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Interplay of Tone and Color: Absolute Pitch and Synesthesia

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ABSTRACT

Absolute pitch is an ability to recognize and properly musically name a given pitch (Levitin, 1994). It is more prevalent among speakers of tonal languages, in which meaning may depend on the pitch (Deutsch, 2009). The emergence of absolute pitch depends on cultural experience and genetic heredity (Deutsch 2006), exposure to early music education and the tempered system (Braun, 2002), while today's rare occurrence of this phenomenon might also be a consequence of transposition (Abraham 1901, Watt 1917). Musicians having absolute pitch have fewer capacities as compared with musicians with relative pitch: incessant naming of tones prevents them from fully enjoying music (Miyazaki, 1992). Absolute pitch may be integrated with other senses – synesthesia (Peacock, 1984). The sample has comprised 28 professional musicians with absolute pitch, aged 15 to 47 of both sexes. It was found that the most common synesthetic experience among professional musicians with absolute pitch is the association of sound and color – the so-called chromesthesia or color hearing (Sacks, 2007). The paper shows whether it occurs during the listening of: 1) an isolated tone played randomly in different register, 2) major and minor chords along the circle of fifths in the basic position on the piano, in the same octave, and 3) Bach's themes of 24 preludes from the "Well-Tempered Clavier". The study strives to find any regularities in the synesthetic experience, i.e. in the connection between sounds and colors in professional musicians with absolute pitch.

I. A FEW WORDS ABOUT ABSOLUTE PITCH

Absolute pitch is a rare phenomenon – it has been established that only one in 10.000 people can connect absolute pitch of an isolated tone with its musical name (Profita and Bidder, 1988). Lack of knowledge of music theory and its terminology, enabling both recognition and naming of a given pitch, disables non musicians from proving their absolute pitch ability. There are five cognitive capacities related to absolute pitch: 1) recognition and naming the tone pitch without a point of reference, 2) recognition and naming of all tones involved in a chord, 3) recognition and naming of the key of a composition while listening (passive absolute pitch), 4) singing a given tone without a point of reference (active absolute pitch), and 5) naming the pitch of surrounding/everyday sounds such as noise, car sirens etc (Bachem 1937, Baggaley 1974, Ward 1999).

Absolute pitch can be an advantage for some instrumentalists to imagine a tone before playing, or for a singer performing atonal music. Contrary to relative pitch, absolute pitch often gets in the way when playing/singing by ear, as opposed to playing/singing from score in a given key, because the constant calculation of distance between tone intervals prevents musicians with absolute pitch from fully enjoying music (Miyazaki, 2003).

Absolute pitch is more present in tone languages. In most Chinese and Vietnamese dialects, as well as Joruba and Mambila language groups in Africa, the meaning of one word depends on its tone pitch (Deutsch, 2004, 2005). Absolute pitch is more frequent among students from East Asia, particularly those who speak tone languages (Deutsch, 2006, 2009) as well with those who spent their childhood in East Asia (Gregersen et al 2000, Deutsch et al 2006, 2007). However, compared to people who developed or had their music education in East Asia, those born in America or Canada of East Asian origin, seldom have absolute pitch (Deutsch, 2007). Therefore, we can deduce that cultural background is far more important for absolute pitch development than genetic origin (Schellenberg & Trehub, 2008). However, a genetic disposition for absolute pitch has also been proved: some authors claim that everybody is born with absolute pitch, but after learning to speak it loses its importance (J. Saffran, 2001).

The absolute pitch phenomenon is rare in European music culture (Deutsch, 2006), although it has been suggested that Europeans unconsciously use and remember tone pitches when they speak (Braun M, 2001). Similarily, in some animal species (blind mice, wolves, birds, monkeys), a given pitch or a music pattern is always related to mating or search for food (Brown, 1999). Compared to early homo sapiense and to modern man, our Neanderthal ancestors had an innate ability of absolute pitch (Mithen, 2006).

There is a theory that absolute pitch is crucial for both music and speech (Mithen S, 2006). The acquisition of absolute pitch in the course of education is analogue to learning another language, with the critical period being the age of eight, when children start finding it difficult to accept and learn the phonemes of a strange language. However, absolute pitch development is possible even in this critical age, if the tone pitches are connected to verbal music signs (Deutsch, 2009). As in language, absolute pitch develops in early childhood, in the critical period between the ages of three and six (Ward 1999). Musicians who start their music education early, more likely develop absolute pitch as opposed to musicians who start later (Sergent 1969, Wellck 1938). Although absolute pitch can be acquired in the later course of education, it requires strong motivation, time and enthusiasm (Meyer 1899, Brady 1970).

Musicians with absolute pitch have a bigger temporal region in the left temporal corpus (Schlaug 1995), and show greater activity of the left frontal cortex compared to musicians without absolute pitch (Zatorre and Beckett, 1989; O. Sacks 2007). Those studies point out the importance of the left hemisphere which is responsible for verbal communication, but also for the analytical – intellectual and cognitive perception of music. The question remains: does the enlarged temporal region genetically enable absolute pitch, or does early music education enlarge this region by continuous mental exercises?

II. SOUND AND COLOR RELATIONSHIPS

The color organ has been known since the 18th century. In 1873 the physicist Von Helmholtz published his findings about the relationship between sound and color. In traditional color theory, red, yellow and blue can not be mixed or formed by any combination of other colors and all the other colors are derived from these three. Secondary colors – green, orange and purple are formed by mixing the primary colors, while tertiary colors, such as yellow-orange, red-orange, red-purple, blue-purple, blue-green and yellow-green, are colors formed by mixing one primary and one secondary color. In the "New Theory of Light and Color" (1669), Newton offered a well known analogy between basic colors and seven tones of a diatonic scale: red corresponds to tone C, orange to D, yellow to E, green to F, blue to G, indigo to A and purple to B. According to Newton, white light was made up of seven different color rays.

Scriabin`s system of colors relied upon the sequence of fifths. It was based on Isaac Newton's *Optics* – except that he used twelve instead of seven colors. In the symphonic poem *Prometheus,* composed in 1911, Scriabin added text describing numerous visual features to follow the musical notation. In this poem he introduced the lighted organ, an instrument specially designed for the performance. Scriabin's opus *Mysterium* was a great event, lasting a full week. It involved music, scent, dance and light, and was performed at the the foot of Himalayas. In his autobiography, Sergei Rachmaninoff wrote about a recorded conversation between Scriabin and Rimski Korsakov, dealing with their associations involving colors and music. For both, D major was golden – brown, Scriabin related E major to violet – red, while Korsakov to blue.

The best known perception theory related to the phenomenon was conceived in the 19th century, when Thomas Young proved that colors can be created by linear combinations of three colors – red, green and blue (T. Young, 1802). Young therefore assumes that the human eye has only three sorts of detectors. A whole century later, in 1965, it was confirmed that in primates, there are only three kinds of conuses in the retina. Therefore our sense of sight is three dimensional.

Sound and light are oscillating waves of different frequences, length and amplitudes. The range of frequency for the sensations heard is between 20 and 20.000 Hz. The range of frequency for visual sensations is between 760 and 380 trillion Hz. The range of sound covers 10 octaves, the range of light covers only one octave. Human optical senses cover exactly one octave of 380 trillion Hz for the lowest red up to 760 Hz for the highest violet. The frequency for tone A is 440 Hz, and it corresponds to app. 619.68 nm which is the frequency of orange color. B flat then corresponds to app. 584.9 nm and yellow color, while B corresponds to app. 543 nm and dark green color. Tone C (523.25 Hz) matches light green color (521.08 nm), C sharp (554.36 Hz) light blue (491.84 nm), D (587.33 Hz) dark blue (464.24 nm). While tones E flat, E and F above middle A belong to the purple color spectrum according to their frequencies, the tones F, F sharp, G and G sharp belongs to the red color spectrum.

We can speculate about red sensors having potential to absorb energy in the range of extremely blue/violet, just as one and the same tone can have different frequencies depending on the octave. Still, it often happens that the red conus in our eye carries a secondary answer which is characteristic of the extremely blue end of the spectrum, only to confirm why violet is perceived as with a red nuance. On one hand, characteristics of red nuances contribute to our feeling of a cycle, which links to Scriabin`s system to see colors in relationship to the sequence of fifths. On the other hand, when colors of a rainbow are perceived, they constantly change their wave lengths, therefore the colors are not seen separately, as opposed to the tone pitch which is more or less constant.

The perceived spectrum consists of seven basic colors: violet, (which has the highest frequency and shortest wave length) indigo, blue, green, yellow, orange and red (with lowest frequency and longest wave length). White light is constructed of the continuous line of all colors of the perceived spectrum. In practice when we see a color, we assume that it is the reflection caused by white light – the color, namely depends on the frequency of the reflection. Most people have absolute memory of color. Still there are numerous nuances of red, in the same way as numerous frequencies of the lower register accompany the upper, middle and lower register. There are millions of colors, but most people have a memory of 12 absolute basic colors.

III. THE PHENOMENON OF SYNESTHESIA

Synesthesia is a a physiological phenomenon. As opposed to absolute pitch, there is a clear sex difference – synesthesia is more developed in women than with men (J. Simner 2006). Moreover, synesthesia is more present with children and it disappears or decreases in the period of adolescence due to hormone changes or the development of abstract thinking. Synesthetic people say that they see colors as realistically as if they were real: scanning the brain of a synesthetic person proves that the phenomenon activates a part of the brain which is known to be responsible for color perception. On the other hand, there are theories that colors activated by synesthesia have characteristics of opposite colors: red versus green, blue vs yellow etc (Cytowic 2003, 2009).

As with absolute pitch, the statistics goes that one person in 10.000 has synesthetic abilities, and that this ability is inherited – synesthetic experiences occur in several members of a family (Asher 2009, Smilek 2005). Many well known artists had this ability such as Tesla, Baudelaire, Kandinsky, Liszt, Scriabin, most of whom were aware of it or considered it a problem. Scientists find that all people are born as synesthetics. For new born babies, senses are not clearly separated. They live in a synesthetic confusion up to their third month (D. Maurer, 2006). The synesthetics who have absolute pitch, frequently compare tones with colors (Peacock 1984) smell or taste (O. Sacks 2007).

Synesthesia, the rare and involuntary (neuro)psychological association of a percept presented in one modality with a concept internally experienced in another modality, has been of interest to cognitive scientists for decades. From a perspective close to our previous studies (Antovic, 2009a, 2009b, 2010), this phenomenon has been relevant since it focused on the connections between music perception and 'multimodal' cognition. More particularly, synesthesia has been related to the problem of concept construction in children – one of the problem areas of cognitive science. For instance, proponents of the so-called generative schools in linguistics usually claim that abstract relations are totally inborn (Chomsky, 1988), but in a somewhat dissenting opinion of cognitive linguists proper, authors think that concepts that we have as adult human beings must have been strongly motivated by the sensory data which we were exposed to in our childhoods. The big question of any such "empirical" concept acquisition theory is whether there is a "primary" sensory modality standing at the root of conceptualization (vision, audition, olfaction, etc.) With regard to this problem, there are authors proposing the leading role of visual cognition (Arnheim, 1969; Sweetser, 1991), schools claiming that concepts come from spatial relations (Jackendoff, 1987; Landau, 2002; Mandler, 2010), sometimes adding that there is no clear-cut distinction between the two (the 'visual-spatial' system, Landau, Dessalengh & Goldberg, 2010, but see Ungar, 2000), and still others, who insist on the perception of force as the engine behind conceptual abstractions (Johnson, 2005; Talmy, 2000; Larson, 2012). More recently, proposals have appeared in cognitive science stressing the importance of combined, 'multimodal' sensory-motor stimuli for the acquisition of concepts (Boroditsky & Prinz, 2008; Gallese & Lakoff, 2005, Forceville & Urios-Aparisi, 2009). For this last group of authors in particular, synesthesia can prove to be a relevant phenomenon.

In one of our earlier studies, requesting verbal descriptions of simple musical stimuli by sighted and blind ten-year-olds, a sighted respondent was a synesthete. Describing short tunes played by the respective sounds of the trumpet and the cello, this US elementary school student persistently talked about "the color of music", invoking "a very bright red" and "quite dark blue" (Antović, Bennett & Turner, in review). Baron-Cohen et al (1996) report approximately one musical synesthete in two thousand persons. Simner et al (2006) also mention synesthesia in 0.05% births. In our case, we found it in the description of one stimulus out of ten by one child out of 133 (the study gathered elementary school pupils from the United States and Serbia, speaking English, Serbian and Romani as native languages, and also nine congenitally blind US students). Rare as it may be, synesthesia is an important phenomenon, in particular if a researcher embraces the multimodal position in his or her concept acquisition theory. Thus, in the mentioned paper we proposed a longitudinal case study with this particular respondent, as an interesting project for the future.

IV. ABSOLUTE PITCH AND SYNESTHESIA

This prior research came upon an interesting case of synesthesia in a musically gifted child, and, as such, it served as a partial motivation for the present study: the quest for musical synesthesia in highly trained and highly musically talented individuals. When musical talent is considered, absolute or perfect pitch (AP) is often labeled a most important musical skill. As we have already stressed, authors define this ability as the perceiver's capacity to recognize and properly musically name a given pitch (Levitin, 1994). To draw a connection with linguistics once again, absolute pitch is said to be more prevalent among speakers of tone languages, in which meaning may depend on the pitch (Deutsch et al, 2009). Thus, it may as well be a part of the 'mental grammars' of some languages (Jackendoff, 1994), triggered by environmental circumstances, but strongly dependent on genetic factors. Accordingly, leading music psychologists today also agree that the emergence of absolute pitch depends on both cultural experience and genetic heredity (Deutsch, 2006). Exposure to early music education and the tempered system seem to be important in the process, too (Braun, 2002). Today there are also studies claiming that the relatively rare occurrence of this phenomenon might be related to the frequent practice of transposition (Abraham 1907, Watt 1917). Yet, while this capacity is in itself peculiar and often related to supreme musical skills, in actuality, musicians having absolute pitch have fewer capacities, as compared with musicians with relative pitch: some claim that their constant naming of tones prevents these people from fully enjoying music, which produces a specific kind of cognitive dissonance (Miyazaki, 1992).

The most frequent case of the comparatively very rare phenomenon of synesthesia is that of associating particular, individual pitches with colors. Studies report that a small number of individuals with absolute pitch also experience a strong color association. This sometimes happens among composers, too (Profita & Bidder, 1988). Interestingly, though, synesthesia appears to exhibit strong familiar aggregation (Baron-Cohen et al, 1996). Since to our knowledge these results have not been studied with the Serbian population before, the first aim of the present study is to inspect the potential synesthetic experiences of Serbian professional musicians (music students) with absolute pitch, and compare them with some resulted obtained in studies worldwide.

For a related, but a bit more complex phenomenon, Caroll & Greenberg (1961), both possessors of absolute pitch and trained pianists, discovered in a conversation that they associated colors not with notes alone, but also with musical keys. On two separate and unrelated occasions, they discovered that the colors they associated with particular keys were the same in what seemed to be much more frequent than chance. Thus the C major tonality was typically experienced as 'white', the G major tonality as 'yellow' or 'orange', while E flat major was either 'gray' or 'blue'. The two authors also noted that the composer Scriabin had had a similar type of synesthesia (although this is somewhat questioned in other studies, cf. Peacock, 1985). The conclusion was that there had to be an underlying mechanism, perhaps innate, motivating the synesthetic experiences of such people. Continuing along this line of research, the second aim of the present study is to test whether not only individual tones, but also chords cause any synesthetic experience among Serbian music students who possess absolute pitch. In our study, chords have been presented to respondents as major triads presented along the circle of fifths, in the same middle octave. While individual chords are certainly not enough for the respondents to infer a particular key, they represent the situation which is 'halfway' between single tones and full tonalities. Thus, any experience of color associated with these triads may provide some new data in the study of musical synesthesia.

Finally, the most complex type of synesthesia that we would like to test would be that of *complete musical tunes* given in different keys. For this, Bach's Well-Tempered Clavier may be singled out as the logical choice. The most famous piece in the history of Western music presenting the tempered system of 24 tonalities with the capacity of limitless transposition, this musical composition was what allowed modulations to distant tonalities that much of later music was filled with. Since it repeats the same tune in 24 different keys, in the present study it can also serve as a good vehicle to test a most complex case of potential synesthesia: the association of the rather abstract notion of a musical *key* and colors.

V. RESEARCH PROCEDURE

The research was carried out in the first half of 2012 with musicians with absolute pitch: 1) students of different profiles and ages at the Faculty of Music University of Arts in Belgrade and Nis in Serbia, and 2) professors of solfeggio and piano of different ages from music schools in Belgrade.

A. Aims

The basic aim was to search for the phenomenon of synesthesia related to absolute pitch according to gender, current age, age of the start of musical training, five categories of absolute pitch ability, and to provide an overview of synesthetic experiences related to a given sound.

The specific aim is to investigate whether there are certain regularities in relation to synaesthetic experiences of tested participants.

B. Methods

Our study included 28 participants, professional musicians with absolute pitch ability. Yamaha digital piano CLP-320 was used in the first two sessions and the procedure was the following:

- identifying individual tones: the naming of the pitches was requested and the possible associative synesthetic experience was reported (written down). A total of 12 tones in different octaves were played *once*;
- identifying major and minor chords (in the middle octave in the root position) and reporting the possible synesthetic experience; the chords were presented along the circle of fifths;
- since piano, as a tempered instrument, does not recognize sharps from flats, we used 24 Preludes from Bach's Well-Tempered Clavier for the third segment of our study; the participants listened to the initial theme of 24 preludes (until the first cadenza, before the onset of the modulation) and reported any cooccurring synesthetic experience. The performance of Sviatoslav Richter was used.

C. Basic results

We tested 28 participants (18 ladies and 10 men). They were all musicians with absolute pitch, from 15 to 47 years of age: the majority of subjects were 19 (4), 20 (6) and 21 (3) years old. Most of them had begun musical training at the age of eight (8), six (5) and nine (5). Three of them started musical training before the age of six (at 3, 4 and 5 years of age). The participants were students of music education (8), music theory (8), piano (1), composition (1), flute (1), music production (1), solo singing (1), violin (3), professors of solfeggio (2) and piano (2) at music schools.

The most common synesthetic experiences are those linking sounds and colors (19), provoking by the sound a sense of touch (5), taste (4) and some other visual associations (6).

In terms of listening to isolated tones, participants can be divided in three groups, those with synesthetic experiences (9), partial synesthetic experiences (7), and no such experiences (11).

When listening to chord structures (major and minor chords along the circle of fifths) some of them fully experience synesthesia (9), some do so partially (9), while some do not report any synesthetic experience (9).

When listening to the initial theme of Bach's Preludes from the Well-Tempered Clavier, 15 participants had complete synesthetic experiences, 4 had partial ones, while 8 had no synesthetic experiences.

Finally, we can say that we had three groups of musicians with absolute pitch: 1) without synesthetic experiences (8), with partial synesthetic experiences (12) and with complete synesthetic experiences (8). Interestingly enough, participants in the first group started their music education earlier (at the age of six on average) than the other two groups (the age of eight on average). We can also say that there was a slight positive trend in relating the quality of absolute pitch ability as well as richness of synesthetic experiences: with absolute pitch abilities being more complete, the synesthetic experiences were richer.

1) Musicians with absolute pitch without synesthetic experiences. Among the total of 8 participants (6 female and 2 male) there are students of music theory (3), music education (2), violin (1), piano (1), a solfeggio professor at a music school (1). Those participants began their music training at the age of 4 (1), 5 (2), 6 (2) and 8 (3). Three of them began their music training at the age of eight and have all five categories of absolute pitch. Two participants began their music education at the age of six and were not able to identify isolated tones: while one of them is able to determine the pitch of isolated tones while playing, but not while singing, the other one can-not determine the key of the composition or hear the pitch of everyday sounds. Two of our participants began their music training at the age of five, and they satisfy all five categories of absolute pitch. One of our participants started playing the accordion at the age of 4 and has all five categories which comprise absolute pitch perception.

2) Musicians with absolute pitch and partial synesthetic experience. Among the total of 12 participants (9 female and 3 male) there are students of music theory (4), music education (2), composition (1), piano (1), violin (1), music production (1) and professors of piano (2). Music training began at the age of 5 (3), 6 (2), 8 (4), 9 (3) and 12 (1). Four participants have all five components of the absolute pitch ability, but their recognition of pitches in chords depends on the complexity of a chord structure. Eight participants have abilities in all five categories of absolute pitch, except for the identification of everyday sounds, which depends on temperation. Two participants were not able to recognize the key of the composition. Seven participants rarely experience colors. One participant in most cases can see colors associated with isolated tones, chords and the initial themes of Bach's Preludes. One participant associates colors only with the initial themes of Bach's Preludes. One participant can sometimes associate colors with the isolated tone, but always when listening to chords and themes of Bach's Preludes. The color associated with the isolated tone (e.g. tone c1) is the same for the related chord (C major or C minor) and a theme of Bach's C major or C minor Prelude. One participant usually connects chords with color and taste (e.g. C major and G minor are bitter, while B flat major is sour). One participant sometimes experiences colors, feels smells (the smell of black locust for C sharp major, or smoke for B flat minor) and the feeling of heat (for B flat major). One participant (congenitally blind) describes all major chords as “masculine” or “male”, except for B flat major and B sharp major which are ”feminine” or “female”, while all minor chords are described as "female" or "feminine", except for B flat minor and B sharp minor which are "male" or "masculine". Two participants reported *light-dark* and *stick out/does not stick out feeling,* depending on the prevalence of black vs white keys in major/minor chords. While the first one reports a feeling of *light* in sharp and *dark* in flat chords, the second one experiences chords with more black keys as they *stick out.*

3) Musicians with absolute pitch and full synesthetic experiences. Among the total of 8 participants (4 female and 4 male) there are students of music education (4), flute (1), solo singing (1), violin (1) and a professor of solfeggio (1). Music training began at 3 (1), 6 (1), 9 (3), 10 (2) and 12 (1) years of age. All 8 participants possess five components of the absolute pitch ability, although chord's recognition depends on the complexity of the chord structure. Synesthetic experiences were those of *color* (8), *taste* (1) and *smell* (2). One participant had synesthetic experiences of colors, fragrances (rain for C minor) and touch (heat for E flat Major, patting for Bach's F minor Prelude, or beading for Bach's B sharp major Prelude). Another participant had synesthetic experiences of *color, scent* (roses, violets, daffodils, dandelions), *taste* (sweet for B sharp major and saline for B sharp minor) and *touch* (heat, hand). There is also one participant who experienced the same colors for the same chord structures and keys of Bach's prelude. The participant with congenital cataract and other vision problems was experiencing colors in nuances while listening to isolated tones, chords and themes of Bach's Preludes.

D. Results in charts

All the results that show the relationship between the experienced color and sound given in the form of isolated tones, major and minor chords, and themes of Bach's 24 Preludes, are presented in individual coordinate systems below. The horizontal side of the coordinate system presents the range of colors, which move from left to right according to the visible color spectrum: black – grey – white (as neutral colors) – pink – purple – dark blue – light blue – dark green – light green – light yellow – dark yellow – orange – red. The vertical side of the coordinate system shows the percentage of experienced colors. All colors represented in the coordinate system are given in relation to the respondents' answers. We have decided to present here only those coordinate systems in which the clear dominance of certain colors can be found.

Figure 1. Graphic display of color experiences for F major chord

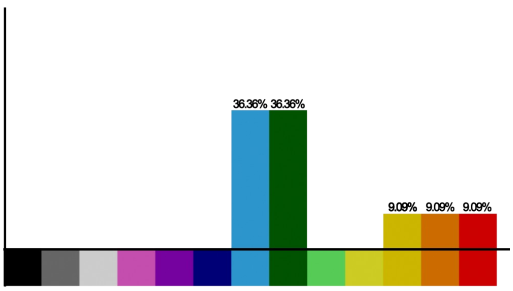


Figure 2. Graphic display of color experiences for F minor chord

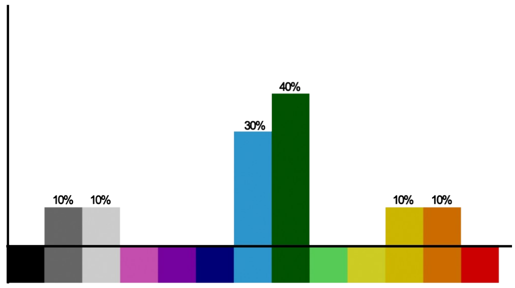


Figure 3. Graphic display of color experiences for F sharp major chord

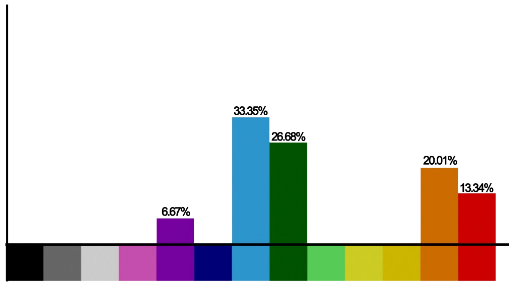


Figure 4. Graphic display of color experiences for Bach's F sharp minor Prelude

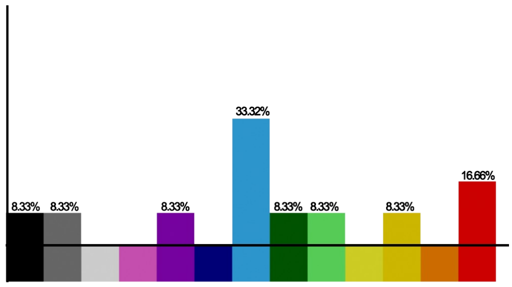


Figure 5. Graphic display of color experiences for E flat major chord

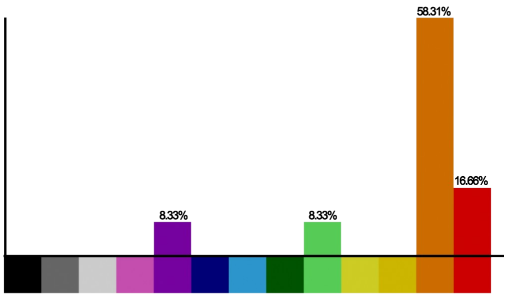


Figure 6. Graphic display of color experiences for E flat minor chord

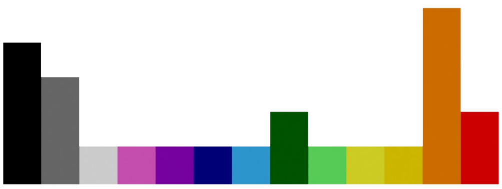


Figure 7. Graphic display of color experiences for Bach's E flat major Prelude

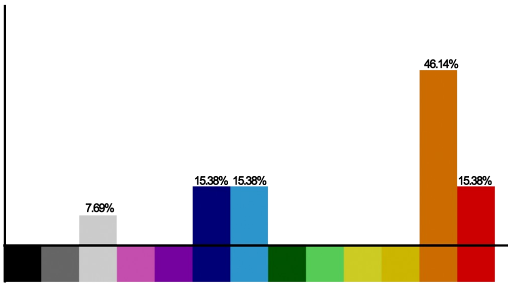


Figure 8. Graphic display of color experiences for isolated tone A1

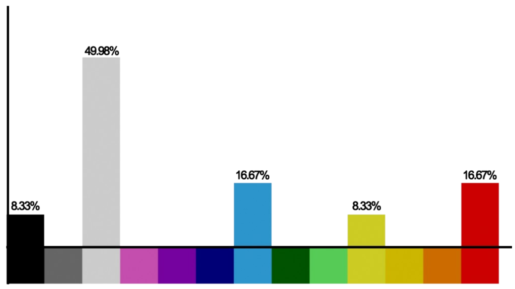


Figure 9. Graphic display of color experiences for A major chord

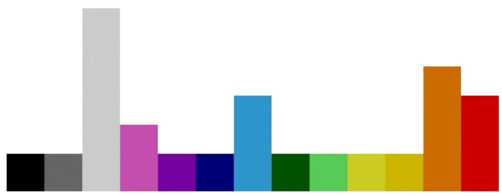


Figure 10. Graphic display of color experiences for A minor chord

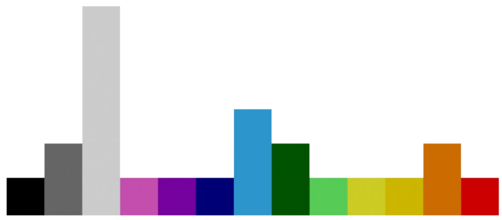


Figure 11. Graphic display of color experiences for Bach's A major Prelude

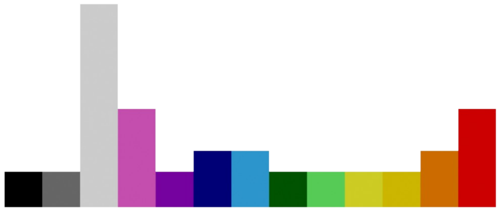
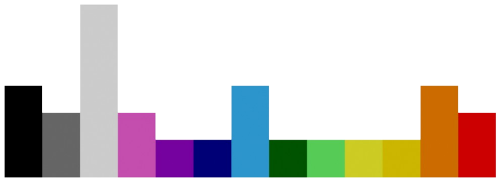


Figure 12. Graphic display of color experiences for Bach's A minor Prelude



E. Specific results

Results indicate the predominance of light blue/dark green color spectrum for F major chord, F minor chord, Bach's F major and F minor Preludes, F sharp major chord, F sharp minor chord and Bach's F sharp minor Prelude. The G major chord appertains to dark green, while Bach's G major Prelude relates to the light green part of the color spectrum. Obviously, the color chromaticism (light blue/dark green/light green) matches chromaticism in music (F/F sharp/G).

On the other hand, the orange/dark yellow spectrum mostly belongs to the E flat major chord, E flat minor chord, and Bach's E flat major Prelude (for Bach's E flat minor Prelude the opposite part of the color spectrum – light blue prevails), A flat major chord and Bach's A flat major Prelude.

The relation between color and music chromaticism could be seen in A and B tones area and white and grey neutral colors: A major chord, A minor chord, Bach's A major and minor Preludes, as well as the isolated tone A1 have been predominantly experienced as white, while B sharp and B flat major chords, B flat minor chord and B3 isolated tone are grey.

F. Implications

The future research will examine the relationship between absolute pitch and chamber-tone frequency: whether absolute pitch depends on chamber-tone frequency, and whether synesthetic experiences change if chamber-tone frequency has been changed.

VI. CONCLUSION

Results of the present research suggest that synesthesia is a relatively common phenomenon among individuals with absolute pitch. Among various types of synesthetic experience, the association of pitches/chords/themes with colors has been the commonest. While individual differences occur and statistical confirmation remains difficult, the tendency of the ranges around E and A to be associated with yellow and orange hues, and those close to the F and G to be associated with green and blue, remains conspicuous. Of most interest for future studies should be the idea that color and music chromaticism are not mere visual metaphors, but are also somehow cognitively, perhaps neurologically, correlated.

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REFERENCES

Abraham, O. (1907). "Das absolute Tonbewußtsein und die Musik (Absolute tone consciousness and music)" (in German). *Sammelbände des Internationalen Musikgesellscht*, *8*: 486–91.

Antović, M. (2009a). Musical metaphor in Serbian and Romani children: An empirical study. *Metaphor and Symbol*, *24* (3): 184-202.

Antović, M. (2009b). Towards the semantics of music: The 20th century. *Language and History*, *52* (1): 119-129.

Antović, M. (2010). From Oceanic Feeling to Image Schemata: Embodied Mind and the Construction of Identity. In: Lopicic V. and B. Misic Ilic (Eds.), *Identity Issues, Literary and Linguistic Landscapes* (pp. 177-194). Cambridge Scholars Publishing.

Antović, M., Bennett, A. & Turner, M. (in review). Running in circles or moving along lines: conceptualization of musical elements in sighted and blind children.

Arheim, R. (1969). *Visual Thinking*. University of California Press.

Baggaley, J. (1974). Measurement of Absolute Pitch. *Psychology of Music, 2* (2), 11-17.

Bachem, A. (1937). Various Types of Absolute Pitch. *Journal of Acoustical Society of America, 9*, 146-151.

Baron-Cohen S., Burt L., Smith-Laittan F., Harrison J., & Bolton P. (1996). Synaesthesia: prevalence and familiality. *Perception, 25* (9), 1073–1079.

Beeli, G., Esslen, M. and Jancke, L. (2005). Synaesthesia: when coloured sounds taste sweet. *Nature, 434* (7029), 38.

Blacking, J. (1971). Music and Historical Process in Vendaland. In K. P. Wachsmann (Ed.), *Essays on Music and History in Africa* (pp. 185-212). Evanston: Northwestern University Press.

Boroditsky, L., & Prinz, J. (2008). What thoughts are made of? In: Semin, G. R. & E. R. Smith (Eds.), *Embodied grounding: Social, cognitive, affective, and neuroscientific approaches*. New York: Cambridge University Press.

Brady, P. T. (1970). Fixed Scale Mechanism of Absolute Pitch. *Journal of Acoustic Society of America, 48*, 883-887.

Braun, M. (2002). Absolute pitch in emphasized speech. *Acoustical Society of America: Acoustics Research Letters Online, 3* (2), 77-82.

Brown, K. (1999). Striking the Right Note. *New Scientist, 164* (2215), 38-41.

Campen, C. van (2007). *The Hidden Sense. Synaesthesia in Art and Science.* Cambridge, MA: MIT Press.

Caroll, J. & Greenberg, J. (1961). Two cases of synesthesia for color and musical tonality associated with absolute pitch ability. *Peceptual & Motor Skills*, 13: 48.

Chomsky, N. (1988). *Language and Problems of Knowledge*. Cambridge, MA: MIT Press.

Cytowic, R. (2002). *Synaesthesia: A Union of the Senses*. Second Edition. Cambridge, MA: MIT Press.

Cytowic, R. (2009). *Wednesday as Indigo Blue: Discovering the Brain of Synaesthesia*. Cambridge, MA: MIT Press.

Deutsch, D. and Henthorn, T. (2004). Absolute pitch, speech and tone language. *Music perception, 21*(3), 339-356.

Deutsch, D., Henthorn, T., Marvin, E. and Xu, H. (2006). Absolute pitch among American and Chinese conservatory students: Prevalence Differences, and evidence for a speech-related critical period. *Journal of the Acoustical Society of America, 119* (2), 719-722.

Deutsch, D. (2006). The Enigma of Absolute Pitch. *Acoustics Today, 2* (4), 11-18.

Deutsch, D., Dooley, K., Henthorn, T. and Head, B. (2009). Absolute pitch among students in American music conservatory: association with tone language fluency. *Journal of the Acoustical Society of America, 125* (4), 2398-2403.

Gallese, V. & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology*, *22* (3/4), 455-479.

Gregersen, P. K. et al (2000). Early Childhood Music Education and predisposition to absolute pitch. *American Journal of Medical Genetics, 98* (3), 280-282.

Jackendoff, R. (1987). *Consciousness and the Computational Mind.* Cambridge, MA: MIT Press.

Jackendoff, R. (1994). *Patterns in the Mind.* Basic Books.

Johnson, M. (2005). The philosophical significance of image schemas. In: B. Hampe (Ed.), *From perception to meaning: Image schemas in cognitive linguistics* (pp. 15-34). Berlin: Walter DeGruyter.

Heaton C. P. (1992). Air Ball: Spontaneous Large-Group Precision Chanting. *Popular Music and Society, 24* (1), 81-84.

Landau, B. (2002). Spatial cognition. In V. Ramachandran (Ed.), *Encyclopedia of the human brain*, Vol. 4. San Diego, CA: Academic Press.

Landau, B., Dessalegh, B., & Goldberg, A. (2010). Language and space: Momentary interactions. In: P. Chilton and V. Evans (Eds.), *Language, cognition, and space: The state of the art and new directions* (pp 51-77). Advances in Cognitive Linguistics Series.

Larson, S. (2012). *Musical forces: Motion, metaphor and meaning in music.* Indiana University Press.

Levitin, D. (1994). Absolute memory for musical pitch: evidence from production of learned melodies. *Perception and Psychophysics, 56* (4), 414-423.

Levitin, D. (1999). Absolute Pitch: Self-Reference and Human Memory. *International Journal of Computing Anticipatory Systems, 4*, 255-266.

Levitin, D. (2007). *This is Your Brain on Music – The Science of Human Obsession.* A Plum Book, a member of Penguin Group, USA.

Mandler, J. (2010). The spatial foundations of the conceptual system. *Language and Cognition*, *2* (1), 21-44.

Meyer, M. (1899). Is the memory of absolute pitch capable of development by training? *Psychological Review, 6* (5), 514-516.

Mithen, Steven (2006). *The Singing Neanderthals: The Origins of Music, Language, Mind and Body.* London: Orion Books Ltd.

Miyazaki, K. (1993). Absolute pitch as an inability: Identification of musical intervals in a tonal context. *Music Perception, 11,* 55-72.

Miyazaki, K. (2004). How well do we understand absolute pitch? *Acoustical Science and Technology, 25* (6), 270-282.

Moore, B. C. J. (1997). *An Introduction to the Psychology of Hearing.* Fourth Edition. New York: Academic Press.

Nikolic, D., Lichti, P. and Singer, W. (2007). Color oponency in synaesthetic experiences. *Psychological Science, 18* (6), 481-486.

Parncutt, R. & Levitin, D. J. (2001). Absolute Pitch. In: S. Sadie (Ed.), *The New Grove Dictionary of Music and Musicians* (pp.37-39). London: McMillan.

Pecaock, K. (1984). Synaesthetic Perception: Alexander Skriabin's Colour Hearing. *Music Perception, 2*, 483-506.

Peacock, K. (1988). Instruments to Perform Color-Music: Two Centuries of Technological Experimentation. *Leonardo, 21*, No. 4, 397-406.

Profita, J. and Bidder, T. G. (1988). Perfect Pitch. *American Journal of Medical Genetics, 29* (4), 763-771.

Sacks, O. (2007). *Musicophilia: Tales of Music and the Brain.* New York: Knopf.

Saenz, M. and Koch, C. (2008). The sound of change: visually induced auditory synaesthesia. *Current Biology, 18* (15), 12-28.

Saffran, J. R. & Griepentrog, G. J. (2001). Absolute pitch in infant auditory learning: evidence for developmental reorganization. *Dev Psychology, 37,* 74-85.

Schellenberg, E. G. and Trehub, S. (2008). Is There an Asian advantage for pitch memory? *Music Perception, 25* (3), 241-252

Schlaug G., Jancke, L., Huang, Y. and Steinmetz, H. (1995). In Vivo Evidence of Structural Brain Asymmetry in Musicians. *Science, 267* (5198)*,* 699-701.

Sergeant, D. (1969). Experimental investigation of absolute pitch. *Journal of Research in Music Education, 17* (1), 135-143.

Siegel, J. A. (1974). Sensory and Verbal Coding Strategies in Subjects with Absolute Pitch. *Journal of Experimental Psychology, 103* (1)*,* 37-44.

Simner, J., Mulvenna, C., Sagiv, N. et al. (2006). Synaesthesia: The Prevalence of Atypical Cross-Modal Experiences. *Perception, 35* (8), 1024-1033.

Smilek, D., Dixon, M. J., Cudahy, C. and Merikle, P. M. (2002). Synaesthetic colour experiences influence memory. *Psychological Science, 13* (6), 548-552.

Talmy, L. (2000). *Toward a cognitive semantics.* Cambridge, MA: MIT Press.

Ungar, S. (2000). Cognitive mapping without visual experience. In: Kitchin, R. & Freundschuh, S. (Eds), *Cognitive Mapping: Past Present and Future* (pp. 221-248). London: Routledge.

Ward, J., Tsakanikos, E. and Bray, A. (2006). Synaesthesia for reading and playing musical notes. *Neurocase, 12* (1), 27-34.

Ward, J., Huckstep, B. and Tsakanikos, E. (2006). Sound-colour synaesthesia: to what extent does it use cross-model mechanism common to us all? *Cortex, 42* (2), 264-280.

Ward, W. D. (1998). Absolute Pitch. In: D. Deutsch (Ed.), *The Psychology of Music* (265-298). San Diego: Academic Press.

Watt, H. J. (1917). *The Psychology of Sound.* Cambridge: Cambridge University Press.

Wellek, A. (1938). Das absolute Gehor und seine Typen. *Beihefte zur Zaitschrift fur Angewandte Psychologie und Charakterkunde, 83*, 1-368.

Young, T. (1802). Bakerian Lecture: On the Theory of Light and Colors. *Philosophical Transactions of the Royal Society London, 92*, 12-48.

Zatorre, R. and Beckett, C. (1989). Multiple coding strategies in the retention of musical tones by possessors of absolute pitch. *Memory and Cognition, 17* (5), 582-589.