THE EFFECTS OF SOUND ON COLOR INTENSITY PERCEPTION

by

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UNITED STATES AIR FORCE ACADEMY
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ABSTRACT

Sensory interaction occurs when the response elicited by a sense modality due to a specific stimulus is significantly affected by the simultaneous stimulation of that sensory system by any other sense modality in the body. This experiment is concerned with the interaction of audition and vision where the auditory conditions consist of no sound, pleasant sound, and unpleasant sound (as judged by the subject), and the visual conditions consist of equal intensity judgments on red, green and blue lights against a white standard. The data from thirty subjects are discussed including main effects and interaction of experimental conditions. The hypotheses concerning the differential sensitivity of the dark-adapted eye to red, green and blue colored lights are confirmed. The hypotheses concerning the influence of audition on vision are not confirmed. The potential influence of the reticular activating system is discussed in light of these findings.

I. INTRODUCTION: PREVIOUS RESEARCH

Design specialists typically consider the complex involvement of man's sensory and motor systems when making decisions concerning the placement of man in machines. Certainly, modern equipment designs place a number of highly involved demands on their operators from both a sensory and a motor viewpoint. Too often, designers are forced to consider the interactive potentials of man's senses as unimportant because of a lack of research data to apply to the problem. Perhaps this type of research will lead to a more adequate collection of data to apply to design problems.

Sensory interaction has been a subject of intensive study by Russian researchers since the early 1930's. In general, they have explored the subject area much more thoroughly than their Western counterparts. The lack of attention to this important area of sensory psychology is amply attested to by these words from Bartley (1958):

> Whereas it is the usual thing to deal with one sense modality at a time, it is not to be inferred that the senses are isolated and do not influence each other. In fact, even in experimental situations it is difficult or impossible to eliminate the operation and participation of senses collateral to the one under study. Often, when the participation of senses other than the one studied is recognized, it is taken to be negligible in its influence upon the experimental results. At other times, if not negligible, it is looked upon as something having constant influence, so that it can be taken as a "constant error." Be that as it may, all too little has been done by psychologists and other biologists directly to study sensory interrelations. Their study is the exception rather than the rule.

English and English (1961) define sensory interaction as "the mutual effect upon each other of sensing processes that are simultaneous: e.g., the size-weight illusion." Vision and audition are the two major input sources of information for man. The mutual effect upon each other of these normally simultaneous processes represents a critical area of concern for those interested in understanding man's interaction with his environment.

In London's (1954) review of the Russian literature dealing with auditory and visual interaction, several relationships seem to hold true. In particular, one relationship involved the central sensitivity of the dark-adapted eye which was found to be more sensitive under blue-green colors and auditory stimulation. Under orange-red lighting and the same auditory stimulation, the dark-adapted eye was less sensitive. The effect did not occur, however, under spectral extremes such as red, violet, and yellow. Other Russian data show that the illumination of a white room with green light increased auditory sensitivity, but that the same room illuminated with red light decreased auditory sensitivity.

Ogilvie (Bartley, 1958) studied the effect of auditory flutter on visual Critical Flicker Frequency (CFF) under four separate conditions of no noise, steady noise, in-phase noise, and out-of-phase noise. He found that noise caused a significant increase in CFF and that binocular CFF significantly increased when the subject was listening to a random noise fluttering in-phase with the flickering light. Kravlov (London, 1954), on the other hand, found that the effects of auditory stimulation on CFF depended upon the monochromatic nature of the light used. For example, under green lights, the CFF was reduced while under orange-red light the CFF was raised.

London's (1954) review concerning intersensory interaction revealed several important variables, such as the strength and the duration of the accessory stimulation as well as the time of measurement under the accessory stimulation. Of special significance for this study were the data concerning the affectivity of the accessory stimulus which indicated that the presentation of harmonious tones raised visual sensitivity to red and yellow light but lowered sensitivity to green and blue light. However, under the presentation of nonharmonious sounds, the above relationships were reversed.

Karwoski and Odbert (1938), in discussing chromesthesia, concluded in a similar fashion that perceived colors may fit the "mood" of the music, or its pleasantness, and that affectivity seems to cut across the perceptual figure and ground, setting up an affective figure and ground which is independent of the perceptual one. In a preliminary study of 274 college students, they found that 60% showed some tendency to associate color with short musical selections, and that subjects claimed to perceive more colors with classical music despite a preference for popular music.

II. PURPOSE OF THE STUDY

The purpose of this study was to investigate the Russian claim that harmonious and nonharmonious sound have differential effects on the perception of color intensity. The Russian literature is vague as to what actually constitutes harmonious and nonharmonious sound so that it was necessary to arbitrarily define this dimension. Assuming that harmonious sound would be identified as pleasant and nonharmonious sound as unpleasant, classical music, judged by the subjects as pleasant or unpleasant, was used as the auditory conditions. Subjects were required to set colored lights to a white standard under varying conditions of the sound dimension. It was hypothesized that the green light would be perceived as most intense, the red light next, and the blue light as least intense under "no sound" conditions. In addition, it was hypothesized that the differential sensitivity to the three lights would change under the sound conditions of "pleasant sound" and "unpleasant sound" as defined by this study and that sequential effects would be found.

III. SUBJECTS

The subjects were thirty Air Force Academy cadets (all male) chosen at random from the introductory psychology course at the Academy. All subjects were Caucasoid, between the ages of 18 and 22 years, and had normal hearing and vision (uncorrected) as specified by the flight surgeon. Participation in the experiment was voluntary with the scheduling of the adaptation and test period arranged at the convenience of the subjects.

IV. APPARATUS

The primary test unit consisted of two Lafayette Light Discrimination Apparatuses, Model 1701. Basically, this device presents two lights coming from a single source that can be varied in intensity by means of side mounted knobs. The single light source remains at a constant intensity in order to avoid variations in spectrum frequencies during changed light intensities. Light intensity is changed by the projection of the constant light source through a precisely tapered slit on a circular disc. The linearity of the scale was checked by the use of a photomultiplier tube. The scales were linear within the range used. The device uses a frosted white glass, one-inch light display. This light was used as the white standard. The colored lights were provided by the insertion of scientific filters (Kodal Wratten, 3-inch) inserted over the white displays. The filters used were Kodak Wratten F (No. 29), Wratten C5 (No. 47), and Wratten X1 (No. 11). Wratten No. 29 provides a bandpass above 600 millimicrons (reaching 90.5% transmittance at 700 millimicrons with a dominant frequency of 632.7); Wratten No. 47 provides a narrow bandpass from 440 to 520 millimicrons (reaching 50.3% transmittance at 440 millimicrons with a dominant frequency of 470.1); and Wratten X1 (No. 11) provides a broader bandpass peaking at approximately 520 millimicrons (reaching 60.2% transmittance at 520 millimicrons with a dominant frequency of 552.5).

Sound conditions were provided by controlled tapes played on a standard stereo recorder. The musical selections used were as follows:

"The Pines of Rome" - Respighi (NBC Symphony Orchestra)
"The Fountains of Rome" - Respighi (NBC Symphony Orchestra)
"The Rite of Spring" - Stravinsky (Paris Conservatory Orchestra)
"Cartridge Music" - Cage (Time Records)

V. METHOD

All Subjects (Ss) initially met as a group and completed a questionnaire designed to give an indication of an individual's prior experience with synesthetic phenomena. Then four classical, instrumental selections were played in the following order: (1) Pines of Rome, (2) Fountains of Rome, (3) Rite of Spring, and (4) Cartridge Music. The selections were played for two-minute intervals starting with the beginning of each selection. Ss were instructed to listen carefully to the musical selections and to note on their questionnaires the selection they thought to be most pleasing and the one they thought to be most displeasing. "Pleasing" and "unpleasing" were defined for the Ss as follows: "A pleasing piece of music is one that you would enjoy listening to for personal pleasure for a considerable length of time. A displeasing piece of music is one that you would not enjoy listening to for personal pleasure and would prefer not to be subjected to for any lengthy period of time." The selections indicated by each S were used later as the pleasant-unpleasant auditory conditions for his individual testing sequence during the experiment.

The experimental testing of the S consisted of his being blindfolded and kept in a completely darkened room for a period of twenty-five minutes. After this period of dark adaptation, the S was moved to the testing room under blindfold and seated in front of the test device. Each S was read the following set of instructions:

> Before you is a display unit with four different lights--a red light, blue light, green light, and white light. You can change the brightness of

> each of these lights by means of their respective dials located on each side of the display unit. The procedure which we will follow throughout the experiment is as follows: I will set the white light to a certain brightness. Your task will be to set the other three lights--the red, the green, and the blue--so that they appear of equal brightness with the white light. Respond accordingly when you are finished setting the lights. We will follow this procedure throughout the period, performing the same task a number of times. Are there any questions?

The S was then required to make fifteen practice settings of the three colored lights under no auditory stimulation. A separate setting consisted of the Experimenter (E) setting the white light to a predetermined brightness, after which the S sets the colored lights so that they appeared of equal subjective brightness as judged against the white standard. Experimental Condition I consisted of a total of fifteen settings under "no sound" as the auditory stimulation. Upon completion, S listened to three minutes of the "pleasing" music selected by him at the earlier group meeting. Condition II consisted of fifteen settings while the auditory stimulation continued to play throughout the time required to accomplish the settings. Once it had started, the music was not interrupted. The S was merely informed when to set the lights upon completion of the adaptation period of three minutes.

Experimental Condition III began immediately after Condition II with a three-minute adaptation period of displeasing music as picked by S. After the adaptation period, S was required to make fifteen settings under the continued "displeasing" music. After completion of this phase, all auditory stimulation was stopped. After a three-minute period of silence, S again made fifteen settings of the dials under a "no sound" condition. This completed a total sequence of sixty trials.

The Ss had been randomly divided into two groups of fifteen. Group A was tested in the order of auditory stimuli presentation just elaborated. Group A, then, received the first sound condition sequence, which was no sound, pleasant sound, unpleasant sound, no sound. Group B received a reversed sound condition sequence, which was no sound, unpleasant sound, pleasant sound and no sound. All other conditions remained the same.

The twenty-five different settings of the white standard light were chosen randomly and used for all *S*s. The order of presentation of the lights on the apparatus was systematically counterbalanced by rotating the lights for each *S* in order to correct for position effect.

VI. RESULTS

The data were analyzed through the use of both a Randomized Block Factorial Design 3.4 (Kirk, 1968) and a Multiple Regression analysis. Since obtained scores varied on both sides of the standard, all scores were subjected to transformation to obtain a positive scale to use in the data analysis. Table 1 shows the results of the analysis of variance.

TABLE 1

Analysis of Variance

Source	SS	df	MS	F
1. Blocks	177027.6	n-1 = 29	6104.4	(1/6) = 14.846**
2. Treatments	122664.9	pq-1 = 11		
3. A	1921.9	p-1 = 3	640.633	(3/6) = 1.558
4. B	118828.2	q-1 = 2	59414.100	(4/6) = 144.500**
5. AB	1914.8	(p-1)(q-1) = 6	319.133	(5/6) = 0.776
6. Residual	131163.3	(n-1)(pq-1) = 319	411.170	
7. Total	430855.8	npq-1 = 359		

$^{**}p < .01$

FIGURE 1

Means of Color Responses

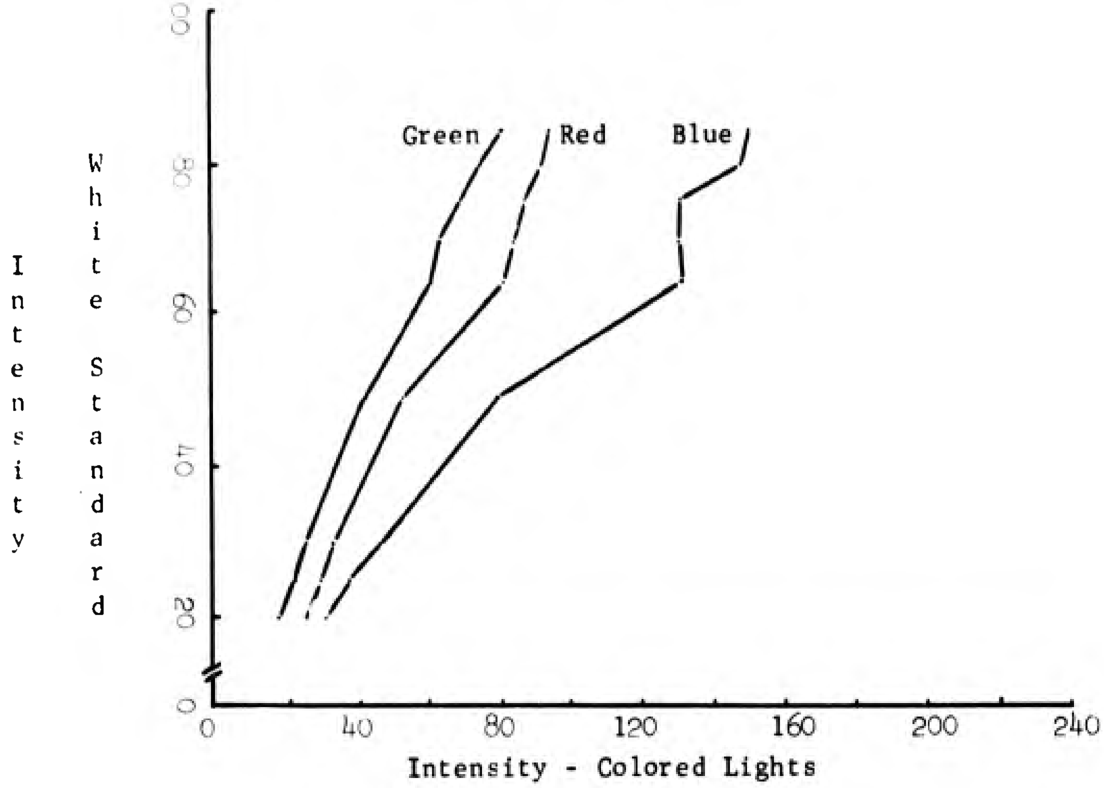
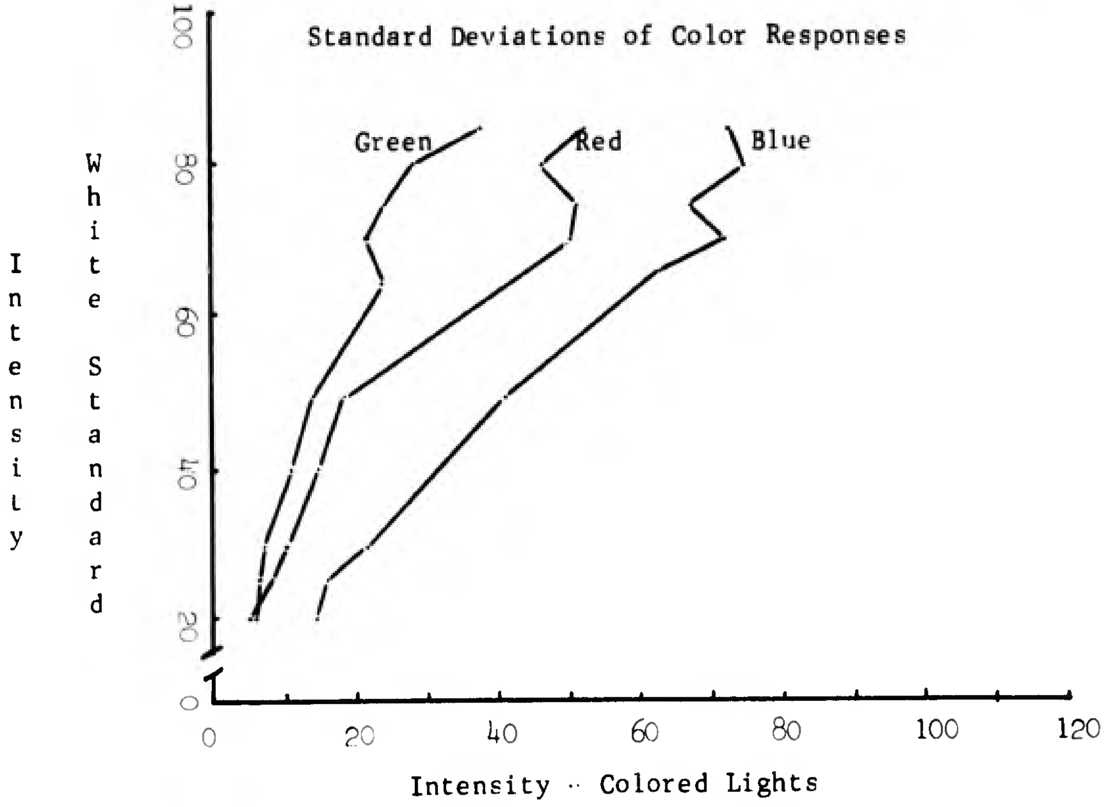


FIGURE 2

Standard Deviations of Color Responses



It is clear from this table that significant differences were found between light conditions (Treatment B) and none between sound conditions (Treatment A). It is of interest to note the high value associated with light differences. The precision of this measurement technique was concise enough to enable an almost exact prediction of the classic luminosity curves for red, blue, and green light sensitivity.

In an attempt to illuminate any effects due to sound, particularly the order of presentation and possible carry-over effects, three separate Multiple Regression analyses were run. Under no condition of analysis did the sound condition, order of presentation, or interaction contribute to the correlation. The total Ss' responses could be predicted to the maximum extent possible by a knowledge of their responses to the lights alone.

Figures 1 and 2 respectively show the mean estimation of each colored light compared to the value of the white standard and the standard deviation of the colored lights around the value of the white standard. For these figures, the sound conditions are ignored since they made no significant contribution to the Ss' responses.

On a lower level of analysis, but of interest, was the fact that on the questionnaire the Ss reported previous experiences with similar phenomena in the following percentages:

Question 1. Have you ever seen a color or colors while listening to music when the color was not actually a part of your immediate surroundings?

Yes - 38% No - 12% Not sure - 50%

Question 2. While listening to music, have you ever associated forms or different patterns of movement with the music?

Yes - 97% No - 0% Not sure - 3%

Question 3. While listening to music, have you ever experienced any sensations such as warmth, cold, pain, smell, touch or taste?

Yes - 68% No - 15% Not sure - 17%

Question 4. While looking at colored objects of any sort, have you ever heard or associated music or sounds with the colors?

Yes - 26% No - 50% Not sure - 24%

Question 5. Do visual patterns or movement remind you of sounds or music?

Yes - 65% No - 24% Not sure - 11%

Question 6. Do any of the normal bodily sensations such as warmth or cold remind you of sounds or music?

Yes - 32% No - 44% Not sure - 24%

VII. DISCUSSION

The hypotheses concerning the differential sensitivity of the dark-adapted eye were confirmed. The green light was perceived as the most intense with the mean of the Ss' responses being closest to the setting of the white standard light and the least variable of the three colored lights. The red light was seen as the next most intense with the mean of the Ss' responses being intermediate in departure from the setting of the white standard light, as well as intermediate in variability. The blue light was seen as the least intense with the mean of the Ss' responses being the farthest from the actual setting of the white standard light. The blue light's settings were also the most variable. It is of interest to note that as the value of the white standard increases, so do the mean overestimations and variability of responses to colored lights increase.

The hypotheses concerning the influence of audition on vision were not confirmed. This finding is in disagreement with the Russian leterature.

As mentioned previously, it is difficult to know what actual experimental conditions are used in Russian research. Terms such as harmonious and disharmonious are particularly vague and subject to a great deal of interpretation. For the purpose of this study, it was decided to use music as the basis for the sound conditions. Certainly, music is both harmonious and disharmonious, with some judgmental latitude being granted to the individual listener. It is difficult, however, to specify what one person would call harmonious as compared to another. This experimental dilemma led to letting the subjects listen to several selections and then selecting for themselves that which they considered to be harmonious, or pleasing, and that which they considered to be nonharmonious, or displeasing.

Classical music was used in an attempt to avoid some of the potential emotional content associated with popular music. In addition, Karwoski and Odbert (1938) reported a higher incidence of chromesthesia under classical music despite a preference for popular music. The selections chosen for use in this study represent a wide range of harmony and dissonance, with the Cartridge Music representing a very dissonant type of music.

The three-minute intervals between conditions were used because Kravlov (London, 1954) found that no effects were observable for one-minute exposures to auditory stimulation but that significant effects were found for three-minute exposures.

The notion of intersensory interaction is based in large part upon findings in physiology. In general, certain pathways connecting the various areas of the brain, such as the auditory and visual areas, give rise to the notion that facilitating and inhibiting reactions are to be expected (Bartley, 1958). This would presumably occur by both direct connections and irradiational influence between juxtaposed neural pathways. According to London (1954), "The fact and feasibility of excitatory irradiation in the region of the corpora quadrigemina, and also of the corporal geniculata seem to be justified, in the main, by foreign work." In other words, in the region of the corpora quadrigemina, the visual and auditory nerve fibers are in close proximity and myelin free. Since nerve action in an unmyelinated fiber is likely to influence that of another nearby fiber, the possibility of interaction is entirely feasible. This being so, the conduction of information over auditory channels would conceivably influence the action of information being transmitted over visual channels and vice versa.

Operating from this point of view, as this study did, one could expect excitation of a sensory channel to show an effect on a proximal channel, such as audition on vision. This did not happen. Considering the difficulty in establishing the exact nature of what was used in previous research, it is entirely possible that the wrong auditory conditions were used. It is also possible that the wrong physiological position has been used previously to assess the phenomena. This is not to say that the previously noted physiological position is not possible or nonoperative in intersensory interaction. It does recognize, however, the extreme complexity of the interactive potential of the central nervous system.

A revised viewpoint requires the consideration of some additional data. Reaction to acoustic stimuli has been found to be shorter in colored light than in darkness. Electric shock used with an acoustic stimulus reduced reaction time by about nine milliseconds. An additional four milliseconds of reduction in reaction time can be obtained by adding photic stimulation. Reaction time to light has been found to be facilitated by the presence of a continuous noise. On the other hand, subjects have shown increased auditory acuity under extremely bright light. When light and tones were experienced together, sensitivity to acoustic stimulation was enhanced. In lighted rooms, tones are reported as higher. Low tones have been found to be manipulative in "brightness" by varying photic stimulation (Bartley, 1958). In Addition, Child and Wendt (1938) found that a short photic pulse would lower auditory thresholds.

This kind of data seems to point to a reticular explanation of intersensory interaction, both facilitation and inhibition. A way of explaining such data would be to draw on the operation of selective attention on the part of the subjects. Attention is one name that can be given to an overall observed organizational pattern in a behaving organism that focuses its activity in some certain direction. Certainly, if the use of a demanding auditory stimulus can succeed in realigning the behaving individual so that he reacts more or less sensitively to a second stimulus, such as colored lights, it would demonstrate a kind of interaction between the stimuli pertinent to two modalities. This type of function is related to the reticular formation.

Grossman (1967) has noted the incompleteness of our knowledge about the complex involvement of the reticular formation in behavior. He said, "The reticular functions are indeed complex and apparently diffuse; however, every addition to our knowledge has tended to bring out specificity where we had suspected nothing but a complete lack of differentiation." It is apparent that the reticular formation exerts pronounced effects on sensory input, cortical activity, and tonic as well as phasic motor reactions. In addition, higher integrative functions have been connected to the reticular formation. In the waking organism, sensory inputs are distorted by a variety of influences which arise from a number of central mechanisms. These are channeled into and integrated by the reticular formation. Livingston (Grossman, 1967) suggested that the impulses conducted through the primary sensory pathways may not, by themselves, provide a sufficient basis for perception. Each sensory input mav need organizing and integration with inputs from other active sensory systems as well as with information from association areas and storage mechanisms. The final result, then, would be the subjective perception of the environment.

According to Grossman (1967), the inhibitory influence of the reticular formation is typically smallest with novel, sudden, intense, or especially significant stimuli. It is largest for duplicated and/or unimportant information. Viewed in this light, the sound conditions used in this study were neither novel, sudden, intense nor especially significant. One might suspect an inhibition of the auditory information under these factors, particularly when the subject was concentrating on a fairly demanding visual task--that of setting the intensities of the three colored lights so that they were subjectively equal to that of the standard.

This way of looking at the problem led us to conclude that a refinement of the auditory stimuli was the next logical step to investigate. Using the knowledge of the reticular functions, it would seem that a series of experiments designed to illumine the parameters of sensory interaction under both upper and lower threshold conditions would be in order. Such investigation would hopefully provide such useful data as the change in the perception of colors under intensive auditory saturation. Research is already underway aimed at looking at the effect of demanding auditory stimulation on the perception of color intensities. Bartley (1958) has spoken to the major difficulty in this kind of research by noting that, "The major reason why we do not possess the kind of information which we desire about synesthesia is possibly because the phenomena cannot easily, if at all, be produced experimentally."

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13. ABSTRACT

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Intersensory Interaction						
Color Perception						
Chromesthesia						
Cross-sensory Phenomena						