

What's the Color of your House? – The Crossmodal Association of Color with Emotionally Weighted House Music

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ABSTRACT

Crossmodal associations have been extensively studied in the context of musical expression and color representation, with emotion proposed as a key mediating factor. This paper presents the findings of an online questionnaire exploring how people associate colors with four music excerpts, each chosen to convey a distinct emotional intention: powerful, peaceful, aggressive, and lonely. Focusing on the House music genre, the study I) identifies patterns in color selection, II) examines variance in responses for participants with and without musical background, and III) evaluates factors that mediate color selection and the undermining human perception mechanisms, building on existent body of research on audio-visual crossmodal associations.

Participants (n=41) listened to musical excerpts and selected a color they felt best matched each piece. Follow-up questions explored the motivations behind their color choices.

The results of this study show patterns in hue, saturation and brightness in color selections associated with music characterized by active/passive and positive/negative emotional tones. No significant difference was found in responses between participants with and without musical background. Finally, the results

show emotion as the main mediating factor in cross-modal associations, but also highlight that semantic, ecological, and visual factors are at play.

KEYWORDS

crossmodal associations, color perception, music cognition, color cognition

I. INTRODUCTION

Music is a universal form of expression that conveys emotions in profound and multifaceted ways. It often encompasses complex emotional states that go beyond simple categorization. In particular, house music—a genre renowned for its ability to evoke a spectrum of emotions, ranging from euphoria to introspection—offers a compelling canvas for exploring more intricate emotional landscapes. House originates in the early 80s, when DJs in underground African-American Gay clubs in Chicago sought to create a realm of ecstasy and safety for their dancers [1]. Building upon previous studies on the connection between color and emotional intent in music [2,3,4] this study explores these connections in house music.

The results of this study may potentially enhance the live performances with visuals being more synchronised with the emotional

intents of the music being played. The findings of this study could aid in real-time performance feedback for music education or facilitate searches within large music databases, where color is used as an emotional index [4].

II. BACKGROUND

Previous Studies

Beyond synesthesia-specific research, which examines the phenomenon of cross-modal experiences involving audio-visual stimuli, there has been a growing body of research exploring cross-modal associations in individuals without synesthesia. Some studies have focused on the relationships between low-level musical elements and their associated colors. These associations are often described in terms of synaesthetic congruency, which defines correlations between stimulus features such as brightness, pitch, and lightness across different sensory modalities [5]. For instance, higher pitches have been found to correspond with lighter colors, while light gray patches are associated with louder sounds, and darker gray patches with quieter sounds [6].

Other studies, however, have investigated higher-level qualities of sensory stimuli and their cross-modal correspondences, often described as semantic congruency. This concept refers to the pairing of auditory and visual stimuli in a way that feels intuitively matched or mismatched, leading to a perceptual binding of the two. For instance, Bresin [4] observed that compositions in minor tonalities were associated with colors of higher saturation, whereas music in major scales was linked to lighter colors compared

to minor scale compositions. In contrast, Palmer et al. discovered that faster music in major scales was associated with more saturated, lighter, and yellow-toned colors, while slower music in the minor key showcased more desaturated, darker, and blue-toned colors [2]. Moreover, Barberie et al. found that gray was associated with sadder music, while red, yellow, green, and blue were more commonly linked to happier music [7]. Despite these findings, it is important to note that these associations may be culturally mediated. The perception of some basic emotions like happiness/sadness in music is independent of the culture a person originates from. However, for more complex emotions like anger, there is a cultural element to their perception. One contributing factor is linguistics; for example, certain cultures have more than one word for an emotion, each with different connotations [8].

In addition to perceptual studies, research has been done on representational mappings of specific colors to music genres. For instance, Holm et al. [9] conducted a study in which participants were given 12 colors and asked to associate them with 18 music genres. While the genres used in the study were relatively general, the results revealed that cyan and pink were the most commonly mapped colors, with significant associations also noted for purple, red, and yellow for electronic and dance music, which contain house as a subgenre.

Crossmodal Associations

A rich body of research focuses on the perceptual level to evaluate the correlations

between associations of stimuli in two different sensory channels.

Patterns of crossmodal associations have been discovered to be dependent on a number of factors such as gender, culture, and patterns acquired by individuals. In fact, some aspects may even have a psychobiological basis [10]. While these crossmodal associations are not limited to specific sensory channels, in the interest of this study, we will focus on the audio-visual cross-modalities.

Each crossmodal association pattern takes place on a different level of neural processing in the brain. Spence [5] recognizes three types of crossmodal correspondence: structural, statistical, and semantic, with an additional fourth category: emotional, empirically confirmed by [10].

The structural crossmodal correspondences occurring at an early processing stage in the brain, are based on the way neurons code sensory stimulation. This is related to the fact that when sensory-specific regions in the brain are located in close proximity, the neural spikes produce a crossmodal capture effect [5]. The ecological crossmodal correspondence is based on statistical co-occurrence and ecological perception. When the same information arrives simultaneously through different sensory organs, or via parallel neurons, it may become associated with an intermediate point in the neural processing path if they both increase the body's arousal or if they have the same effect on emotional state. This mechanism relies on learning from prior exposure to the stimuli.

Cognitive level crossmodal associations are learned consciously based on descriptive terminology and language, and are subject to people's control, inspection, and training.

On the pre-cognitive level, crossmodal associations are mediated by emotion [2]. In

the context of music-color association, it was proposed that following exposure to the auditory stimulus, emotion arises and this influences the choice of corresponding color [2].

The studies had three main limitations that our project responds to. Firstly, they tend to overly focus on the role of emotions as a mediating part of crossmodal associations. While we aim to test this in our studies, we would like to remain open to examining other mediating mechanisms that may have an equal role in mediating the crossmodal association mechanisms. Secondly, some studies limit the color options given to the participants which may lead to generalisation and lack of nuanced and accurate results. Similarly, the abovementioned studies display color patches in parallel or other patterns introducing the spatial effect and contrast, skewing the perception of colors [3].

Finally, the majority of the studies tend to focus on music that by its nature, does not involve vocals, such as classical or film music. While we still examine songs without lyrics, we chose a music genre that often involves vocals, and is more common.

III. METHODOLOGY

I. Study Design

The aim of the project was to explore the participants' subjective interpretations of the music excerpts and their associations with specific colors and emotions. By further analyzing the meanings, themes, and patterns emerging from the participants' responses, this study employed a qualitative approach to gain a deeper understanding of the interplay between auditory stimuli, emotional experiences, and color associations. An

additional aim was to examine whether the chosen genre of house music can evoke unified emotional responses.

The project was conducted in four main stages: music excerpt selection, development of the online questionnaire, data collection, analysis.

A) Music Excerpts

Based on the literature review, we have decided to explore a music genre that has not been researched in the context of audio-visual associations. Collectively, 4 music excerpts were selected from house genre, each conveying a distinct emotion representative of the Valence-Arousal model [11].

The four final music excerpts are as follows:

Emotional intent	Emotion Axes	Artist	Title	BPM	Key	Duration
Powerful	positive/active	Avicii	<i>Silhouettes</i>	128	A♭ major	14 s
Peaceful	positive/passive	Holo	<i>Oceanside Girl</i>	118	E♭ major	16 s
Aggressive	negative/active	Justice	<i>Waters of Nazareth</i>	124	D minor	14 s
Lonely	negative/passive	Luttrell	<i>Sunrise Song</i>	122	C# major	16 s

To mitigate the impact of other factors that might have influence on the color selection, or the music perception, the study was limited to using vocal-free music excerpts to eliminate the impact of lyrics on emotion perception. Furthermore, selected excerpts were normalized for loudness and restricted to short durations with 100ms fade to ensure consistency, as well as uniformity of emotion conveyed by the performance.

B) Online Questionnaire

We have decided to develop an online questionnaire, as our primary emphasis was on capturing immediate, subjective responses. Since listening and experiencing

music is a form of entertainment, we believe the lab environment might have a significant impact on music perception. We wanted our participants to participate in this study from the comfort of their homes, where most often they may listen to music. This also allowed for a larger sample and more culturally diverse responses.

The questionnaire was developed using custom HTML, CSS, Bootstrap, JavaScript, PHP, and MySQL to create a user-friendly interface. The color picker functionality within the form was implemented using a jQuery plugin - Bootstrap Form Helper, which provided the required intuitive and visually consistent color selection tool for participants.

The background of the interface was black, with a white primary content area containing black text and elements. The interface was completely designed in grayscale shades to eliminate any color bias.

Before being presented with the excerpts and the color pickers, participants were required to confirm: the light in their environment is normalized, they were using headphones, deactivated the screen-color altering modes, colors in the color test image seemed to be displayed correctly, and sounds are played back properly and at comfortable levels. Without confirming these prerequisites, they were not able to proceed with the following questions.

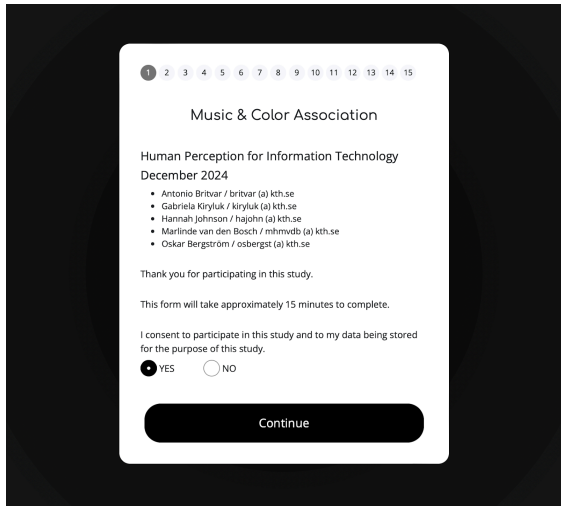


Figure 4.1. Starting screen of the questionnaire.

All musical excerpts were always presented in the same order: Powerful, Peaceful, Aggressive, and Lonely. To ensure proper collection of impromptu responses and mitigate the contrast effect, participants were not able to go back to the questionnaire's previous screens. Furthermore, in order to enable the color selection feature, participants needed to have played the excerpt in order to respond and proceed to the following screen. This was implemented to ensure participants listened to the excerpt.

Following the introductory screen, participants were presented with 4 music excerpts each present on a separate screen. For each excerpt, participants were asked to select the color they felt corresponded to the music. Later they were shown the selected color and were asked to describe why they selected that color, and what emotion it evoked. When choosing colors, the participants were able to see the full-color spectrum and freely select rather than having individual control over RGB values.

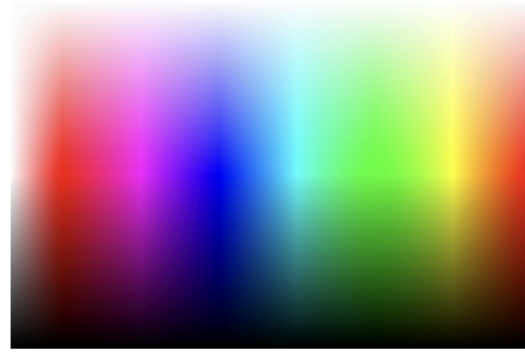


Figure 3.1. Color picker interface.

C) Data Collection

Participants were given one week to complete the 15-minute questionnaire, during which the responses were collected and stored. The results were then analyzed and interpreted. Each participant was provided with a hyperlink to access the questionnaire. They were instructed to complete it in a single session without interruptions, setting aside at least 15 minutes of time. On the first screen of the questionnaire, participants were presented with a consent statement.

II. Participants

The participants were selected through random sampling from the researchers' pool of acquaintances. In total, 44 participants completed the study. Criteria for exclusion included synesthesia (2 cases), color blindness (0 cases), and hearing impairment (1 case). The final sample consisted of 41 respondents, with ages ranging from 22 to 57 years ($M = 29.10$, $SD = 10.16$). The median age was 25 years.

Among the final 41 participants, 18 of them (44%) reported having a musical background, while 12 of them (29%) reported having a dance background. Most of

them were from Sweden (12), Croatia (8), Poland (8), Serbia (2), and Italy (2), while individual participants came from Greece, Guyana, India, Indonesia, Mexico, Spain, Sri Lanka, Taiwan, and the United States.

The music preferences reported by the final pool of participants showcased a diverse range of genres, with commonly mentioned pop (13), rock (7), jazz (7), indie (6), and soul (4). This suggests the majority of the respondents prefer genres that incorporate vocals, which showcases the need to expand the research to a wider spectrum of music genres.

IV. RESULTS

The open-ended exploration reveals three main findings in the association of colors with emotionally toned house music excerpts.

- (1) The general trend in hue, saturation, and brightness in color selection across excerpts.
- (2) The impacts of musical background on color selection.
- (3) Mechanisms underlying the cross-modal associations for music and color.

The main analysis quantitatively examines participants' color choices, broken down into hue, value, and saturation, and their associations with the selected emotions. Follow-up questions about how the music excerpts made the participants feel were designed to serve as a secondary layer of analysis.

For the calculations of mean hues in the statistical analysis, a circular mean was used to get more representative values, since hue is

expressed in degrees in the HSV form. For example, a data set of hues normalized within the range (0, 1) with values close to 0 and 1 would result in a mean hue around 0.5 if a standard mean was to be used, which would be misrepresentative as 1 and 0 represent the same hue.

I. Trends in Hue, Saturation, and Brightness

The hex codes for participant-selected colors were converted to hue, brightness, and saturation using MATLAB. Based on Ware's color selection recommended for use in color coding [12], the hue values were divided into 12 color categories. Figure 5.1 illustrates the distribution of color selections for each music excerpt. The following patterns occur:

- Excerpt 1, Powerful
(Avicii – Silhouettes)
Many participants chose bright and saturated colors, with hues spread across the range, but with a greater density mid-range (greens and cyans).
- Excerpt 2, Peaceful
(Holo – Oceanside Girl)
Participants frequently selected cooler hues, like blue, purple, and green, with a preference for distributed brightness and high saturation.
- Excerpt 3, Aggressive
(Justice – Waters of Nazareth)
The dominant hue was red, with high saturation and distributed brightness that notably included lower values than other categories.
- Excerpt 4, Lonely
(Luttrell – Sunrise Song)

Compared to the other songs, more blue, purple, and orange were selected. Participants often chose pastel colors: lower saturation and high brightness.

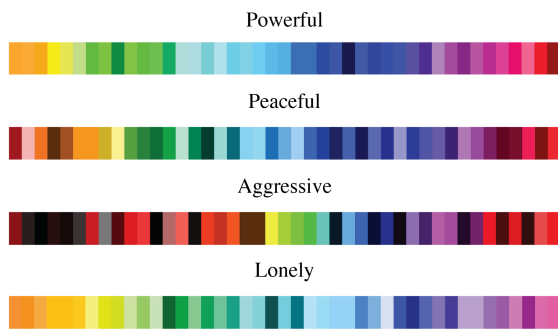


Figure 5.1. All responses were categorized by musical excerpt and sorted by hue.

Across all four music excerpts red, cyan, blue, and magenta were the most frequently selected hues, illustrated in Figure 5.2. This perception result supports previous representational findings of cyan and magenta being associated with dance and electronic music [9].

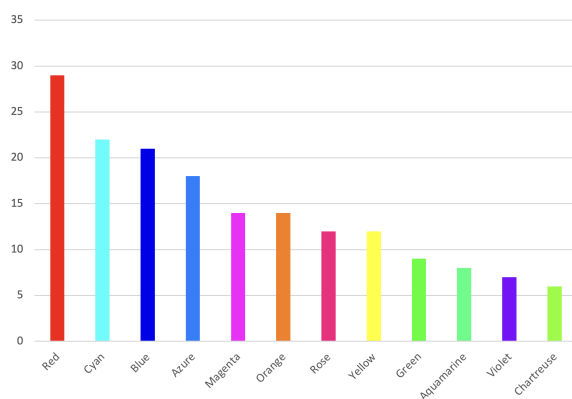


Figure 5.2. Frequency of hue selection across all four excerpts overall.

II. Participants' Perceived Emotions and Associations to Color

Participants interpreted a wider spread of emotions for each music excerpt than intended. In the first excerpt, chosen to

represent the feeling of power, participants identified feelings of energy, empowerment, euphoria, and happiness. For the second excerpt, symbolizing peacefulness, participants associated emotions of calm, peace, energy, and relaxation. For the third excerpt, in addition to the intended emotion of aggression, participants also identified feelings of anger, anxiety, and confusion. Finally, for the last excerpt chosen to represent loneliness, participants associated feelings of calm, energy, and positivity.

Based on the colors the participants selected for the tracks as well as the emotions they reported that they felt were evoked by the songs, some general trends could be identified. Negative emotions, such as anger, aggression, chaos, and confusion seemed to be associated with mean hues close to red, while emotions like happiness, positivity, calmness and peace tended towards blue and cyan (Fig. A5). In the same figure, we can also see the mean saturations for the emotions, which show a slightly higher mean saturation for the feelings of excitement, and euphoria and the lowest mean saturation for the feelings of neutrality and indifference. For the mean color values, negative emotions, such as anger, aggression, anxiety, and unease, seemed to correlate to lower color values, while more positive emotions such as energy, empowerment, happiness, positivity, hope, and freedom seem to tend towards higher mean color values (Fig. A6).

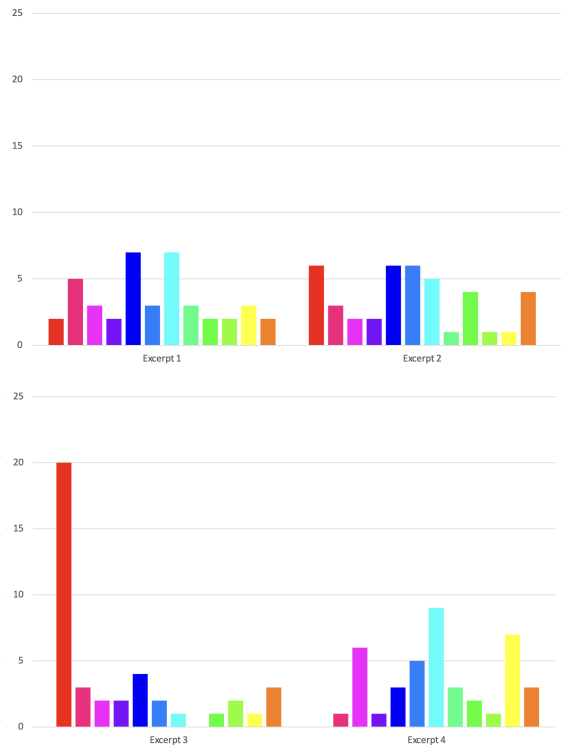


Figure 5.3 Frequency of hue selection across individual musical excerpts.

See the appendix for distribution graphs for hue, saturation, and brightness for each excerpt.

III. Impact of Musical Background

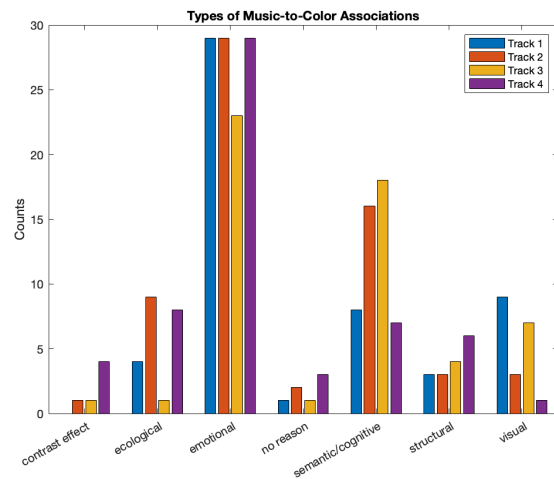
A significant portion of study participants identified as having a musical background, prompting an analysis of its potential impact on color-music associations.

The results revealed no significant differences between participants with and without a musical background for hue associations. For the tracks evoking powerful and lonely emotions, the circular means of the selected hues were predominantly skewed toward blue and cyan (Figures A1–A1b and A2–A2b). Conversely, the aggressive track was consistently associated with red hues (Figures A3–A3b). Notably, the mean values and standard deviations for

both groups were remarkably similar for the aggressive track. This finding could potentially be attributed to the red hues being at the extreme end of the color palette interface available to participants.

The peaceful track was the only to show a distinct divergence between the groups: participants with a musical background associated it with hues closer to red, whereas those without a musical background favored hues closer to blue (Figures A2–A2b).

IV. Crossmodal association mechanisms



Following the color selection, participants were asked to explain why they chose a particular color, giving insight into possible crossmodal association mechanisms, as categorized in Fig. A. Confirming previous study results, the majority of the responses highlight the role of emotions in color selection. Surprisingly, the second most frequent crossmodal associations were on cognitive/semantic basis, suggesting that for some respondents the color-music associations may be solely mediated by reason. However, in 36 % of responses, multiple mechanisms were identified based

on the participant's written answers. This finding gives rise to methodological considerations, suggesting that perhaps other forms of data collection such as interviews, or brain scans may deliver more insights into the crossmodal association mechanisms. Furthermore, the contrast effect has been identified as a mechanism that influences the color selection for participants.

V. DISCUSSION

The aim of this study was to evaluate people's crossmodal associations between house music and colors. Through an open-ended exploration, authors have identified 3 themes in the results of the study: trends in hue, saturation, and brightness in color selection across excerpts, the impacts of musical background on color selection, and mechanisms underlying the cross-modal associations for music and color.

Consistent with prior research [2,3], emotion emerged as the primary mediator in music-color associations. Aggressive music was strongly linked to red hues and negative emotions like anger, while the peaceful and lonely excerpts were associated with cooler hues such as blue and cyan, reflecting calmness and positivity. These findings align with established theories on warm hues representing arousal and tension, and cooler hues symbolizing serenity [5].

While emotion was the main factor in these cross-modal associations, several other mechanisms, such as ecological, structural, and visual, were identified by participants. Cognitive/semantic mechanisms played significant roles, as participants frequently

referenced the associations with certain colors that were mediated by their knowledge of color symbolism, culture, and language. This shows that in addition to cultural influences highlighted by Argstatter, the color-music cross-modal association is a multifaceted one and a singular factor cannot be examined as the sole influence on color selection (2016). Future research needs to consider these factors, developing more robust and comprehensive methods to examine the interplay between these mechanisms.

The lack of significant differences between participants with and without musical training may suggest these associations are broadly universal.

Project Assessment

The main strengths of this project are a relatively large sample size (N=41) with diversified data across ages, genders, and countries of origin. The online design of the study facilitated distributed data, avoiding the demographic limitations associated with an in-person study. The freedom of filling in the study in the comfort of participants' own home is another strength as participants may behave differently or feel rushed to pick the right color while in a lab setting.

Furthermore, the study focuses on the house music genre, something that previous studies in color-music associations have not conducted before, hence enriching the body of research with new findings. Lastly, the project also incorporates the underlying mechanisms influencing people's color associations, expanding our search beyond solely emotionally mediated results.

However, there are some areas for future improvement. Following previous studies, asking participants to rank the amount of each emotion in the music excerpt on a Likert scale instead of open-ended responses would have produced more analyzable data. Since this was not done in the study, there is an unnecessarily strong reliability on researchers' coding which may have influenced the results.

Finally, to get a real insight into the crossmodal association mechanisms, interviews would have provided more information. However, our study provides an invitation to further examine these mechanisms by adopting different methods.

VI. FURTHER DEVELOPMENTS

Studies in the field of audio-visual associations tend to focus on instrumental music, such as film scores or classical pieces, which inherently lack vocals. However, it is important to expand research to a broader range of genres, including those where vocals play a significant role in shaping the music. Future research could explore the influence of lyrics on the emotional responses evoked by music and examine how they mediate the association between music and colors.

Since some of the participants identified that the comparison between sequential music excerpts impacted their color selection, it is important that future studies consider this factor. To mitigate the contrast effect, tests should present the music selection in a random order and a large participant pool.

It is important to emphasize that in order to ensure accurate results, the hypothesized mechanisms of crossmodal correspondences—structural, statistical, semantic, and emotional—should be studied using neuroimaging methods. By analyzing these mechanisms, which operate at different levels of information processing, neuroimaging can provide precise insights into why respondents associate specific colors with particular stimuli.

Broader areas, such as the exploration of additional emotions or genres, connections to other expressive modalities like facial expressions or actions, and cultural or individual variance in emotional perception, are not addressed in this study. These elements, as well as the philosophical question of who defines emotional expression in music, remain beyond the scope of this research, leaving opportunities for future studies.

VII. CONCLUSION

This study has explored cross-modal associations between colors and instrumental house music. It has found emotional association to be the most common form of relating musical excerpts to color. The results also show that musical excerpts conveying aggressive emotions tend to be associated with colors of lower brightness and hues closer to red; music conveying more positive emotions, such as powerful and peaceful, has hues centered around green, blue and purple, with high saturation and brightness; and music meant to convey the emotion lonely stands out with its correlation to pastel colors, (i.e. high brightness and low

saturation). Furthermore, musical background does not seem to be a factor that significantly impacts the association between color and musical excerpts. It's difficult to draw decisive conclusions from a study such as this one in isolation, but combined with previous and future research in the area, it might give a basis for understanding how we associate colors to music across genres, which can be valuable for enabling visual feedback in applications where emotional intent of music or musical performances needs to be conveyed through color.

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APPENDIX

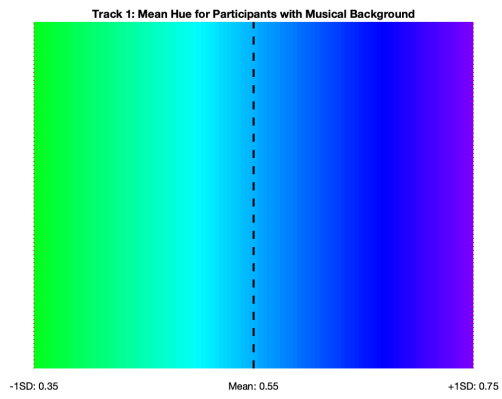


Figure A1

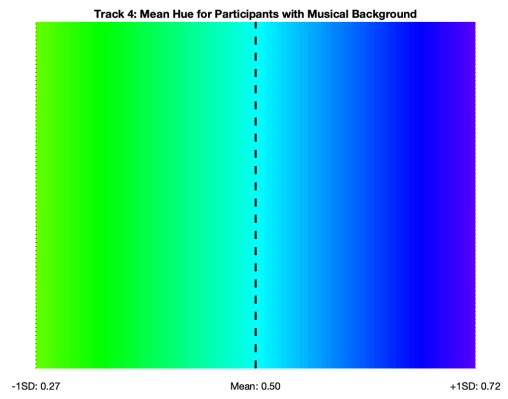


Figure A4

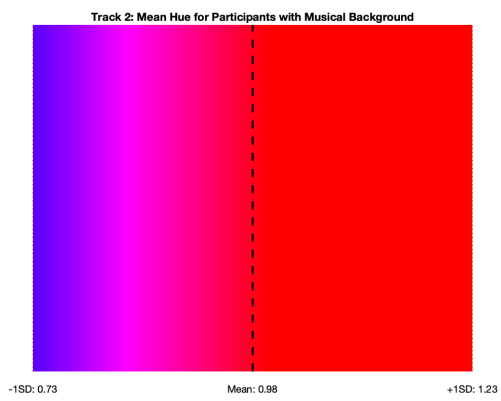


Figure A2

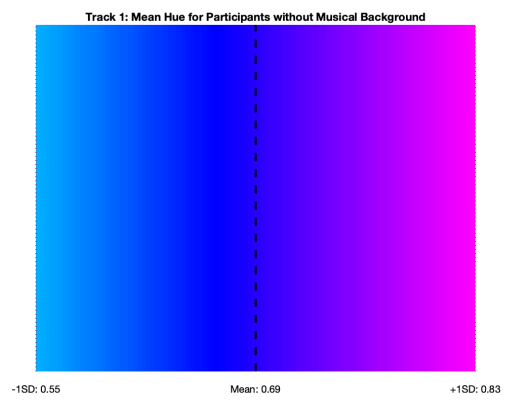


Figure A1b

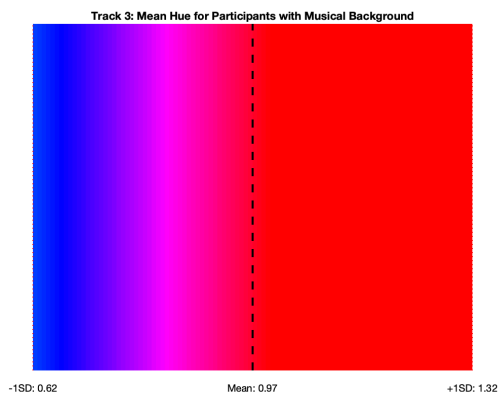


Figure A3

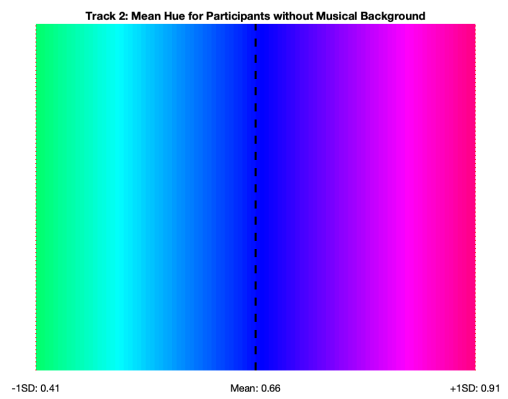


Figure A2b

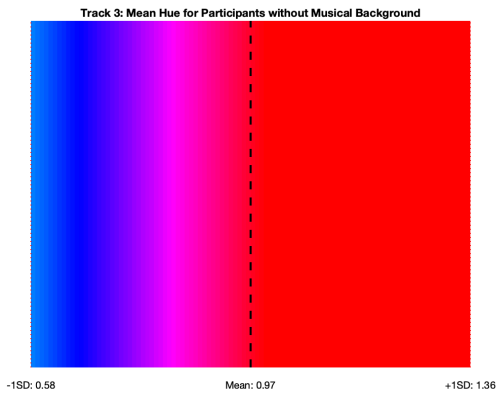


Figure A3b

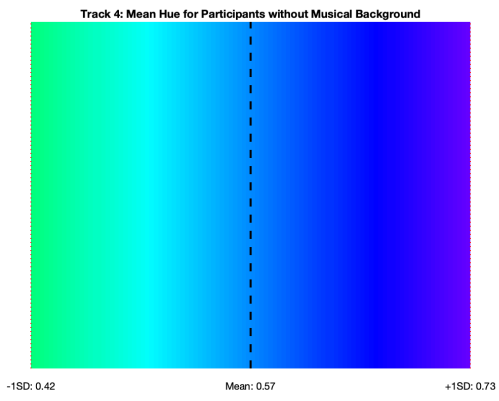


Figure A4b

Mechanism	Directed to	Description	Quotes
contrast effect	comparisson	respondent highlights how their color choice was impacted by listening to the previous song	"Similar to the musical excerpt 2"
ecological	nature	respondent highlights the association between the music excerpt, nature and the associated colors	"It's sad, it makes me think of a rainy weather." "It feels deep like a deep ocean and it makes you float."
emotional	feeling/ emotion	respondent highlights how the specific color felt in correspondence to the music excerpt - use of words such as: it felt like, it feels, emotion specific words	"Because it's very relaxed and calmed "
	imagery	respondent brings a memory of a scene or imagines where appropriate color would be visible in the context of the heard song	"It felt very much like soft dancing in your room "
	vibe	respondent highlights the "vibe" of the heard song and how the color corresponds to that. It overlaps with a feeling, but it seems like a separate category too	"Chill in the forest kinda vibe" "It gives me a vibe of "deep focus music" on Spotify. And because of that it feels calm but also in a way cherish "
no reason	no reason	respondent is not able to identify the reason behind their color choice	"Not sure actually"
cognitive/ semantic	audiovisual	respondent uses language that can both describe the audio and visual aspects	"It seems energetic like the song, it's bright and the music seems bright as well" "The music has a happy feel but is simultaneously pretty calm and low energy which matches a sort of dark blue/almost purple-y"
	association	respondent highlights how the music makes them think of something (e.g. scene) where specific colour is present	"The song reminded me of an artist which i listen too who makes use of red in her videos."
	colour conventions	respondent associates different elements of the music excerpt with colors that are culturally symbolising specific emotions, feelings	" I associate the light blue colour with calmness and technology."
structural	activity/ movement (imagined)	respondent highlights how the chosen color corresponds to movement evoked by a song or specific structural elements of the song such as beat, tone, rhythm, tempo etc.	"The synth sounds and the chord choices gives this one somewhat of a moody aquatic feel witch matches a sort of aquamarine" "A bit up beat but not too much, like giving you time to slow down and not in a rush."
visual	visual event	respondent highlights how the heard song makes them visualise a particular color	"club lights but dark", "I see the computer bits and somehow blue felt like the color. It just popped up."

Figure A5

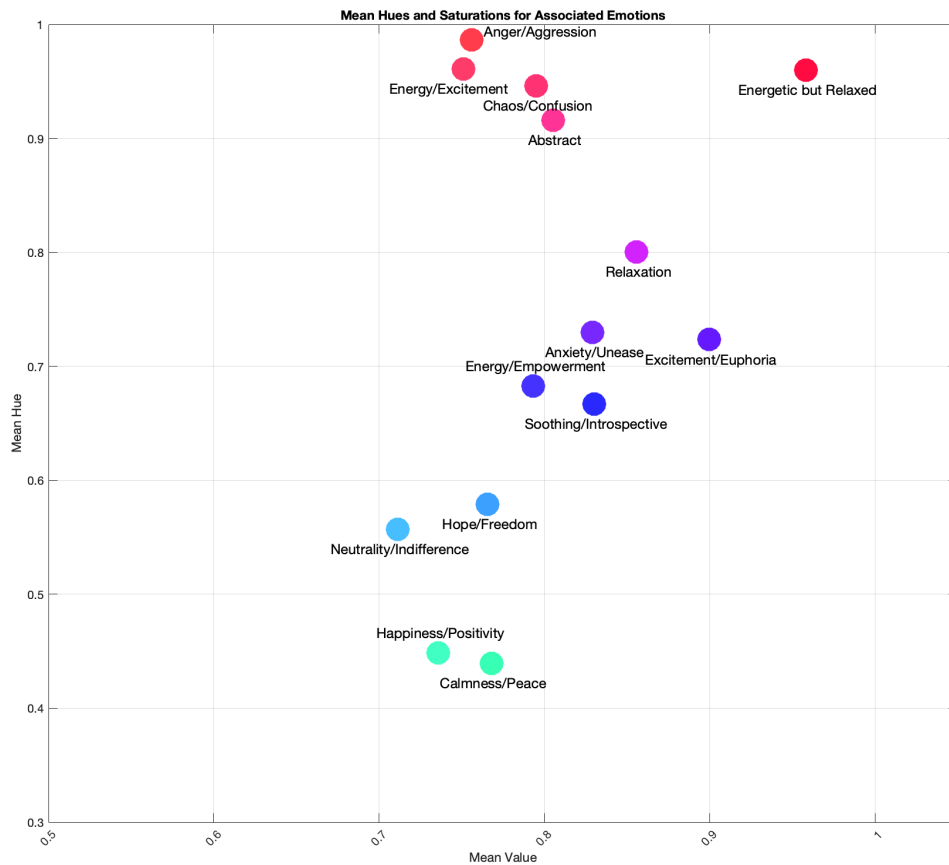


Figure A6

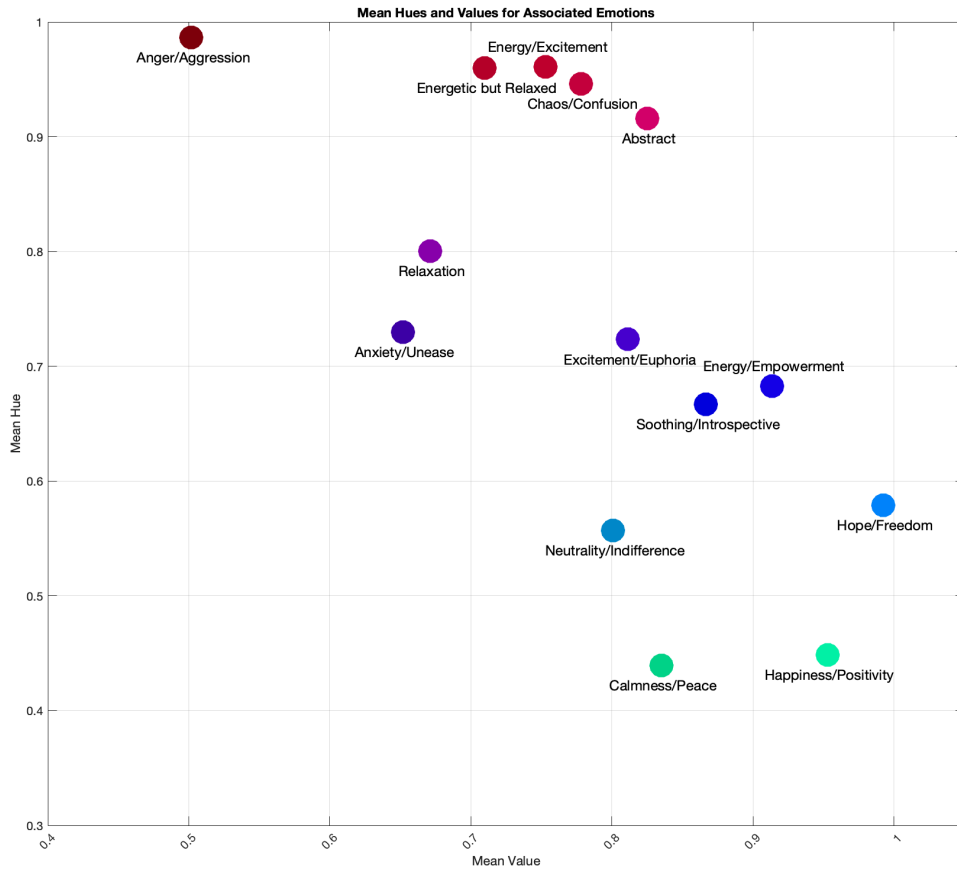


Figure A7

