Why is Bach blue instead of red? Different strategies moderate people's color-music associations

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Abstract

People have strong intuitions about which colors do and do not match particular pieces of music — a phenomenon often conceptualized through semantic mediation. We further explored the specific strategies people employ to navigate these color-music associations which offers crucial insights to identifying the cognitive mechanisms that enable such cross-domain associations. We show that while some people rely more on intuition, other people actively seek justification of association by consulting common linguistic descriptors, emotional contents, and environmental cues. We found that more spontaneous strategies lessen the role of semantic mediation, while more evaluative strategies, especially those involving the use of language, amplify it. Notably, the use of evaluative strategies introduced an asymmetrical effect for matching and mismatching colors. Additionally, individuals employing similar strategies associated a given music excerpt with more similar colors, suggesting that strategy alignment enhances the consistency of color-music associations. Interestingly, this pattern of convergence was not observed among individuals who predominantly relied on guessing.

Keywords: color-music mapping; emotion; language; cross-modal correspondence;

Introduction

When Franz Liszt instructed his orchestra to perform the music in a "bluer fashion," aligning with the tonal demands of the piece, the notion was initially dismissed as mere whimsy: music obviously doesn't have color. We now believe that Liszt had sound-to-color synesthesia, experiencing certain sounds as colors (Marks, 1975). Genuine sound-to-color synesthesia is rare, present in less than 1% of the population (Barnett et al., 2008; Niccolai, Jennes, Stoerig, & Van Leeuwen, 2012; Simner et al., 2006). But even absent synesthesia, people show robust associations between music and colors (Palmer, Schloss, Xu, & Prado-León, 2013; Palmer, Langlois, & Schloss, 2016; Whiteford, Schloss, Helwig, & Palmer, 2018; Isbilen & Krumhansl, 2016; Lindborg & Friberg, 2015). For example, when asked to select colors that are most consistent with a piece of music, both U.S. and Mexican participants associate faster music with lighter, more saturated, and yellower colors (Palmer et al., 2013).

Why do people agree? And what determines which colors go with which music? One explanation is that associations between these two disparate domains involve a common mediator, such as emotions. For example, people might construe a certain musical piece as happy and so match it to colors that they also construe as happy (Arnheim, 1986; Palmer et al., 2013; Whiteford et al., 2018; Levitan, Charney, Schloss, & Palmer, 2015; Spence, 2020; Curwen, Timmers, & Schiavio, 2023; Barbiere, Vidal, & Zellner, 2007). Evidence supporting this hypothesis usually comes from studies that use semantic differentials (Osgood, 1952; Osgood, Suci, & Tannenbaum, 1957), asking people to rate sensory stimuli on semantic dimensions anchored with antonyms, e.g., happy-sad; warm/cool; lively/dreary.[1] A general finding is that music that is rated as, e.g., more joyful tends to be matched with colors that are also rated as more joyful; music rated as sad tends to be associated with colors also rated as sad. We call the tendency of people to make cross-modal mapping based on shared meaning, semantic mediation.

While there seems to be general group-level music-color correspondence based on semantic mediation, there is individual variability in people's music-color mappings, and it remains unclear whether everyone's associations are similarly mediated by semantic. One possibility is that people's color choices are motivated by implicit and automatic connections between music and color, connections that are high-dimensional, and beyond linguistic description. People might not consciously understand why a particular color matches a specific musical piece, but intuitively sense some link between them. Another possibility is that people explicitly draw on concepts with emotional content or semantic connotations of music and colors to make associations. Prior research showed that language facilitates the formation of those concepts by distilling a broad spectrum of physiological responses and psychological states into more discrete emotional categories (Lindquist, Barrett, Bliss-Moreau, & Russell, 2006; Doyle & Lindquist, 2017). The semantic processing of emotion concepts seems to require language both in their offline conceptualization and during real-time emotional experiences (Satpute & Lindquist, 2019, 2021). We hypothesize that the strength of semantic mediation effect depends crucially on the strategies people use during color-music association.

We investigated how individual differences in strategies influence color-music associations. To do so, we designed an experiment based on prior study (Whiteford et al., 2018)

[1] Prior work referred to these dimensions as emotion dimensions, but also indicated a lack of strong commitment to them being necessarily measures of emotion. To avoid confusion and controversy, in this paper we will refer to them as measures of semantic dimensions.

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where people make judgments about which color is consistent and which color is *in*consistent with a given piece of music. They then rated the colors and music on semantic dimensions and filled out a survey about different strategies that they used during the color-music mapping task. The main questions are: do people use different strategies when associating colors with music? Does semantic mediation work differently for people with different strategies? Do people use similar strategies also *behave* similarly by choosing more similar colors?

Method

Participants

A total of 79 participants participated[2] in exchange for course credit. They included 58 native English speakers, 3 Spanish speakers, 6 Mandarin Chinese speakers, 2 Korean speakers, 1 Japanese speaker, and 1 Gujarati speaker. During the experiment, the experimenter monitored for any instances of inattentiveness to the task and took note of unusually quick and repetitive responses. Based on these criteria, data from six participants were excluded from the final analysis.

Material

We used the same materials used by (Whiteford et al., 2018) which includes a collection of 34 musical pieces from various genres such as Blues, Salsa, and Heavy Metal. Each musical piece was selected based on the following criteria: (1) the absence of lyrics to prevent semantic interference, (2) a general unfamiliarity to the average undergraduate participants, (3) the representation of a spectrum of emotions, and (4) distinct musicality to ensure each excerpt was uniquely recognizable. The excerpts were standardized by trimming to a 15-second length and incorporating a 2-second fade-in and fade-out to each. Music was presented through closed-ear headphones, with volume levels uniformly calibrated by two research assistants across different laboratory computers.

For the colors, we employed the Berkeley Color Project 37 (BCP-37) palette, previously studied by Palmer et al. (2013). As shown in Figure1 ,this palette features eight hues: red (R), orange (O), yellow (Y), chartreuse (H), green (G), cyan (C), blue (B), and purple (P). Each hue was presented in four different saturation/lightness variations: saturated (S), light (L), muted (M), and dark (D).

Tasks

There were three tasks and one survey involved in our experiment, with all participants progressing through the tasks in a sequential order: Task1, Task2, Task3, followed by the survey. The experiment in total took about 75 minutes.

[2]Synesthesia was not a focus of this study, and we did not administer a full synesthesia battery (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007). We did ask "Does hearing a sound make you perceive a color? For example, does a shrill car horn cause you to see the color green? Does a C sharp note make you see pink?". Surprisingly, 18 participants responded affirmatively. There were no differences in response patterns between those who responded 'yes' or 'no' to this question.

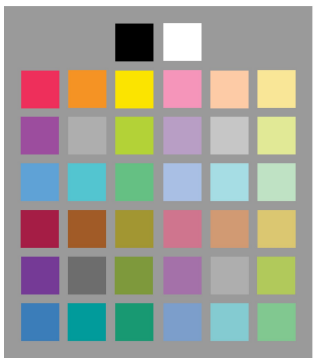


Figure 1: The 37-color palette from the Berkeley Color Project. The top left and bottom right shades of gray were each included twice in the color set.

Task 1: Music-to-color associations Participants listened to 34 musical 15-second excerpts presented in a random order, while simultaneously viewing an array of 37 colors. The task was completed in dark rooms, with all monitors adjusted with a Calibrite ColorChecker Display Pro to ensure color accuracy and consistency across different monitors. After hearing the excerpt once, participants were able to begin color selections, being prompted to first select the three colors they thought best matched the music, followed by the three colors that were *least* consistent with the music. The music looped until all six colors were chosen.

Task 2: semantic ratings of color ratings After completing the music-to-color association task, participants rated each of the 37 colors on 11 bipolar semantic dimensions (Figure 2). The dimensions were taken from (Whiteford et al., 2018). We added weak/strong and passive/active to better capture the potency and activity aspects of the EPA (evaluative, potency, activity) framework of semantic space as conceptualized by (Osgood, 1964). We omitted like/dislike dimension that was included in (Whiteford et al., 2018) from our study because it was not a significant predictor in the findings of (Whiteford et al., 2018). Participants completed all 11 ratings for a single color before moving on to the next.

Task 3: semantic ratings of musical excerpts Participants evaluated all 34 musical pieces on the 11 semantic dimensions using the same procedure as the color-emotion ratings. This process mirrored the approach used for color ratings. The musical excerpts were presented in a randomized order, and participants were required to listen to each piece entirely before rating it on the scales. Ratings for all eleven scales were completed for one musical piece before moving on to the next.

Strategy Survey Participants were asked to reflect on and rate the strategies they employed when determining the colors that best aligned or least aligned with each musical excerpt. These strategies included: When I listened to music, a color or series of colors automatically pops into my mind.

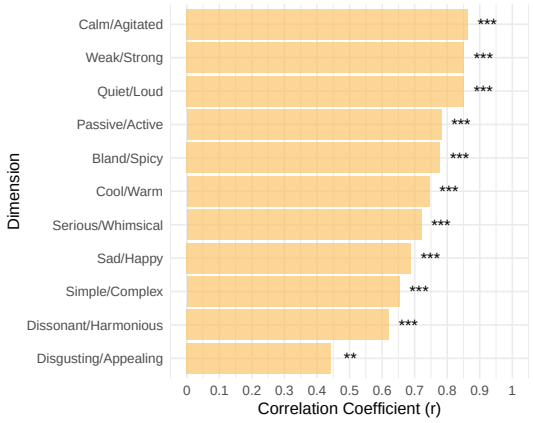


Figure 2: Correlations across 11 semantic dimensions between the average ratings of the 34 musical excerpts and the average of ratings for colors identified as most consistent/ inconsistent with the musical excerpts. The notations *** and ** denote significance levels, with *** indicating $p < .001$ and ** indicating $p < .01$, respectively.

So I chose a color closest to that (*popout*); I relied on my instinct (*instinct*); I was guessing (*guessing*); I thought about the emotion content (e.g., happy, sad) of the music and the color (*emotion*); I thought about the words that could be used to describe both music and color (e.g., wild, mysterious) (*linguistic description*); I imagined the environment in which the music is often played and the colors associated with that environment (*environment*). Participants rated how well do the above sentences describe the strategy/reason they used from *not at all* (0) to *all the time* (10). The survey also asked for basic demographic data and several questions concerning musical and art preferences and training.

Semantic mediation of color-music association for consistent and inconsistent color matches

First, we sought to replicate previous studies regarding the semantic alignment between color and music. To examine the dimensional correspondence between music and color, we computed the music–color association (MCA) score for each of the 34 musical selections along each of 11 semantic dimensions as rated by the same participants. The music-color association score was computed as the average ratings for colors participants chose as being as *consistent* subtracted by the average ratings for those chosen as *inconsistent*. In contrast to earlier studies that applied varying weights to colors based on their order of selection as consistent or inconsistent, we treated all colors, whether chosen first or last, with equal weight in our evaluation as we did not find a significant difference in semantic alignment for different orders of selection.

As depicted in Figure 2, we found large correlations between music and color across each of the semantic dimensions. This result successfully replicated the findings of Whiteford et al. (2018).

We next examined if judgements of consistent vs. inconsistent colors were differentially predicted by semantics. The pattern we observed for consistent color choices showed a positive correlation with the semantic ratings of music (e.g., happy music with happy colors). As expected, the chosen inconsistent colors showed a significant negative correlations with the semantic ratings of music across dimensions (e.g., happy music with unhappy colors). There was also a significant interaction between the type of color choices (consistent/inconsistent) and the absolute magnitude of the semantic mediation effect: the absolute magnitude of semantic mediation for inconsistent colors ($\beta = -.05, t = 16.71, p < .001$), when averaged across participants and musical pieces, was smaller ($\beta = -.06, t = -12.7, p < .001$) compared to that of consistent colors ($\beta = .11, t = 34.69, p < .001$), suggesting people's inconsistent color choices are less semantically mediated than their consistent choices.

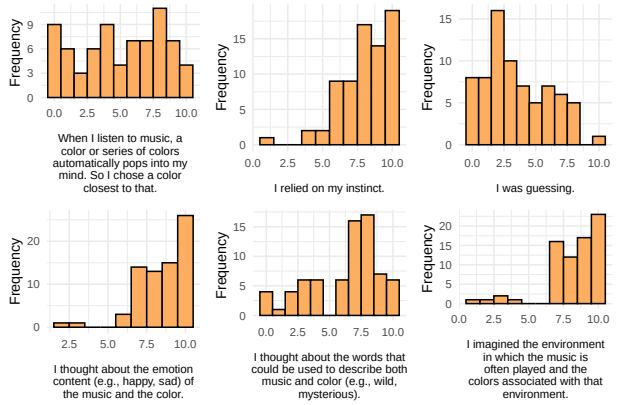


Figure 3: Histograms of the statements that best describe people's color-music association strategies.

Individual differences in people's strategy

As shown in Figure 3, there were substantial individual differences in the strategies people reported using when matching music to colors. Strategies such as *emotion*, *environment instinct*, were most commonly reported, with the majority of participants rating these strategies above five on a scale from 0 to 10. There were larger variations in endorsement of strategies like *linguistic description*, *popout*, and *guessing*.

We examined relationships between different reported strategies using hierarchical clustering (Ward D2 method known for its effectiveness in creating compact, balanced clusters based on squared Euclidean distances, Figure 4). The first cluster suggests a more analytical and evaluative approach, involving strategies such as associating descriptive words with both music and color, recognizing shared emotional content, or identifying common environmental contexts. Specifically, there was a trend for positive correlation between the strategies of *emotion* and *linguistic description* ($r = .2, p = .1$), indicating that individuals who frequently contemplate the emotional content also tend to think about descriptive words applicable to both color and music. The second cluster (*guessing* only) and the third cluster (with *instinct* and *popout*) are both negatively correlated with the

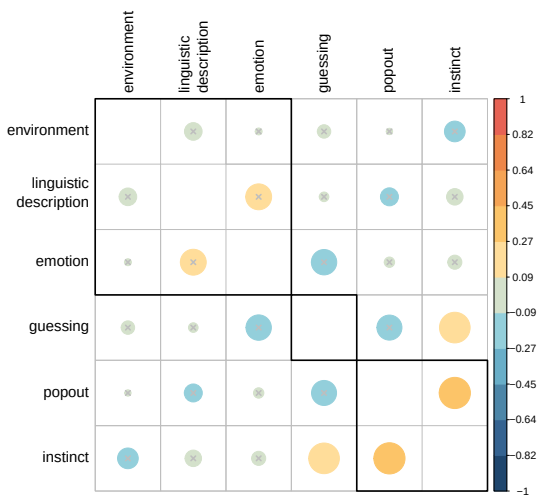


Figure 4: Correlations between reported strategies. Non-significant correlations are marked with "X". Strategies are grouped based on the results of the clustering analysis.

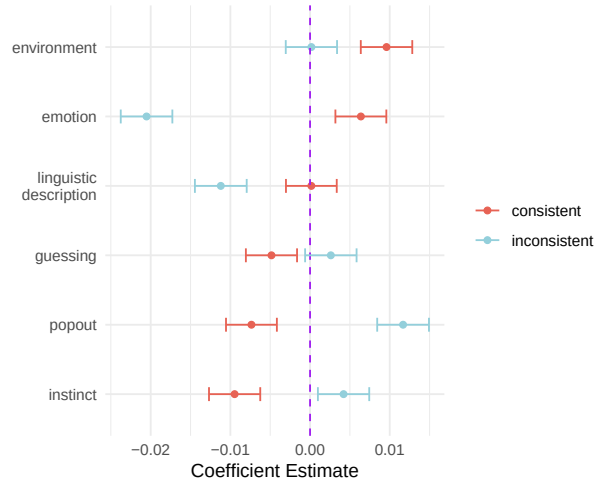


Figure 5: The strength of semantic mediation for consistent and inconsistent color choices for people reporting different strategies for selecting which colors go with (consistent) or do not go with (inconsistent) with a given musical piece.

first cluster. There was a significant positive correlation between the *"popout"* and *"instinct"* strategies, and between *"instinct"* and "*guessing*" respectively.

Is semantic mediation different for people reporting different strategies?

We next examined whether semantic alignment is influenced by participants' reported strategies. Semantic alignment was quantified by modeling the relationship between the semantic ratings of music across various dimensions and the semantic ratings of colors, with the regression coefficient's magnitude indicating the extent of the semantic mediation effect between color and music. Our primary interest lay in understanding how this coefficient's magnitude is affected by the strategies used by participants and whether this influence differs when selecting consistent versus inconsistent colors.

First, we regressed music's semantic ratings on the averaged color's semantic ratings for that color, and looked at how different strategies and domain experiences moderated the mediation effect by including an interaction term between colors' semantic rating and strategy. We also accounted for within-subject variance by including random intercepts for both subjects and musical pieces. The analysis was done in R using lme4 packages (Bates, Mächler, Bolker, & Walker, 2014). Notably, *emotion* significantly increased the semantic alignment effect ($\beta = 0.02, t = 3.27, p < .001$), indicating that participants who reported focusing more on emotional content tend to exhibit a stronger semantic alignment effect. Conversely, those reporting that the colors just popped out to them *popout* ($\beta = -.01, t = -2.38, p < .01$) and those who reported *guessing* ($\beta = -.01, t = -2.35, p < .01$) showed significantly reduced coefficients, suggesting that their responses were less accounted for by semantic mediation.

We next examined the semantic mediation effect separately for the prompt asking them to choose which colors *most* go with the music (consistent choices), and colors that do *not* go with the music (inconsistent choices). As shown in Figure 5 , *environment* ($\beta = .005, t = 2.97, p = .002$) and *emotion* ($\beta = .006, t = 2, p = .046$) significantly increased the semantic mediation effect for consistent color choices, *linguistic description* does not significantly change the semantic mediation effect ($\beta = .0002, t = .959, p = .3$). For inconsistent colors, *emotion* ($\beta = -.02, t = -6.34, p < .001$) and *language* ($\beta = -.01, t = -3.45, p < .001$) significantly increased the magnitude of semantic mediation effect, while *environment* did not significantly impact the semantic mediation for inconsistent color choices ($\beta = -.0002, t = -.96, p = .3$). Interestingly, there were significant interactions between consistent/inconsistent choices and both emotion and linguistic description: the magnitude of semantic mediation effect (i.e., the absolute magnitude of negative/positive correlation for inconsistent/consistent colors) became significantly larger for inconsistent color choices than for consistent color choices (emotion: $\beta = .014, t = 3, p = .003$; linguistic description: $\beta = .01, t = 2.36, p = .018$). In other words, people who reported thinking more of emotion content or linguistic descriptions for color and music tend to exhibit stronger semantic mediation when it comes to selecting inconsistent colors than selecting consistent colors, as shown by stronger semantic mediation for inconsistent music-color associations. There was also a significant interaction between consistent/inconsistent choices and *environment* strategy, though in opposite direction: the more *environment* strategy people reported, the larger the magnitude of semantic mediation effect for consistent compared to inconsistent colors ($\beta = -.01, t = -2.02, p = .028$). In other words, people become more semantically mediated by thinking about the environmental context when it comes to selecting consistent colors than selecting inconsistent colors.

Strategies characterized by more impulsive or spontaneous

responses, such as *guessing*, *instinct*, or *popout* on the other hand, tend to decrease the semantic correlation for consistent color choices (*popout (*$\beta = -.007, t = -2.3, p = .02$*)*, *instinct* ($\beta = -.009, t = -2.95, p = .003$) , or *guessing* ($\beta = -.004, t = -1.5, p = .13$)) while also reducing the magnitude of semantic correlation effect for inconsistent choices of colors (*popout (*$\beta = .01, t = 3.6, p < .001$*)*, *instinct* ($\beta = .004, t = 1.3, p = .19$) , or *guessing* ($\beta = .003, t = .8, p = .4$). This pattern suggests that as participants' reliance on impulsive strategies increases, the magnitude of semantic mediation decreases for consistent selections as well as inconsistent ones. In other words, the magnitude of semantic mediation becomes smaller and smaller as their reliance on impulsive strategies become larger and larger. Unlike strategies like *linguistic description/emotion/environment* which shows asymmetrical effect for consistent vs inconsistent color choices, there was no significant differences observed in the magnitude of semantic mediation effect between consistent and inconsistent color choices for *popout (*$\beta = .005, t = -.87, p = .4$*)*, *instinct* ($\beta = .006, t = 1.21, p = .22$) , or *guessing* ($\beta = .002, t = .61, p = .54$).

Are people using different kind of strategies choosing more similar/dissimilar colors in response to specific music?

We've shown that the strategy employed significantly influences the semantic mediation effect. However, an important question arises: does the choice of strategy affect the actual colors selected in response to specific music? Are there observable patterns in color selection preferences among individuals who employ similar strategies? To explore this, we conducted hierarchical clustering based on the strategies reported by participants. Although no single strategy was unique to any one cluster, the resulting three-cluster model demonstrated distinct patterns. Each strategy varied in its relative contribution across the clusters (Figure 6a). Notably, two clusters predominantly encompassed an instinct-based approach. One of these clusters emphasized a *popout* mechanism (termed *instinct/popout*, $N = 35$), while the other was characterized by a guessing strategy (labeled *instinct/guessing*, $N = 19$). The third cluster was distinguished by a combination of emotional response, linguistic description, and environmental factors, which we refer to as *language & emotion* ($N = 19$). Interestingly, individuals with varying strategy profiles exhibited different response time patterns in color-music association tasks. Participants who predominantly relied on guessing tended to respond the quickest ($meanRT = 4374.4ms, sd = 6086.1ms$). This was followed closely by those who demonstrated a strong 'popout' effect in their strategy use ($meanRT = 4503.04ms, sd = 6357.45ms$). Meanwhile, individuals who heavily referenced strategies involving linguistic description, emotion, and environmental factors generally exhibited longer response time ($meanRT = 4920.59ms, se = 6580.1ms$). Controlling for nonindependence of responses given each subject and each music, responses in cluster *language &emotion* has a trend to be slower than *instinct/guessing* ($b = 546, t = 1.72, p = .08$).

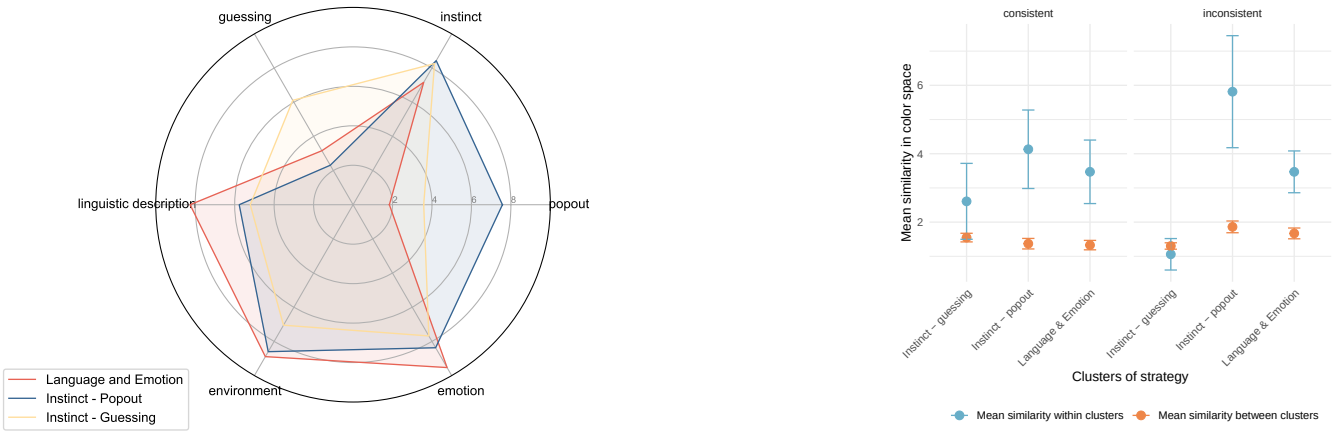
We next measured the pairwise inverse Euclidean distances between the corresponding vector of participants' color choices within the CIELAB color space to assess the similarity of color choices within each music-induced cluster. As illustrated in Figure 6b, across consistent and inconsistent color choices, our analysis revealed that individuals employing instinct/guessing strategies did not exhibit a notably higher similarity in their color selections within the cluster compared to between clusters ($b = .4, t = .67, p = .5$). In contrast, for the 'instinct/popout' ($b = 3.36, t = 3.34, p = .001$)and 'language & emotion' ($b = 1.97, t = 3.51, p < .001$) clusters, the within-cluster color similarity was significantly greater than the between-cluster similarity. This suggests that individuals using these two strategies made more consistent color choices, aligning closely with others within the same cluster.

Discussion

Our research successfully replicated prior findings regarding the semantic mediation effect in color-music association: individuals tend to select colors that match semantically with the accompanying music when prompted to make color-music associations. Specifically, we found this effect might stem from an instinctive reaction to the music, or from an assessment of the meaning that one might attribute to the musical stimuli. We further sought to understand how different approaches might exhibit different patterns for semantic mediation especially when dealing with choices of colors that are either consistent or inconsistent with the music.

We found that people's reported strategies were capturing distinctive patterns of semantic mediation. One is based on deliberate assessment, where individuals consciously reflect on the words, emotions, and contexts that connect music and colors. This deliberate contemplation enhances the semantic mediation effect, as individuals actively engage with the conceptual meanings and contextual relevance of the music and color pairings. On the other hand, people can also rely on their gut feelings, bypassing detailed analytical thought. Interestingly, impulsive responses tends to diminish the semantic mediation effect, suggesting that an immediate, non-reflective reaction to music and colors might not tap into the deeper semantic connections as effectively as the evaluative strategy.

We also found that strategies seem to influence selections of consistent and inconsistent colors differently. Overall, choosing inconsistent colors was less mediated by semantic dimensions. However, people who reported using more analytic strategies involving language and deliberation to link music and colors showed stronger semantic mediation for selecting inconsistent colors compared to consistent ones. The discrepancy between judging inconsistent colors and consistent colors reveals that these two kinds of judgements are not



(a) (b)

Figure 6: Profiles of reported strategies for three clusters of people (a) and similarities between color choices on CIELAB space for within vs between clusters averaged across music (b).

based on the same cognitive process, unlike what prior work assumed (Palmer et al., 2013; Whiteford et al., 2018). A possible mechanism that drove this discrepancy is that judging which colors are inconsistent with a given piece of music requires engaging in explicit negation, which has been found to be more linked to language (Nordmeyer & de Villiers, 2019; De Villiers, 2014).

Pinpointing the specific dimensions that differentiate the music and color requires a focused reduction of the complex, multidimensional semantic space. Here, language emerges as a powerful tool. The ability to articulate and verbalize the distinctions may help to streamline the process, guiding individuals through the high-dimensional semantic space. This finding echoes previous findings regarding language's role in low-dimensional categorization (Lupyan, 2009; Perry & Lupyan, 2014; Lupyan & Mirman, 2013) , which suggest that verbalizing and labeling can enhance the focus on specific, relevant features, aiding in the categorization and differentiation process, especially when dealing with more complex, high-dimensional tasks like selecting inconsistent colors in music-color associations. On the other hand, while thinking about the environment boosts the semantic mediation effect for consistent color choices, it doesn't impact inconsistent color selections. This could be because it is generally easier to consider what colors are present in a given context than to think of what colors are absent.

We also found that people who used similar strategies tend to converge more on their color selections. Those who impulsively 'see' colors in their mind tend to pick similar colors to others who do the same. Similarly, individuals who select colors based on language and emotion also choose colors like others using these criteria. However, this similarity doesn't hold for those who often guess the colors. This suggests that imposing systematic constraints on the association between color and music prompts a greater degree of alignment in color selection among individuals.

Finally, our studies have several limitations. First, the collection of strategy using ratings rather than free responses likely under-represents the range of strategies people used. Future studies could benefit from using open-ended questions to better capture the diversity of participants' approaches. Second, individuals likely use different strategies as they match multiple musical pieces to colors. The post-experiment survey is thus a snapshot of the strategies participants were most aware of using. Third, the relationship between strategy reported and the semantic mediation is correlational, not necessarily causal. It is unclear whether a less effective semantic mediation prompts individuals to adopt a more impulsive approach, or if it's the impulsive approach that leads to poorer semantic mediation. The current data cannot disentangle these two possibilities. Future studies should aim for a more controlled environment, possibly involving random assignment to different strategic approaches and/or employing methods like verbal or visual interference to understand how these impact processing/assessment of color music association.

Lastly, our research does not adequately account for cultural and linguistic variations. While we did not rigorously differentiate the semantic mediation effect across speakers of different languages due to the limited number of non-English speakers, a preliminary comparison suggests that native English speakers and speakers of certain Asian languages (e.g., Mandarin Chinese, Korean, Japanese, Vietnamese) exhibit significant differences in the semantic mediation effect. It's uncertain whether this discrepancy is due to a less nuanced understanding of the semantic dimensions in a non-native language or if it reflects inherent differences in how music and color are semantically interpreted across cultures. Consequently, a more detailed cross-cultural analysis with a diverse linguistic sample is necessary to further elucidate these distinctions and to understand the broader applicability of our findings.

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