. (See text.)

Figs. 10 - 12. English Group II. Labelling frequencies and latencies, ABX discrimination and sweep discrimination functions for individual Ss. The number of observations per point are 10, 10, 24, and 20 for each function respectively. Included also are ABX discrimination values as well as baseline (B.L.) sweep discrimination values based on the number of responses emitted between sweeps. (See text.)

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