DURMS
Durham Undergraduate Research in Music & Science

Is There a Trend in Non-Synaesthetes for Choosing Colours in Relation to Keys?

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ABSTRACT

Objective: To investigate whether there were any trends in colour choice when non-synaesthetes were presented with a musical extract transposed into eight different keys (C, A, Eb, F# majors and minors). The two hypotheses were:
1) Light colours would be majoritively chosen for the extracts in major keys and dark colours would be majoritively chosen for the extracts in minor keys.
2) Musicians would generally make more similar colour choices than non-musicians.
Method: 16 university students participated: four male musicians, four female musicians, four male non-musicians and four female non-musicians. Participants were presented with a colour palette consisting of 14 colours, and listened to 8 transpositions of a novel piano extract. For each extract they were asked to pick one colour that was best associated with the music.
Results: The hypotheses were largely realised. All major keys prompted a majority of light colour choices, and all but one minor key elicited dark colour choices. F# minor yielded equal light and dark colour choices from the participants. The musicians had more similar colour choices than the non-musicians. As the tonic pitch height of the extract increased, more light colours were chosen. Similarly, as the tonic pitch height of the extract decreased, more dark colours were chosen.
Conclusion: Certain trends emerged in the colour choices of non-synaesthetes for the different musical extracts.

1. INTRODUCTION

The current study addressed the trend in colour choices of non-synaesthetes who were presented with a musical extract transposed into eight different keys. To understand this study's place in the scholarship field, synaesthesia will first be discussed, with reference to both its definition and its origin. Then a few of the most relevant studies from the current research field will be observed, with a particular focus on the perception of specific colours, and how emotion is seen to act as a mediator between music and colour. Lastly, the current study will be discussed, specifically its unique aims and its place in the scholarship field. It is interesting to investigate this topic in order to begin to understand cross-modal associations between musical sounds and visual imagery in the general population, not just the rare group of people with synaesthesia. The current research also begins to explore the important question of whether there are any consistent patterns that emerge across people in these sound-to-colour mappings, or whether such mappings are affected primarily by individual differences (e.g. differences in musical training, gender, etc).

Synaesthesia can be defined as:

> a developmental condition involving cross-communication between sensory modalities or substreams whereby an inducer (e.g. a sound) automatically envokes [sic] a concurrent percept in another modality (e.g. a colour) (Farina, Mitchell and Roche, 2017: 2)

Synaesthetic perceptions are 'involuntary, automatic, and consistent over time' (Eagleman, 2010: 221). They can occur from an early age, due to a brain injury, or through the use of drugs such as LSD (Grossenbacher & Lovelace, 2001). Many different types of synaesthesia exist, such as grapheme-colour, music-shape and music-colour synaesthesia. The most common kind is associating colour in relation with days of the week or letters of the alphabet (Mulvenna & Walsh, 2005). Types of synaesthesia are defined by a compound adjective - the first element indicating the stimulus that induces the synaesthetic perception and the second element denoting the additional synaesthetic perception. For example, in music-colour synaesthesia, music triggers additional perceptions in colour (Moos, 2013). Synaesthesia is one-directional, i.e. whilst music triggers colour, colour might not trigger music (Mulvenna & Walsh, 2005).

As synaesthesia only affects approximately 4% of the population (Moos, 2013), it was decided that this undergraduate project would test exclusively non-synaesthetes. Past research in the field includes a number of studies testing both synaesthetes and non-synaesthetes, while some in-depth research has been done on specific individuals with synaesthesia, such as the research by Farina, Mitchell and Roche (2017). Ward et al. (2006) identified the differences between synaesthetes and non-synaesthetes as 'consistency of colour associations, specificity of colour section and the automaticity of the colour associations' (Patera, Tsiounta & Staniland, 2013: 3).

A prevalent theme in the scholarship field of music-colour synaesthesia is that of the mediator between colour and music. For those with absolute pitch, the process might look something like the following:

Musical pitch → pitch class name → colour (Itoh &Nakada, 2018)

Another mediator might be visual memory, when the 'sound source can be recognised and visually recalled' (Patera, Tsiounta & Staniland, 2013: 2). Examples of this might include the sound of an alarm with the colour red, or the sound of waves with the colour blue. However, the most commonly held idea for the mediation between music and colour is emotion. In this instance, the psychological process would look somewhat like this:

Music → emotion → colour (Whiteford et al., 2018)

Research by Tsiounta, Staniland and Patera (2013) concluded that non-synaesthetes invoked similar mental processes to synaesthetes when associating colours with music, and made similar pairings. Moreover, Palmer et al. (2013) tested non-synaesthetes and confirmed a correlation between both emotional state and music, and emotional state and colour. Participants were asked to complete emotional ratings for both musical excerpts and colours, and results showed a similarity between the two ratings. Thus, it was concluded that emotion must act as a mediator between music and colour. Alongside this research, other sources show that certain colours are often associated with emotions. This is generally a cultural instillment, and could include connotations such as red for 'alert' or 'anger' and green for 'envy'. Whilst they might differ between cultures, many of these connotations are universal (Beaumont, 2003). Furthermore, cultural differences introduce a question of language and whether it is a hindering and limiting factor in expressing emotions and opinions. For instance, colour terms differ from language to language, and the number of 'basic colour terms' varies. (A basic colour would be red, rather than crimson or ruby, for example.) English has 11 basic colour terms, whereas a lesser-developed language might not have as many. Therefore, one must appreciate language as a mediator (and a potential hindrance) between music and colour (Beaumont, 2003). Fortunately, all the participants in the current study were native English speakers, so this issue was evaded.

Preferences play a large part in a participant's colour choice. If one did not like the music, one would not be likely to associate it with a colour they liked, and vice versa. Theo Gimbel's (1980) research states that blue is generally preferred to other colours in over 30% of the population, with red being less popular in general, but more preferred by young people. Green is not as liked as red or blue, and yellow is less favoured still. Brown, grey, black and white are the least liked of all the colours.

The study carried out by Beaumont (2003) and that of Patera, Tsiounta and Staniland (2013) both followed similar study designs to that of the current study. These were both larger studies and had participant sample sizes of 53 and 32, respectively. Beaumont's study used a colour chart of 250 colours, each chosen to 'effectively represent colour space' (Beaumont, 2003: 98). A four-part extract, composed by the experimenter, was transposed into all twelve keys and played to each participant in the same order. The author hypothesised that the association between key and colour would be 'non-random' (Beaumont, 2013: 100) and this hypothesis was realised. It was concluded that the colour choice for each key could have been explained by 'chroma differences, pitch height, or a combination of both' (Beaumont, 2013: 101). Patera, Tsiounta and Staniland's (2013) study used 20 musical extracts which were only 3.4 seconds in length, and used a colour palette of 36 colours. This piece of research focused on music genre, and concluded that certain genres provoked a 'high level of colour agreement amongst the participants' (Patera, Tsiounta & Staniland, 2013: 2). Classical music was the genre that generated the most agreement (28%). A reason for this could be that it is the most globally ubiquitous and well-known of the genres, compared to 'Byzantine' and 'Greek traditional', for example.

The current study was an adaption of these studies, with a focus on systematically exploring certain musical features, such as mode and pitch height. Half of the participants in the current study were musicians and half were not, in order to compare between the two, and none of the participants had absolute pitch. Eight keys were used (including both major and minor), as opposed to twelve minor keys, so comparison could be made between major and minor tonalities. The extract used was composed by the experimenter, but was originally in a major key, rather than a minor key. These aspects meant that this study brought a new slant of scholarship, whilst simultaneously building on previous research. The hypotheses of the current study were as follows:

Light colours would be majoritively chosen for the extracts in major keys and dark colours would be majoritively chosen for the extracts in minor keys.

Musicians would generally have more similar colour choices than non-musicians.

The first hypothesis was created as an exploration expanding the common idea that major keys are 'light' and minor keys are 'dark' - adjectives that are often associated with the modalities whilst teaching music at a basic level. The second was another hypothesis of an exploratory nature, investigating whether the harmonic perception of musicians and their familiarity with keys might lead them to have similar colour associations with one another.

2. METHOD

Design. The aim of the study was to discover if there were any trends in colour choice between non-synaesthetes when they were presented with the same extract of music played in eight different keys. The participants were given a colour palette whilst they listened, and were asked to choose a colour that best suited the music of each extract. The dependent variable in this study was the colour choice and the independent variable was the musical extracts.

Participants. 16 participants were recruited to carry out this study - four male musicians, four male non-musicians, four female musicians and four female non-musicians. All participants were between the ages of 20 and 22 years (M = 21.19, SD = 0.75), and were students at Durham University at the time of testing. A 'musician' was defined as someone who had either studied music at A-level or higher, or who had an

ABRSM grade 8 qualification. None of the participants had absolute pitch, nor were any of them colour blind.

Materials/Stimuli. The pre-testing questionnaire included questions regarding the participants' age, gender, whether they had absolute pitch and if they were colour blind. Figure 1 displays the colour palette that was employed.

Figure 1. Colour palette

Each colour was chosen with care, following the advice of an RGB-value chart ("RGB Color Codes Chart," 2019), and was occasionally adapted so the palette was suitable both on a computer screen and on paper, i.e. the colours were sufficiently contrasting. The palette comprised 14 colours in total, with a top level of light shades and a bottom level of dark shades. The three primary colours - red, yellow and blue - were spaced evenly in the centre of the palette, and the colours in between them were their products if they were to be combined; i.e. red and yellow combine to produce orange, thus orange stood between red and yellow. Pink and purple were placed on either end of the palette, being similar in hue to red and blue respectively.

The music used in this project was the author's own piano composition, which lasted 28 seconds and consisted of a simple diatonic melody with a broken-chord accompaniment. The reason for the extract being self-composed was to ensure that the music was unfamiliar to the participants, that it established an obvious key, and that it did not deviate from the tonic.

The extract was transposed into eight different keys. The chosen keys were the northern, southern, eastern and western points of the Circle of Fifths: C, A, F# and Eb majors and minors (see Figure 2).

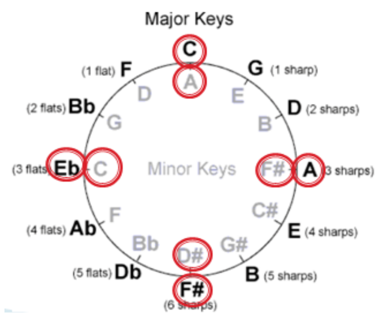

Figure 2. Keys chosen

Procedure. The testing procedure was as follows: the participants came to the studio with their own laptops and headphones. They were each given a 30-minute slot, and were tested in groups of three. On arrival, they were required to fill out the pre-testing questionnaire. After this, they were presented with a numbered colour palette on a piece of paper in front of them (see Appendix), and were directed to the audio file online.

The audio file consisted of the eight transpositions of the extract, each separated by ten seconds of white noise. This white noise was incorporated so that the participants would not be affected by the previous musical extract. The whole track, including the music and the white noise, was five minutes in length. The order of extracts was tailored to each participant. There were eight listening orders, so each participant listened to the music in the same order as one other participant. The listening orders are presented in Table 1. For instance, Participants 1 and 9 listened to the extract in A major first, then F# major, then Eb minor and so on, listening to the extract in Eb major last. (N.B. An upper-case letter denotes a major key, and a lower-case letter denotes a minor key.)

Table 1. Listening Orders

Participant Numbers	Order	Order of Keys Played
1, 9	Order 1	A, F#, eb, c, C, f#, a, Eb
2, 10	Order 2	c, eb, C, A, Eb, a, F#, f#
3, 11	Order 3	Eb, c, F#, eb, C, a, A, f#
4, 12	Order 4	A, f#, F#, a, eb, Eb, c, C
5, 13	Order 5	c, eb, A, F#, f#, a, Eb, C
6, 14	Order 6	eb, a, A, C, f#, c, Eb, F#
7, 15	Order 7	c, C, a, Eb, F#, f#, eb, A
8, 16	Order 8	A, eb, Eb, C, a, c, f#, F#

Although it was difficult to control, participants were advised to close their eyes whilst they listened to the music. They were asked to focus on the music and then choose the colour with which they thought the music was most associated. After the track finished, the participants were free to leave the studio.

3. RESULTS

The overall results of this study are shown in Figure 3. The colour choice of each participant is outlined, and in this diagrammatic representation, each cell denotes one participant's colour choice. From this, one can note that C major, F# major and Eb major initiated the most similar results between participants. Eb minor produced the most varied results.

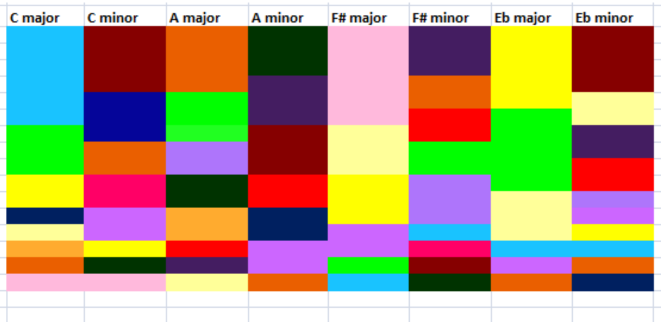

Figure 3. Overall results

The results produced in this study largely supported the hypotheses. Light colours were majoritively chosen in association with the extracts in major keys, and dark colours were majoritively chosen for those in minor keys. F# minor was an exception as half the participants chose a light colour, whilst the other half chose a dark colour. Table 2 displays these results (Note that numbers highlighted show the choice of the majority).

Table 2. Light vs. Dark Colour Choice

	Key	Light Colour Choice (number of participants)	Dark Colour Choice (number of participants)
Major Keys	C major	12	4
	A major	9	7
	F# major	13	3
	Eb major	10	6
Minor Keys	C minor	3	13
	A minor	4	12
	F# minor	8	8
	Eb minor	7	9

A t-test was run to determine the statistical significance of these results. It transpired that there was a significant effect of key (major vs. minor) on whether a light colour was chosen. The results were such that a major key was significantly more likely to induce a light colour choice from the participants ($t(15) = 2.67$, $p = 0.018$). The effect of key on whether a dark colour was chosen was also significant ($t(15) = -2.67$, $p = 0.018$).

The second hypothesis was realised, as overall, the musicians chose a total of 41 colours. Non-musicians chose 43 - two more colour choices than the musicians. This was calculated by determining the number of colours chosen per key, and combining them. Please see Figure 4 for a representation of colour choices from musicians and non-musicians, with the number of colour choices indicated underneath each key.

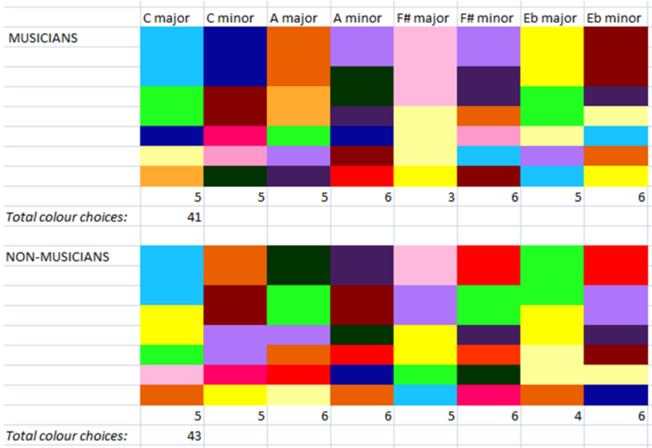

Figure 4. Musicians vs. non-musicians

Pitch height also had an effect on the results in this study. The original extract was written in C major, with the melody beginning on middle C. For each transposition thence, there was a choice as to whether to transpose the three remaining keys up or down in pitch. It was decided that, in order to keep the extracts within as small a pitch range as possible, the starting notes were as follows: middle C, A below middle C, Eb above middle C and F# above middle C. This meant that the tonics of all extracts were within an interval of a major sixth. Although these precautions were taken in order to minimise the effect of pitch height skewing results, it still affected the colour choices. Please see Figure 5 portraying the results of colour choices in order of increasing pitch height.

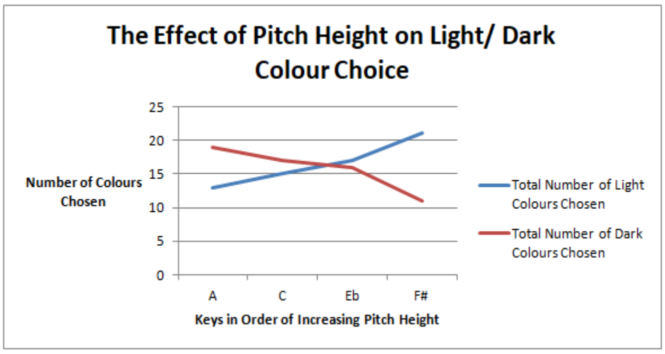

Figure 5. The effect of pitch height on light/dark colour choice

The number of light colour choices increased as the pitch height increased, and the number of dark colours decreased as the pitch height increased. This agrees with previous scholarship carried out by Mills, Boteler and Larcombe (2003). A chi-square test analysis was carried out on these results, which showed that the colour choices were not distributed evenly across the keys, and confirmed the statistical significance of these results (p = 0.006). Please see these results represented in Figure 5.

Overall, light green was the most popular colour choice, followed by light purple. Dark pink and light orange, in contrast, were the least popular choice of the participants. Interestingly, the least popular colours were spaced evenly on the left-hand side of the palette, with the most popular colours evenly spaced on the right-hand side of the palette (see Figures 6 and 7).

Figure 6. Choice frequency

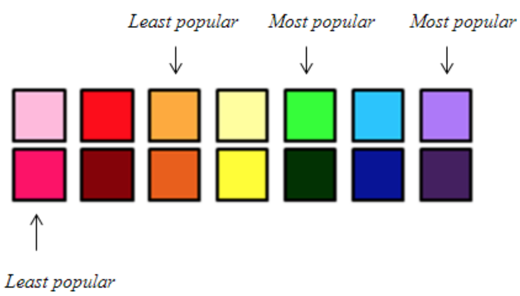

Figure 7. Most popular and least popular colour choices

Thus, to conclude, the first hypothesis was largely realised and the second hypothesis was fully realised. All major keys drew light colour choices, and all but one minor key prompted dark colour choices. The extract in F# minor yielded 8 light colour choices and 8 dark colour choices from the participants. As the pitch height increased, more light colours were chosen and as the pitch height decreased, more dark colours were chosen. The musicians did have fewer disparities than their non-musician counterparts, with a total of 41 colour choices as opposed to 43. Light green was the most popular colour choice, followed by light purple, and dark pink and light orange were the least popular colour choices.

4. DISCUSSION

This study contributed new and exciting data to the scholarship field, which in part agreed with previous research. The first hypothesis was that light colours would be chosen for the extracts in major keys and dark colours would be chosen for the extracts in minor keys. This choice of hypothesis was based on the natural associations of major keys being ‘happy’ or ‘light’ and minor keys being ‘sad’ or ‘dark’. The basis on which this hypothesis was made reflects the much-researched idea that emotion is a mediator between listening to music and choosing colours (e.g. Whiteford et al., 2018). All of the extracts in major keys prompted a majority of participants to choose light colours, whilst almost all of the minor keys prompted a majority of dark colour choices. The only exception to this was F# minor, which yielded eight light and eight dark colour choices. Therefore, there were statistically significant effects of key on whether light colours were chosen, as well as whether dark colours were chosen.

Looking at the results overall, the colour choices did not concur with some past research, namely the study by Beaumont (2003). His research followed a very similar study design, although the musical excerpt was only played in minor keys. Beaumont used a chart of 280 colours, which he grouped into 6 categories for ease of comparison. In contrast to the current study, the most popular colour choice for A minor was red, F# minor was green, and D# minor and C minor were yellow. Nonetheless, the participant sample size was much larger in Beaumont’s study (53), which suggests the need for a larger participant number in the current study. Only 11 of the participants in Beaumont’s research had ‘reasonable musical training’ (Beaumont, 2003: 97), which also implies that the relative lack of musicians might have swayed results.

The second hypothesis of the study was that musicians’ colour choices would generally be more alike than non-musicians. This was realised as, in total, musicians chose 41 colours, whereas non-musicians chose 43. A number of reasons could explain this. Firstly, it could be argued that their musical upbringing would have led them to naturally associate certain colours to certain keys. Furthermore, musicians are naturally more attune to musical keys due to having worked with them extensively. This, along with their superior harmony perception, might have instilled stronger opinions on the colours associated with keys. This might also have been an explanation as to why F# minor was answered more ambiguously. Moreover, when learning an instrument, F# minor is a more complex key so it comes later in learning, thus it might have been less familiar to participants, even musicians.

The results gathered in this research allowed for comparison between men and women; an analysis of a purely exploratory nature. Over the testing, the men and women chose the same number of colours (42), thus showing their similarity in frequency of colour choice. However, the specific colours they chose varied cross-gender. For instance, for C major, the women chose almost exclusively light green and light blue (87.5%), whereas the men had a much more varied response. The women had a total of three colour choices for C major, in contrast to the men who had seven. Furthermore, F# major yielded very similar colour choices across both men and women, with 75% of responses being either yellow or pink, including both dark and light. A breakdown of the colour choices for F# major is presented in Table 3.

Table 3. F# Major Results

Colour choice	Total participants
Light pink	6
Dark yellow	3
Light yellow	3
Light purple	2
Light green	1

75% of females and 75% of males chose pink and yellow, showing the unanimity across genders. As few other studies have investigated colour choices cross-gender, it is difficult to explain the similarities and differences between men and women's choices. More research must be done here to produce clearer and more conclusive reasoning. However, in agreement with Beaumont, these colour associations could have been because of 'chroma differences, pitch height, or a combination of both' (Beaumont, 2003: 101).

In fact, pitch height had a large impact on the participants' colour choices in this study and meant that their colour choices were not evenly distributed across the keys. As pitch height increased, more participants made light colour choices, whilst as pitch height decreased, more dark colour choices were made. These results were statistically significant (p = 0.006). Thus, the combination of tonality and pitch height might explain the overall results of this study. A further explanation might be our relationship with colour as a concept. Whilst we might describe colours as 'warm' or 'cool', there is often ambiguity around these classifications, for example, the colour yellow. Despite not containing a trace of red, it is still considered by many to be a warm colour (Beaumont, 2003: 28). This could explain the high number of 'dark' yellow choices for Eb major, despite it being a major key. Kandinsky's research, carried out in 1977, claimed that green is a neutral colour, which perhaps explains its popularity in this study (see Figure 6), as it can be applicable to many different emotions and therefore different keys (if emotion is agreed to be a mediator between music and colour). Not only described as warm or cool, colours can also represent 'German Romantic theories', such that red might be 'outgoing assertion' and green might be 'confidence' (Beaumont, 2003: 31). These phrases, along with associations such as 'green with envy' or 'red alert' all stem from people 'wishing to attach linguistic meaning or emotional loading to experiences that are otherwise unutterable' (Beaumont, 2003: 25). The same could be said for the response of non-synaesthetes during this testing. They do not have the automatic, immediate response of associating a colour with music as synaesthetes do, thus they need to attach something to either aspect (both music and colour), in order to connect them. The most plausible mediator in this instance is arguably emotion, i.e. the participant listens to the music, experiences an emotion, associates that emotion with a colour and therefore chooses said colour.

Limitations. Being an undergraduate piece of research, there were a number of limitations. Firstly, increasing the participant size would have ameliorated the validity of results. Secondly, it was difficult to control participants' concentration on the task at hand, and they might not have had their full attention on the music and/or the colour palette during the testing. Thirdly, although the participants were able to talk to the experimenter after the testing, no formal interview was put in place to discuss their reasons for choosing each colour, which might have been beneficial for data analyses. Lastly, the colour palette was limited in its colour options and so it would be beneficial to expand this considerably.

Future Directions

If this study were to be rerun, there are a number of ways it could be developed and expanded. Firstly, the aforementioned limitations should be rectified by increasing the number of participants, and interviewing each participant after the testing to gather qualitative data as to why they might have chosen each colour. The limitation of concentration could be eliminated by ensuring that each participant is tested individually, with no visual or auditory distractions in the testing room. It would be beneficial to rerun the test with a more extensive colour palette, perhaps classified by hue and RGB value, rather than simply 'light' and 'dark'.

The music in this study could be altered, by perhaps changing the volume, the instrumentation or the genre. Changing the instrumentation would be an interesting endeavour, as various instruments and textures are often described as having different 'colours'. Therefore, one could note if this affected the colour choices of participants. Finally, the testing could be done on multiple days with the same participants, in order to see if the results gathered in this study were anomalous. This might be an effective exercise to improve the validity of results, and to gather more data than that of one testing day.

In conclusion, this study was a small but necessary step in expanding the scholarship field with regards to the link between tonality and colour for non-synaesthetes. The two hypotheses were largely realised: the first that light colours would be chosen for major keys and darker colours would be chosen for minor keys, and the second that the musicians would choose more similar colours to each other than non-musicians. All major keys drew light colour choices, and all but one minor key prompted dark colour choices. F# minor yielded 8 light colour choices and 8 dark colour choices from the participants. The musicians did have fewer disparities than their non-musician counterparts, with a total of 41 colour choices as opposed to 43. Additionally, increased pitch height favoured light colour choices and decreased pitch height favoured dark colour choices. Therefore, this is a valuable study, from which a lot can be learnt.

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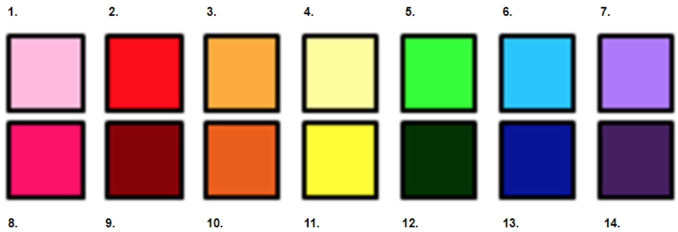
APPENDIX

Colour Palette and RBG Values



Number	R	G	B
1	255	185	220
2	255	0	0
3	255	171	47
4	255	255	153
5	33	255	33
6	25	195	255
7	174	117	251
8	255	0	102
9	134	0	0
10	234	95	0
11	255	255	0
12	0	51	0
13	5	5	153
14	68	29	97