Music Notation-to-Colour Synesthesia and an Alternative to Müller's "Law of Specific Nerve Energies"

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Abstract

Music notation-to-colour synesthesia is a neurodivergence that poses an exception to Johannes Müller's "law of specific nerve energies", challenging its core principles. Müller's law is still studied and used in psychology today (Rachlin, 2005, p. 43), proposing that there are no commonalities between the quality of a perceived object and the actual sensorial perception of that object in the brain. This theoretical article explores Müller's law and posits that it is insufficient to describe the perceptual process of music notation on the part of music notation-to-colour synesthetes. Rachlin (2005) suggests that a visual stimulus, once processed by the appropriate sensory organ, yields a single sensation at the cortical level. Solá Chagas Lima (2020) suggests otherwise in a more recent study, proposing that synesthetic concurrent sensations can be multiple and multimodal on a cortical level, thus challenging the single-tier approach in Müller's law. A given musical pitch notated on a page, in this case, may be perceived by the appropriate sensory organ (eyes), engaging various brain regions (Ward, 2013) and eliciting multiple sensations in the brain (Solá Chagas Lima, 2020). Concurrent synesthetic sensations are generally consistent throughout a synesthete's lifetime, presenting both challenges and advantages for music learning (Ward, 2013; Solá Chagas Lima, 2015, 2019, 2020). This article explores the mechanisms underlying this perceptual process, offering further revisions to the model outlined in Solá Chagas Lima's (2020) study, arguing that synesthetes not only experience multiple sensations on a cortical level but also that synesthetic experiences are only indirectly dependent on the perceiving sensory organ.

Keywords: music notation, music synesthesia, synesthesia, music perception, law of specific nerve energies

Introduction

Music notation-to-colour synesthesia is one of the many possible variants of neurodivergence, in which the affected individual experiences automatic, consistent, involuntary concurrent visual sensations of colour when exposed to the visual stimulus of a musical note or other notational symbols (Solá Chagas Lima, 2015, 2019, 2020). In a recent cross-cultural qualitative study, Solá Chagas Lima (2020) surveyed this specific subgroup of synesthetes, concluding that the processing of music notation on the part of these synesthetes has a conceptual basis and that the concurrent sensations of colour depend primarily on the semantic value of music-notational symbols, rather than their shape, contour, or similarity to other grapheme or numeric signifiers. The research also focuses on developmental synesthesia, considering both the proximal components (genetics, structural differences) and distal components (functional differences, environment) that corroborate the manifestation of this neurodivergence, which occurs in approximately 4% of the population (Cytowic, 2018; Simner et al., 2006; Simner & Hubbard, 2013).

Concurrent synesthetic sensations are generally consistent throughout a synesthete's lifetime (Ward, 2013) and may pose both challenges and advantages for music cognition, including music learning. General consistency is a fundamental aspect of developmental synesthesia and should not be confused with "absolute" consistency. Although the "internal mental colours of synaesthetes become less saturated in older subjects," (Simner et al., 2017, p. 407), other qualia of synesthetic perception remain the same. For example, the automaticity of perceptual mechanisms, the involuntary nature of concurrent sensation triggering, the reality of synesthetic sensation, the semantic/semiotic value of the percept (Solá Chagas Lima, 2020), and the concurrent colours themselves are consistent elements of grapheme-colour (visual-visual) synesthetic perception.

The present article focuses primarily on developmental synesthetes' perceptions of music notation, which overlaps with other visually induced forms of synesthesia involving the semantic content of signifiers, such as grapheme-colour and number-colour. Solá Chagas Lima (2020) argues that purely musical notational symbols (such as pitch notation) are compounded with various other notational symbols denoting elements of sound, such as dynamics, rhythmic duration, articulation, and fingering, to name a few. Many of these elements are found in complex music notation of the Western tradition, as illustrated in Figure 1.

Figure 1. Excerpt (mm. 24-34) from Franz Liszt's Piano Sonata in B Minor (1854), S. 178, showing various notational symbols recurrent in the Western canon of concert music.

This wide variety of symbols and their semantic denotations constitute a language complex enough to generate potential perceptual overload, conceptual overlaps, or incongruence among synesthetic concurrent sensations of colour, thereby impacting behavioural responses among musicians with this mode of synesthesia. This impact is especially significant for music students in the early stages of their education. Solá Chagas Lima's (2020) research discusses the effects of these advantages and challenges on the learning of music notation at the elementary stages of music education, with special attention to differentiated methodologies for teaching music notation to synesthetes with this mode of the condition.

To illustrate this information overload, Figure 2 depicts the author's synesthetic associations elicited by notational symbols and their semantic content.

Figure 2. This colour scheme is a rough approximation of how the author experiences this passage of music from Liszt's sonata (S. 178), depending on focal attention.

Notation-to-colour synesthesia thus poses many advantages for recognizing musical patterns, such as an enhanced ability to memorize passages of music and ease in extemporizing according to colour combinations. However, it also poses challenges when involving similar colours elicited in connection with related musical events.

This mode of synesthesia challenges core principles of Johannes Müller's "law of specific nerve energies". Since the present article involves the synesthetic perception of visual inputs in music notation, this theory is worth exploring in greater depth. Müller is considered a paragon in the history of visual sense physiology today (Riese & Arrington, 1963). His law or "doctrine", as it is also called, is still studied and used today in the field of psychology (Rachlin, 2005, p. 43) to understand perception, albeit with adaptations and further contributions. Notably, this principle has dramatically influenced the philosophy of psychology, as evidenced by its priority for both qualitative and quantitative methodologies addressing individual perceptual experiences.

In "The Law of the Specific Energies of the senses", Müller proposes that there are no commonalities between the quality of a perceived object and the actual sensorial perception of that object in the brain (p. 43). Figure 3 illustrates this rationale with nomenclature revisited in the sections below.

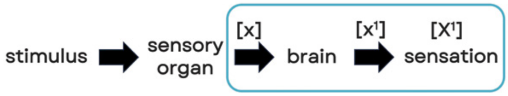

Figure 3. Graphic representation of Müller's law.

In other words, sensory organs merely mediate perception and the neural pathways it involves (Rachlin, 2005). In Hellekant's (2024) words:

> It makes no difference for the sensation, for example in the case of audition, if the receptor in the cochlea or its sensory fiber is stimulated mechanically or electrically, or in any other manner, provided the action potential reaches the auditory area of the cortex." (p. 32)

The same or similar sensations can be elicited by means other than the stimulus with which one normally associates those sensations. Müller (apud Riese & Arrington, 1963) formally addressed the theory for the first time in 1826, and his initial formulation of the law read:

> "The colors do not exist for the sense as a finished and external something, so that the sense when struck has only the sensation of it, but that the visual sense substance itself if activated by any stimulus, whatever its kind, brings its affection to sensation in terms of the energies of the light, the dark, and the colored." (p. 180)

The first version of the law was almost exclusively subjective. Müller's introduction of anatomical considerations in 1840 gains momentum in psychology due to the direction which this field of inquiry took in the second half of the nineteenth century. The growing reliance on scientific methods during the first half of the twentieth century also helped propel Müller's law regarding its anatomical contributions.

Hermann von Helmholtz, famed among musicians for his discussions of acoustics and sound properties, was Müller's pupil at the University of Berlin between 1833 and 1858. Helmholtz propagated Müller's law in an objective, "scientific" sense. Helmholtz is said to have eclipsed Müller's law (Finger & Wade, 2002; Riese & Arrington, 1963, p. 182), "filtering" or "re-rendering" the theory in a purportedly scientific light and for a scientific scholarly community. Helmholtz also suggested that impressions of the qualities of the outer world "depend… solely on the central connections of the affected nerve", thus substituting the brain for the nerve (p. 181).

Yet Müller used the term "energy" metaphorically, resting on the Aristotelian and metaphysical sense of the term rather than the anatomical or physiological argument. In his "scientific" priority, Helmholtz overshadowed Müller's original proposition, which suggested that the stimulus, as mediated by the sense, precludes and, to some extent, determines sensation. Although Müller predated continental phenomenology as it came to prominence in the late nineteenth and early twentieth century, he was more interested in the experience/phenomenon than the purely anatomical neural activity, which eventually became dominant in psychology.

Perceptual models analysed

The following paragraphs explore Rachlin's (2005) rendition of Müller's law, chiefly articulated in two perceptual models. This analysis is followed by an application of Rachlin's models to the colour-based synesthetic perception of music notation, revisiting a more recent study (Solá Chagas Lima, 2020) and expanding its tenets. Rachlin's (2005) postulations have been superseded since their coinage (Chirimuuta, 2015), yet the present analysis is relevant due to their past use in extant synesthesia literature.

Rachlin's model 1

Figure 4 shows a graphic representation of Müller's law (Rachlin, 2005, p. 42), depicting the perceptual process of visual inputs. Rachlin suggests that a visual stimulus, when passing through the respective sensory organ and processed in the mind, yields a singular sensation. Here, Rachlin discusses the perceptions of red (R) and green (G) colours: $\mathbf{R \rightarrow x \rightarrow x^1 \rightarrow X}$.

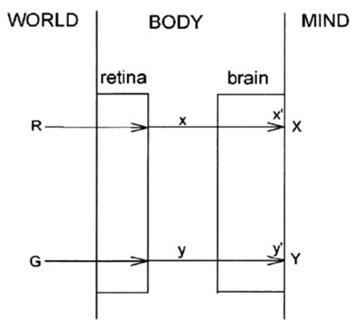

Figure 4. Perceptual model in Rachlin (2005, p. 42).

In applying this model to the context of the present paper, a hypothetical musical note, A, for instance, as represented by a visual symbol notated on a page of music, would be processed in the brain as $\mathbf{x} \rightarrow \mathbf{x^1}$, ultimately causing the sensation **X**: $\mathbf{A} \rightarrow \mathbf{x} \rightarrow \mathbf{x^1} \rightarrow \mathbf{X}$. This sensation would then be mentally associated with the idea of that musical note, which carries many semantic values, such as pitch, timber, a specific range, a physical area on the keyboard or the fingerboard, etc. According to this model, Müller's law would remain consistent for any other musical notes or notational symbols, e.g., $\mathbf{B} \rightarrow \mathbf{y} \rightarrow \mathbf{y^1} \rightarrow \mathbf{Y}$, and so forth.

Rachlin's model 2

In a critical review of Müller's law and expansion of its theoretical propositions, Rachlin (2005) also posits that different individuals may process stimuli differently, suggesting that the conceptualization or labelling of that sensation is a cultural construct. As illustrated in Figure 5, Rachlin (2005, p. 44) compares "Jill", a "normal" individual, with "Jack", an "abnormal" individual, who hypothetically has switched sensations for the colours red (R) and green (G).

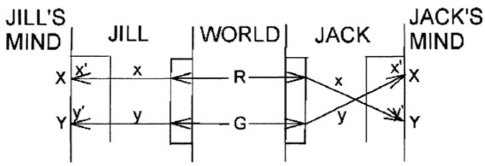

Figure 5. This perceptual model, as depicted in Rachlin (2005, p. 44), shows how different individuals may experience unique sensations elicited by the same stimulus.

Rachlin maintains that the "mental state" between Jill's ultimate X and Jack's ultimate Y sensations is essentially the same. The conceptual labels are, thus, arbitrary. If "normality" serves as the standard for comparison, the sensations are different.

Rachlin's models reevaluated

In considering these historical and scientific narratives, along with qualitative data discussed in Solá Chagas Lima's (2020) grounded theory study, this article proposes that current readings of Müller's theory may be insufficient in describing the perceptual process of music notation on the part of music notation-to-colour synesthetes. It also maintains that concurrent sensations, on a cortical level, can be multiple and multimodal in ways Müller's law does not account for—at least not in its generally held sense.

This article proposes several alternatives. Firstly, as a counterpoint to Rachlin (2005), it compares the perceptual process of visual input on the part of synesthetes and non-synesthetes. It also examines how multiple "mental states" coexist in the synesthete's brain, occurring in normally non-correlated areas. In the "normal" brain, these areas often develop to work more independently and process different stimuli through different senses and brain regions. In other words, in music notation-to-colour synesthetic perception, the quality of colour is not present in external reality (in the Müllerian sense) but is a product of synesthetes' association with the original stimulus as a concurrent, secondary sensation.

Figure 6 illustrates an adaptation of Rachlin's proposition applied to notation-to-colour synesthesia (Solá Chagas Lima, 2020, p. 5). A given musical pitch, A, for example, notated on the page may in this case be perceived by the appropriate sensory organ (eyes) and elicit multiple sensations in the synesthete's brain (in this case, colour) which are a unique and multimodal response to the stimulus: $\mathbf{A} \rightarrow \mathbf{x} \rightarrow \mathbf{x^1} \rightarrow \mathbf{X^1}$; or $\mathbf{A} \rightarrow \mathbf{x} \rightarrow \mathbf{x^2} \rightarrow \mathbf{X^2}$; or $\mathbf{A} \rightarrow \mathbf{x} \rightarrow \mathbf{x^n} \rightarrow \mathbf{X^n}$. The same holds for other musical notes (B, for instance): $\mathbf{B} \rightarrow \mathbf{y} \rightarrow \mathbf{y^1} \rightarrow \mathbf{Y^1}$; or $\mathbf{B} \rightarrow \mathbf{y} \rightarrow \mathbf{y^2} \rightarrow \mathbf{Y^2}$; or $\mathbf{B} \rightarrow \mathbf{y} \rightarrow \mathbf{y^n} \rightarrow \mathbf{Y^n}$, and so forth.

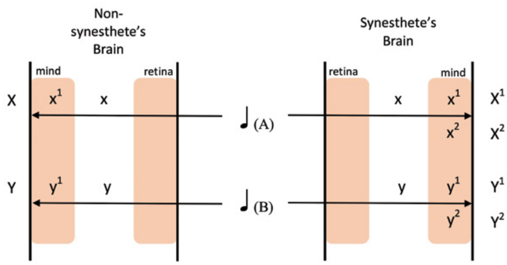

Figure 6. Elaboration of Rachlin's (2005) perceptual model, as found in Solá Chagas Lima (2020, p. 5).

This perceptual process differs from a normal brain's response not only in that the "nerve energy" (or pathway via the sensory organ) is different,, as in Jill and Jack's case, but also in that the additional, concurrent sensations occur on a cortical level. Perceived visual stimuli, such as musical notational elements, can elicit multiple sensations that may involve more than one brain area (Ward, 2013) at the latest perceptual stage, in addition to "normal" multimodal sensations.

Further considerations

In revising the application of Rachlin's (2005) models in Solá Chagas Lima's (2020) study and further arguing that music notation-to-colour synesthesia has a conceptual basis, this essay posits that the multimodal concurrent sensations of colour must take place on a cortical level, as illustrated in Figure 7, rather than as a perceptual bifurcation of the original percept.

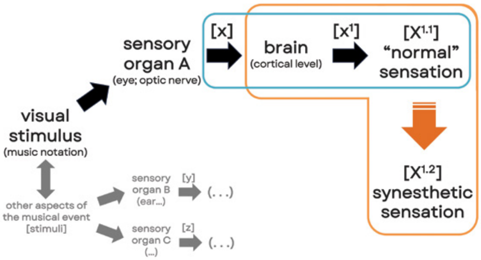

Figure 7. A revision of the graph in Figure 6 (Solá Chagas Lima, 2020, p. 5). This reconceptualization of visual perceptions regards synesthetic sensations as dependent on the primary, "normal" sensation in the brain.

The synesthetic sensation is only indirectly dependent on the sensory organ, which in this article is exemplified by the eye or optic nerve. Hence, the optic nerve is not directly connected to all these adjacent brain areas. Instead, these areas are connected in the synesthete's brain due to the genetic, structural, functional, and environmental differences that cause synesthesia. Therefore, synesthetic sensations of colour lie *outside* the scope of Müller's, Helmholtz's, and Rachlin's perspectives. While they may depend on the same inducing stimulus, they are ultimately concurrent with a primary sensation. This perspective also aligns with Hong & Blake's (2007) suggestion that early visual mechanisms themselves do not influence synesthetic colour:

> Of course, synesthetic colours arise consequent to the presence of alphanumeric characters and not other spatial forms, implying the existence of connections between higher brain areas involved in orthographic processing and colour processing mechanisms. (p. 1024)

The authors also conclude that "all, however, appeal to activity within brain structures involved in the analysis of colour, structures present in all colour-normal individuals" (Hong & Blake, 2007, p. 1024). This theoretical revision, thus, allows for a more overt recognition of other aspects of the musical event. These multimodal perceptions may influence the processing of notational (visual) elements—an aspect of synesthetic perception that remains for further research to uncover.

Finally, it is also important to address the semantic implications embedded in extant definitions of concurrent colour sensations. Since synesthesia is phenomenologically defined, many models and mechanisms discussed in the literature often rely on terminology concerned with the experience or phenomenon. It is in this sense that the present article uses these terms in relation to concurrent synesthetic sensations. Nevertheless, much like other synesthesia research, they ultimately describe neurological processes that demand consistency across disciplines. Chirimuuta (2015; 2024) has aptly pointed to the crystalized tendency of cognate fields to utilize terminology inconsistently and often inaccurately, which poses significant complications for thorough understandings of neurological mechanisms across disciplines, particularly as fields and subfields of academic inquiry continue to evolve and specialize. Literature on synesthesia, insofar as it describes neural mechanisms that are also subjective experiences, needs to continue refining the terminology and concepts in order to differentiate brain activation from potential meanings of the term "experience". This is especially true of inquiries in music notation-to-colour synesthesia research. Although this article recognizes this need for refinement, it is beyond its scope to mitigate this problem.

Conclusion

Since research on synesthesia has advanced significantly in the last five decades, it has prompted a rethinking of models of perception that are neurological (structural, physiological, functional) and, especially, purely phenomenological. The very idea of a model-based theory can pose a rigid and limiting approach to experience and the phenomenon at hand, particularly when exploring or evaluating modes of perception that fall outside the norm.

Müller's theory may have been misappropriated from its original context and is rendered today in a different ("eclipsed") light. The law is usually applied to experimental approaches to visual perception grounded in "scientific methods" that, while an essential aspect of documenting synesthesia as a neurodivergence today, often fail to account for the experience of the synesthetic phenomenon. This study suggests a return to Müller's original phenomenological scope.

Synesthesia is phenomenologically defined (Jewanski, 2013), and, like many other neurodivergences, prompts the field of music cognition - along with other related fields, such as music psychology and philosophy - to rethink the models that have dominated research and refine terminology (Chirimuuta, 2015; 2024). Scholars emphasize the need to return to the original implications of Müller's doctrine: the "betweenness" that mediates stimulus and sensation (Isaac, 2019). This shift is especially illuminating in the documentation of neurodivergences that are phenomenologically defined and qualified, such as various learning differences and perceptual abilities or disabilities.

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