Color and emotion caused by auditory stimuli

Elena Partesotti
University of Valladolid
Department of Didactics of Musical,
Bodily and Plastic Expression
elena.partesotti@alumnos.uva.es

Tiago Fernandes Tavares
University of Campinas
Department of Music
Interdisciplinary Nucleus of Sound Communication
tiago@nics.unicamp.br

ABSTRACT

Recent studies have shown correlations between perceived colors and aspects of a musical piece such as tonality, tempo and musical articulation. Other studies have demonstrated that major and minor tonalities of music trigger people to perceived a different hue of colors. The purpose of this study is to investigate the correlation between musical aspects and the attribution of colors and emotions, as well as to observe if a specific correlation exists in the population tested. Furthermore, the results of this experiment will be considered for a therapeutic application. We conducted an Internet-based experiment evaluating whether musical stimuli would be consistently linked to perceived emotions and colors. The stimuli consisted of short sound excerpts containing a variety of musical phrases played in different styles and on different instruments. Thus, we were able to gather more data than that obtained by similar past studies, because we tested with a larger variety of music. The result analysis shows that the combination of sound and ascribed emotion forms a more reliable prediction of color perception than emotion alone or sound alone. In addition, we found a number of correlations between perceived emotions and the spectrum of selected colors; however, these results have shown to be insufficient for a precise prediction.

1. INTRODUCTION

The purpose of this research is to find a correlation between musical parameters, color, and emotion. This correlation could be beneficial to the development of mixed reality technologies. In particular, the study will help the design of E-mocomu prototype. E-mocomu stands for E-MOtion, COlor and MUsic; it is a technology in development for a therapeutic application in Music Therapy. So far, different theories have been designed in order to establish an association scale between color and sound. These have mainly been based upon the correspondence between the respective physical properties of color and sound. In 1704 Newton elaborated, in his treatise Opticks, analogies between sound waves and light, the latter of which causes the perception of colors. Munsell in 1907 [1] observed that, by analogy with musical systems such as intervals and harmony, the artistic field also needed to elaborate its structures based on colors characteristics (hue, saturation, and lightness). In 1971 Vernon [2] elaborated a theory of color-sound based on the parameter of of pleasure/displeasure; in particular, she discerned that Western society has its own preference of colors, and the scale of preference starts from blue. She also observed that since primitive civilization, colors have usually been associated with emotions derived from daily life, and for this reason are remembered easily. Today the perception of and emotional response to colors is thought to be affected by cultural traditions and the work environment. Another study [3] approached the color-sound association by linking the chromatic circle in visual images to the cycle of fifths in music. Sebba [4] agreed in the existence of a common relation between expressing music and color; that was evident, for instance, in "a common denominator in the selection and organization response to the composition of sounds bearing a clear emotional message". In this perspective the language of color is connected to psychology and understood as something that is mediated by the physiological effects of music. This study paves the way for a theory in which emotion, sound, and color are correlated. In the artistic field, so-called synesthetes have long experienced correspondences between sound and color. In fact, many notable figures in the history of Western music reported sound-to-color synesthesia, also known as chromesthesia, in which sounds consistently evoke experiences of color. Synesthesia is a condition in which the five senses are intertwined, that is, there is a particular cross-activation between brain regions involved in conceptual and perceptual processes; the regions implicated depend on the type of synesthesia. In chromesthesia for example, the parts of the brain activated are related to the auditory cortex and fusiform gyrus. Kandinsky, Scriabin, and Messiaen have elaborated theories based on synesthesia-induced correlation. Kandinsky in 1971 [5] wrote a treatise in which he provided new insights into the emotional dimension of sound-color correlation. Unfortunately, it was not able to establish a valid sound-color correlation based on chromesthesia, which is why we aimed to identify the correlation that exists between color and sound as one that is mediated by emotion. Juslin [6] outlined the importance of musicians efforts to convey certain emotions in their performances, which contribute to the association of specific musical characteristics with particular emotions. More recently, this emotional dimension of musical perception has been taken into account in diverse experiments that consider the relation between music and color. A previous experiment [7], that considered all three variables, linked basic emotions to different parameters of tempo and musical writing to set emotional coloring of performances, while other studies [8, 9], shown that minor and major tonalities are related to darker and lighter colors and associated with negative and positive emotions, respectively. Yet another experiment that involved music, emotion and color found a significant correlation between emotional characteristics and color components (hue, saturation, and brightness). The author proposes an interface called ExpressinBall, for a graphic visualization of music performances [10]. A different study [11] examined the correlation between color and emotion following the theory of ecological valence. In this study, peoples color preferences was shown to be affected by their preferences for material objects. A previous experiment [12] shown the importance of considering the affective response in order to grasp the association of color and music. A more recent experiment from 2013 [13] revealed that tempo in music is a crucial variable to be considered in sound-color association. In addition, other studies [14, 15] of color preferences proposed a two-level theory of color-emotion and urge us to consider responses across cultures in order to assess associations between emotion and hue; as well as concepts of harmonic-disharmonic in music. In our study, we detailed the preferences of the listeners in an attempt to establish a more solid correlation between musical properties, emotional experiences, and color perception. We performed an Internet-based experiment, in which users were asked to access a website, listen to musical stimuli, and answer what emotions (from six predefined choices) were triggered, as well as what color (from a color wheel with millions of choices available) was perceived as most related to those stimuli. The participants chose the colors by dragging a cursor and clicking on the appropriate one. Using the website, we were able to gather 981 data points, which is significantly more than previous individual experiments. Hence we verified that there is evidence of correlation between the stimuli and the perceived emotion; however, no correlation with color was found.

2. METHODOLOGY

2.1 Participants

Our online questionnaire with musical stimuli could be accessed and completed anonymously. We advertised our experiment through online communities at the University of Campinas and in a social network. The participants, therefore, presented diverse cultural backgrounds, age and gender. Each participant was assigned a random audio excerpt and asked which emotions and what color he or she would attribute to that excerpt.

2.2 Structure

We proposed six different emotional states: anger, happiness, melancholy, arouse, relaxation, and apprehension. Each listener could choose more than one emotion for each stimulus. Also, listeners could choose colors from a color wheel with millions of different hue, saturation, and lightness shades available. The stimuli could be listened to as many times as the user wanted. The audio excerpts used were taken from popular music, such as jazz and rock, solos by unaccompanied instruments, and the Ode of Joy. While we offered audio excerpts that ranged from classical to popular music, we also introduced a different set of emotions to the listener, to maintain this diversity across variables, because one excerpt of music may stimulate more than one emotion per time.

2.3 Procedure

The experiment was executed using a website which could be accessed from any location. Figure 1 shows the design of the website page.

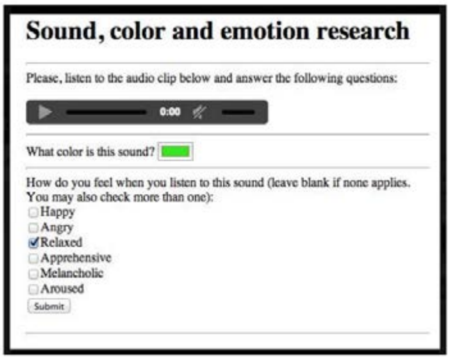


Figure 1: Screenshot of website.

The system was easy to use, so that participants would not need more than one minute to respond to each musical excerpt. Each subject was asked to listen to an excerpt of music that was selected at random from a total of 20 excerpts. The excerpts varied from 4 to 30 seconds. Next, subjects were asked to rate this excerpt in terms of emotion and colors. Listeners had the opportunity to redo the experiment as many times as he or she wanted; however, each time they would hear a different, randomly selected excerpt. This way, we were able to gather a large number of data points, which allowed for different kinds of analyses.

2.4 Data Analysis

Our data analysis was aimed at extracting useful information from the estimated histograms of $P(e|s)$ (probability of emotion e being triggered by sound s, considering the frequency over all data), $P(c|s)$ (probability of color c being triggered by sound s, considering the frequency over all data), $P(c|e)$ (probability of color c being triggered by emotion e, considering the frequency over all data) and $P(c|e, s)$ (probability of color c being triggered by emotion e and sound s, considering the frequency over all data).

These histograms were calculated independently for hue, saturation, and value of the color responses. It was possible to observe some general trends regarding $P(c|s)$. In fact, as shown in Table 1 , for the unaccompanied Alto Sax excerpt we retrieved a high value, with the hue either red or yellow; for Flute, a high value; for Violin Tremolo, dark shades of gray; for Piano, average shades of gray; and finally, for the Ode to Joy, mainly red or green.

Audio content	Color polarization
Gipsy Alto Sax	High value, hue either red or yellow
Violin Tremolo	Dark shades of gray
Piano	Mid shades of gray
Ode to Joy	Mainly red or green

Table 1: Few polarizations for color with a given sound.

After identifying the above trends, we made similar observations for $P(c|e)$. Again, we revealed a number of general tendencies among the respondents, which are shown in Table 2.

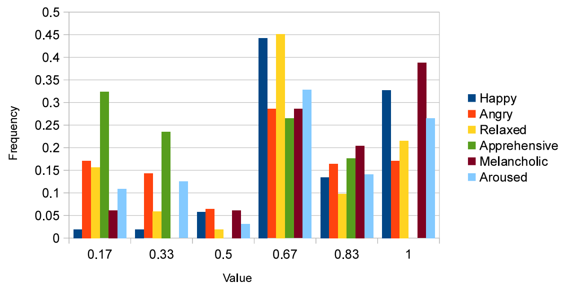
Emotion	Hue	Saturation	Value
Angry	Red	Low	Mid
Happy	Orange, Red	Any	High
Melancholic	Any	Mid	High
Apprehensive	Red	Low	Low
Aroused	Red	Low	Mid
Relaxed	Orange, Red	Low	High

Table 2: Remarking characteristics of $P(c|e)$.

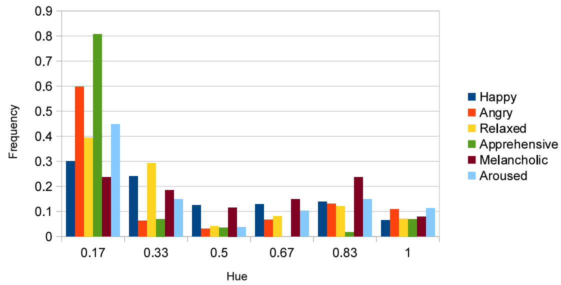
Figure 2 provides histograms that show the respective distributions of value, hue, and saturation for chosen colors for each emotion.

From here, our analytical procedure consisted of two contrasting approaches, which corresponded to two separate hypotheses. First, we aimed to find whether audio stimuli would be consistently correlated to one or a group of perceived emotions. Second, we tried to detect whether the emotions triggered by the musical stimuli could help predict color perception. In the first analysis, we calculated the probability $P(e|s)$ that a certain emotion would be triggered by a stimulus. This probability was calculated based on the frequency that each emotion e was selected by users, divided by the total number of responses to each stimulus s. After that, Wilsons interval of confidence was used to give a lower bound for $P(e|s)$ with a certainty of 95%.

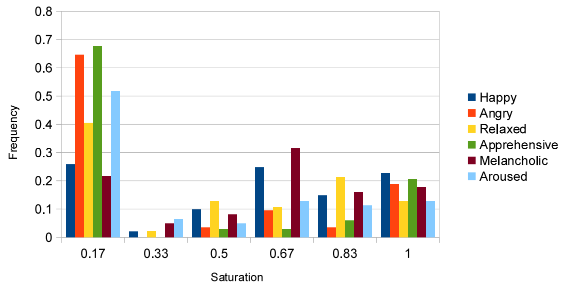
We verified that, for many of our stimuli, $P(e|s)$ is significantly high, reaching levels of 80%, which means there is a high chance that a particular emotion is triggered by musical excerpt. However, there are many stimuli that do not consistently trigger a limited number of emotions in random individuals. Both these findings are useful for therapy purposes, even if predictions are not reliable enough to substitute an individual assessment of the emotion, as all subjects do not share the same response. In the second analysis, we used the hue, saturation, and value of the



(a) Distribution of value.



(b) Distribution of hue.



(c) Distribution of saturation.

Figure 2: Result histogram.

colors attributed to each stimulus to generate six-level histograms, estimating the probabilities $P(c|s)$, $P(c|e)$ and $P(c|e,s)$. If emotion is relevant to the prediction of color, then the entropy of $P(c|e,s)$ will be much lower than that of $P(c|s)$ and $P(c|e)$. Hence, we calculated the entropy of all spectrograms and verified the significance of the difference between averages using a t-test.

We have verified that, indeed, $P(c|e,s)$ has much lower entropy than $P(c|s)$ and $P(c|e)$ ($p < 0.5\%$). This means that knowing that a particular sound triggers some emotion in an individual allows a better prediction of the related color. However, we have also verified that the estimated colors are not exact, as the results show as areas in the color spectrum.

3. CONCLUSION

We presented an Internet-based experiment that aimed at detecting whether auditory stimuli would trigger particular emotions or color in a comparatively large number of respondents. Our results show that sound and emotion, jointly, are capable of a better prediction of the perceived color than sound alone or emotion alone. Although general trends in color perception are visible, it is still not possible to estimate a unique response that is valid for all individuals. This means that there is still need for calibration in therapeutic applications. We can conclude that, while emotional responses are informed by cultural norms, the correlation between sound and emotion is more consistent than the correlation color-sound; and this may depend on the different cultural heritage of each listener. Furthermore, our results contradict an earlier study of colors and emotions [13]. This probably occurs because we retrieved data from participants from a diversified cultural background, while the study in question relied on only 10 participants. This also confirms the hypothesis that there is a valid correlation of color-sound for small groups of people, that cannot be verified for large groups; however, the correlation of a small group cannot be generalized and applied to others small groups. Moreover, our experiment also finds that for the population tested, the predominance of red and orange was significant. This leads us to consider the possibility that previous studies, conducted predominantly with Western participants, have found different kinds of predominance of hue due to differences in respondents cultural heritage. In conclusion from this study, it appears that there is no exact correspondence between color-sound and color-emotion in the population tested; however, there is some level of consistency in the chosen colors. From a therapeutic perspective, this research shows that some characteristics of colors connected to music (such as hue and saturation) can reflect emotional states; thus, the color preferences (including the absence of colors) may be used to evaluate emotional states in subjects with particular psychological disorders and needs. From this perspective, we propose the application of a technology that correlates the three dimensions of color, sound, and emotion for therapeutic purposes. Indeed, the results of our experiment will be considered in the design of E-mocomu technology. Finally, we observed that instrumental solos of shorter length lead to polarizations (this did not hold true for our only classical music excerpt, from the Ode of Joy, which lasted 37 seconds). This may be caused by the minor tonality used in the excerpt, therefore being linked to the underlying cultural perspective. From this point of view, the classical piece and the instrumental solos (popular music) represented cultural bias. Nevertheless, differences in cultural backgrounds may be a factor in the differences between our results and those obtained in previous studies and must therefore be carefully assessed. This consideration provides a clear direction for future research.

Acknowledgements

The authors thank FAPESP (proc. 2013/17329-5).

4. REFERENCES

[1] A. H. Munsell, *Color Notation, A measured col- orsystem, based on the three qualities Hue, Value, and Chroma*. Boston, 1907.

[2] M. D. Vernon, *The Psychology of Perception*. Penguin Books, 1907.

[3] A. Wells, "Music and color: Relations in the psychophysical perspective," *Color Research and Application*, vol. 17, no. 1, pp. 57–61, 1980.

[4] R. Sebba, "Structural correspondence between music and color," *Color Research and Application*, vol. 16, no. 2, pp. 82–86, 1991.

[5] W. Kandinsky, *Concerning the spiritual in art*. New York: Wittenborn, 1912.

[6] P. N. Juslin, "Emotional communication in music performance: a functionalist perspective and some data," *Music Perception*, vol. 14, no. 4, pp. 383–418, 1997.

[7] R. Bresin and A. Friberg, "Rule-based emotional colouring of music performance," in *Proc. of the 2000 Int. Computer Music Conf*, San Francisco, 2000, pp. 364–367.

[8] R. Bresin, "What is the color of that music performance?" in *Proc. of the 2005 Int. Computer Music Conf*, Barcelona, 2005, pp. 367–370.

[9] N. Kaya and H. Epps, "Relationship between color and emotion: A study of college students," *College Student Journal*, vol. 12, no. 38, pp. 396–405, 2004.

[10] R. Bresin, "Real-time visualization of musical expression," in *HUMAINE Workshop 'From Signals to Signs of Emotion and Vice Versa'*, Santorini, 2004, pp. 19–21.

[11] K. B. Schloss and S. Palmer, "Ecological valence and theories of human color preference," *New Directions in Colour Studies*, 2011.

[12] K. B. Schloss, P. Lawler, and S. E. Palmer, "Rule-based emotional colouring of music performance," in *8th Annual Meeting of the Vision Science Society*, Naples, 2008, pp. 364–367.

[13] Y. Tawany and K. Schloss, "Associations between color and music are mediated by emotion and influenced by tempo," *The color of Music*, pp. 82–92, 2013.

[14] Cupchik, "A cross-cultural comparison of colour emotion for two colour combination," *Color Research and Application*, vol. 37, no. 1, pp. 23–43, 2012.

[15] E. Heller, *A psicologia das cores, como as cores afetam a emoccao e a razao*. Ed. Gustavo Gili, 2012.