

An Introduction of Synesthesia's Psychological Symptoms and its Correlation with Major Neuropsychiatric Disorders

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Abstract. Synesthesia is defined as a subjective phenomenon that a stimulus could spontaneously evoke a concurrent but unrelated sensation. Previous studies have predominantly focused on understanding the phenomenon in isolation, examining various aspects such as different types of synesthesia, their causes, etiology, and heredity. By conducting studies on synesthesia alongside existing investigations, researchers can gain valuable knowledge about how the non-synesthetic mind operates, shedding light on aspects such as awareness and neurological disorders. This literature review aims to examine the psychological symptoms and psychiatric characteristics of synesthesia, focusing on three common types that pertain to color, numerical cognition, and synesthetic-like experiences. Additionally, the review will explore the intersection between synesthesia and major types of neuropsychiatric disorders, highlighting that the occurrence of mental illnesses or neurological impairments among synesthetes aligns with the prevalence in the general population. Thus, synesthesia could serve as an additional tool for studying the human brain and cognition. There are still a lot of limitations in the present research that we need more evidence and data to further support it. The study of synesthesia might provide a promising platform for testing various concepts and theories across diverse realms of cognitive science.

Keywords: synesthesia, schizophrenia, autism.

1. Introduction

Synesthesia also spelled synaesthesia, is a perceptual phenomenon in which a person experiences at least one automatic concurrent sensation when stimuli are presented through a primary modality (Brang and Ramachandran, 2011). In the past centuries, scientists had hypothesized synesthesia is hereditary and practice required (to keep it constantly activated). The first documented synesthete experienced mental imagery, as a branch of synesthesia, which might be inherited from his father who also reveal using it. According to Barnett et al. (2008), approximately 40% of synesthetes indicate the presence of the condition in a first-degree relative. Also, this is a “use-or-lose” ability. Like muscles, regular exercise could keep them active and maintain their normal functions. Corresponded with cell pruning hypotheses claimed by Baron-Cohen in 1996 and Maurer in 1997, suggesting that all newborns may experience synesthesia, but lose it during normal cell apoptosis and body metabolism. Those who still retain such a condition may be a result of genetic predisposition (Simner et al., 2006) or undergo atypical projections (Ward and Simner, 2005) that failed to prune. Such deduction is supported by the fact that a specific form of synesthesia is presented variously in the same family (Barnett et al., 2008).

A synesthete may experience a direct crossing of senses, referred to as a “secondary sensation”, which is automatically evoked through a primary stimulation, also called a “trigger”. Hence, differentiating synesthesia from other seemingly comparable phenomena like illusions and hallucinations (which lack an inducer) relies on two crucial factors: the inducer-concurrent pairing and the element of automaticity. The inducer-concurrent patterns varied largely, with ongoing discoveries of new combinations. Linguistic elements such as letters, digits, and words are the most prevalent synesthetic inducers (Simner et al., 2006). Visuals in nature are the most common concurrent, including colors and spatial forms that sequences are organized in visually arranged in visually linear or intricate landscapes (Sagiv et al., 2006). With such a large range of inducers and concurrent combinations, any automatic associations could be classified as synesthesia. Simner proposed exploring the underlying causal pathways that can trigger synesthesia, which may vary among different groups, rather than focusing solely on superficial characteristics (Simner, 2012).

The phenomenon of synesthesia exists in two distinct forms: developmental synesthesia, which persists throughout an individual's lifespan without a known triggering event, and acquired synesthesia, which occurs as a consequence of an inciting event such as sensory loss (Ward, 2013). An ongoing dispute centers on the potential common neurological mechanisms underlying these two causes, questioning whether they necessitate separate theories to explain each. The primary controversy lies in determining whether the same causal mechanisms would drive conventional forms of synesthesia.

In a study carried out by Simner et al. in 2006, it was found that around 16% of the population has experienced synesthesia, with a female-to-male ratio of 6:1. Synesthesia is a condition that deserves further research. Since it is an integrated topic, knowing more about synesthesia helps provide a better understanding of psychology, cognitive science (language processing specifically), and others. Due to the limitation of available resources and data, three main types of synesthesia are mentioned in this review, including how they occur and their major presentations in synesthetes. This review will examine the connections between synesthesia and other neurological diseases. Synesthesia can be considered a case of an individual cognitive variation (Ward, 2013), which presents an alternative standpoint for exploring the human cognitive system. The lack of extensive clinical research on synesthesia has constrained exploration in this area. However, with an increased investigation into the psychiatric characteristics of synesthesia, we can anticipate the emergence of more reliable and evidence-based research in the near future. The findings in synesthesia can significantly contribute to our comprehension of its correlation with other neurological disorders, facilitating the classification of distinct neurology syndromes and informing psychological treatment approaches.

The review will examine the psychiatric characteristics of synesthesia and its significance in studying other neurological disorders.

2. Psychiatric Symptoms

Synesthesia exhibits psychological symptoms characterized by involuntary cross-sensory perceptions (such as tasting shapes or hearing colors), the consistent interplay between senses triggered by specific stimuli, and the ability to articulate these extraordinary perceptions to others (Watson, 2018). Following Cytowic (2002), synesthesia is described as: (1) Involuntary and automatic, (2) Consistent and generic, (3) Spatially extended, (4) Memorable, and (5) Affect-laden. It is worth noting that the scientific community largely agrees on the first two criteria (Hochel & Milán, 2008, p. 95), making them the focal points of this article.

2.1 Involuntariness and Automaticity:

The involuntary nature of synesthesia pertains to the inability to manipulate or consciously suppress synesthetic perceptions. Unlike memories triggered by sensory stimuli associated with the external world, synesthetic experiences are largely impervious to voluntary control. It is not possible to cease seeing, hearing, or smelling stimuli from the outside world unless the sensory input itself is eliminated (Hochel & Milán, 2008, p. 95).

Understanding the neuronal mechanism behind synesthesia would allow a better understanding of automaticity. In the brains of synesthetes, two potential agents can be observed: (i) the presence of additional neural connections, likely stemming from early pruning failures that resulted in an excess of connections, or (ii) inhibition failure due to disinhibition feedback signals, possibly originating from a "multisensory nexus" (Kadosh & Henik, 2007, p. 181). Consequently, a process can transition from being naturally voluntary to becoming obligatory. Although automaticity can happen quickly, it prevents the emergence of new brain connections. In this situation, processes with predetermined, robust neural connections that allow for the manipulation of inhibition are more likely to become automatic than processes with fewer connections (Kadosh & Henik, 2007, p. 181).

2.2 Consistency and Heredity:

Since synesthesia is acquired in early developing stages and lasts throughout the lifespan, synesthetes experience the same concurrent in response to the corresponding triggers. In the studies during the 1980s, synesthesia is tested on measures of test-retest consistency (Ward, 2013). During the test, participants receive a list of inducers, with synesthetes being instructed to generate their concurrent experiences, while controls are asked to freely associate with a concurrent. These steps are often repeated after several weeks or months to assess test-retest consistency. It has been reported that individuals with grapheme-color synesthesia show consistency rates ranging from 80% to 100%, whereas controls exhibit compatibility rates of 30% to 50% (Mattingley et al., 2001). The stability of the connection between inducing stimuli and concurrent experiences in synesthetes over time cannot be attributed solely to memory performance. However, high consistency is not a definitive factor for diagnosing synesthesia. Controls trained to have high consistency in word-color associations do not activate the color-sensitive region in the brain to the same extent as synesthetes when presented with the same words (Ward, 2013). Detecting synesthesia poses challenges in differentiating innate synesthetic experiences from learned associations. Gaining a deeper understanding of synesthesia development necessitates converging evidence from various sources, including experiments designed to demonstrate the involuntary nature of photism experiences, perceptual experiments that confirm synesthetes' perception of synesthetic percepts when exposed to inducing stimuli, and subjective reports that complement and enhance these objective investigations (Hochel & Milán, 2008, p. 97).

Furthermore, the remaining characteristics distinguish synesthesia from other phenomena like hallucinations observed in psychotic disorders. Synesthetic experiences are typically generic, accompanied by fundamental perceptual qualities. The inducing stimulus can act as a mnemonic cue, enhancing memory efficiency. For instance, number-color synesthesia may aid in remembering telephone numbers (Hochel & Milán, 2008, p. 96). Despite the claim made by Cytowic (2002) that synesthetic experiences are not graphic or loaded with semantic information, some people with letter-color instances may visualize a word printed in colors when they hear it.

3. Relation with major neuropsychiatric variation

In recent years, there is considerable interest in finding potential relations between certain types of synesthesia and other neuropsychiatric variations, such as Post-Traumatic Stress Disorder (PTSD), Autism Spectrum Disorder, and Schizophrenia. Scientists are trying to explore the potential connections and overlap with other brain-related traits using molecular epidemiology.

3.1 Post-Traumatic Stress Disorder (PTSD)

Post-Traumatic Stress Disorder is a neuropsychiatric alternation related to visual and other cognitive processes. Grapheme-colored synesthetes will see colors that are provoked by numbers and/or colors. Studies have been conducted to validate the association between grapheme-color synesthesia and PTSD. In 2019, Hoffman et al. surveyed 1370 veterans who all had previous warzone service experiences, with an average age of 59.6 among whom 95.1% are male (Hoffman et al., 2019). The current prevalence of post-traumatic stress disorder (PTSD) was determined to be 7.6% (95% confidence interval [C.I.] = 6.5-9.0), whereas among veterans, it was observed to be 3.4% (95% C.I. = 2.7-4.4). Grapheme-color synesthesia was found to be present in 3.4% of veterans. Initial bivariate analyses demonstrated a significant correlation between synesthesia and current PTSD, with an odds ratio of 3.3 ($p < 0.001$). By conducting multivariable stepwise logistic regression, Hoffman's research team further validated the association between PTSD and grapheme-colored synesthesia (odds ratio = 2.33, $p = 0.019$).

In Ward's 2021 summary, valuable insights are provided regarding whether synesthesia serves as a risk indicator in the overall development of post-traumatic stress disorder (PTSD), encompassing both veterans and non-veterans. This information carries implications for future PTSD diagnostic screening and treatment approaches. Notably, when synesthetes are prompted to recall past non-

traumatic events, they exhibit a higher likelihood of re-experiencing sensory elements and reporting a sense of relief from a first-person perspective. This particular inflexibility in memory may serve as a clinical safeguard against experiencing flashbacks following exposure to traumatic events (Ward, 2021).

Both studies confirm that synesthesia is among the most prominent known risk factors associated with the onset of PTSD. The investigation of synesthesia also offers an additional tool for enhancing the study and diagnosis of PTSD in the future.

3.2 Autism Spectrum Disorder

Synesthesia is closely linked to autistic traits and the perceptual processing characteristics associated with autism. The notable increase in the prevalence of synesthesia in individuals with autism suggests the possibility of shared underlying mechanisms between the two conditions (Baron-Cohen et al., 2013). Recent research conducted by van Leeuwen et al. (2021) discovered that the intensity of grapheme-color synesthesia was associated with autistic traits in the domain of Attention to Detail, as well as sensory hypersensitivity but not hyposensitivity.

The study by van Leeuwen et al. involved the recruitment of twin pairs who met the criteria for an autism spectrum diagnosis or other neuropsychological disorders. The results indicated that the association between synesthesia and autism was more pronounced among non-related individuals, adding to the growing body of evidence supporting a link between the degree of grapheme-color synesthesia and perceptual features associated with autism. Notably, a different measure of sensory sensitivity was utilized in this study. In another study by Tilot et al. (2019), approximately 723 unrelated individuals with grapheme-color synesthesia were genotyped for common DNA polymorphisms across the genome. The study aimed to examine whether polygenic scores derived from large-scale genome-wide association studies of two relevant neuropsychiatric disorders were associated with synesthesia status compared to a matched control group.

Both sets of findings challenge the notion of a consistently detail-focused attentional style in synesthesia and may instead be linked to enhanced memory or mental imagery in individuals with more pronounced synesthetic experiences (van Leeuwen et al., 2021).

3.3 Schizophrenia

Schizophrenia patients often suffer from perceptual deficits while synesthetes experience additional sensations. Schizophrenia polygenic scores were found to have a slight commonality with synaesthesia, similar to that seen in studies of schizophrenia polygenic scores and creativity conducted by Power RA et al.(2019). Non-veridical perceptions could impact a person's behavior shown by neuropsychiatric disorders (i.e. delusions and hallucinations) (Schreier et al., 2019). In Fisher & Tilot's summary, synaesthesia is applied as a model to ask whether non-veridical perceptions can also affect healthy individuals' behaviors. For the experiment part, researchers used a behavioral paradigm that combines the Go/Nogo Task (a cognitive task aimed at determining the ability of an individual to inhibit a response deemed inappropriate; Georgiou & Essau, 2011) to measure inhibitory control in 19 grapheme-color synaesthetes. They also applied electroencephalography methods to probe the neurophysiological correlations (Fisher & Tilot, 2019). The team concluded that non-veridical perceptions can impact behavior even in non-pathological cases. They proposed that these effects are attributed to higher-level executive control processes that connect perceptions to motor responses.

In another study of inter-individual variability in perception among schizophrenia patients, synesthetes, and controls, the researchers hypothesized that perceptual differences arise from variations in how sensory evidence and prior knowledge are weighted, specifically in terms of precision (van Leeuwen et al., 2020). In their study, van Leeuwen et al. (2020) investigated the visibility thresholds of three groups by manipulating the availability of sensory evidence and embedding stimuli in noise. The groups included synesthetes, schizophrenia patients, and a control group. The results revealed that synesthetes exhibited reduced thresholds specifically for stimuli that

induced synesthetic experiences. This finding suggests the presence of highly precise long-term priors in synesthetes. Additionally, in both synesthetes and schizophrenia patients, the introduction of explicit short-term priors during the hysteresis experiment led to decreased thresholds. However, the perception was not fully normalized, indicating that these short-term priors did not completely restore perception to the level observed in the control group. These findings suggest that variations in the precision assigned to prior beliefs and sensory evidence may contribute to perceptual variability among individuals, including those with synesthesia and schizophrenia (van Leeuwen et al., 2020). Incorporating synesthesia into research would provide valuable insights for studying other neuropsychological disorders.

4. Conclusions

This literature review highlights the significant psychological symptoms associated with synesthesia and its intriguing relationship with other neurological diseases. Synesthesia is characterized by the unique experience of cross-modal sensory perceptions, which occur involuntarily and consistently. Although synesthesia is generally regarded as a benign phenomenon, recent research has shed light on its potential associations with diverse neurological disorders. Investigations have revealed a higher occurrence of synesthesia among individuals diagnosed with conditions such as autism spectrum disorder, post-traumatic stress disorder (PTSD), and schizophrenia. Furthermore, the presence of synesthesia has been linked to altered cognitive processing, including enhanced memory and attentional abilities. Understanding the psychological symptoms and their relationship with other neurological diseases in individuals with synesthesia is of great importance for unraveling the underlying mechanisms of these conditions. Further research is warranted to elucidate the complex interplay between synesthesia and neurological disorders, shedding light on potential shared etiological factors and informing therapeutic interventions for individuals with these conditions.

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