HEMISPHERIC ASYMMETRY IN MUSICALLY-INDUCED COLOR IMAGERY

Donald J. Polzella, Audrey M. Kuna,
David W. Biers, and Frank DaPolito
University of Dayton

Seventy two college students rated the strength of color photisms and the degree of listening enjoyment which was evoked by musical excerpts (Handel's Concerti Grossi, Op. 6) heard in the left ear, right ear, or both ears. The results suggested that chromesthesia is primarily a right hemispheric function and is related to changes in musical tonality. Contrary to expectation, the results were not affected by music experience. Chromesthetic intensity and listening enjoyment were positively correlated.

The most obvious quality of music is aural. However, music is linked to other sense modalities in subtle yet demonstrable ways. A musician has even attempted to exploit this fact in one of his compositions, its performance documented in a 1915 issue of *Scientific American:*

> New York concert-goers, on Saturday evening, March 20, 1915, witnessed a novel departure from the conventional symphonic programme when the Russian Symphony Orchestra presented the tone-poem "Prometheus," of the Russian composer Alexander Scriabine, with the employment for the first time, as an "orchestral unit," of an instrument for producing colors, designated by the composer the "tastiera per luce" or "clavier lumiére" (Plummer, 1915, p. 343).

Apparently the performance was not a total success, since it was hampered by a technical inability to create visual effects intense enough to complement the sound. Whatever its merits, "Prometheus" is not a part of the current symphonic repertoire and has probably never been performed as envisioned by Scriabin.

The intersensory phenomenon that Scriabin explored in "Prometheus" is termed synesthesia. It involved "production, from a sense impression of one kind, of an associated mental image of a sense impression of another kind" ("Synaesthesia," 1970, p. 373). Although synesthesia occurs among many sense modalities, the most common type of synesthesia, in which color images (photisms) are evoked by auditory stimuli, is termed *chromesthesia.*

The extensive scientific literature on chromesthesia dates back over 2000 years. A great deal of this literature is anecdotal and suggests that the relationship between auditory stimuli and color photisms is idiosyncratic and complex. However, the experimental evidence indicates that there are certain predictable relationships. The most frequent reports of chromesthesia are color photisms evoked by speech sounds. In these cases the brightness of the photism is a direct function of the pitch of the vowel. For example, acute (high-pitched) vowels like /i/ and /e/ tend to evoke bright colors, while grave (low-pitched) vowels like /o/ and /u/ tend to evoke darker colors. More subtle links occur between the ratio of the frequencies of the second to first formants of the vowel

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and the redness and greenness of the photism. For example, compact vowels like /a/ and /o/ tend to evoke red, while diffuse vowels like /y/ and /i/ tend to evoke green (Marks, 1975).

When color photisms are evoked by musical stimuli, the relationships are similar to those for colored vowels. The brightness and size of the photisms are a function of the pitch and loudness of the stimuli; however, the relationships are clearest for colors and single tones (Wicker, 1968). When the stimuli are actual pieces of music the photisms are a function of the interaction of many stimulus attributes and are less reliable (Karwoski & Odbert, 1938), but they appear to be mediated by a "cognitive space" that is common to both music and color (Lehman, 1972; Odbert, Karwoski, & Eckerson, 1942).

In a previous experiment (Polzella & Kuna, 1981) we sought to determine whether particular color photisms could be reliably evoked by one stimulus attribute that characterizes musical compositions, namely, tonality or musical key. College students heard taped excerpts (1-2 min.) from each of the 12 Concerti Grossi (Opus 6) by G. F. Handel. Following each excerpt they were asked to "choose one color, red, yellow, green, or blue, as the one that was most apparent while you were listening." The excerpts were equivalent in scoring (string orchestra) and tempo (allegro), but they differed in musical key. Four of the excerpts were in major keys, four in minor keys, and four in mixed or modulated keys. There were several discernable patterns in response. The major excerpts tended to evoke yellow (34%) and, to a lesser extent, green photisms (30%), the minor excerpts tended to evoke blue (33%), while the mixed excerpts evoked the least consistent pattern.

In a subsequent experiment (Polzella & Biers, Note 1) we attempted to explain these results. Independent groups of students were asked to rate the excerpts and the color names on a series of semantic differential scales in order to derive two sets of profiles, one for the music and one for the colors. The correspondence between these profiles was then compared to the results of the previous experiment. The findings supported the hypothesis that particular photisms are evoked by particular musical excerpts to the degree that there is cognitive similarity between them.

The present experiment is concerned with the origin of chromesthesia. According to Critchley (1977) there are two hypotheses which account for these phenomena. One hypothesis states that chromesthetic responses are mediated by learning. Specifically, they are "the product of a chain of mental associations, some of the intermediate links having dropped out of awareness" (p. 229). The other hypothesis states that chromesthetic responses reflect underlying neural correspondences between sensory systems, a kind of "unity of the senses." There is ample evidence that such correspondences exist (Letourneau & Belanger, 1981; London, 1954), although their relationship to chromesthesia is unclear.

If chromesthesia is learned, it could vary as a function of musical experience. On the other hand, chromesthesia may be unaffected by musical experience, in which case certain neuropsychological indicators (e.g. cerebral hemispheric functional asymmetry) could suggest a physiological basis.

Method

Subjects

The subjects were 72 introductory psychology students (36 males and 36 females). They participated as part of a course requirement.

Stimuli

The stimuli were the same taped excerpts from Handel's Concerti Grossi, Op. 6 (Handel, 1739/1968) that were used in the previous experiments. The major excerpts were from Concerti 1 (pp. 3-5), 7 (pp. 95-96), 9 (pp. 119-170) and 11 (pp. 152-153). The minor excerpts were from Concerti 4 (pp. 54-55), 6 (pp. 88-91), 8 (p. 117) and 12 (pp. 169-171). The mixed excerpts, with major/minor or minor/major modulations, were from Concerti 2 (pp. 20-21), 3 (pp. 34-35), 5 (pp. 72-72), and 10 (pp. 139-142). The performances were conducted by Jean-Francois Paillard (Musical Heritage Society, MHS 806-809).

Procedure

Equal numbers of male and female subjects were assigned to each of three experimental groups. The subjects in each group heard all excerpts in random order through either the left, right or both channels of stereo headphones. Following each excerpt, the subject rated the strength of the evoked photisms on a 0 to 5 scale, where 0 indicated "no color image" and 5 indicated "strong color image." This was done for the four colors, red, yellow, green, and blue. The subject then rated his/her enjoyment of the excerpt on a 0 to 5 scale, where 0 indicated "did not enjoy listening" and 5 indicated "enjoyed listening very much."

After responses to all twelve excerpts were obtained, the subjects were requested to provide additional information concerning their musical background: They reported the number of years, if any, of formal music instruction and also noted whether or not they could read music. Finally, they rated their familiarity with the excerpts on a 0 to 5 scale, where 0 indicated "totally unfamiliar" and 5 indicated "very familiar."

Results

Color Photisms

The raw data consisted of each subject's four image strength ratings (red, yellow, green, blue) of the twelve excerpts. The experimental design for analyzing these data was 3(Ear) and 2(Gender) by 3(Tonality) by 4(Color) by 4(Excerpt nested within Tonality) with repeated measures on Tonality, Color, and Excerpt.

A significant main effect of Ear was obtained, $F(2,66) = 6.99, p < .01$. Mean image strengths for left ear, right ear, and both ears were 2.47, 1.83, and 2.40 respectively. A Dunn post-hoc multiple comparison test (Keppel, 1973, pp. 147-149) indicated that left-ear and both-ear image strengths did not differ and were significantly greater than right-ear image strength ($p < .05$).

Overall image strength did not differ as a function of Tonality, $F(2,132) = 1.08, p > .20$. However, Tonality significantly interacted with Color, $F(6,396) =$

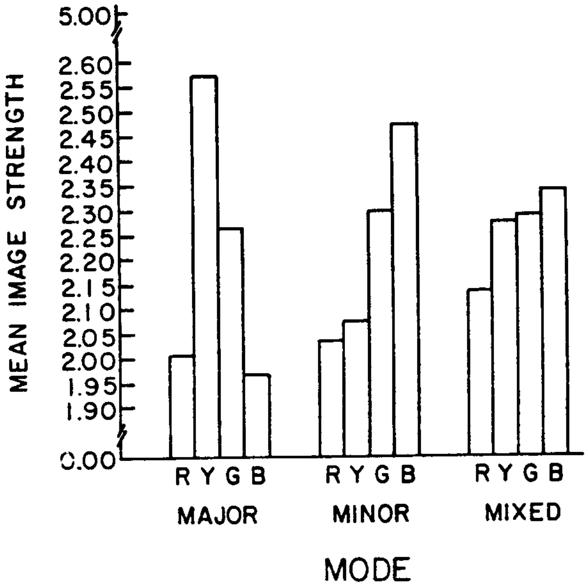

Figure 1. Mean color image strengths of red, yellow, green, and blue photisms for major, minor, and mixed excerpts.

4.19, $p<.001$, and with Gender, $F(2,132) = 3.35$, $p<.05$. The Tonality by Color interaction is graphically displayed in Figure 1. The interaction was statistically evaluated by computing simple effects analyses for each tonality. (See Keppel, 1973, pp. 325-327.) For major excerpts the effect of Color was significant, $F(3,66) = 6.22$, $p<.001$. Dunn tests indicated that yellow images were strongest, red and blue, weakest ($p<.05$). The effect of Color was also significant for minor excerpts, $F(3,66) = 2.78$, $p<.05$. Dunn tests indicated that blue images were strongest, red, weakest ($p<.05$). The analysis of simple effects for mixed excerpts was not significant indicating that the image strengths were statistically equivalent.

The Tonality by Gender interaction was statistically evaluated by computing simple effects analyses for each gender. The effect of Tonality was significant only for the male subjects, $F(2,66) = 4.94$, $p<.025$. Dunn tests indicated that images were strongest for mixed excerpts, (2.2) next strongest for minor excerpts (2.1) and weakest for major excerpts (2.0). Female image strengths were 2.39, 2.35, and 2.34 for major, minor, and mixed.

There was a significant Ear by Gender by Color interaction, $F(6,198) = 2.28$, $p<.05$. However, the source of this interaction was not revealed by simple effects analyses. The remaining effects either were not significant or involved differences among particular excerpts and were not considered to be of primary importance.

Enjoyment

The raw data consisted of each subject's rated enjoyment of the 12 excerpts on the 6-point scale. The design and computational program were the same as those used to analyze the color photisms data, except that the Color source of variability was not represented.

The overall mean enjoyment of the excerpts was 3.24 which implies that the subjects did enjoy listening. The analysis of variance revealed only one significant source of variability, a weak Ear by Gender by Tonality interaction, $F(4,132) = 2.52$, $p<.05$. Since the locus of this interaction was not revealed by simple effects analyses, it was considered to be of limited importance.

Musical Experience

The number of years of formal musical training ranged from 0 to 9. The distribution was positively skewed with a mean of 1.9 years and a standard deviation of 2.6. Fifty-three percent of the sample reported that they could read music. Prior knowledge of the Concerti Grossi was apparently limited; the mean familiarity was 1.67 with a standard deviation of 1.31.

Intercorrelations

Table 1 presents a matrix of intercorrelations among the five dependent variables. In order to derive the matrix, mean ratings for image strength and enjoyment were computed by averaging over the twelve excerpts.

Table 1
Matrix of Intercorrelations among the Dependent Variables

	I	E	F	Y	R
I	1.00	.41**	.17	.15	.14
E	.41**	1.00	.32*	.41**	.20
F	.17	.32*	1.00	.52**	.48**
Y	.15	.41**	.52**	1.00	.61**
R	.14	.20	.48**	.61**	1.00

*$p<.01$
**$p<.001$

Note: I = Image strength (0-5), E = Enjoyment (0-5), F = Familiarity (0-5), Y = Years of musical training, R = Ability to read music (0 = No, 1 = Yes)

Image strength and listening enjoyment were significantly correlated ($p<.001$) with stronger images associated with greater enjoyment. In contrast, image strength was unrelated to any of the other variables. This was true regardless of listening condition, i.e., Ear.

The remaining correlations were predictable. Thus, years of musical training, ability to read music, and familiarity with the excerpts were significantly intercorrelated ($p<.001$), as were enjoyment, years of training, and familiarity.

Discussion

The results of this experiment parallel those of our previous research (Polzella & Kuna, 1981) in demonstrating a link between color photisms and the tonality of these excerpts. The replication of the earlier findings, using a different sample of subjects and a revised methodology, suggests that the phenomenon is robust. However, the method should be extended to other musical excerpts in order to determine the generality of this phenomenon.

It is not apparent why the intensity of photisms should vary as a function of tonality. Nor is it apparent why this, in fact, occurred for males but not for females. Since the color of the photisms significantly interacted with tonality, the finding implies that, for males, the intensity of photisms is not independent of their hue. Unfortunately, the results do not help to clarify the issue of gender differences in music perception.

The finding that color photisms were strongest when evoked by left or both ear stimulation supports the hypothesis that chromesthesia primarily reflects right hemispheric processing. The hypothesis is premised on the fact that the contralateral neural pathways from ear to brain are stronger than the ipsilateral pathways (Kimura, 1967). This finding is consistent with previous evidence of right hemispheric specialization for color discrimination (Pennal, 1977) and for tasks involving spatial integration and creative-associative thinking (Dimond & Beaumont, 1974).

The issue of hemispheric processes in music perception is a complex one. Gates and Bradshaw (1977) have presented evidence that both hemispheres are involved, and they attribute hemispheric asymmetry to differential processing strategies. Processing by the right hemisphere is holistic, and the right hemisphere is superior for tasks that require an appreciation of the whole sound. In contrast, processing by the left hemisphere is analytic, and the left hemisphere is superior for tasks that require responses to musical elements. In terms of this dichotomy, the present findings suggest that chromesthetic responses are holistic.

It is important to consider that neither the pattern nor intensity of the evoked photisms changed as a function of musical experience. This implies that chromesthetic responses do not depend on learned associations; rather, as Marks (1975) suggests, they appear to represent "a cross-modal manifestation of meaning in its purely sensory . . . form" (p. 326).

Finally, given the association between increased listening enjoyment and increased image strength, it is reasonable to ask whether music and color can be combined to produce a heightened aesthetic experience. We assume, of course, that the aesthetic response includes an affective component (cf. Abeles, 1980, p. 105). Perhaps there is some validity to Scriabin's attempt to exploit the correspondences between sound and light.

REFERENCE NOTE

1. Polzella, D.J., & Biers, D.W. *Validating chromesthetic responses by measuring the correspondence between independent judgments of color names and musical excerpts.* Paper presented at the meeting of the Psychonomic Society, Philadelphia, November 1981.

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FOOTNOTE

This research was initially presented as a paper at the Research Symposium on the Psychology and Acoustics of Music, University of Kansas, April 1982. The experiment was conducted by the second author in partial fulfillment of the requirements for the degree of Master of Arts in Psychology.

Requests for reprints should be sent to D.J. Polzella, Department of Psychology, University of Dayton, Dayton, Ohio 45469.