Creativity and Consistency in Musical Perception of Tangible Objects

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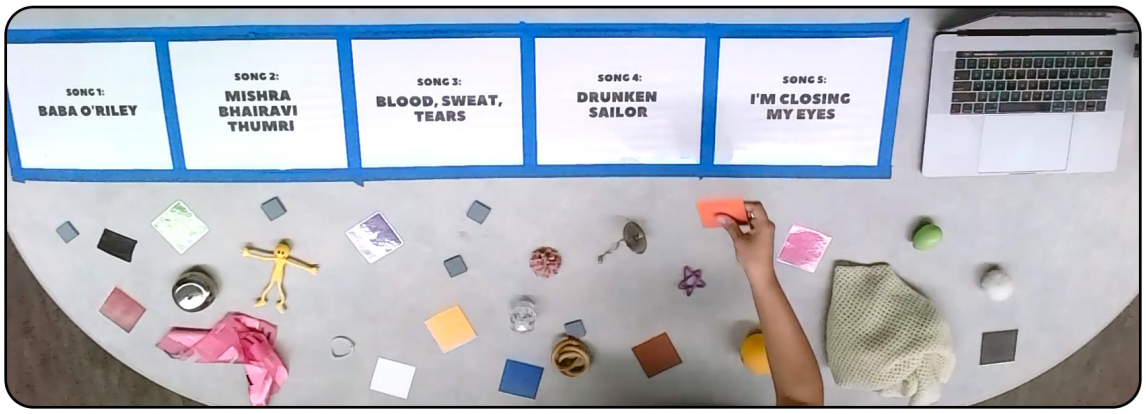

Fig. 1. Human study setup: participants associated physical objects with the piece of music that felt most appropriate.

Interacting with tangible objects can enhance our immersion in and the understanding of the experience of music. Associating tactile properties with sounds is an inherently creative process, but we lack a quantitative perceptual basis for these associations. A better understanding of this process of creative association can open new avenues for music appreciation or enhanced tangible musical experiences. When presented with a collection of objects and a collection of music, we found that study participants often associated specific objects with specific songs in consistent ways, while still using various creative ways to make these associations. Their explanations for the matchings identified possible salient perceptual features present in these pairings. Along with the results of our study, we offer a categorization of perceptual relations that can help us design meaningful physical representations of music in the future. With these understandings, we provide a basis for a new aspect of creativity research in music perception of tangible objects.

Additional Key Words and Phrases: music perception, creativity, tangible

1 INTRODUCTION

Making the rich medium of music available via more of our senses enhances our experience of music. This work explores how people come to associate aspects of music with the tactile and interactive characteristics of tangible objects. It has been shown previously that there is creativity present in the perception of music [23], and we demonstrate that this connection extends to music object associations. These kinds of associations are of interest to those studying embodied cognition, which explores how interacting with the physical world around us affects our perception of reality [7].

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Succeeding in creating connections between sounds and tactile properties could open up new avenues for expanding music appreciation that compliment cochlear (listening-based) modes of experience [18, 20].

In this paper, we report on an 11-participant study to understand how people associate attributes of physical objects with features in musical pieces. Rather than only experimenting with low-level stimuli like physical texture samples or auditory tone samples, we offered our participants a range of objects including both complex and semantically ambiguous options [Figure 3]. By sorting objects into groups based on their association to songs and verbally justifying their choices, participants communicated relevant features of the objects and songs in addition to identifying when specific features made strong connections across the physical and musical modalities. By interpreting their choices and explanations, we are able to infer a taxonomic space of significant features and verify the existence of common modes of association across several participants. These results offer a foundation for future theoretical and empirical research into the creation of effective tangible and tactile music-inspired objects.

2 BACKGROUND

2.1 Creativity in Music Perception

Perception of music is an inherently creative process that involves different networks of our creative imagination underlying various multi-disciplinary cognitive aspects [12, 15]. Modern music perception research expands upon raw acoustic characteristics of music, like pitch, loudness, tone, etc., to include more diverse and experiential aspects of listening, such as feelings, memories, cultural context, and individual cognitive creativity [6, 23]. In this expanding field of music perception, we would like to explore this emerging concept of creativity, an inter-sectional idea that envelops the aforementioned concepts.

van der Schyff et al. state that creativity in a listener can be seen as the combination of individual and environmental factors that allow varied interpretations of music [26]. Schavio et al. propose the idea that music perception requires meaningful and active interactions between a subject and their environment, which can lead to greater creative outcomes [23]. This understanding of music creativity extends the experience of listening to music past internal cognitive processes and incorporates external stimuli in the form of bodily interactions. These interactions can be as simple as tapping your foot to a beat, feeling the vibrations through a sub-woofer, or interacting with any physical objects. These tangible interactions with physical objects can change the cognitive understanding of music within a listener. Thus both internal and external factors drive the creativity behind listening to music and suggest a connection between music perception and embodied cognition [23, 26].

2.2 Psychology of Embodied Cognition

One of the research interests in the quest to better understand how our brains understand the world around us is the study of *embodied cognition*. Embodied cognition is the idea that many aspects of the way we perceive the world around us are influenced by the combination of our experiences in the physical world, including tangible and sensory interactions [9]. As highlighted by Dourish, embodied cognition has been of interest in the human-computer interaction domain as well laying importance on the primacy of natural physical interactions over abstract cognition in everyday activity [7]. Metatla et al. were also interested in multimodal sensory associations with physical objects, with their focus being on smell as opposed to touch [17]. Castilho et al. target their analysis more on 3D printed objects that can be used in an embodied way to understand our interactions with daily activities [5]. We share similar intentions as

Metatla et al. to allow multi-sensory inputs of cognition in music listening while pulling from Castilho's use of 3D printed objects to curate the set of possible objects available for our study.

Physicality plays an important role in the various perceptions of music meaning as shown in their work by Pon et al. where they physicalize muscle tensions of live music performers for an immersive audience experience in the perception of music [21]. Styven also provides important evidence in the role of embodied cognition for music perception citing a positive music engagement correlation with an increase in tangibility preferences, among other subjective factors [25]. Further, Braganca et al. explore synesthesia research in relation to how music sensations aid the construction of multiple abstract associations and provide pointers to different perceptual aspects involving embodied cognition that are interconnected in the cognitive process of meaning making [2]. Our work serves to bridge the gap in providing evidence for the connection between auditory and tactile means of music perception and thereby explore aspects of cognitive creativity lying in the underpinning of such associations.

PHYSICALIZATION FEATURES

	SEMANTIC	TACTILE	PHYSICAL ATTRIBUTES
SHAPE	Physical symbolism Textual symbolism	Texture	**Geometric shape** Visual complexity Physical size
SHAPE-MATERIAL	Recognizability as everyday object **Object symbolism**	Squishiness Vibration Flexibility	**Capability of specific motion**
MATERIAL	**Fabricated media** Combinatory media Psychophysical disruption	Taste **Softness** Stickiness Furriness Temperature Smoothness Slipperiness	Scent **Color** **Density** Weight Transparency Chemical properties

SOUND FEATURES

	RAW ACOUSTIC FEATURES	MUSIC FEATURES
DATA	**Beat** Pitch Energy Loudness Digitalness **Instrumentation**	Lyrics **Flow** Novelty Repeatability **Danceability** Homogeneity Immersability **Affect (emotion)**
METADATA	License Sample rate (hz) Length (seconds) Number of channels Recording technology Context-based recording details	**Era** **Genre** Artist Popularity Explicitness **Cultural origin**

Fig. 2. Our taxonomies categorizing physical attributes and features of music that are relevant for tangibility in music perception. Bolded features were consistently chosen by the participants, based on our qualitative analysis of study data.

2.3 Methods for Studying Perceptual Associations

The main techniques relevant to this work for studying perceptual associations can be found in previous research in both music perception psychology and human-computer interaction [6, 14]. In the field of music perception psychology, Dibben et al. had participants listen to music and everyday noise samples and asked them to identify which noise sample best matched the music through verbal explanations for their choices. Within human-computer interaction, Isbister et al. created a set of physical objects for participants to identify with detailed emotional responses after being exposed to a digital media experience.

We combine the methodologies of the two studies. Similar to Dibben et al., our participants classify items according to similarity to given music samples. Similar to Isbister et al., our participants manipulate and sort physical objects. While we do not aim to offer our specific collection of objects as a reusable benchmark, we would like the features that participants ascribe to them to be examined in future work.

3 PERCEPTUAL FEATURE TAXONOMY

Before performing our study, we got inspired from prior work on physical imperfection and various types of texture [22, 24] and brainstormed a list of salient features of music and physical objects that we thought would be relevant to making cross-modal associations. After grouping these features into taxonomic categories, we selected the range of objects to be used in our study, making an effort to sample a wide variety of features. After the study, we revised our taxonomy to account for new categories of features mentioned by participants. Our taxonomy of sound and physicalization features [Figure 2] categorizes these features and represents aspects often mentioned in participant responses in bold. A future effective theory of music physicalization would provide advice on how to map specific musical features to specific physical features.

4 STUDY DESIGN

We conducted an in-person study that involved participants associating songs with a mixture of both simple and relatively complex objects [Figure 3]. Simple objects depict a single feature in our taxonomy, from which we presented laminated cards to represent colors and 3D printed tiles to represent various textures. We chose texture and color specifically to classify our simple objects as they are important characteristics as observed in prior perceptual psychology literature [2, 19, 25]. The remaining complex objects are composed of many different attributes (like shape, weight etc.) that can be used for making complex associations with music. As a preliminary study, our main focus for choosing the physical objects was general variation and availability rather than seeking examples of specific form types or material qualities. The inclusion of more complicated and feature-rich objects allowed study participants to comment on the relative importance of different features within a single object or song. These physical objects were chosen so that they might represent overarching features as well as the detailed and nuanced temporal structures of music.

The 3 researchers selected 5 clearly distinct types of music genres — Indian Classical, K-Pop, 70s Hard Rock, Sea Shanty, and Lo-Fi. The purpose behind doing so was to have a wide variety of music components among all songs (such as instruments, musical era, beat rhythm, emotional valence, energy, danceability, etc.) so that participants have a large and wide enough mixture to make physical associations with whatever aspects they feel closest to. Each researcher selected 1 song from each genre. After listening to all the 3 songs from each genre and then discussing the validity and distinctiveness of its musical components, we narrowed our selection to 1 within each genre. The final song selection included — "Baba O' Riley" (70s Hard Rock), "Mishra Bhairavi Thumri" (Indian Classical), "Blood, Sweat, Tears" (K-Pop), "Drunken Sailor" (Sea Shanty) and "I'm Closing My Eyes" (Lo-Fi). We limited the total number of songs to 5 as the participants had to also interpret the song after listening and we did not want to overload a participant with too many options.

4.1 Participant Selection and Institutional Approval

Participants were recruited through university-wide graduate student mailing lists, and no restrictions were placed on what department the participants could be in. We recruited a total of 11 participants, 4 out of these were non-musicians, and 7 were musicians who could read and write musical information, as well as play at least one instrument. The musical knowledge of participant data will be marked as (n) for non-musician and (m) for musician.

In preparation for this study, we submitted documentation to the Institutional Review Board (IRB) at our institute for Research Compliance Administration and our study was deemed as exempt from further review due to the low risk involved.

Fig. 3. The set of objects participants were tasked with associating with their choice of five songs.

4.2 Study Procedure

4.2.1 Introduction phase. The introduction phase of our study involved a brief questionnaire to gauge participant's knowledge of music. This involved asking participants about their musical skills like being able to read sheet music, play an instrument, or creating musical compositions as well as if they had a formal or professional background in any musical area.

Participants were shown how to play back each of the 5 music samples and place each of the 29 physical objects into groups around each music sample. The color and texture tiles were identified with label stickers, but no specific label was provided for the more complex objects; an example of this is the object that is called "smiley man" in our analysis. These instructions were intentionally worded to avoid setting expectations that can limit participant interaction with objects and music.

4.2.2 Interaction phase. Participants were instructed to sort all objects; each object would be associated with a song, but the objects did not have to be evenly distributed among the songs. They were encouraged to interact with the objects and songs in whatever order or method they would like. During the interaction phase, the participant was left to interact with objects and music with no input from the researchers. Facilitators were taking note of all the assigned objects and supervising any technical difficulties. An aerial view of the interaction area was recorded, to obtain a record of hand interactions and live feedback [Figure 1].

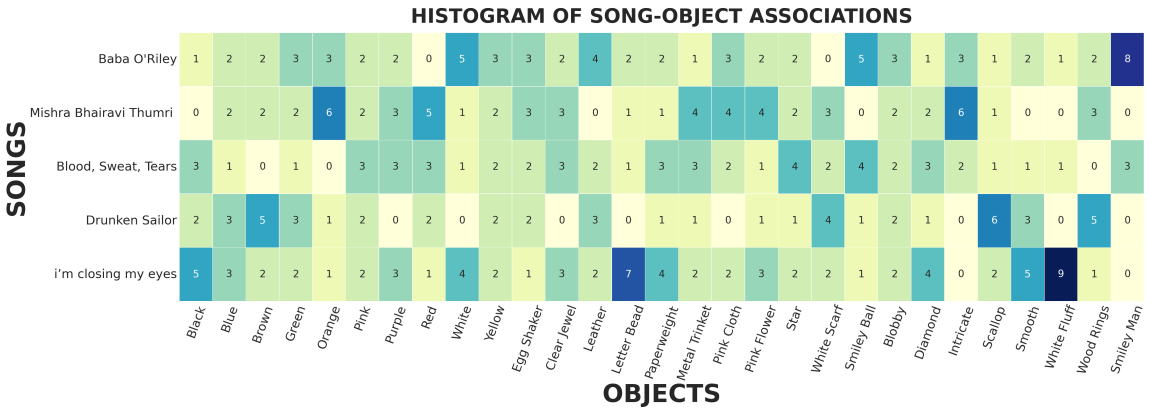


Fig. 5. A heatmap showing the frequencies of specific object–song pairings.

Q1) What did you feel were the most intuitive audio-physical pairing of features among all these selections that you made? Why?

Q2) Did you feel confused by any object [or did any object could convey multiple meanings]? If yes, why?

Q3) Can you talk about the reason for each of your object-song associations, other than the already mentioned?

Q4) Did you associate emotions with any objects? If yes or no, please give examples. Were some associations stronger than others?

Q5) Do you think some objects were able to represent subtle music features? If yes or no, please give examples. Were some physical objects able to capture the overall essence of a song?

Q6) Other 2D representations of music exist such as music visualizers with waveforms, equalizer bars, etc. In what way are 3D representations better than 2D and/or how are classic 2D representations better? Explain?

Fig. 4. The questions that participants were asked during the post-study interview.

4.2.3 Interview phase. The post-interaction interview phase explored the reasoning behind participants' object–song associations and included guiding questions to evoke an explanation for emotional or intuitive pairings. Although our interpretation of the qualitative results in the next section focuses on the most frequent object–song associations, comments in the interview phase were open to all associations. Figure 4 mentions our set of questions that we used for our interviews.

5 RESULTS

5.1 Quantitative Analysis

Participants' object–song associations were documented to create a histogram for the purpose of depicting significant trends. As shown in [Figure 5], several hot spots appear that suggest the importance of certain object–song associations.

Consider the null hypothesis that there is no general association between a given physical object and our offered selection of music choices. We applied the chi-square test to understand whether the associations showed patterns not explainable via random selection. Of the 29 objects in our study, five showed a statistical significance level below $p \leq 0.05$. The orange color tile and the intricate texture tile had p-values less than .05 and chi-square scores of 10.36 and 11.27 respectively. The letter bead, white fluff, and smiley man had p-values less than .01 and had chi-square scores of 14.00, 26.27, and 22.18 respectively. The presence of hot spots depicting these significant data points in this histogram points us in the direction of some general association mechanism operating across many participants, even if that mechanism cannot be applied to every object in the collection. We provide evidence of these hot spots through our qualitative observations as well.

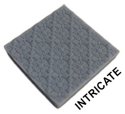
 + **I'm Closing My Eyes**	**P5(n):** "This feels kind of fluffy, its light" **P11(m):** "This one (Lo-Fi) is soothing, so putting some soft objects there. It reminds me of a blanket."	**4/11** people suggested that the object **softness** captured the overall essence of the song. **P10(m)** suggested the reason behind this to be the empty spaces in the song which was represented by the soft light object. Others further associated the neutral **tone** of the song with neutral grayscale **colors**.
 + **Baba O'Riley**	**P6(n):** "I wanna put these (Smiley Man and Ball) there, mostly because of that 60's smiling face kind of symbol." **P1(m):** "The 2 objects (Smiley Man and Ball) made me feel like fight for something, but the smiley face made me happy to do something like that."	**3/11** people suggested that the **object symbolism** reminded them of 60's and 80's upbeat rock **era** vibe. **P1(m)** mentioned that the **vibe** of the song put them of an uplifting rebel mood. In the same emotional tone, **P9(m)** and **P10(m)** played with bendy nature **(flexibility)** of the object and intuitively felt it goes with the **genre** of the upbeat song.
 + **I'm Closing My Eyes**	**P5(n):** "The sensation of Lo-Fi conjures an emotional state of late night, in city." **P1(m):** "The letter here...even just like that little snippet to me sounds like the person is talking about knowing someone. This (object) feels like knowing someone, of having some sort of intimacy."	**4/11** people suggested that the object reinforced the music theme of a calm and intimate emotional state, reminding them of late night relaxing musical **vibes**. Further some participants related the object to grayscale **color** and the **softness** representing the overall **vibe** of Lo-Fi music. Lastly, the letter on the bead gave **P1(m)** a sense of intimate connection with someone through some sort of **textual symbolism**.
 + **Mishra Bhairavi Thumri**	**P8(m):** "That sound is very like earth toney for me, so that's why I put the orange there" **P11(m):** "I always think of flowers as a foreign Indian when I think of this song. It reminds me of bollywood movies where people are like dancing, there's sometime some flowers, like marigolds which expresses happiness."	**2/11** participants related the orange **color** to the earthy **vibes** of the Indian song. **P2(m)** mentioned that the combined orange and yellow **colored** squares reminded her of the sunset **(object symbolism)** which somehow related to the aesthetics or **instrumentation** in the song. **P11(m)** related the orange **color** of the tile to the color of marigold flowers **(object symbolism)**, as usually expressed in Bollywood movies and related that to happiness **(vibe)**.
 + **Mishra Bhairavi Thumri**	**P5(n):** "This pattern is intuitive with Indian music, I can associate the sitar...with psychedelic music which matched with this particular texture." **P6(n):** "This particular pattern reminds me of the waves, a lot of Saudi Arabian, Iranian, Iraqi context for viewing art. Instead of depicting human forms, it's resting primarily on a lot of these geometric patterns. Even though that's not the context of India, it's putting me in that colonialist, orientalist vibe."	**5/11** people commented that the wavy **flow** and **texture** of the Indian music was relatable to the wavy **texture** in the intricate tile. Most people held the object in their hand and felt its texture and intuitively went with the relation it made to the Indian musical instruments **(instrumentation)** without providing a reason, but just implying that it made sense. **P6(n)** related the pattern of the tile to the geometric patterns **(object symbolism)** in the Middle East, and related how the instrument **flow** in the song related to the culturally relevant Middle East sounds and architecture.

Fig. 6. This figure shows the **consistency** across participant associations through quotes from various participants about why they made some of their object–song associations. Words highlighted in purple are associated with physical qualities while words highlighted in blue are related to qualities of sound found in our taxonomy. We demonstrate participant musical knowledge as (m) = musician, (n) = non-musician.

Some songs attracted more objects than others, but we are unable to interpret this result in terms of physicalization. Such disparities might result from some songs being more interesting or popular than others. This might suggest that some songs offer more attachment points for cross-modal associations, but our study design cannot disambiguate these.

5.2 Qualitative Analysis

We used thematic analysis for analyzing user interviews in exploring two overarching themes — creativity and consistency in cognitive associations [4]. We initially used a set of research themes from prior musical and physical fabrication knowledge of all researchers [Figure 2] to inductively code user interviews. We then deductively came up with new unique themes based on user insights from the study. Two researchers on our team analyzed all of the video transcripts of the sessions in two rounds. The entire team then reviewed the transcripts for detailed evidence in favor of overall patterns.

Figure 6 provides interview evidence for the consistent and significant music-objects associations across different participants. Participants consistently chose 5 objects — simple objects (orange color, intricate texture), complex objects

PREFERENCE, CULTURE & LIVED EXPERIENCE	**P6(n):** "I'm mostly reacting on this one to the lyrics of the song and the context of sailor songs. So like these wooden objects remind of like rope...blue is reminding me of the ocean..." **[Wood Rings & Blue, Sea Shanty]** **P11(m):** "The 1970s, I feel like that time was colorful...it's taking me back to when my parents were also young, they played these types of songs in the radio." **[Pink Scarf & Star, Hard Rock]**	**11/11** participants referred to personal and cultural experiences when explaining their associations. Prominent cultural associations across participants included the **1970s era** popular culture in relation to Baba O'Riley or **Indian cultural** iconography such as flowers in relation to Mishra Bhairavi Thumri. Lived experiences were prevalent in terms of song familiarity and contextual knowledge. For example, a majority of participants related Drunken Sailor to artifacts found in **nautical settings** as a result of familiarity with sea shanty music in those contexts and the metadata presented such as the title.
AFFECT (EMOTION)	**P4(n):** "The yellow man with BTS was the easiest to place because it has a wonky happiness to it." **[Smiley Man, K-Pop]** **P3(m):** "The vibe, the slowness I'm getting from this song...kind of forlorn, longing, sadness, love. I feel like a lot of those are heavy emotions so I would place this pretty heavy object." **[Paperweight, Lo-Fi]**	**8/11** participants noted emotional associations. The two most notable yet contrasting emotions were **happiness** and **sadness**. **Happiness** and related sentiments like "fun" and "upbeat" were associated to both the K-Pop and Rock songs. Further, this resulted in object associations with greater color vibrancy or depicting the positive affect of smiles. **Sadness** and "calm" feelings were often related to the Lo-Fi song. Object associations consistently included soft items and/or muted colors. These trends imply a relationship between a song's enegry and loudness to emotional and physical evocations.
MUSIC FEATURES	**P1(m):** "I added the square that looks like it has ripples on it. The song feels like a ripple effect and I think it pairs well with the depth of the song once the other instruments start to come in ...the depth of the instruments." **[Scalloped Texture, Indian]** **P2(m):** "Something about the synthesizers in the background and the shape of that." **[Pink Flower, Hard Rock]**	**9/11** participants observed music features in their associations. **Instrumentation** and **beat** were the most prevalent raw acoustic features noted by participants. The **shape, color,** and **texture** of objects were often related to these music features. Participants had varying affinites to these physical features like **P2(m)** mentioning better understanding of music in terms of shapes while **P7(n)** thought textures were easier to associate than colors. Despite having varying perceptions, these findings hint at intersensory associations commonly found in synesthesia research.

Fig. 7. This figure shows **creativity** and diversity across participants associations. These interview quotes revealed three overarching themes: cultural and lived experience, affect(emotion), and music features. Words highlighted in purple are associated with physical qualities while words highlighted in blue are related to qualities of sound found in our taxonomy. We demonstrate participant musical knowledge as (m) = musician, (n) = non-musician.

(letter bead, fluffy ball, smiley man), to express their different preferences and choices of how they related to different properties of an object based on the experience of music.

Figure 7 provides interview evidence of various creative ways in which participants made cognitive associations. We discovered three themes that were most significant among participants in making creative and diverse cognitive associations across the musical and physical modalities. These themes were — "Preference, Culture & Lived Experience", "Affect (Emotion)", and "Music Features."

While our initial set of vocabulary was helpful in realizing the salient physical and musical perceptual features of our objects, based on our analysis, we came up with new terms to represent novel actions undertaken by participants in our study as can be seen in Figure 2. While we used terms like "immersability" and "danceability" that were agreed upon based on our experience of prior music information literature, we came up with some new features like "squishiness" and "recognizability as everyday object" based on analysis of physical objects and how they can be interpreted when listening to music. Bolded features [Figure 2] were consistently chosen by the participants across their significant associations in the selection of musical and physical objects provided.

6 DISCUSSION

Our results suggest that the way that people associate features of physical objects with features of music is not simply a process of matching up the most salient features of each item in isolation. Rather, this process is much more complex and certain objects could be classified as more consistent or universal in terms of the perceptions that they offset among different people, while other objects have a more creative experiential and cultural basis for associating the meaning with music.

For example, while all participants referred to the “white scarf” object as a scarf, no participant used "scarf-ness" as the basis for their association of the “white scarf” with any particular piece of music. Instead, they used the *color*, *texture*, or *capability of motion* to justify their choices. These could be defined as object affordances which change their meaning based on the experience of the song as opposed to experiences in daily life usage.

Another data point of interest was that few participants tried to shake the “egg shaker” object. When they did, they were often surprised to experience the sensation of shaking and often changed which song they associated it with. Similarly, the heaviness of the "paper weight" was discovered relatively late in the sorting process but revealed a weight or density feature that strongly influenced their assignment of the object to a song. This is an example where a feature of an object very salient for cross-modal association was not strongly salient for the object by itself.

In terms of number of objects associated per song, the song "I’m Closing My Eyes" had the most (77) objects associated to it overall, whereas "Drunken Sailor" had the least (51) which could be potentially misleading. If some objects or music items seemed to contain more information content than others, we might see them used in more associations for purely numerical reasons rather than specific participant preferences. While we were not able to regulate informational content in our objects, asking participants to enumerate all relevant properties and tailoring specific controls for each item they are considering might help estimate the amount of information content as done in the study by Becker et al. [1]. However, that would also significantly increase the burden on participants, so future researchers might consider this as a tradeoff.

During the interview phase of our sessions, several participants reported that engaging with the objects increased their sense of immersion with the music. The task of reflecting on the properties of the object to match it with music was unfamiliar and nudged them to find more creative aspects of the music to involve in the association. One participant described this as the objects having “more impact on emotions” while others used words like “depth” to describe this effect. It is difficult to measure and understand the magnitude of this effect in comparison to other immersion-enhancing interventions like using studio-quality headphones instead of speakers.

When thinking about associations with physical objects based on music perception, we can use both musical (instrumentation, lyrics, flow, structure, genre, etc.) and non-musical (personal preferences and moods, lived experiences and cultural backgrounds) cognitive associations in a hierarchical feature space to highlight both surface-level features (non-musical), as well as deeper subtler features (musical) of a musical entity. Such a hierarchy can add an experiential layer of information that provides the context guiding the association of physical objects to music. These non-musical cognitive associations add a more personal and diverse aspect of creativity to music perception, which results in unpredictability and variation in interpretation.[11].

Further stressing on non-musical cognitive associations, 50% (2/4) of the participants with non-musical background only leaned on their personal preferences and moods, lived experiences and cultural backgrounds for making associations. Cross-referencing participant remarks with their reported level of music making experience, it seemed that musicians used a different vocabulary of musical features for justifying their associations. For example, while many participants sorted objects for the Indian song *Mishra Bhairavi Thumri* on the basis of a vague sense of culture, P9 and P10 (musicians) often made remarks about the song’s instrumentation and flow of music in general.

Musical aspects of songs had consistent associations to shape, color, and texture based on participant preferences. P2 consistently mentioned seeing music as shapes and related flowery shapes to synthesizer sounds. On the other hand, P1 closely related musical sounds as physical textures as they associated the depth of instruments to the ripples on the scalloped texture tile. On similar lines, P9 consistently made connections of music with color and associated a drum sound to the red color. These findings imply that creativity and consistency in music cognition is connected to

synesthesia research which expands upon the role of multi-sensory engagement in music perception such as connections between hearing and vision or touch. [2]. Moreover, non-musical associations are also prevalent in synesthesia research emphasizing that sound-activated sensory associations are largely influenced by contextual information such as memories, images, and emotions. [10]

7 FUTURE WORK

We believe that creating varied, creative ways in which we can associate aspects of physical features with musical data can not only help us better understand music, but can also enable deeper discussions about the various subtleties in music through multiple modes of sense perception. The results from our study suggest that both objects and songs were polysemous (validly associated with multiple meanings at the same time). To unpack these associations, future work should aim to decompose complex objects into one perceptual facet at a time to alleviate the cognitive load in the process of music perception. Such a study could use tangible assets of identically-colored objects or vary the shape of 3D printed objects with uniform density and texture such as those found in prior interaction research [3, 14].

In addition, future studies should aim for more structured methodologies to better understand how people apply creativity when making associations. Creative experiences can be unpredictable and thus considered non-linear [11], yet a common ground can be formed by presenting participants with common terminology. For example, a study can have all participants make use of a controlled vocabulary of terms, which could be based on our taxonomy, in order to make and justify their choices in a completely quantitative manner. Such a study could show that certain features or categories of features were consistently used more often than others. Our results suggest such a relation should exist, but the unrestricted vocabulary used by our participants precludes us from drawing statistical conclusions at this granularity.

Moreover, our current ongoing work on understanding physical aspects of music can improve access to musical culture to those with limited to no hearing. When participants can sense little to no acoustic features from the audio, there exists an implication that they have adapted to using other sensorial skills to perceive music in their everyday life through unconventional methods such as vibrations or visualizations [8, 13, 16]. It will be valuable to see how individuals with limited-hearing use vision and touch to apply cognitive creativity in music perception. Such a study would likely reveal additional dimensions of musical perception that have likely been ignored by the larger music visualization community as well as garner interest in possibilities of music physicalization.

8 CONCLUSION

Our study reveals that there are somewhat consistent patterns in how people associate music and physical objects. Specifically, we found certain music associations with color (orange), texture (intricate), and complex objects (letter bead, fluffy ball, smiley man) to be widely consistent. Further, the features that prompted the associations were not always the most salient features of the objects or pieces of music by themselves. Additionally, we discovered that the encouragement to verbalize justifications for cross-modal associations nudged people to have a deeper experience with the music items they were considering. Overall, our work offers clear evidence that the associations between music and physical objects goes beyond simple perceptual salience; it is a creative activity that depends on preferences, cultural exposure, affect, and personal experiences.

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