Music-Color Synesthesia: A Historical and Scientific Overview

by Vanessa Hawkins

Abstract: Music-color synesthesia is a phenomenon in which the sensation of color is experienced when perceiving music. This paper chronicles the development of the concept of music-color synesthesia, from theorized connections between color and music to the establishment of the study of synesthesia as a science. It also details the leading theories on the cause of synesthesia itself and various forms of expression of music-color synesthesia. A case study by the author on her own experience with music-color synesthesia is included, proposing ideas for further areas of research in this field.

A blind man who had long attempted to understand light and colors boasted one day that he now knew the meaning of the color scarlet. His friend, in doubt, asked him what scarlet was, and the blind man replied, "It was like the sound of a trumpet"[1]. The composer and pianist Franz Liszt notoriously asked an orchestra to perform sections of his compositions "bluer," or "not so rose,"[2] and Pharrell Williams knows when a song is in the correct key if it "matches the same color."[3] These people come from vastly different backgrounds and time periods, but they all share a condition known as music-color synesthesia. Synesthesia is a neurological anomaly in which perception of one stimulus results in both the usual sensation and an additional sensation not normally caused by that stimulus.[4] Music-color synesthetes are explained by their name; they experience color upon hearing music.[5] The ways in which this phenomenon influences musical perception may be explored through a systematic investigation into the history, neuroscience, and expression of music-color synesthesia.

History of a Music–Color Relationship

While the study of synesthesia itself has only been prevalent for the last two hundred years, an interest in finding an association between music and color was common among many early thinkers. Throughout history, certain individuals designed arbitrary systems to assign color (and even sight or taste) to certain musical tones or intervals, but there were a few scientists that attempted to find a quantifiable reason for color to be linked to music. One of the first to conceptualize a possible music-color correlation was the Greek mathematician and philosopher Pythagoras, circa 550 B.C.[6] Pythagoras considered music to be a subdivision of mathematics, and is

[1] John Locke, *An Essay Concerning Human Understanding* (London: A. Churchill and A. Manship, 1721), 29, Google Play Books.

[2] Friedrich Mahling, "Das Problem der 'Audition colorée': eine historisch-kritische Untersuchung," *Archiv für die gesamte Psychologie*, no. 57 (1926): 165-301, trans. by Sean Day, quoted in Sean Day, "Synesthete Composers and Musicians," Synesthesia, July 11, 2021, http://www.daysyn.com/synesthete-composers-and-musicians.html#anchor_147.

[3] "Pharrell Williams on Juxtaposition and Seeing Sounds," *NPR*, December 31, 2013, https://www.npr.org/sections/therecord/2013/12/31/258406317/pharrell-williams-on-juxtaposition-and-seeing-sounds

[4] Lisa Herman, "Synesthesia," *Encyclopedia Britannica Online*, accessed December 4, 2021, https://www.britannica.com/science/synesthesia.

[5] Ibid.

[6] Sean Day, "A Brief History of Synesthesia in the Arts," Synesthesia, July 5, 2011, http://www.daysyn.com/History.html.

credited with the discovery of the 3:2 ratio between the frequencies in a perfect fifth interval.[7] He worked to apply this relationship between mathematics and music to numerous observable phenomena, attributing to each a tone, a harmonic interval, a number, a name, a color, and a form.[8] Pythagoras endeavored to explain much of the natural world in this way, including the constellations, the harmonic relationship of the planets, and the elements.[9]

A little over seventeen hundred years later, the well-known mathematician and physicist Isaac Newton made a more specific inquiry into a link between music and color. He published his treatise *Optics* in 1704, which featured an analysis of the visible spectrum seen when directing white light through a prism.[10] Newton rather arbitrarily separated the visible spectrum into seven colors; he associated these with the seven tones in the major scale, introducing the barely-distinguishable orange and indigo as its half-steps.[11] Unfortunately for Newton, his color theory was disproved—when attempting to mathematically correspond the frequencies of visible light to the frequencies of tones in the major scale, it became apparent that the range of frequencies in visible light spanned an interval of about a major sixth, rather than the octave Newton had initially imagined.[12] Nevertheless, his arbitrary color assignments happen to be the origin of the well-known acronym ROY-G-BIV used to describe the visible spectrum today.[13]

A French Jesuit monk named Louis Bertrand Castel had a different idea: he wanted to combine color and music as related to artistic expression. Using color theory from artists at the time, he designed a music-color relationship using solfège around twenty years after Newton devised his color theory:

> The green corresponds to *re*, and will doubtless make them [the audience] feel that this note *re* is natural, rural, sprightly, pastoral. Red, which corresponds to sol, will give them the idea of a warlike note … . The deaf in this way will be able to see the music of the ears, the blind to hear the music of the eyes, and we who have both eyes and ears will enjoy music and colors better by enjoying them both at the same time.[14]

Castel conceived an instrument known as the color organ, in which each key produced not only a rich sound but also a dazzling hue.[15] He even dreamed of having the music of an opera painted out on the walls of a room; to have concerts live on through color after the music fades away.[16] While Pythagoras and Newton approached the link between music and color from a scientific standpoint (which is a logical conclusion, as both sound and light are composed of waves), Castel's perspective was to find an emotional connection between the two.

Pythagoras, Newton, and Castel all theorized objective relationships between music and color. Before synesthesia was understood objectively, let alone defined, Georg Tobias Ludwig Sachs recorded the first subjective encounter with a color-music

[7] Thomas Stanley, *The History of Philosophy* (London: Humphrey Moseley, and Thomas Dring, 1655), quoted in "The Pythagorean Theory of Music and Color," Sacred Texts, https://www.sacred-texts.com/eso/sta/sta19.htm.

[8] Ibid.

[9] Ibid.

[10] Ashley Taylor, "Newton's Color Theory, ca. 1665," The Scientist, LabX Media Group, March 1, 2017, https://www.the-scientist.com/foundations/newtons-color-theory-ca-1665-31931.

[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Louis Bertrand Castel, *Esprit, Saillies et Singularités du P. Castel*, trans. Irving Babbit (Boston: The New Laokoon, 1910), 55, quoted in Erika von Erhardt-Siebold, "Harmony of the Senses in English, German, and French Romanticism," *PMLA* 47 no. 2 (1932): 578. https://www.jstor.org/stable/pdf/457897.pdf.

[15] Erika von Erhardt-Siebold, "Harmony of the Senses in English, German, and French Romanticism," *PMLA* 47 no. 2 (1932): 578. https://www.jstor.org/stable/pdf/457897.pdf.

[16] Ibid., 578.

connection.[17] Widely considered to be the first documented synesthete, Sachs actually published his medical dissertation on albinism, which was exhibited both by himself and his youngest sister.[18] His thesis also featured a chapter describing the curious blending of senses he experienced but could not quantify; he associated color with intervals of the musical scale as well as numbers, days of the week, letters of the alphabet, and other similar ideas.[19] Sachs's account is detailed and objective, making it very useful today in understanding the concept of synesthesia and recognizing it in people, but it garnered little attention when first released.[20] The condition was not even a respectable scientific subject until the end of the nineteenth century, following the research of a few pioneers in the field.[21]

In 1881, Eugen Bleuler and Karl Bernhard Lehmann conducted the first comprehensive study of synesthesia as young medical students in Switzerland.[22] Blueler himself was a grapheme-color synesthete.[23] After recognizing Bleuler's quality as unique, the two scientists began an investigation of this quality in their family members, eventually branching out to an inquiry into other sensory associations with a larger sample size (596 people, and the largest synesthesia study of its time).[24] Bleuler and Lehmann discovered six new types of synesthesia, which they called "secondary sensations."[25] These included sound to color synesthesia, which they believed to be the most frequently displayed secondary sensation.[26] Bleuler and Lehmann calculated that 12.8% of people are synesthetes, though this result is much higher than what is generally assumed today and is likely due to a large portion of their sample size being genetically related.[27] Importantly, they did not reduce "secondary sensations" to a form of mental illness, but rather described it as a condition to which everyone is predisposed at some level.[28]

Bleuler and Lehmann paved the way for more scientists to contribute to this growing field of study. After the first international symposium on synesthesia in Paris in 1889, Romanian psychologist Eduard Gruber developed a questionnaire that examined in great detail multiple causes of synesthetic events, which are now known as synesthetic inducers.[29] Théodore Flournoy, a professor of psychology at the University of Geneva, published his *Des Phénomènes de Synopsie* (Synopsia Phenomena) in that same year; it is considered to be the most comprehensive analysis on the topic in the nineteenth century.[30] At the end of the nineteenth century, the term "synesthesia" was coined by several scientists across the world as fascination on the topic became widespread.[31] However, as the concept of behaviorism (which posits that human and animal behavior is influenced by their environment and not internal factors) began to dominate among psychologists beginning in the

[17] Maria Konnakova, "From the Words of an Albino, a Brilliant Blend of Color," *Scientific American*, Springer Nature, February 26, 2013, https://blogs.scientificamerican.com/literally-psyched/from-the-words-of-an-albino-a-brilliant-blend-of-color/https://blogs.scientificamerican.com/literally-psyched/from-the-words-of-an-albino-a-brilliant-blend-of-color.

[18] Ibid.

[19] Ibid.

[20] Matej Hochel and Emilio Gomez, "Synesthesia: The Existing State of Affairs," *Cognitive Neuropsychology* 25, no.1 (March 2008): 94, https://www.researchgate.net/publication/5510942_Synaesthesia_The_existing_state_of_affairs.

[21] Ibid.

[22] Jörg Jewanski et al., "The 'Golden Age' of Synesthesia Inquiry in the Late Nineteenth Century (1876–1895)," *Journal of the History of the Neurosciences* 29, no. 2 (2019), https://www.tandfonline.com/doi/full/10.1080/0964704X.2019.1636348.

[23] Ibid.

[24] Ibid.

[25] Jörg Jewanski et al., "The Evolution of the Concept of Synesthesia in the Nineteenth Century as Revealed by the History of its Name," *Journal of the History of the Neurosciences* 29, no. 3 (2019), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7446036.

[26] Ibid.

[27] Ibid.

[28] Ibid.

[29] Jewanski et al., "Synesthesia Inquiry."

[30] Ibid.

[31] Jewanski et al., "The Evolution of the Concept of Synesthesia."

1920s, the number of synesthesia studies diminished, as the ideas contradicted.[32] Following the cognitive revolution in the 1980s and a renewed acceptance of human thoughts and feelings as relevant to scientific investigation, a resurgence of interest in synesthesia developed.[33]

Neuroscience Behind Synesthesia

While early research on synesthesia seldom breached the surface of mere observation and documentation, as the timeline of the condition's history arrives at the twenty-first century, the search for an explanation of the cause of synesthesia begins. The invention of the MRI machine in the 1990s allowed researchers to observe that synesthetes experience activity in areas of the brain that process each simultaneous sensation they perceive (e.g., for a music-color synesthete, a stimulus would affect both the auditory cortex and the visual cortex).[34] It follows that there must be some connection that occurs between different sensory processing areas in the brain for certain stimuli in synesthetes.

There are two primary theories that use this idea to explain mechanics of synesthesia. The first of these is the disinhibited feedback theory, developed in 2001 by Peter Grossenbacher and Christopher Lovelace.[35] Grossenbacher and Lovelace proposed that synesthesia is caused by a difference in brain function in the cortex, which deals with higher-level processes such as perception.[36] When one hears a concert A played on a piano, for example, the central nervous system carries the sound signal from your ear to the auditory cortex. Each of the five senses correlates to a different sensing area in the brain, and these sensing areas feature concurrent sensory pathways that are organized from simple associations to more complex associations caused by a stimulus. When a person perceives a stimulus, such as hearing a concert A, specific neurons along these pathways are fired or inhibited to produce the thought that corresponds with the stimulus. The combination of neurons utilized to perceive a certain sensation is known as the inducer pathway. Information feeds forward along the inducer pathway from a primary sensory region of the brain, such as the auditory cortex, to higher-order sensory association areas of the brain. When these higher-order association areas can be accessed by multiple pathways, they reciprocate the feedforward signal with a feedback signal that travels in the opposite direction. Grossenbacher and Lovelace's theory posits that in synesthetes, the brain does not sufficiently inhibit certain concurrent sensory pathways from being activated as the feedback signal travels along the inducer pathway.[37] This causes the feedback signal to travel along the concurrent pathway as well as the inducer pathway, thus activating additional areas of the brain that would not otherwise be affected by a certain stimulus.[38]

A second prominent theory of the underlying cause of synesthesia attributes the condition to a difference in brain composition, as opposed to a difference in brain function. Developed in 2001 by Edward Hubbard and V. S. Ramachandran; the cross-activation theory proposes that synesthetes have direct neural connections between areas of the brain activated by the inducer pathway of a stimulus and areas of the brain activated by the concurrent pathway of the same stimulus, instead of a connection caused by disinhibition of the concurrent pathway.[39] This theory is supported by significant evidence that suggests that there exist in infancy and childhood synaptic connections between different areas of the

32 "History of Synesthesia Research," Wikipedia, last modified April 6, 2021, https://en.wikipedia.org/wiki/History_of_synesthesia_research.

33 Ibid.

34 Siri Carpenter, "Everyday Fantasia: The World of Synesthesia," *Monitor on Psychology* 32, no. 3 (2001), https://www.apa.org/monitor/mar01/synesthesia.

35 Peter Grossenbacher and Christopher Lovelace, "Mechanisms of Synesthesia: Cognitive and Physiological Constraints," *Trends in Cognitive Sciences* 5, no. 1 (2001), https://www.sciencedirect.com/science/article/pii/S1364661300015710?via%3Dihub#BIB33

36 Ibid.

37 Ibid.

38 Ibid.

39 V.S. Ramachandran and Edward M. Hubbard, "Synaesthesia—A Window Into Perception, Thought, and Language," *Journal of Consciousness Studies* 8, no. 12 (2001): 3, http://chip.ucsd.edu/pdf/Synaesthesia%20-%20JCS.pdf.

brain that are "pruned away" with age.[40] A failure for this to occur could be caused by a mutation in the gene that regulates this process, lending further credibility to cross-activation, as synesthesia is believed to be a genetically inherited trait.[41]

While these may be the leading theories on the neurology behind synesthesia, neither has been proven. Most neuroimaging studies focus on grapheme-color synesthetes, and while there is support for the cross-activation theory from these studies, it cannot follow that this theory would necessarily apply to all other forms of synesthesia—it could be argued that each type of synesthesia is brought about in a different manner.[42] Furthermore, in several neuroimaging studies conducted on sound-color synesthetes within the last fifteen years, neither the disinhibited feedback theory nor the cross-activation theory could be definitively proven as the cause of synesthesia.[43] Additional studies suggest that music-color synesthesia occurs at a conceptual level, rather than through perceptual processing of stimuli.[44] An alternative theory of synesthesia's cause that aligns with the findings from these studies is known as the semantic vacuum hypothesis, developed by Danko Nikolić.[45] He asserts that synesthesia is "created" when a person is presented with a semantic vacuum; which occurs when there is no preexisting meaning for the brain to associate with an abstract concept like Thursday, the sound of a G flat, or the name Robert.[46] The brain instead forms a connection with a more concrete sensation to define the concept.[47] This type of association would occur more frequently in children, as they have limited world experience.[48] Nikolić further proposes a redefinition of synesthesia as ideasthesia, "a mental activation of a certain concept or idea [that] is associated consistently with a certain perception-like experience."[49]

Expression of Music-Color Synesthesia

Regardless of which of these potential explanations of synesthesia is correct, the recognition of the relationship that each posit between a sensation and an idea is given additional significance when attempting to differentiate synesthetic and non-synesthetic experiences in relation to music. There are decidedly non-musical qualities of music perception shared between music-color synesthetes and any ordinary person, known as normal cross-modal associations. For example, in pitch recognition among the general population, higher pitches are usually associated with small size, lightness, and elevation; and lower pitches are usually associated with large size, darkness, and depth.[50] Emotion and color psychology also play significant roles in cross-modal associations; in studies on non-synesthetes led by Stephen E. Palmer, a general trend

[40] R.C. Kadosh, A. Henik, V. Walsh, "Synesthesia: Learned or Lost?" *Developmental Science* 12 no. 3 (2009), quoted in "Synesthesia: Opening the Doors of Perception," *Dartmouth Undergraduate Journal of Science* (Spring 2010), https://sites.dartmouth.edu/dujs/2010/05/30/synesthesia-opening-the-doors-of-perception.

[41] Ramachandran and Hubbard, 3.

[42] Anna Zamm et al., "Pathways to Seeing Music: Enhanced Structural Connectivity in Colored-Music Synesthesia," quoted in Caroline Curwin, "Music-Color Synesthesia: Concept, Context, and Qualia," *Consciousness and Cognition* 61 (2018): 98, https:// www.sciencedirect.com/science/article/pii/S1053810017305883.

[43] Caroline Curwin, "Music-Color Synesthesia: Concept, Context, and Qualia," *Consciousness and Cognition* 61 (2018): 99, https://www.sciencedirect.com/science/article/ pii/S1053810017305883.

[44] Tessa van Leeuwen, Wolf Singer, and Danko Nikolić, "The Merit of Synesthesia for Consciousness Research," *Frontiers in Psychology* 2 (2015), quoted in Caroline Curwin, "Music-Color Synesthesia: Concept, Context, and Qualia," *Consciousness and Cognition* 61 (2018): 100, https://www.sciencedirect.com/science/article/pii/S1053810017305883.

[45] Danko Nikolić, "Synesthesia / Ideasthesia," Prof. Dr. Danko Nikolić, accessed December 4, 2021, https://www.danko-nikolic.com/synesthesia-ideasthesia.

[46] Ibid.

[47] Ibid.

[48] Ibid.

[49] Danko Nikolić, "Is Synaesthesia Actually Ideasthesia? An Inquiry into the Nature of the Phenomenon," quoted in Caroline Curwin, "Music-Color Synesthesia: Concept, Context, and Qualia," *Consciousness and Cognition* 61 (2018): 100. https://www.sciencedirect.com/science/ article/pii/S1053810017305883.

[50] Curwin, 95.

of relating major keys with bright, saturated, warm-toned colors and minor keys and dark, pale, cool-toned colors was discovered.[51] Though this research may initially seem to pose a discredit to music-color synesthesia in its entirety; the arbitrary, consistent, and individual nature of synesthetic associations define them separately from normal cross-modal associations.[52]

Characteristics such as mood, tempo, or tonality of a piece of music may produce similar connotations for any listener, but the diverse manners in which music can be experienced creates unique, complex sensory variations for all music listeners. Consider the nearly indescribable contrast in one's mental state when listening to music in the car compared to through a pair of earbuds, hearing *Greensleeves* performed on the clarinet compared to a child's recorder, or practicing a piece on a Yamaha piano versus a Steinway, just to name a few examples. This may seem tedious to discuss, but it is useful in understanding differences in music-color synesthesia from a non-synesthete perspective. Since synesthesia is subjective in itself, it follows that any colors perceived by music-color synesthetes will vary from person to person—notably, the composers Franz Liszt and Nikolai Rimsky-Korsakov disputed the "correct" colors of musical keys.[53] In addition, different music-color synesthetes may respond to one or perhaps a combination of distinct inducers, the most common being compositional style, timbre, tonality, and pitch.[54] One music-color synesthete might associate colors with each of the twelve musical tones, while another might associate colors with different instruments.

This paper develops an extensive understanding of the phenomenon of music-color synesthesia, from the early conception of a link between music and color to the in-depth analysis of the neurological condition. Several early thinkers explored possible relationships between color and music from both logical and emotional standpoints, but until the first documented synesthete Georg Tobias Ludwig Sachs published his thesis featuring a segment on his synesthesia, a neurological connection had not been considered. Modern research has identified several potential causes of general synesthesia, such as a difference in brain function, a difference in brain composition, or the inability to associate meaning with a new, abstract concept. Music-color synesthesia can be expressed in multiple ways and from a variety of inducers, similarly to how anyone can experience slight changes in mental state from differently presented music experiences. Synesthesia is sometimes presented as an unusual, almost superhuman sense—but really, it's just one way to perceive the world around us. Every person has their own qualities and experiences that shape this perception, whether scarlet means red or scarlet means the sound of a trumpet.

Author's Note

The author of this research paper wishes to disclose her personal experience with music-color synesthesia to add further insight into the subject, though her associations are intuitive and difficult to express in words. She also intends to differentiate her synesthetic experience from normal cross-modal associations, which may often be misunderstood. It is worth mentioning that most research on synesthesia to date has examined the qualities of grapheme-color synesthetes; aural forms of synesthesia are often mistaken for normal cross-modal associations (Glasser). In addition, concerning music-color synesthesia, it is often difficult to find both research professionals and participants with a background in music theory to be able to explain concepts in a thorough manner (Glasser).

Expression of synesthesia. The author experiences an association of color with tones in the musical scale (e.g., C is blue, D is violet, etc.). She also associates color with chords as a combination of the colors of

51 Ibid.

52 Jamie Ward et al., "Sound-Colour Synaesthesia: To What Extent Does it Use Cross-Modal Mechanisms Common to Us All?" *Cortex* 42, no. 2, quoted in Caroline Curwin, "Music-Color Synesthesia: Concept, Context, and Qualia." *Consciousness and Cognition* 61 (2018): 96, https:// www.sciencedirect.com/science/article/pii/S1053810017305883.

53 "Synesthesia," Wikipedia, last modified December 2, 2021, https://en.wikipedia.org/ wiki/Synesthesia.

54 Kenneth Peacock, "Synesthetic Perception: Alexander Scriabin's Color Hearing," *Music Perception* 2, no. 4 (1985), quoted in Caroline Curwin, "Music-Color Synesthesia: Concept, Context, and Qualia." *Consciousness and Cognition* 61 (2018): 95, https:// www.sciencedirect.com/science/article/pii/S1053810017305883.

the pitches utilized in the chord with an emphasis on the color of the root of the chord—for example, a G major chord is mostly green (G) with lesser amounts of gold (B) and violet (D), but a first inversion G major chord is mostly gold (B) with lesser amounts of violet (D) and green (G). Pitches of higher frequency have lighter colors, while pitches of lower frequency have darker colors, though this is likely influenced by normal cross-modal associations. These color associations become weaker as the combination of pitches in unison increases; single notes are the most vivid, while jazz chords are frequently colorless. The author associates color with tonality as well; the color of the key of any musical piece corresponds with the color of its note name, regardless of major or minor quality (e.g., A major or minor is dark blue). She cannot physically observe these colors or even other shapes as some synesthetes do but sees the correct color in her mind's eye when hearing or referring to the pitch or tonality in question. She does not associate color with different compositional styles or with instruments of different timbres; this is likely because she only associates color with pitch.

Potential benefits. The author has noticed a few influences of music-color synesthesia in her perception of music, both as a musician and an audience member. These observances are not intended as statements of universal truth, but rather as a list of potential hypotheses that may be worth investigation. The author happens to have perfect pitch in addition to music-color synesthesia, and she notices a very strong correlation between the two. To identify any note, she has noticed that she must first identify what "color" she is hearing. The same process is applied to identifying a chord or the key of a piece of music. It is unclear to the author whether her quality of perfect pitch or synesthesia aids her the most in analyzing music, or if these qualities developed in relation to each other. In addition, the author has noticed that the genres of music she enjoys best contain a variety of colors that are subconsciously identifiable (e.g. she enjoys folk music, but seldom hip-hop). She has also noticed that she tends to enjoy listening to songs in certain keys more than others due to their colors.

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