



Behind the Colors of Synesthesia

Zihan Fahira^{1)*}, Angeline Freshbi Chesa Halim²⁾, Rosalia Katarina Lamanepa³⁾, Amr Yazid Pikoli⁴⁾, Supra Wimbrawati⁵⁾, Sri Kusrohmaniah⁶⁾
¹²³⁴⁵⁶⁾ Faculty of Psychology, Gadjah Mada University

*Email: zihanfahira@mail.ugm.ac.id

ARTICLE INFO

Article history

Received : 05 May 2024
Revised : 22 June 2024
Accepted: 30 June 2024

Keywords

Experiences
Color
Perception
Synesthesia

ABSTRACT

Synesthesia is a neurological phenomenon that affects perception, in which stimuli are affected by one thing (such as letters and numbers), thus generating unusual secondary sensory experiences such as color. Purpose of the research is to know the mechanisms of synesthesia in the body. Method for hypothesis testing with the cross-activation, cortical disinhibition, and the re-entrant feedback theory. A person who experiences synesthesia has an extraordinary mentality because they can see the color of sounds, numbers can be colored, and words can have taste. Synesthesia affects an individual's perception and experience in everyday life. This impacts their interaction with the environment and their understanding of sensory information, potentially affecting the allocation of attention. A common hypothesis states synesthesia arises due to excessive neural connections between cortical regions. Synesthesia can have a significant impact on an individual's visual perception and abilities, leading to unique experiences and potentially enhancing the processing of certain visual information in eve

This is an open-access article under the [CC-BY 4.0](https://creativecommons.org/licenses/by/4.0/) license.



INTRODUCTION

Synesthesia is a neurological phenomenon that affects perception, in which stimuli are affected by one thing (such as letters and numbers), thus generating unusual secondary sensory experiences such as color. (Bouvet et al., 2017; Ward & Simner, 2022) define synesthesia as a subjective phenomenon in which the perception of one stimulus automatically leads to the perception of the other sensory modality. Synesthesia can occur when sensory modality stimuli (e.g. vision) consistently trigger unintentional co-perception experiences in the same or other modality (Craver-Lemley & Reeves, 2019) Individuals with synesthesia reach about 4% of the population have unusual secondary sensory experiences when facing or experiencing trigger stimuli, usually against the background of normal nervous development. (Tilot et al., 2019). A person who has synesthesia has an extraordinary mentality because he can see the colors of voices, numbers can be colored, and words can have a taste (Ward et al., 2018; Ward & Simner,

2022) Many types of document synesthesia may reach 152 or more, some are relatively common, but others are rare and special. Ward and Simner (2022) referred to several types of synesthesia, including Grapheme-color synesthesia, Chromesthesia (sound-color), Mirror-touch synesthesia, Lexical-gustatory synesthesia, Auditory-tactile, Spatial sequence synesthesia (time-space), Number form, Ordinal-linguistic personification, Misophonia (sound-emotion). (Craver-Lemley & Reeves, 2019; Ward & Simner, 2022) One unique type of synesthesia was found in a Craver-Lemley and Reeves (2019) study that explains that synesthesia can specifically have a reliable brown color and give rise to the taste and tint of a thick crimson. Grossenbacher and Lovelace (2001) mentioned the important characteristics of synesthesia consisting of two aspects, namely the stimulus that triggered it (called the inducer) and the experience of the synesthetic itself. (concurrent). The experience of synesthesia is usually described as an automatic experience, consistent all the time, and of a perceptual nature although this characteristic cannot be generalized universally (Ward et al., 2018) The criteria for synesthesia are not universally acceptable, but the factors affecting synesthesia almost occur in many cases of synesthetics, Tilot et al. (2019) explain that various sources indicate that genetic factors influence synesthesia. The nature of this factor remains unclear, but several mechanisms are believed to be involved, ranging from rare variants of DNA with large effects (similar to monogenic inheritance) to combinations of common polymorphism. (Carpenter, 2001) added factors that triggered synesthesia, such as excess neurons in the brain, genetics, the ability to associate two senses simultaneously studied since childhood, and neuron factors that moved backward into the sensory areas of the brain that overlapped resulting in a synesthetic experience (called Feed-Backward Connections) (Tilot et al., 2019)

Ward (2021) stated that any theory of the cause of synesthesia should be able to explain a series of observations or observations accurately and clearly. Synesthesia is very varied in its manifestations and some people may have more than one type of synesthesia. Synesthesia affects individual perceptions and experiences in everyday life (Bouvet et al., 2017) Individual experiences of synesthesia vary, due to variations among individuals in their unconsciousness of the frequency of the experience, as well as their rejection of the lack of experience, because they regard it as normal (ALMA et al., 2023a) So they only experience synesthesia when they realize other people don't experience the same. The sensory experiences experienced by people with synesthesia have an impact on everyday life. It can affect their interaction with the environment and their understanding of sensory information, potentially affecting the allocation of attention. (Kann & Monsalve-Mercado, 2021) mention that the synesthetic nature is disruptive, where synesthetic perception replaces the original perception in memory, becoming a challenge for individuals to focus on conversation and maintain attention. The findings aim to give an idea that people with synesthesia are experiencing challenges in their daily lives, especially when performing activities that require full attention and concentration. Although synesthesia was first studied more than a hundred years ago, the study of synesthesia itself has since been regarded as a curiosity in psychology and neuroscience (Ramachandran & Hubbard, 2001)

According to the American Psychological Association (APA), about one in 2,000 people experience synesthesia, and some experts suspect that as many as one in 300 people have some variation of this condition. However, there are no accurate data related to synesthesia cases in Indonesia. Research by (Latuny et al., 2023) explains that cases of synesthesia are still very rarely studied, although not much gained more emphasis among



the Indonesian population, the synesthetic anomaly exists and is being done for further research.

METHODS

The study uses the literature review method of previous studies to discuss the relationship between synesthesia and brain activity and its relationship to behavior in everyday life. Pare & Kitsiou (2017) formulate a literature review method that begins with formulating questions and purposes of research, continues the search for literature according to inclusion criteria and keywords, performs literature filtration, carries out data extraction, and analyzes the data obtained.

The criteria for inclusion in this study are all English-language empirical research topics with synesthesia involving variables of brain activity and its impact on everyday life. The research methods used are all methods except the literature review. In addition, this article limits itself to the latest research in the last ten years, 2014-2024.

Questions and objectives must be formulated to determine the direction of the research. In this study, three research questions were used, namely: (1) how synesthesia affects individual perceptions and experiences in everyday life?, (2) how brain activity in individuals with synesthesia, and (3) how does synesthesia influence cognitive processes such as memory, attention, and creativity?

The literature search is intended to obtain reading material that forms the basis for mining research thinking. From the seven databases, the authors used the same keywords to search using the English words "synaesthesia", "perception", "brain", "daily activity" and "neuropsychology". Based on the search, the researchers obtained one article from Google Scholar, one from Nature, nine from PubMed, two from Research Gate, one from Sage, and two from Scopus. After performing article searches, data extraction is carried out through exclusion criteria that have been specified by previous researchers. The article will be deleted if (a) it is a literary study so that it does not provide empirical data, and (b) the published article is a recent article i.e. the last ten years or 2014-2024.

From the data extraction process, a total of 16 articles were obtained, consisting of one article from Google Scholar, one from Nature, nine articles from PubMed, two articles from Researchgate, one article by Sage, and two articles by Scopus, taking into account the similarities of articles from the four existing databases. Filtering is done to sort high-quality journals and meet the requirements of research explanation as well as the criteria for inclusion. Analysis techniques begin with reading articles based on research questions, after which the information obtained is inserted into tables so that the data can be easily processed.

DISCUSSION

Synesthesia Mechanism Hypothesis

There are three hypotheses of synesthesia mechanisms, namely: the cross-activation, cortical disinhibition, and the re-entrant feedback. (Janik McErlean & Banissy, 2017)

1. The Cross-activation model

Hubbard et al. (2011) say that the general idea of hyperconnectivity in a particular region of the brain is considered the location of synesthesia. The cross-activation model makes three specific predictions. First, the nerve representation of

the trigger and at the same time must be in a highly connected region. These regions are often close to each other, but not necessarily. Secondly, genetic factors lead to a decrease in cutting, and such anatomical differences are responsible for the synesthesia experience. Finally, the activation passes directly from the neuron that encodes the trigger to the simultaneously encoding neuron.

2. Cortical disinhibition

Cortical disinhibition suggests that there is an obstacle from the multisensory (Grossenbacher & Lovelace, 2001) or executive control region (Tulchinsky et al., 2023) to the non-sensory brain area is a source of synesthesia. It is related that synesthesia arises as a consequence of differences occurring in cortical excitation through mechanisms similar to stimuli that prevent removed or perceptual unmasking.

3. The re-entrant feedback theory

The re-entrant feedback theory or model suggests that there is cross-communication between the parts of the brain that process shape and color (Smilek et al., 2001). This theory also emphasizes the important role of the top-down process performed by the connection of feedback from the brain regions involved in conceptual representation to the parts involved in color processing, thus emphasizing the vital role of activation of conceptional representation in color acquisition. (Janik McErlean & Banissy, 2017)

Synesthesia and Brain Activity

Synesthesia is a neurological condition in which a stimulus on one of the sensory or cognitive pathways automatically triggers a sensation on the other sensory or cognitive pathways. It allows individuals to sense colors through hearing, visual sound, or feel a sensation when touching an object. This phenomenon requires cooperation between different parts of the brain that are generally not directly connected. Research has shown that synesthesia affects more areas of the brain than just the areas that are responsible for basic sensing. Brain activity in individuals with synesthesia is characterized by cross-activation between different sensory areas of the brain, which leads to the simultaneous activation of several sensory modalities (Bouvet et al., 2017). Synesthesia is associated with changes in patterns of brain activity and connectivity. A study conducted by (Craver-Lemley & Reeves, 2019) using neuroimaging techniques such as functional magnetic resonance imaging (fMRI) has shown that synesthesia shows increased activation in areas of the brain associated with modalities that generate synesthetic experiences, as well as in areas involved in cross-modal processing. Ward et al. (2018) also used fMRI in their research and found that in synesthesia there was an enhanced connectivity between brain regions that played a role in sensory and perceptive processes (Ward et al., 2017, 2018). For example, in grapheme-color synesthesia (where letters or numbers trigger color experience), increased activity was found in the visual cortex, including V4, which was involved in color processing when the synesthetic individual was confronted with an inducer. (letters or numbers). It suggests that there is a more intense interaction between the area of grapheme processing and the color processing area in the synesthetic brain compared to non-synesthetic. In addition, there is evidence suggesting that synesthesia may be related to "cross-activation" between anatomically separated sensory areas in the brain or due to excessive "feedback" from the associative cortex to the primary sensory area. This can explain why stimulation in one sensory domain can trigger experiences in another sensory field. For example, in grapheme-color synesthesia, where letters or



numbers produce a particular color, increased activation has been observed in the fusiform gyrus involved in visual processing, as well as in the parietal cortex associated with attention and spatial processing.

The fusiform gyrus which covers areas for visual identification and grapheme processing indicates higher region interconnectivity in synesthesia, indicating a potential nerve base for grapheme-color synesthetics (Hauw et al., 2023). In human color synesthesia, where personality produces a particular color, Lamley's study (2024) has shown increased activation in areas of the brain involved in social cognition and emotional processing, such as the anterior and insular cortex. Research conducted by (Ramachandran & Hubbard, 2001) found differences in structural brain connectivity in patients with synesthesia and suggested that synesthetic experiences may be associated with changes in neural connections. (ALMA et al., 2023b, 2023a) conducted a neurological study comparing patients with synesthesia and non-synesthesia who focused on the area of localization and the flow of communication between areas of the brain using brain tomography, magnetoencephalography, and functional magnetic resonance imaging (fMRI). They found that people who underwent grapheme color synesthesia experienced simultaneous automatic activation processes of the temporal occipital cortex (visual function) and the parietal lobes (other sensory functions, such as hearing).

Rothena et al. (2018) conducted an experimental study of non-synesthetic people divided into two groups. Group one consisted of 22 people as the experimental group and group two contained 18 as the control group. The results of the experiment showed that synesthesia was associated with specific nerve changes, including increased cortical excitability and altered sensory processing. The study suggests that synesthesia is shown with increased modality-specific cortical excitability, which is believed to contribute to the additional perceptual experience they experience. Electroencephalography (EEG) studies have shown an increase in the visual potential triggered in response to untrained patterns in patients with synesthesia, indicating specific cortical changes. Transcranial magnetic stimulation (TMS) study has shown lower phosphene thresholds in synesthesia, further supporting the presence of specific cortical changes. (Ward et al., 2017)

The general hypothesis states that synesthesia arises due to excessive neural connections between the cortical regions, along with the more specific hypothesis that grapheme-color synesthesia is caused by cross-activation between the grapheme and the color processing area in the ventral visual stream. Itoh (2024) found that synesthesia surface phenotypes are determined probabilistically by the neurobiological properties underlying the synesthetic disposition. Overall, several studies have provided insight into the nerve base in individuals with synesthesia and revealed different patterns of brain activity as well as connectivity in individuals who have synesthesia. Synesthesia may be related to differences in nerve shrinkage during development that cause abnormal connections between brain areas. The specific nerve mechanisms underlying synesthesia are still not fully understood, but it is believed to involve a combination of genetic, developmental, and environmental factors, requiring further research.

Effects of synesthesia on cognitive processes

Tilot et al. (2019) conducted a family-based study of 723 individuals who had no association with grapheme color synesthesia (SynGenes group). The research finds that

synesthesia is linked to improved memory, mental image, and sensory sensitivity. Tilot also argues that there is a genetic overlap between synesthesia and schizophrenia, affecting perception-related traits. This condition is influenced by individual factors, environment, and neural development, not just genetic factors. Synesthesia is often associated with perceptual experiences triggered by specific stimuli rather than affecting cognitive processes such as memory, attention, and creativity directly. However, synesthesia training, which involves extensive cognitive training of letters-colors associations, has proven to produce phenomena such as synesthesia (Tarekegn & Sherry, n.d.) This training can cause changes in the excitability of the cortex and increased visual potential triggered, indicating plasticity in human visual perception. Although the specific effects of synesthesia on cognitive processes such as memory, attention, and creativity are not directly discussed in the given source, Lemley et al. (2014) argue that changing perceptual experiences in synesthesia may indirectly affect these processes. Individuals who experience synesthesia usually report associations of different colors with some commonalities (Witthoft & Winawer, 2013). Some report that the grapheme-color he experienced appeared externally, like the projected overlay, so it seemed to him to be a classic projector.

Dixon et al. (2004) mentioned in their research that individuals with synesthesia who see colors externally are referred to as "projectors", while those who internalize synesthetic colors are called "associators". It can be said that individuals with synesthesia can show greater fluency, originality, and flexibility in thinking, which can contribute to creative problem-solving and the generation of ideas. According to (Rouw & Scholte, 2016) synesthesia has been associated with increased creativity because synesthesias often have unique sensory experiences that can create new ideas and associations. The mixing of senses in synesthesia can facilitate the generation of creative insights and artistic expression. Synesthesia has also been associated with increased creativity because individuals with synesthesias often have unique sensory experiences and can inspire new ideas and associations as well the combination of sensors in synesthesia may facilitate the creation of creative perspectives and expression of art (Ward et al., 2017, 2018; Ward & Simner, 2022)

Based on the available literature, it can be concluded that synesthesia can affect cognitive processes such as memory, attention, and creativity. Individuals who experience it often show better memories for certain types of public events, better memory for certain sequences or patterns due to their synesthesia associations, and potential benefits in attention and creative thinking due to the unique sensory experience. However, the relationship between synesthesia and creativity is complex and can vary depending on individual differences and specific types of synesthesia.

The influence of synesthesia on individual perceptions and experiences in everyday life

Synesthesia affects individual perceptions and experiences in everyday life. Synesthesia causes individuals to experience cross-modal sensory stimuli, such as associating colors with sounds or tastes with shapes. A certain sensory stimulus is induced by an object, person, or event without any real stimulus in the sensory domain (Bottini et al., 2022) For example, people with synesthesia can see fluctuating shapes when listening to saxophone sounds, feel the letter "A" written in bright red, and smell almonds as "black blue". This perception of synesthesia can be automatic and involuntary, affecting how individuals view and interpret the world around them (Bouvet et al., 2017) Whenever they see a



written text, the synesthetic grapheme-color patients naturally associate colors with the text, have a specific color assigned to each letter/digit, and often see the text as if it was written with those colors. According to Uno et al. (2021), synesthesia is a condition in which the perception of stimuli in one mode (induction) automatically triggers secondary sensations in another mode or processing stream.

Synesthesia can cause sensory interference or intersection (such as seeing colors when hearing voices or smelling words), thus disrupting individual attention and concentration in daily activities (ALMA et al., 2023a; Craver-Lemley et al., 2024; Tilot et al., 2019) Kann and Monsalve-Mercado (2023) argued that the nature of synesthesia interferes with everyday life due to the presence of perceptive disorders that replace the original perception in memory so that it is a challenge for individuals with synesthesia to focus on conversation and maintain attention. Individuals with synesthesia have a different nature of experience (Kann & Monsalve-Mercado, 2021). There are variations in terms of unconsciousness of the frequency of the experience, as well as the rejection of the lack of experience because they consider it normal (ALMA et al., 2023a, 2023b) According to (Dance et al., 2021) synesthesia is a natural of neural development in which senses are intertwined. For example, listening to music can trigger the experience of color for synaesthetic sound-color or taste in the mouth for synesthetic sound volume, while synesthetic sequence-space thinks about other units of time and sequence (letter, number) in spatial patterns (for example, synaesthetics may feel that the days unfold in zigzag lines across the visual field, or that the calendar months wrap around the body.). It leads individuals with synesthesia to live different lives without them realizing it. On the other hand, synesthesia can lead to a relatively specific improvement in performance and experience of abnormal perception. This is because synesthesia affects the function of the visual system which causes differences in visual abilities (Dance et al., 2021; Ward & Simner, 2022)

Individuals with synesthesia have a significant impact on their daily lives. This condition can occur because of the intersection of different sensory perceptions, such as seeing colors when hearing voices or feeling the taste of words. This perception happens automatically and unintentionally, so it can affect how the individual sees and interprets the activity/things around him. Although it can improve certain abilities such as memory and creativity, synesthesia can also disrupt attention and make it difficult for individuals to concentrate on daily conversations or activities. The impact of synesthesia is highly individual and depends on the type and severity of the condition experienced. However, in general, synesthesia provides a unique and different perceptual experience in living everyday life for those who suffer.

Future direction

Some hope is needed for further research. First, to be able to understand the genetic and neurobiological foundations so further research is needed to understand more deeply the genetic and neurobiological bases of synesthesia. By identifying the genes and neural pathways involved, we can gain new insights into how this condition develops and how it differs from normal perception. Secondly, the importance of exploring the impact of synesthesia on cognitive function, although some studies have shown the effects of synesthesia on memory, attention, and creativity, still requires further research. By

understanding how synesthesia affects cognitive processes, we can develop strategies to leverage these conditions in education and other settings. Third, it is hoped that further research will develop better brain imaging methods. Current brain imagery techniques have limitations in detecting subtle changes in nerve activity and connectivity associated with synesthesia. Fourthly, studying the variations and subtypes of synesthesia is important because synesthesias have many types and subtypes, such as color-sound synesthesia, spatial sequence, and so on.

Further research is needed to understand the differences and similarities between this subtype, as well as the factors that influence the manifestations of different synesthetics. Fifthly, the application of synesthesia in other fields is essential through an understanding of how it affects perception and cognition, research can be done to explore potential applications of synesthesia in fields such as art, design, education, and therapy. This understanding can help develop new methods and tools to enhance learning and creativity. Six, longitudinal studies and the development of synesthesia still need to be carried out. Longitudinal research that follows the evolution of synesthesia from childhood to adulthood can provide valuable insights into how these conditions evolve and change over time. It can also help identify factors that affect the onset and persistence of synesthesia. Seventh, multidisciplinary collaboration can be considered of advanced research theme because of the complex nature of synesthesia involving genetic, neurobiological, cognitive, and behavioral aspects, requiring multidisciplinary collaborations among researchers from various fields, such as neuroscience, psychology, genetics, and cognitive. This integrated approach can provide a more holistic understanding of the phenomenon of synesthesia. By continuously expanding research in this field, we can gain a deeper understanding of synesthesia and its potential applications in various fields, as well as new insights into how the human brain processes and integrates sensory information.

CONCLUSION

Synesthesia is a unique neurological condition in which sensory or cognitive stimulus of an automatic pathway in the brain triggers sensory and cognitive experiences in another pathway, such as hearing colors or seeing sounds. This condition indicates a unique interaction between different areas of the brain that are unusually connected, indicating the extraordinary capabilities and capacities of the human brain. It affects the perception and experience of the individual in everyday life significantly.

Synesthesia can also cause mixing or intersection of sensory perceptions, such as seeing colors when hearing voices or feeling the taste of words, which can interfere with attention and concentration. Neurologically, synesthesia is associated with increased activity and connectivity in areas of the brain involved in sensory processing and perception, as well as specific changes such as increased cortex excitability and stronger visual perception processing. The nerve mechanisms underlying synesthesia are still not fully understood but involve a combination of genetic, developmental, and environmental factors. Synesthesia can also affect cognitive processes such as memory, attention, and creativity. Individuals with synesthesia often show better memory for public events and certain patterns/sequences, as well as potential benefits in attention and creative thinking due to their unique sensory experiences. However, the specific effects of synesthesia on cognitive function can vary between individuals and depend on the type of synesthesia experienced.



SUGGESTION

For further research, a deeper understanding of the genetic and neurobiological foundations of synesthesia is required, exploration of the impact of synesthesia on cognitive function, the development of better brain imaging methods, the study of variations and subtypes of synesthesia, the application of synesthesia in other fields, longitudinal studies and development of synesthesia, as well as multidisciplinary collaboration. By continuously expanding research in this field, we can gain a better understanding of the phenomenon of synesthesia and its potential applications in various fields.

REFERENCES

- ALMA, L., ÇOKSAN, S., & KOCA-ATABEY, M. (2023a). Colors of Hearings: A Subjective Experience of Synesthesia Among Six Siblings. *AYNA Klinik Psikoloji Dergisi*, 10(1), 124–144. <https://doi.org/10.31682/ayna.1144465>
- ALMA, L., ÇOKSAN, S., & KOCA-ATABEY, M. (2023b). Colors of Hearings: A Subjective Experience of Synesthesia Among Six Siblings. *AYNA Klinik Psikoloji Dergisi*, 10(1), 124–144. <https://doi.org/10.31682/ayna.1144465>
- Bottini, R., Nava, E., De Cuntis, I., Benetti, S., & Collignon, O. (2022). Synesthesia in a congenitally blind individual. *Neuropsychologia*, 170, 108226. <https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2022.108226>
- Bouvet, L., Barbier, J. E., Cason, N., Bakchine, S., & Ehrlé, N. (2017). When synesthesia and savant abilities are mistaken for hallucinations and delusions: contribution of a cognitive approach for their differential diagnosis. *The Clinical Neuropsychologist*, 31(8), 1459–1473. <https://doi.org/10.1080/13854046.2017.1288269>
- Carpenter, S. (2001). Everyday fantasia: The world of synesthesia. *American Psychological Association*.
- Craver-Lemley, C., Dillon, C., McGraw, A., & Reeves, A. (2024). Synesthetic Colors Associated with Personality. <https://doi.org/10.1177/02762366231223709>, 43(3), 229–248. <https://doi.org/10.1177/02762366231223709>
- Craver-Lemley, C., & Reeves, A. (2019). Taste modulator influences rare case of color-gustatory synesthesia. *Brain Sciences*, 9(8). <https://doi.org/10.3390/brainsci9080186>
- Dance, C. J., Jaquiere, M., Eagleman, D. M., Porteous, D., Zeman, A., & Simner, J. (2021). What is the relationship between Aphantasia, Synaesthesia and Autism? *Consciousness and Cognition*, 89. <https://doi.org/10.1016/j.concog.2021.103087>
- Janik McErlean, A. B., & Banissy, M. J. (2017). Color Processing in Synesthesia: What Synesthesia Can and Cannot Tell Us About Mechanisms of Color Processing. *Topics in Cognitive Science*, 9(1), 215–227. <https://doi.org/10.1111/tops.12237>
- Kann, K., & Monsalve-Mercado, M. M. (2021). *Coloring the Black Box: What Synesthesia Tells Us about Character Embeddings*. <http://arxiv.org/abs/2101.10565>
- Latuny, M. R., Rochmad, H., & Happy, D. (2023). Synesthesia dan Pengalaman Seni Fotografi. In *Jurnal Desain Komunikasi Visual Asia (JESKOVSIA)* (Vol. 07, Issue 01).

- Ramachandran, V. S., & Hubbard, E. M. (2001). Synaesthesia-A Window Into Perception, Thought and Language. In *Journal of Consciousness Studies* (Vol. 8, Issue 12).
- Rouw, R., & Scholte, H. S. (2016). Personality and cognitive profiles of a general synesthetic trait. *Neuropsychologia*, 88, 35–48. <https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2016.01.006>
- Tarekegn, A., & Sherry, S. (n.d.). *Synesthesia and Musical Perception*. www.JSR.org
- Tilot, A. K., Vino, A., Kucera, K. S., Carmichael, D. A., Van Den Heuvel, L., Den Hoed, J., Sidoroff-Dorso, A. V., Campbell, A., Porteous, D. J., Pourcain, B. S., Van Leeuwen, T. M., Ward, J., Rouw, R., Simner, J., & Fisher, S. E. (2019). Investigating genetic links between grapheme-colour synaesthesia and neuropsychiatric traits. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 374(1787). <https://doi.org/10.1098/rstb.2019.0026>
- Tulchinsky, T. H., Varavikova, E. A., & Cohen, M. J. (2023). Measuring, monitoring, and evaluating the health of a population. *The New Public Health*, 125–214. <https://doi.org/10.1016/B978-0-12-822957-6.00015-6>
- Ward, J., Ipser, A., Phanvanova, E., Brown, P., Bunte, I., & Simner, J. (2018). The prevalence and cognitive profile of sequence-space synaesthesia. *Consciousness and Cognition*, 61, 79–93. <https://doi.org/10.1016/J.CONCOG.2018.03.012>
- Ward, J., Rothen, N., Chang, A., & Kanai, R. (2017). The structure of inter-individual differences in visual ability: Evidence from the general population and synaesthesia. *Vision Research*, 141, 293–302. <https://doi.org/10.1016/j.visres.2016.06.009>
- Ward, J., & Simner, J. (2022). How do Different Types of Synesthesia Cluster Together? Implications for Causal Mechanisms. *Perception*, 51(2), 91–113. <https://doi.org/10.1177/03010066211070761>