Synesthesia and Emotional Sound

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2.1 Introduction

The etymology of synesthesia is derived from the Greek *syn* meaning "together" and *aisthesis* meaning "sensation" or "perception." Often translated as "a union of the senses," the concept expresses the idea of combined or simultaneous perception [1, 2]. Aisthesis was the term used by the philosopher Aristotle (384 BC–322 BC) in the fourth century BC and later by physicians such as Soranus of Ephesus and Aretaeus of Cappadocia, both of the second century AD. Three ways of interpreting synesthesia are discussed in this paper: rhetorical, developmental, and medical.

The first, rhetorical, metaphoric, or stylistic, unifies different sensory spheres linguistically or imagistically. Before scientific investigations ensued, it was frequently assumed that all references to synesthesia fell into this category. A painting might depict visual music, or language combinations might evoke sensory experiences through references to bright colors, warm voices, or clear sounds.

Constitutional or developmental synesthesia, the second type discussed below, refers to a genetic trait found in a subset of normal people. The literature has identified at least 60–200 subtypes of synesthesia that fall into this category [3]. The condition occurs in about 4% of the general population [4, 5]. There is evidence that it involves genetics because it has been shown to run in families, most commonly from mother to daughter (synesthesia is more prevalent among females) [6]. The most common form of synesthetes in this category is grapheme-color synesthesia

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(64%). The second form is time unit (e.g., names of days or months) color synesthesia (22%), followed by musical sound color synesthesia (18%) [7]. Scientific investigators of this benign, alternative form of perception began to examine the possibility of genetic synesthesia related to cognition and physiology in the nineteenth century. Present from an early age, constitutional or developmental synesthesia does not change significantly during one's lifetime. In this form, stimulation of one sensory or cognitive pathway leads to automatic, involuntary experiences in a second sensory or cognitive pathway.

The third type, medical synesthesia, refers to a form that is either a neurological disorder or comes about following psychotropic drug ingestion. It occurs independently and inadvertently during adulthood as a result of pathological conditions. In contrast to its developmental counterpart, this type of synesthesia does not demonstrate either idiosyncrasy or automaticity [8–10].

Emotional reactions play a part in the synesthetic process. Additionally, cerebral structure processing emotions are differents in developmental synesthesia and in the acquired form [11, 12]. Given this and the research that demonstrates that all three types of synesthesia link to music perception [13], we hypothesize that forms of synesthesia that include music potentially have an influence on well-being.

2.2 Historical Foundations and Philosophical Debates

Natural philosophy, a precursor to modern science, included several foundational ideas about perception and sensory experience. Aristotle (384 BC–322 BC), for example, wrote that the harmony of colors was like the harmony of sound describing the five senses distinctly [14–16]. Although he additionally emphasized that the various senses can interact with each other creating different sensory modalities, his view is not the kind of genetic synesthesia now discussed in the constitutional and developmental literature. This is because at that time a joining of the senses, or synesthesia, was largely considered neurologically abnormal because it was at odds with the five distinct senses Aristotle notably codified [17].

Further evaluation of the relationships among the senses was an issue in the seventeenth century in the work of John Locke (1632–1704), particularly "An Essay Concerning Human Understanding" published in 1690 [18]. Locke grappled with a question raised by the Irish natural philosopher William Molyneux (1656–1698) [19] on the role of the senses regarding human knowledge: he had asked if a blind man, who recognizes objects by touch, would be able to recognize and define them by sight alone when he suddenly regains that sense. In particular, he raised the question of the hierarchy of the senses and the translatability of sensory data among them [20]. Others, such as Johann Gottfried Herder (1744–1803), a pupil of Immanuel Kant (1724–1804), came to a more active and complex conception of the human sensory structure, seeing it as a central feature of the human senses. Its "meaningfulness" (*Besonnenheit*) is evident because it allows one to become aware of the immediate recognition of objects.

Just as Locke and Herder disagreed, there were contrasting color theories, largely discussed in relation to the senses and harmony. The idea of harmony within the Baroque era (seventeenth and eighteenth centuries) was built on ideas that equated color harmony with the spheres by Johannes Kepler (1571–1630) and the color theories of Athanasius Kircher (1601–1680) and Isaac Newton (1642–1727).

Newton, in the 1660s, had the opportunity in Cambridge to organize the results of his earlier optical research and follow-up on his interests in Descartes' work, including *Géométrie* [21]. Shortly after his 1672 election to the Royal Society, Newton presented his first public paper, a controversial study on the nature of color. In this paper, he also investigated the coincidence of the seven colors of the spectrum with intervals of a musical scale [22]. René Descartes (1596–1650) gave a scientific explanation for the rainbow's formation in 1637 [23] and Newton added color to Descartes' arc. In 1704, he created the disc that bears his name (based on the idea of natural equivalence between the spectrum of colors and musical notes).

His main detractor, Johann Wolfgang von Goethe (1749–1832) [24], pointed out that color depends not only on light but also on our senses and how we perceive them [25]. He realized that colors are the product of the visual system and do not depend only on the light that reaches the eye.

Goethe's views on color influenced nineteenth-century painters, especially the Impressionists. Many modern paintings refer to the pure abstraction of musical training processes and impose an essential consideration of relations and interferences between music and painting. The distinction between seeing and hearing, as relevant from the physiological point of view, has never been enough to prevent mutual interaction. One of the most well-known interactions between eye and ear, the so-called "hearing colors" (colored hearing), has been a vast subject of numerous experiments and observations [26, 27].

Synesthesia as a specific sensory feature of human nature also played a part in philosophical anthropology for the first half of the twentieth century, thanks to Max Scheler (1874–1928) and Arnold Gehlen (1904–1976). Their fundamental assumptions bind human nature and multisensory perception: the first being phylogenetic, which distinguishes men from other animals through their morphology, and the second ontogenetic allowing men to distinguish themselves through multi-sensorial plasticity.

2.3 Scientific Development of the Term Synesthesia

Rare and anecdotal cases of synesthesia described before the nineteenth century show that the phenomenon was not well understood [28–30]. Modern scientific studies began to emerge in the late eighteenth and early nineteenth centuries as the neurosciences studied the relationship between the mind and the human nervous system [31–33]. In 1812, there was an initial description of the phenomenon of synesthesia by Georg Ludwig Sachs (1786–1814), who was suffering from albinism, as was his sister [34–36]. In Italy [37], the first descriptions of the relationship between sounds and colors were those of Carlo Botta (1766–1837), who in 1801

published an essay on the individual ability to associate sounds and colors based on the theory of Newton's color disc [38, 39]. In 1848, the Swiss ophthalmologist Charles Auguste Édouard Cornaz (1825–1911) considered the Sachs case in his doctoral thesis entitled "Des yeux des abnormalités congénitales et de leur annexes," concluding it was a common, inherited disorder afflicting males, characterized by an alteration of color perception, which he called hyperchromatopsia or "alteration du sens de la vue." In 1863, M. Perroud proposed that the perceptual disturbance was due to a psychological defect, following the ideas of the experimental psychology of the time. A year later, D. Chabalier changed the term hyperchromatopsia to pseudochromestesia, confirming psychological theories such as a "trouble des idées", or mental disorders such as the false association of ideas [40]. In 1864, Andrea Verga (1811–1895), quoting Chabalier, considered pseudochromestesia as an alteration of visual perception or a possible mental disorder based on a false association of ideas [41]. The debate was enriched by the contribution of Antonio Berti (1812–1879), who considered the disorder as having a psychic origin, characterized by a disturbance of memory and not connected to a disturbance of visual perception [42] and called it dyschromesthesia [43]. The pre-synesthetic debate ended with Berti, whose work on the issues of visual perception and the psychological component raised interest among French and Italian neuro-psychiatric schools.

The word synesthesia also made its appearance in 1865 in both France and Italy. In France, Alfred Vulpian (1826–1887) used the term. The Italian physiologist Filippo Lussana (1820–1897) [44–47] coined the word in the same year, using the term to describe the relationship between sounds and colors and connecting them to an alteration of the nervous centers of the brain [48]. Lussana, influenced by the theories of brain localization, from his point of view – still weakly related to phrenology – suggested that the centers for "color" and "melody" were located in the frontal convolution. He contributed to asserting that synesthesia is a neurological phenomenon: the brain's ability to take action for the integration of the various sensory perceptions. Lussana's research on musical notes led him, among other things, to also take an interest in the anatomy and physiology of the inner ear, contributing to a better understanding of how it works [48–50]. In 1873, J. A. [recte F. A.] Nussbaumer (1848–post 1887) added to the debate with a description of two brothers affected by synesthesia using a questionnaire, the first reported in history [40]. Later researchers, such as Gustav Theodor Fechner (1801–1887) in 1876, the psychiatrist Eugene Bleuler (1857–1939), along with his student K. Lehmann in 1881, and then Francis Galton in 1883, carried out epidemiological studies to quantify the phenomenon in the population and found that it had a certain distribution [51, 52]. Bleuler found that 12% of 600 patients had synesthesia. Using the recently developed psychoanalytic theories of Sigmund Freud (1856–1939), he concluded that synesthesia was a phenomenon characterized by a disorganized, widespread abnormal perception in schizophrenic patients [52, 53].

Cesare Lombroso (1835–1909) and Aleksandr Romanovich Luria (1902–1977) studied synesthetic phenomenon from an anthropological and psychological standpoint in the late nineteenth century. Lombroso's book "The Man of Genius" (Appendix VI) [54] mentioned colored hearing and reported a presentation by

Edouard Gruber [55]. Lombroso classified colored hearing in his theories on heredity, degeneration, and atavism. He considered it to be a pathology characterized by excesses, such as polydactyly. Synesthetes mentioned include the physicist and philosopher Fechner, a key figure in the founding of psychophysics, and the poet Arthur Rimbaud (1854–1891) [56]. The word was more widespread at the Congress of Physiological Psychology (1889), where it was associated with the term *audition colorée* "colored hearing" [57].

In 1892, Jules Millet introduced the term synesthesia in his thesis, together with that of "colored hearing" (audition colorée). In addition, in 1898 Jean Clavière [58] printed a remarkable bibliography. In the twentieth century, Luria studied Solomon Venianinovič Šereševskij, a young synesthete, for decades. Luria's observations were published in a small book, *The Mind of a Mnemonist: A Little Book About a Vast Memory* [59, 60]. This work's methodological importance stems from its concern with the relationship between super memory and synesthesia, also emphasized by Macdonald Critchley (1900–1997) [61]. These authors argued for a superior memory in synesthetes, with a study confirming this possible aspect [62]. However, it remains unclear as to what extent superior memory is a characteristic of all synesthetes and Luria's case focused on that superior memory rather than the fact that the subject had synesthesia [63]. In 1976, Luria highlighted the importance of the Šereševskij case as a paradigm for a scientific non-reductionist view, having been defined by the Russian psychologist in terms of romantic science [64].

2.4 Science, Romanticism, and Synesthesia

A noteworthy quality of the early scientific research was the difficulty in engaging quantitatively with the synesthetic experience. The work of Théodore Flournoy (1854–1920), a Professor of Psychophysiology, shows this well. A student of William Wundt and a friend of William James, Flournoy was a part of the rising movement striving to establish psychology's legitimacy as a science [65]. His synesthesia research, which endeavored to bring basic sensations, consciousness, and ideas together, resisted the kind of experimental testing practiced by Wundt because of the difficulty in devising quantifiable, independent measures for examining the experience. This led him to employ discursive introspective methods that were closer to William James' methods [65]. Although he relied on subjective data, his case studies on synesthetic personification are now considered pioneering and insightful.

By contrast, the romantic poets and writers considered synesthesia their manifesto. They saw the phenomenon as a tool in capturing the elements of nature, allowing them to recognize the various correspondences between all the senses and to unravel the mysteries that are hidden behind appearances. For example, Charles Baudelaire (1821–1867), in his essay "Writings on Art" [66], examined the relationship between color, sound, and smell. Baudelaire was not the main architect of this *raison d'être*; a group of poets and writers also adopted this view. These included Julie Théophile Gautier (1811–1872), Arthur Rimbaud, and Pierre Joris-Karl

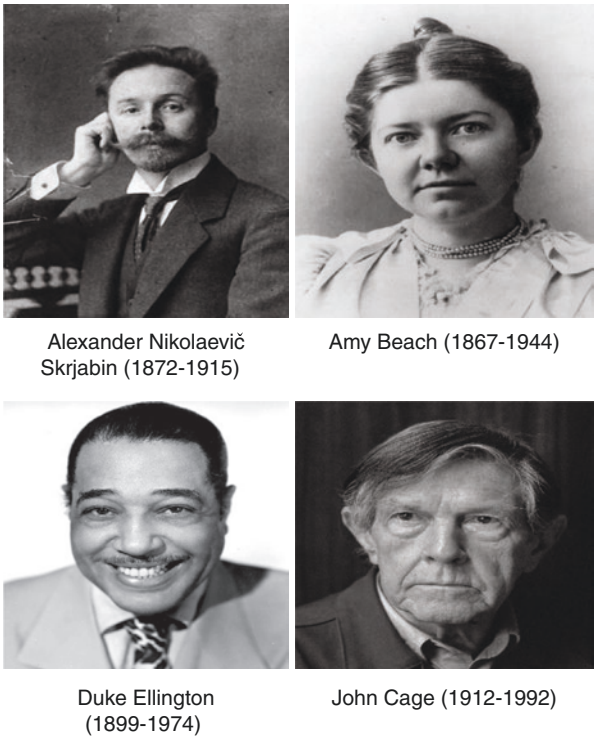

Fig. 2.1 Some musician synesthetes (public domain)

Husmans (1848–1907) [67]. The list of artists associated with synesthesia in the nineteenth and twentieth century is impressive. Musicians include Franz Liszt, Alexander Laszlo, Jean Sibelius, Alexander Scriabin, Amy Beach, Duke Ellington, John Cage, and Olivier Messiaen [68–73] (Fig. 2.1).

Examples in the visual arts include Vassily Kandinski, Johannes Itten, and the abstract painter Luigi Veronesi. Painter-musicians such as Mikalojous Konstantinas Čiurlionis are also included [74, 75]. For them it was essential to listen to their inner-self. Their reasoning was that the five senses were rooted in the soul and served as a foundation for artistic creativity. For these artists, a combination of certain colors is compared to combinations of different tones. When in a proper agreement, an intensification of a tonal coloring results. This concept is mirrored in the field of music, as with modern orchestration, to which Richard Wagner (1813–1883) and Claude Debussy (1862–1918) contributed. This musical sensitivity developed and spread, involving different forms and genres of music that led to synesthetic representations of various kinds, such as jazz and pop [76, 77]. Like Flournoy's early case study work, the artist reports are based on qualitative data. Therefore, we can neither definitively validate any reports nor separate metaphoric examples from genetic ones. This validation problem is one reason scientific interest waned until objective measures of testing were developed late in the twentieth century.

2.5 Neurodevelopmental and Acquired Pathological Synesthesia

Synesthesia has only recently been seen as a pathological condition in neurodevelopmental disorders like Asperger's syndrome and Williams syndrome [78, 79]. While we characterize pathological synesthesia, which is acquired or adulthood variety [12] as a separate type here, it is prudent to note that this is largely because recent research has refined our understanding of the synesthete experience. With the range of current research in mind, it is also important to note that historical papers did identify pathologically acquired synesthesia in epilepsy, migraine, and in other neurological disorders, so there is a connection between recent work.

Oliver Sacks (1933–2015), in his book *Hallucinations,* mentions that the first pathological synesthetic phenomena were described in 1881 by William Richard Gowers (1845–1915), who in his essay *Epilepsy* gave various examples of patients affected with epilepsy who spoke of hearing "the sound of a drum," "hissing," "ringing," and "rustling" as a hyperphysiological state. In the same period, other clinicians reported cases affected by epilepsy, such as the Scottish David Ferrier (1843–1928), who worked in London and mentioned an epileptic patient with a remarkable synesthetic aura, in which she would experience "a smell like that of green thunder" [80–82]. John Hughlings Jackson (1835–1911) reported on several cases, the first in 1863, describing a woman with colored vision associated with epilepsy [83]. Other clinical cases in the following years were reported by Jackson and classified with the name of "uncinate group of fits" due to different causes, as confirmed by various researchers [84–86]. Neckar and Bob demonstrated that a specific synesthetic-like mechanism could increase temporal-limbic excitability [87].

On the other hand, little has been published on synesthesia occurring as a migraine aura symptom [88, 89]. In 1939, Critchley proposed that aura and confusional states might occur in migraine and epilepsy as synesthetic phenomena [81]. Sacks and Podoll described patients suffering from migraine with aura and considered their attack as a synesthetic equivalence between auditory stimuli and visual image [90–92]. Based on the prevalence in the general population, about 2 in 1000 migraineurs would be affected by some kind of synesthesia, most of them of the visual type [89, 93]. The patho-mechanisms of auditory-visual synesthesia in migraine are obscure.

Synesthetic episodes are reported in patients after a thalamic ischemic stroke as well. Studies demonstrate a double dissociation in the patient's secondary somatosensory cortex (increased response to auditory stimulation and decreased responses to somatosensory stimulation) and suggest that stroke insult-induced plasticity can result in abnormal connections between sensory modalities that are normally separate, and synesthesia can be caused by inappropriate connections between nearby cortical territories [10, 94, 95]. In the last 50 years, other neurological disorders have been described in association with synesthesia, such as in retinitis pigmentosa [96, 97] and in the presence of gliotic mass [96, 98] with unclear explanation on their mechanism [96]. Other cases have been reported in association with irritable

bowel syndrome and a possible involvement in multiple sclerosis with a plausible role of the immune system in the nondevelopmental synesthesia [99–101].

Since the first studies by Bleuler, few have addressed if synesthesia is linked to more widespread abnormalities in perception in neuropsychiatric subjects in understanding the mechanisms that mediate the development of a possible typical and atypical perceptual experience [52, 53, 102]. On the other hand, since the beginning of scientific research on psychedelic drugs [103], numerous observations attest that a wide range of chemical substances elicit synesthesia with a possible implication of the serotonergic system [104, 105]. We need further studies on developmental and acquired pathological conditions to understand the neurophysiological and neurochemical mechanisms underlying the synesthesia phenomenon.

2.6 Music Synesthesia and a Possible Influence on Well-being

Different studies investigated the capacities of people to associate sound synesthesia with colors, with a strong correlation between the emotional associations of the music and those of the colors chosen to go with the music [106–110]. Through this work, the association of sound synesthesia and emotion with pleasant perceptions has recently emerged, although some experts have raised questions about this relationship, noting unpleasant perceptions of some musician synesthetes [111, 112].

The pleasurable response is present in all stages of childhood and adulthood [113]. Researchers have also found that in later life the synesthetic colors are less chromatics [114, 115], and with particular personality traits and cognitive characteristics, there is a significant relationship with anxiety [116] and mood [117–119]. Factors to consider include the type of music and which instruments in an orchestra stimulates the synesthetic emotion/sensation to determine environmental properties [120, 121].

Fruitful investigations have probed how pleasure, associated with sound in the form of music or noise, affects taste. Various studies have demonstrated the presence of sound-gustatory synesthesia by looking at the possible effects of background music on the perceived taste in different settings. In a coffeehouse, sweetness was perceived more while listening to the “slow” music. The perception of sourness increased with the tempo of the music track, even when sour and salty components were not present in their drinks. There was a sensation of bitterness when normal and fast music was played; sourness and saltiness, and the perception of sourness increased with the speed of the music track [122–125]. Also, emotional synesthetic percepts were described in acquired cerebral disorder in a patient who had a posterolateral thalamus hemorrhage. This patient experienced blue photism, intense extracorporeal sensation when hearing brass instruments [10, 126]. In addition, color association with music is prevalent in our society and every day sounds can trigger emotions and feeling of well-being with involvement of the left anterior insular cortice to construct a dynamic representation of the current state of emotional well-being [127–129].

Music listening may offer a means to better mediate musical understanding and meaning. As such, it serves as a potentially valuable tool for music educators to explore their students' musical understanding and imagination and nurture their well-being [113, 130, 131]. Digital tools can assist in this. They can play an important role in creating the types of emotions associated with sound synesthesia, allowing more accessibility to the experience. For example, through interaction with video in synesthetic ways, we can stimulate and support user creativity. We can also use digital tools to learn more about the synesthesia experience through monitoring how videos influence and are influenced by users and we can study the ambient when they are being played [132, 133].

2.7 Conclusion

Over time our understanding of human physiology and the physiology of perception has grown and changed conclusions about sensory modalities. We now know that synesthesia is probably more diffuse than formerly thought. Recent research has also shown that synesthetic experiences take many forms. In addition, the wide variety of sensory reports has added fascinating avenues for multidisciplinary studies with a possible benefit on our well-being.

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