Associations between Color and Music are Mediated by Emotion and Influenced by Tempo

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Historically, there have been a number of attempts to characterize the relationship between perceptions of color and perceptions of music (e.g., McClain, 1978; Cuddy, 1985; Shaw-Miller, 1959; Arnheim, 1986). One line of recent research suggests that associations between color and music are based on the shared emotions that they evoke (Schloss, Lawler, & Palmer, 2008). The current study explored this hypothesis further by examining particular features of music contributing to color-music associations. Corroborating previous research, we found consistent correlations between emotional ratings for musical selections and emotional ratings for colors. Specifically, we show that the same piece can be associated with different colors on the basis of manipulating tempo alone.

INTRODUCTION

Synesthetes are famed for their ability to "hear" colors or "see" sound. However, the widespread use of such colorful phrases as "white noise" and "the blues" suggests that ordinary people, too, perceive relationships between sound and color. Most individuals understand what it means for a color or a sound to be "bright" or "dark" or to have a "warm" tone versus a "cool" one. Novice and professional artists alike can agree that a trumpet is a "bright" instrument and that red is a "warm" color. In addition to these linguistic analogies, the historical concurrence of certain artistic and musical movements with overlapping elements, such as impressionism and minimalism, has led some to posit perceptual relations between the experiences of color and music (e.g., Simon, 1959; Arnheim, 1986).

Historically, the cognitive underpinnings of the relationship between color and music have been a heady source of investigation and debate for philosophers and psychologists. Plato, Aristotle, and Newton theorized associations between specific musical intervals and specific colors (for a historical overview, see, e.g., McClain, 1978; Cuddy, 1985). The findings of these thinkers dovetail with their metaphysical starting points. Plato, for example, drew on Pythagorean theory to link the interval of a perfect fourth to yellow. Newton was influenced by his optical experiments to link this same interval to orange due to the similar wavelength properties of light and sound (Westfall, 1962). More recent attempts to model the relationship between music and color have similarly been based on correspondences between their physical properties. For example, the psychophysical theory of music and color (Pridmore, 1992) explains this relationship as a function of amplitude and wavelength. Another proposal maps hue onto pitch and saturation onto timbre (Caivano, 1994).

Other models focus on the emotional experiences that engender perceived similarities between color and music. Prior research has demonstrated that color and music independently carry emotional valence (e.g., Ballast, 2002; Kaya, 2004; Schubert, 2007; Hunter, 2010). For example, fast, major musical excerpts are reliably perceived as happy while minor excerpts are reliably perceived as sad (Hunter, 2010). Similarly, light colors are associated with more positive emotions while dark colors are associated with more negative emotions (Kaya, 2004). These effects extend to more complex emotions as well. One study found that Western-European university students consistently associated red with "excitement" and yellow with "playful" (D'Andrade & Egan, 1974). Moreover, associations between particular musical pieces and paintings may be drawn if both carry the same emotional effect. One study showed that participants use different color profiles to classify the same piece of

music depending on instrumentation and the musician's emotional interpretation of the piece (e.g., happy, sad, shameful, or angry; Bresin, 2005). However, this study did not measure how participants judged the emotional content of the recordings or colors and did not explain how musicians' emotional intent was translated into performance (e.g., by change in articulation or dynamic range). Idiosyncrasies in both performance and personal preference may have influenced these color-music associations. A more recent study helped account for these ambiguities (Schloss et al., 2008). In addition to associating colors with musical excerpts, participants provided emotional ratings for the two types of stimuli. Tempo and mode were identified as features of music that influence these associations. For example, saturated and light colors and fast and major music were independently rated as happy and were also associated with each other.

Despite narrowing the factors that influence the emotional experience of music and its perceived associations with color, several other features besides tempo and mode may have accounted for the findings of Schloss et al. (2008). For example, stimuli were symphonic pieces that also varied in orchestral size and instrumentation. Considering that many of the terms used to describe music and color apply to timbre (e.g., brightness, warmth, saturation), it is conceivable that the differences that these authors found in color-music associations could be due to such factors.

The current study aimed to control for timbre, genre, and instrumentation in an attempt to clarify how much of the variation in documented music-color associations can be attributed to tempo and mode alone.

Whereas previous studies used a variety of instruments to evaluate music-color associations, the current study only used piano pieces for musical stimuli. In addition, we electronically manipulated the speed of the excerpts such that stimuli representing fast and slow tempos were derived from a single piece. We also selected major and minor pieces from the same genre or compositional collection in order to narrow the amount of artistic and stylistic difference represented in our stimuli, in turn minimizing participants' unique responses to idiosyncratic features.

STUDY

Method

Participants
Ten undergraduates (3 male; all between 20-25 years old) enrolled in a course on color perception participated in this study on a voluntary basis. No participants had any known color deficiencies.

Musical stimuli
Thirty-second excerpts from six classical piano pieces were used to create 12 stimuli. The six original pieces were composed by J.S. Bach, Robert Schumann, and Frederic Chopin, each of whom contributed one major and one minor composition to our stimuli (see Appendix). Each major and minor piece reflected a single genre, which reduced the amount of stylistic variation between modes for composers. The composers were selected based on their prolific contributions to the standard piano repertoire and their representativeness of the Baroque, Classical, and Romantic periods. Where possible, pieces within the same genre (e.g., prelude to fugue, ballade, and sonata) were

recordings from the same pianist on the same piano. These six selections were also relatively slow in tempo (mean tempo: 77 +/- 16 beats per minute).

The original, full-length pieces were downloaded from http://www.pianosociety.com, a free classical music website with a large selection of piano works. The tempos of the pieces were sped up using Pitch 'n Time (Serato Audio Research, Auckland, New Zealand; http://serato.com/pitchntime), computer software from the Levitin Laboratory for Music, Perception, Cognition, and Expertise at McGill University. This manipulation did not leave any sound artifacts, such as distorted pitch. Mean tempo for the faster versions was 138 +/- 21 beats per minute.

Thirty seconds of music were excerpted from the original six pieces using a program called Audacity. All excerpts ended on a cadence, suggesting a natural stopping point in the music. For the sped-up versions, the excerpted material was looped until it reached 30 seconds in length.

Color Stimuli
The stimuli consisted of 37 colors from the Munsell color system (see Appendix). These included eight hues (red, yellow, green, blue, orange, chartreuse, cyan, and purple) with four saturation/lightness conditions: maximum saturation at medium lightness, medium saturation at medium lightness, high lightness, and low lightness. Five stimuli were achromatic, ranging from black to white.

Apparatus
Visual displays were presented using Power-Point Mac 2004 on a MacBook Pro computer that was connected to a color projector. Musical stimuli were WAV audio files that were embedded into the PowerPoint slides, allowing for the simultaneous presentation of auditory and visual material. Speakers were also used to amplify the music so that it could be heard clearly.

Procedure
The experiment was separated into three blocks. In the first block, participants were asked to rate the emotional content of 37 color stimuli. The stimuli were displayed in a random order on a projector screen for 40 seconds each. During this time participants rated each color on five dimensions: sad/happy, calm/angry, weak/strong, passive/active, and dislike/like. Ratings were made on a scale from -5 to 5, with 0 indicating a neutral response.

In a second block five weeks later, participants were asked to associate these colors with the twelve aforementioned musical clips. Participants first previewed fifteen-second versions of each selection and were told that although some selections might sound the same, none of them were identical. Participants were then played the full thirty-second clips. After hearing each clip, participants were presented with the 37 colors encountered in the first block of the study and given 40 seconds to rank-order the five colors which they felt were most consistent and most inconsistent with the clip.[*] Consistency was explained as colors that participants most strongly associated with the music. Similarly, inconsistency was explained as colors that participants would

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[*] Sound files were presented in pseudorandom order so that a slow or fast version of the same piece was not heard consecutively. Trials were only repeated for cases in which participants could not complete color associations in the allotted forty seconds.

not associate with the music. Participants were instructed to make their music-color associations based on the experience of the current music without relating it to other pieces heard either in the experiment or in real life.

The third block occurred a week after the second one. During this block, participants made music-emotion associations. The pro-cedure was very similar to the color-emotion association task in the first block. For each of the 12 musical excerpts, participants rated their emotional response on the five dimen-sions previously mentioned (sad/happy, calm/angry, weak/strong, passive/active, and dislike/like). As in the color-emotion association task, ratings were made on a scale from -5 to 5. The clips were presented
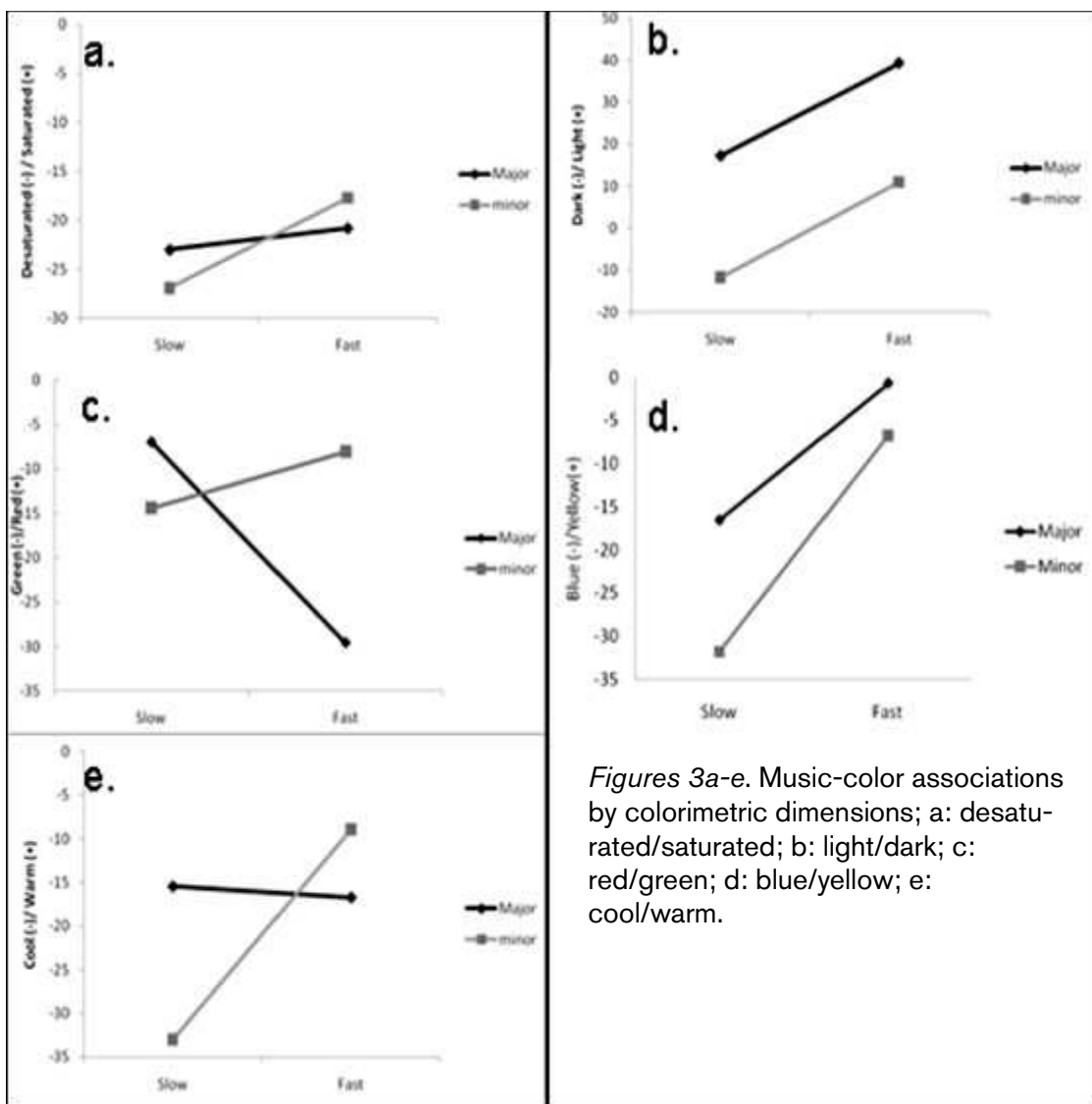
Figures 3a-e. Music-color associations by colorimetric dimensions; a: desatu-rated/saturated; b: light/dark; c: red/green; d: blue/yellow; e: cool/warm.

in the same order as in the previous week.

Results

Color-Music Association

Just as music can be analyzed in terms of timbre, tonality, and mode, every color can be broken down in terms of its colorimetric composition: saturation, lightness versus darkness, red versus green, blue versus yellow, and cool versus warm. These dimensions provide a standard basis for analyzing which component of the colors lends itself the most to color-music associations. In order to condense the selections into a single music-color association for a given piece,
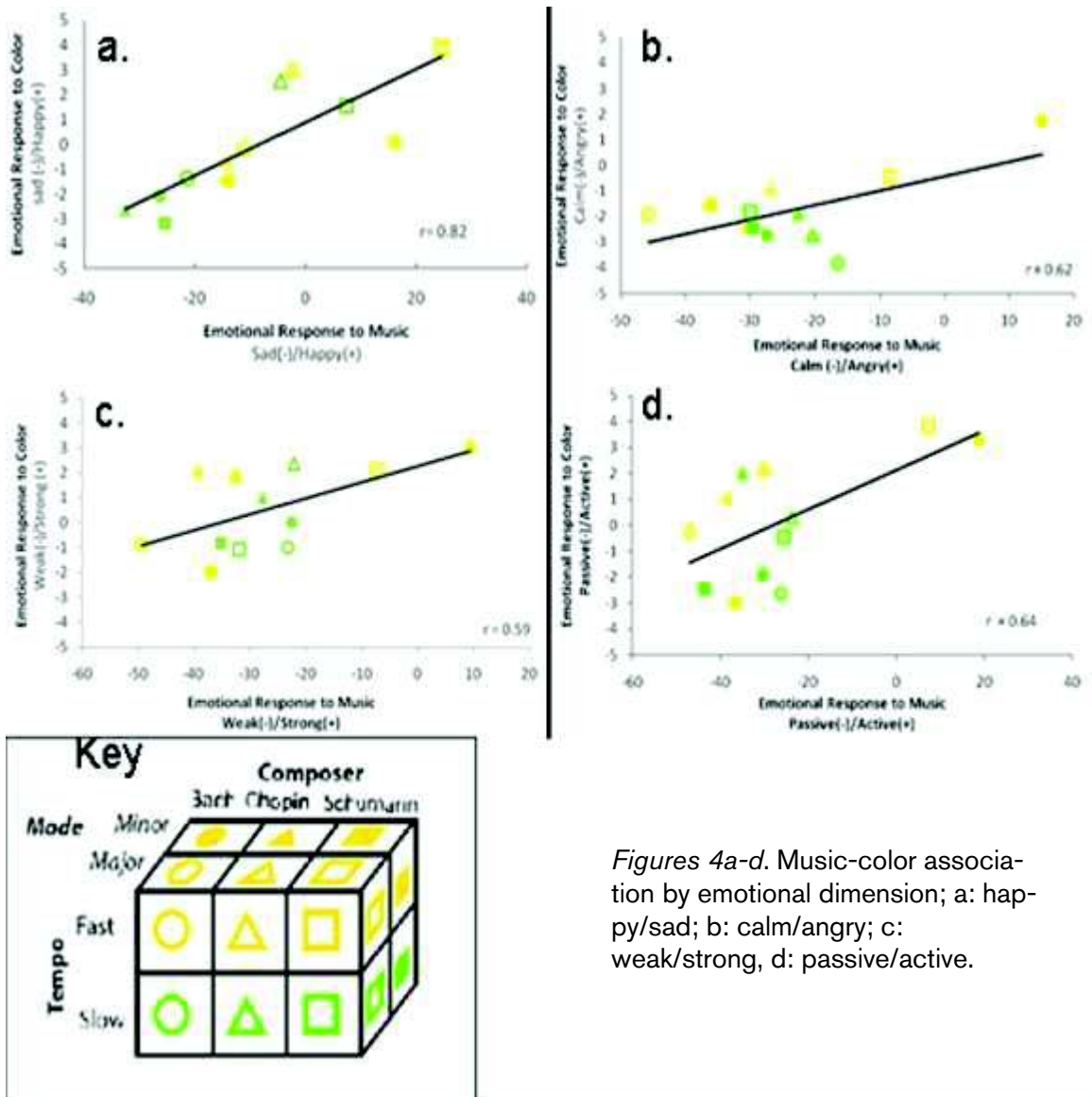
Figures 4a-d. Music-color association by emotional dimension; a: happy/sad; b: calm/angry; c: weak/strong, d: passive/active.

colors that were ranked most consistent or most inconsistent were weighted more heavily according to the rank given to them by the participant. To quantify color-music associations, we conducted the following calculation for each music clip under the five colorimetric dimensions:

$C_D = 5c_{1,D} + 4c_{2,D} + 3c_{3,D} + 2c_{4,D}. + 1\ c_{5,D}$, where C = consistency score, D = dimension, and $c_{i,D}$ = the ith color chosen

$I_D = 5i_{1,D} + 4i_{2,D} + 3i_{3,D} + 2i_{4,D}. + 1i_{5,D}$, where I = inconsistency score, D = dimension, and $i_{i,D}$ = the ith color chosen

Saturation
For ratings of saturation, there was no main effect for composer, mode, or tempo: (F(2, 18) < 1; mode: F(1, 9) < 1; and tempo: F(1, 9) < 1). Participants generally associated all music selections with desaturated colors (Figure 3a). This contrasts with Schloss et al.'s (2008) findings that both faster music and music in the major mode are associated with more saturated colors.

Lightness/darkness
We did find a significant main effect on the light/dark colorimetric dimension (Figure 3b). Music that was in the major mode and at faster tempos was associated with lighter colors (Mode: F(1, 9) = 9.51, $p < 0.05$, Tempo: F(1, 9) = 8.50, $p < 0.05$).

Red/green and blue/yellow
All excerpts were associated with colors that contained more hues of green than red (Figure 3c). No main effects were observed for composer, mode, or tempo (Composer: F(2,18) < 1, $p > 0.05$; Mode : F(1,9) = 1.48, $p > 0.05$; Tempo: F(1,9) = 4.27, $p > 0.05$). However, there was an interaction between mode

and tempo (F(1, 9) = 10.31, $p < 0.05$). Participants perceived faster major selections to be greener than their slower counterparts. In the blue/yellow colorimetric dimension, slower musical selections were associated with bluer colors than those associated with fast musical selections (F(1, 9) = 8.13, $p < 0.05$; Figure 2d). Minor musical selections were associated with colors that were more blue than major selections, although this effect was not quite statistically significant (F(1,9) = 1.28, $p > .05$).

Warmth/coolness
In general, participants associated the musical selections with colors that were cool (Figure 3e). A main effect was observed for tempo (F(1, 9) = 8.06, $p < 0.05$): the faster music selections were on average associated with less cool colors. This effect appeared especially strong for the minor pieces, but could not be shown to be statistically significant (F(1, 9) = 4.55, $p = 0.62$).

In sum, participants tended to associate the musical selections with desaturated, green, blue, and cool colors. Faster musical selections and those in a major key were associated with lighter colors. Music-color associations were significantly influenced by tempo alone. This accounts for how the same piece of music could be connected with two different colors.

Emotional Ratings

We examined whether these associations were mediated by participants' emotional reactions. The color-emotion ratings taken during the first block were averaged across participants to yield a single score for every color along the five emotion dimensions (sad/happy, calm/angry, weak/strong, passive/active, and dislike/like). These scores

were used to replace the 10 color selections made for each music stimuli. A music-emotion score was created for each musical stimulus by averaging the difference in color-emotion score between the five most and least consistent colors.

Happy/sad emotional dimension

We found consistent correlations between the emotional ratings of each musical selection and the emotional ratings of the colors that were chosen as consistent or inconsistent with the music. The correlation for emotional responses between color and music was highest for happy/sad ratings ($r = 0.82$, $p < 0.001$; Figure 4a). For any given piece, the faster version was happier than the slower version. Major selections were also rated happier than minor ones. For musical selections in which mode and tempo were incongruent (i.e., slow/major and fast/minor), happy/sad ratings were more neutral. This finding is consistent with the music-emotion ratings found in Hunter (2010). Moreover, musical selections that received a higher happiness rating were associated with colors that also received high happiness ratings.

Calm/angry, weak/strong, and passive/active emotional dimensions

Music and color were also correlated along other emotional dimensions, although to a lesser degree. The colors participants selected for musical stimuli had similar calm/angry ($r = 0.62$, $p < 0.05$), weak/strong ($r = 0.59$, $p < 0.05$), and passive/active ($r = 0.64$, $p < 0.05$) ratings as the corresponding musical stimuli (Figures 4b-d).

There was also significant overlap in how participants rated their emotional responses to musical selections in the calm/angry, passive/active, and weak/strong dimensions (correlation between weak/strong and calm/angry ratings: $r = 0.98$, $p < 0.001$; correlation for passive/active and weak/strong ratings: $r = 0.95$, $p < 0.001$; correlation between weak/strong and passive/active ratings: $r = 0.97$, $p < 0.001$). In other words, selections that were rated as calmer were generally rated as weaker and more passive, suggesting that these emotion dimensions may be variations of each other. Moreover, these selections were strongly correlated with colors that received similar emotional ratings. To give an example of how tempo modified music-color associations, the fast minor Bach selection was rated the most intense (i.e., most angry, active, and strong), and the fast major Bach selection was rated the least intense (i.e., most calm, passive, and weak). By contrast, the original, slow versions of these selections received similar emotional ratings along the three dimensions. This difference could be based on the accentuation of particular musical features under fast tempo.

DISCUSSION

The findings from this study underscore previous research demonstrating that color-music associations are mediated by the similar emotional responses that they evoke. In addition, by controlling for genre and composition in our musical stimuli, our findings reveal an important—if still open-ended—role for tempo and mode.

Importantly, considering the flexibility and variability of tempo from one performance of a musical piece to another, our findings suggest that music-color associations can vary significantly for different manifestations of musical stimuli even when

other features such as pitch, harmonics, and instrumentation are held constant. Considering that participants made independent color-emotion, music-emotion, and music-color associations at different points in time, the influence of tempo appears to be robust.

It is possible that tempo influences emotional response, in general, by accentuating particular features of musical pieces such as note density, chromaticism, and rhythm. This effect can take a variety of forms. For example, anger was more intensely perceived in the fast minor Bach excerpt than in the original slow version. Moreover, while slow minor stimuli were associated with greener colors than slow major stimuli, speeding up the music produced opposite associations; minor stimuli were associated with colors that were less green and major stimuli with colors that were greener. This was especially true for music-emotion ratings in the weak/strong and calm/angry dimensions.

It is worth noting that because excerpts from the fast conditions were looped in order to match the length of the slow selections, participants heard the same musical material more times in the fast conditions than in the slow ones. This repeated exposure could have influenced participants' responses. According to the basic assumptions of the mere exposure effect (e.g., Zajonc, 1968), such repetition could have produced more positive emotional ratings (i.e., happier or calmer). However, our data do not support this possibility; the musical selections from the fast condition did not necessarily receive more positive emotional rat-

ings than those from the slow condition. For example, the fast major Schumann selection was rated as angrier than the slow version of it (Figure 4b).

A number of gaps in the present study present potentially fruitful avenues for further research. One shortcoming of the present study is that dynamic range was not held constant. Some music selections were much louder than others, which may have influenced both the emotional rating and corresponding color association. Moreover, musical selections were not uniformly sped up. For example, the fast version of the major Schumann piece was twice as fast as the slow version, whereas both of Chopin's *Ballades* were sped up to be 50% faster than the original versions. At the same time, our stimuli were limited to fast and slow tempos, with no "medium" condition. Further idiosyncrasies in our stimuli and results suggest an even broader range of future studies. For example, most of the music used here was associated with desaturated and cool colors. And despite intuitive connections between slow speed and lethargy, nearly all the fast stimuli were associated with passivity. These results may in part be due to the unique timbre of the piano. Overall, given the myriad dimensions upon which musical stimuli vary, as well as the documented influence of cultural and environmental conditions on color preferences and their associations with emotion (e.g., Terwogt & Hoeksma, 1995), we hope that our study is only one of many to come.

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APPENDIX

Musical selections

	Bach	Chopin	Schumann
Major	*Prelude No.7 in E-flat Major*	*Ballade in F Major*	*Album fur die Jugend, opus 68, No 1*
Minor	*Prelude No. 4 in c-sharp minor*	*Ballade in g minor*	*Album fur die Jugend, opus 68, No 9*

The 37 color stimuli