A review of Synesthesia: historical and current perspectives

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ABSTRACT

Synesthesia can be defined as a subjective phenomenon in which an individual may experience a "mixing" of sensory modalities. This could include a range of perceptions combining an externally or internally sensory stimulation that evokes an automatic secondary sensory affective experience. In other words, a synesthete, or a person with synesthesia, may experience concurrent sensory perceptions. This literature review will discuss the history of the study of synesthesia and key findings from influential researchers. Further, it will discuss various types of synesthesia such as grapheme-color synesthesia, chromesthesia, and mirror-touch synesthesia. Advances in synesthesia research have used cognitive and behavioral tasks to reveal important regions and pathways that might play a role in synesthesia. Theories to explain why synesthesia occurs include the prominent cross-activation theory and the hyperconnectivity theory and some lesser-studied theories such as learned association. In addition, this review will discuss acquired synesthesia, a phenomenon occurring in non-synesthetes that still result in synesthesia-like experiences: examples include hypnotic synesthesia and drug-induced synesthesia. We contend that there are many limitations in the field and there still a need for controlled research studies to explain the underlying causes of synesthesia. Furthermore, we have presented suggestions on areas in the field that need more attention, for example, the role that emotion plays in synesthesia events. **Keywords**: synesthesia, synesthetes, grapheme-color, mirror-touch, hyperconnectivity, cross-activation, learned association, acquired synesthesia

INTRODUCTION

Synesthesia, sometimes spelled synaesthesia, is a condition wherein a person automatically perceives a concurrent sensory perception, sometimes called a "secondary sensation," after experiencing a primary sensation, also referred to as an "inducer." The primary sensation is experienced by non-synesthetes as well as synesthetes. However, a *concurrent* sensation is a sensation that only a synesthete will experience, resulting in a dual experience of having two sensations present at the same time. For example, a non-synesthete who does not have a visual impairment may read the number "4" as a primary sensory perception, however, the ink of the text could be black, a detail which a non-synesthetes might ignore. Conversely, a synesthete may instead perceive the color or a different color when viewing or reading the number "4." In this case, perceiving a color different than the ink is the concurrent sensation. The type of synesthesia described in the example is known as grapheme-color synesthesia.

Synesthesia is a condition that lacks detailed research studies, as a result, there are still many unanswered questions surrounding the condition. In addition, there various types of synesthesia, therefore how they occur and how they present themselves in different individuals may also vary. Further, there are various conceptual and neurological theories that are revealed by a combination of behavioral and neuroimaging studies. This will be discussed in the following sections of this review. Here we aim not only to clearly define the current views on synesthesia but also to provide an up-to-date resource for those who want to learn about this unique condition. With renewed interest in studying synesthesia in recent years, along with the advancement of science and technology, more evidence-supported answers will likely come forward regarding this condition.

HISTORY OF SYNESTHESIA

The first documented case of synesthesia was a case study conducted by George Tobias Ludwig Sachs in 1812. George was the researcher as well as the sole participant in the study. At the time, synesthesia was not well documented or well-understood, thus this case was frequently overlooked as the first documented case of synesthesia (Jewanski, et al., 2019). In George's study, he discusses the phenomenon of "crossing of several sensations" which today would be encompassed under the term synesthesia. Specifically, he experienced seeing colors when hearing music, today this is called chromesthesia (Jewanski, et al., 2009). After George's investigations, synesthesia research declined substantially and very little information was documented about the condition until the late 1800s, as a result, it is still unknown the exact classification of George's synesthesia.

One notable contributor to the study of synesthesia was Sir Francis Galton who studied synesthesia as a variant of mental imagery from 1880-1883. Mental imagery is defined today as a quasi-perceptual experience in the absence of external stimuli (Kaur, et al., 2019). The first case that he studied was George Bidder Jr. who was a math prodigy that spoke of using mental imagery. George's deceased father also reported using mental imagery, which led Galton to hypothesize that the condition had a hereditary component (Jewanski, et al., 2019). Later the mental imagery that Bidder experienced would be called sequence-space synesthesia, or sometimes referred to as "number-form synesthesia." Individuals who experience sequence-space synesthesia perceive sequential concepts such as numbers or months in a pattern in the physical world around them (see Figure 1). These patterns can vary in the shape they take (i.e. "spiral" or "linear") and they can also vary in form, meaning these concepts can be three-dimensional or two-dimensional (Ward, et al., 2018).

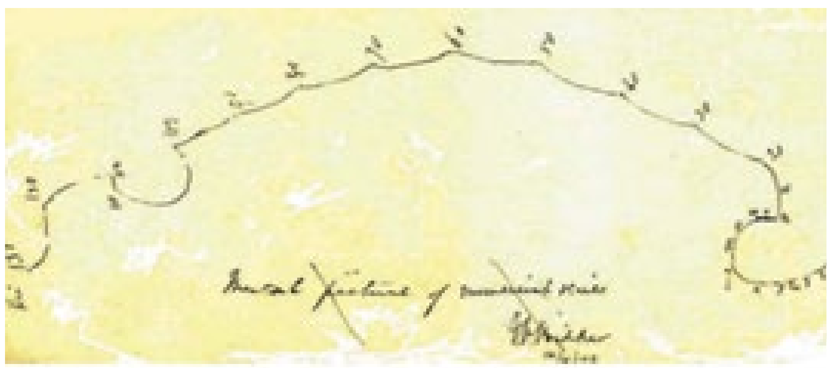

Figure 1. A drawing from George Bidder Jr. sent to Galton. The drawing shows the mental imagery George saw when he heard numbers.

Galton also hypothesized that synesthesia was a "use it or lose it" phenomenon, however, this notion is at odds with the current findings on synesthesia. The "use it or lose it" phenomenon states that the brain is similar to a muscle therefore it must be exercised to maintain its strength and/or functionality. Galton strongly believed that concurrent sensations, if left unexercised, would decline, and become non-existent over time if they were not repeated multiple times (Almond, 2014). After studying the Bidder family, Galton conducted several surveys to gather more data about mental imagery. Through his surveys, Galton discovered two other forms of mental imagery that would later be identified as synesthesia: sequence-personality synesthesia and tickertape synesthesia. Sequence-personality synesthesia, sometimes called ordinal linguistic personification, is when a synesthete personifies inanimate representations, such as numbers, similarly to how animals or elements are personified in literature. For example, the number "9" being personified as an angry person, or the letter "G" being personified as a happy person. Tickertape synesthetes hear a number and see it represented in a physical form, such as hearing the word seven and then seeing the number "7."

Two other researchers that have made considerable contributions to the world's current understanding of synesthesia are Paul Bleuler and Karl Lehmann. After studying synesthesia, Lehmann's career was spent focusing on hygiene and microbiology. Bleuler would later be influential in psychiatry, especially in regard to schizophrenia. Bleuler himself was a synesthete, likely diagnosed with chromesthesia because he often said the sound of certain letters were associated with certain colors. Bleuler reported that some of his relatives had chromesthesia as well (Jewanski, et al., 2019). They were the first to document primary sensations that were not part of the auditory and visual systems, specifically they found pain, olfactory, and gustatory primary sensations and began their research in 1881 (Jewanski, et al., 2019). Their findings showed that other sensory systems can play a role in synesthesia besides the auditory and visual systems.

In 1889, The International Conference of Physiological Psychology convened and discussed what would later become known as synesthesia. This turned out to be an important step in the history of synesthesia because it was the first time the condition was internationally recognized. (Jewanski, et al., 2020). The term "synesthesia" was first coined by Mary Calkins when she used it in her research between 1892-1895. Previously, the condition had been described by various words that would describe an individual's perceptual experience, particularly for how individuals would perceive colors. This is because, until Bleuler and Lehman, most examples of synesthesia were related to how the visual system interprets colors. For example, one previous term used to name the phenomenon of synesthesia was hyperchromatopsia, which roughly translates to "the perception of too many colors at once" (Jewanski, et al., 2019). It is important to note that Mary Calkins was not the first one to use synesthesia in an academic paper however, she is the one who popularized the term. Jules Millet also used the term first in his medical dissertation in 1892 (Jewanski, et al., 2019).

For quite some time after the nineteenth century, interest in studying synesthesia diminished significantly. For a while, many individuals did not consider synesthesia to be a real condition. Those that viewed synesthesia as a scientific and psychological curiosity felt that because the condition was not known to cause bodily harm, there was no need to treat or cure the condition. In 1989, a neurologist named Richard Cytowic published the book *Synesthesia: A Union of the Senses*, which caused an increase in interest for synesthesia (Jewanski, 2014; Cytowic, 2014). The book discussed many topics surrounding synesthesia that not only included scientific findings, but also first-hand accounts from synesthetes on their experiences. He released a second edition of the book in 2014 with updated information based on current research and understandings. Cytowic also stated three researchers that he considers to be leading the way regarding synesthesia research: himself, Baron-Cohen, and Hinderk Emrich (2014). In 2014, there were 60 recognized types of synesthesia (Safran & Sanda, 2014). As of 2020, there were between 100 and 200 hundred recognized cases (Jewanski, et al.).

MAJOR TYPES OF SYNESTHESIA

As previously stated, synesthesia is a broad term that describes a condition where a person experiences at least one primary sensation along with an automatic concurrent sensation. The three major types of synesthesia, grapheme-color synesthesia, chromesthesia, and mirror-touch synesthesia, will be discussed in the following sections. This is because much more research has been conducted on these types of synesthesia.

Grapheme-Color Synesthesia

The most common type of synesthesia is grapheme-color, about 64.4% of synesthetes experience grapheme-color synesthesia (Safran & Sanda, 2014). Roughly 1.2% of the general population are grapheme-color synesthetes (Carmichael, et al., 2015). For many years, long-term testing and retesting of sensory perceptions was how a diagnosis of synesthesia was determined. In 1987 Baron-Cohen and colleagues created a test of "genuineness" that was used for grapheme-color synesthesia (Curwen, 2018). Based on this test of "genuineness," the synesthesia battery test, which was sometimes called "The Battery," was developed. The Battery test began with a questionnaire to help identify the type of synesthesia that the participant may have then they are tested using software programs. For grapheme-color synesthesia battery, a control primary sensation is shown three times along with several other primary sensations of similar nature, such as letters or numbers. They then are asked to select a concurrent color option from the 16.7 million color options available. The test then tracks the consistency of how often the same concurrent color is selected for the same primary sensation. A color variation score is then calculated and those that score less than a 1 are considered to be a verified synesthete (Curwen, 2018). This test was later validated by seeing if the same prevalence, observed with the Battery test of grapheme-color synesthesia, matched that in the general population, which it did (Carmichael, et al., 2015).

As previously stated, grapheme-color synesthetes perceive a color when seeing a number and/or letter. However, there are a few other verified side effects of the condition. The first being that grapheme-color synesthetes have enhanced working memory, specifically their color working memory. This was found to be independent of the participant's color discrimination ability and color familiarity (Terhune, et al., 2013). The discovery of grapheme-color synesthetes having an enhanced working memory was corroborated in a study conducted in 2018. Rothen, Ward, and Seth (2018) found that grapheme-color synesthetes experienced enhanced episodic memory compared to non-synesthetes. It has been speculated that this is due to the fact that grapheme-color synesthetes have enhanced sensory processing when sensory-perceptual awareness is high, and thus they are able to process simultaneous sensory information, leading synesthetes to consolidate those simultaneous sensory connections as an event or episode (Rothen, et al., 2018). There is some evidence to suggest that grapheme-color synesthetes have enhanced sensory memory as well. It has also been shown that grapheme-color synesthetes have improved color discrimination capabilities (Rothen, et al., 2018).

Chromesthesia

Chromesthesia, the type of synesthesia that George Bidder had, is known by a few different names, such as "colored-hearing" or "music color synesthesia" (Curwen, 2018). Within the classification of chromesthesia, there is much variation to the concurrent visual perceptions, however, one commonality is that it is typically associated with a sound. There are many components to sound and music so it can be difficult to test for consistency of concurrent perceptions in these individuals. For example, one must consider things such as tone, timbre, tempo, background noise. Some chromesthesia synesthetes can even experience textures, shapes, or spatial landscapes (Curwen, 2018). Further, variations can occur in which synesthetes perceive a color combined with a concurrent sensory perception found in other types of synesthesia. Some are classified as associators, meaning they see the color in their mind's eye. The mind's eye is another term for mental imagery. Some individuals may project their experience by perceiving the color outside of their body, these individuals are referred to as "projectors." Some projectors perceive the color as being in front of them and some perceive the color as originated from the location of the perceived concurrent sound (Curwen, 2018).

Mirror-touch synesthesia

Mirror-touch synesthetes perceive a sensory experience when they see someone else being touched. It has been hypothesized that this type of synesthesia is linked to mirror neurons (Linkovski, et al., 2017). Mirror neurons have been studied in different primates: monkeys, humans, and macaque. These neurons fire when a primate performs an action, specifically one that involves a hand interacting with an object. Interestingly, the observer's mirror neurons also fire when they witness someone else performing the same action (Linkovski, et al., 2017). There are currently two prominent theories that seek to specifically explain why mirror-touch synesthesia occurs. One theory is the threshold theory which states that mirror-touch neurons are the somatic extension of mirror neurons, which are found in all humans. The implication is that mirror-touch synesthesia is an extreme endpoint, or exaggeration, of the normal mirror-touch mechanism. In mirror-touch synesthetes, the activity of mirror neurons reaches a certain threshold that facilitates the perception of touch despite only seeing someone being touched (Linkovski, et al., 2017). The second prominent theory is the self-other theory that says mirror-touch synesthesia is the result of a disturbance in the ability to distinguish oneself from other people. This theory is meant to provide further support for the threshold theory (Ward & Banissy, 2015).

A few commonalities have been observed among all synesthetes. One is that their concurrent perceptions do not decline or change over time unless they are afflicted with some diseases, have a serious injury, or their abilities can be temporarily changed due to drug use (Safran & Sanda, 2014; Sinke, et al., 2011). As previously stated, there is no agreed-upon cause of synesthesia and thus there is no proven mechanism for why concurrent perceptions do not decrease over time. Another interesting commonality amongst adult synesthetes is that they have an increase in white matter between sensory areas in their brains that are related to their condition, which may support the neural pruning theory because of the increased connectivity seen with increases in white matter (Nair & Brang, 2019). Prior work has shown that grapheme-color synesthetes have increased white matter between the area of their brains that process color and the area that processes shapes and numbers, further, that this can vary for projector and associator synesthetes (Rouw & Scholte, 2007). More specifically, greater connectivity in the white matter was found in the temporal inferior cortex for projector synesthetes, further, both projector and associator synesthetes had increased white matter in the superior parietal and the frontal cortex (Rouw & Scholte, 2007).

COMMON CURRENT RESEARCH METHODS

Research methods vary based on what type of synesthesia is being studied. Cytowic also points out in the second edition of his book that the discipline background of the researcher will alter the angle at which they approach studying synesthesia. For example, clinicians rather than experimenters are more likely to focus on patients and their first-hand accounts of synesthesia for research purposes (Cytowic, 2014).

One way that researchers are currently approaching research on synesthesia is through cognitive or behavioral testing. For grapheme-color synesthetes, this is often done using the Stroop Effect. Grapheme-color synesthetes experience a concurrent color perception when they see numbers or letters, like the example given in the introduction. The Stroop Effect, sometimes called the Stroop Incongruity Effect, is the delay in reaction time between automatic and controlled processing of information caused by incongruences within the stimuli (Ruhl, 2020). For example, individuals can be tested in this task by asking them to describe the color of the ink for certain words where the text displays an incongruent or different color (see Figure 2). In a study where a control group of non-synesthetes and experimental groups of grapheme-color synesthetes were presented with various different stimuli, i.e. colored numbers, synesthetes were shown to take more time to identify a stimulus and more frequently misidentify a stimulus. However, when grapheme-color synesthetes were given stimuli in which the number's color matched the color of their concurrent perception, they scored just as well or better as the control group. This study suggests that synesthesia perception is automatic because it did not take the synesthetes more time to identify the stimulus correctly when the colors matched their concurrent perception, but it did take them longer to correctly identify the stimulus when an incongruency was present, i.e., when the concurrent perception did not match the color of the ink. This is because they likely had to exert more effort in order to identify the color of the ink since their automatic perception would have been different than the intended correct answer (Hubbard & Ramachandran, 2005).

RED

BLUE

GREEN

Figure 2. An example of the Stroop Effect that is commonly used when studying grapheme-color synesthesia.

An approach to studying all types of synesthesia has been to use more objective measures like neural imaging to help indicate areas of the brain that are active while synesthesia events are occurring. Even with the advancements in functional brain imaging, the regions of the brain that might be involved with synesthesia are still not entirely understood, and thus the interpretations of functional brain imaging in synesthetes are difficult to parse out. One study showed that the V4 region of the brain, also part of the extrastriate of the visual cortex, appears to be active, but the specificity of the activity and the extent they could not determine (Hubbard & Ramachandran, 2005). This conclusion was reached by Hubbard and Ramachandran after conducting their fMRI study on grapheme-color synesthetes paired with a modified Stroop effect assessment and comparing their findings to several other studies that found conflicting data (Hubbard & Ramachandran, 2005; Alemann, et al., 2001; Weiss, et al., 2005). The V4 is a cortical area that is a part of the ventral visual pathway and plays an important role in visual recognition and visual attention (Roe, et al., 2012). One limitation with current neural imaging studies is that most of them have been conducted on grapheme-color synesthetes so there is minimal evidence that hyperconnectivity exists between different sensory systems for non-grapheme-color synesthetes (Nunn, et al., 2002).

THEORIES TO EXPLAIN WHY ALL TYPES OF SYNESTHESIA OCCUR

Neurological, biological, and learned association theories

Since there is limited research on synesthesia there are a few competing theories on why synesthesia occurs. One such theory is sometimes referred to as the hyperconnectivity theory or "lack of neural pruning theory." It is classified as a neurophysiological theory because the theory attempts to explain synesthesia by using neural pruning. Neural pruning is the removal of synaptic connections between areas of the brain when those connections are not given frequent enough stimulation or are unused. This theory states that synesthesia is a result of neural pruning, or the lack thereof, which leads to continuing connections between the senses that may have existed during gestation (Hubbard & Ramachandran, 2005). Converging evidence for this theory, derived from neural and anatomical imaging of infant's brains, shows hyperconnectivity that supports cross-modal influences on perception in the infants that create synesthesia-like events (Maurer, et al., 2019). However, this hyperconnectivity is often lost in neural experience-dependent pruning that occurs naturally during development and for some reason, it may not occur in synesthetes. This hyperconnectivity between different sensation processing areas of the brain is proposed to be the cause of synesthesia. A study was conducted to test the neural pruning theory by showing synesthetes and non-synesthetes nonnative categories, such as phonemes that were not included in the participant's native language. Synesthetes were able to recognize the groups consistently better than non-synesthetes, this finding is similar to how infants under 6 months were able to do better than infants over 6 months (Maurer, et al., 2019). This suggests that there is existing hyperconnectivity in individuals with synesthesia that was not removed through experience-dependent neural pruning (Maurer, et al., 2019)

Another theory is that synesthesia occurs due to learned associations made by individuals early on in life (Safran & Sanda, 2014). The learned association occurs because of a perceived close relationship between two sensory perceptions at a young age. The relationships between the two perceptions may or may not be forgotten by the synesthete later on in life (Calkins,1895). For example, a synesthete might associate an emotion with a color so happy words might be seen in pink (Calkins, 1895). It is important to note that some say that familial cases make a strong case that synesthesia is a brain-based condition that has a hereditary component rather than caused by learned association (Cytowic, 2014).

Galton proposed that there are genetic components involved with synesthesia. The idea that synesthesia occurs at least partly because of genetics is still the current view of how synesthesia develops, however, researchers have been unable to locate a specific gene related to synesthesia. A genetic study was conducted with monozygotic twins, however, the study was unable to pinpoint a particular gene linked to synesthesia (Smilek, et al., 2002). The Smilek studied concluded that the gene was more complicated than a dominant X-linked gene as had been previously hypothesized (Bailey & Johnson, 1997). To make matters more complicated, there is contradicting information that has been spread around about synesthesia. One study has indicated synesthesia is more common in women than men (Baron-Cohen, et al., 1996). However, more recently when random sampling has been conducted, no discrepancies have been indicated between sexes so the Baron-Cohen study may have studied an under-reported male synesthete population. Another contradictory piece of information is the prevalence of synesthesia. Different statistics have been used to describe synesthesia's prevalence ranging from 1 in 20 people having synesthesia in Galton's 1883 research, to 1 in 25,000 in Cytowic's 1989 book *Synesthesia: A Union of the Senses* (Hubbard & Ramachandran, 2005). Even though it is unknown what role genetic factors play in synesthesia, it is hypothesized that the genetic factor of synesthesia might be what causes the lack of pruning in synesthetes (Hubbard, et al., 2011).

Architectural theories of synesthesia

Architectural theories are conceptual models which can describe the cause of synesthesia in a way that relates to how the brain is anatomically designed, some studies refer to these theories as neurological theories as well. Currently, two well-known architectural theories attempt to explain why all types of synesthesia occur. The first theory being the local cross-activation theory, which suggests that adjacent sensory areas of the brain are connected, thus causing synesthesia (Hubbard & Ramachandran, 2005). Specifically, the cross-activation theory states that synesthesia occurs because of three main points (Hubbard, et al., 2011). The first being neural representations of the primary and concurrent sensations are in densely interconnected regions of the brain. The second being genetic factors can lead to a decrease in pruning. The third being that activation passes through neurons that code for the primary and concurrent sensations (Hubbard, et al., 2011). For example, it is proposed that grapheme-color synesthesia occurs because there is cross-activation between the grapheme areas of the brain, such as the inferior temporal cortex, and the color processing areas, such as V4 (Brang, Hubbard, Coulson, Huang, Ramachandran, 2010; Hubbard, Brang, Ramachandran, 2011). The cross-activation theory has been used to explain other types of synesthesia besides grapheme color, such as sequence-space synesthesia. Based on neural imaging studies, it is generally agreed that the parietal cortex is the region where most numerical and spatial processing occurs (Hubbard, et al., 2005). Cross-activation could explain this type of synesthesia if differing areas in the parietal region are interconnected (Brang, et al., 2011). The second architectural theory is the top-down disinhibited feedback theory, sometimes referred to as simply the disinhibited feedback theory (Hubbard & Ramachandran, 2005). This theory suggests that synesthesia is the result of disinhibited feedback, possibly from a multisensory area of the brain. A study using EEG provides more supporting ideas for this theory. In the EEG study, the researchers postulated that a decreased range in long-range couplings in the theta frequency band could support this model because this occurrence can create a top-down effect (Safran & Sanda, 2014).

Finally, there exists an architectural theory that only tries to explain why visual types of synesthesia occur specifically for grapheme-color synesthesia, referred to as the “re-entrant processing theory.” This theory suggests that besides the processing from V1 to V4 that takes places in the posterior inferior temporal and anterior inferior temporal regions, there is a neural activity from the anterior inferior temporal region that goes back to the posterior inferior temporal region and the V4 region that contributes to synesthesia (Smilek et al., 2001).

All the theories discussed in this paper leave room for interpretation on whether the causes of synesthesia only exist in synesthetes or if they exist in non-synesthetes as well. For example, concerning the disinhibited feedback model, it is unknown if a multisensory area of the brain is unique to synesthetes or if this hypothetical structure exists in most people. It is also important to note that some researchers have even suggested that the reason why synesthesia might occur could be due to a combination of these theories (Hubbard & Ramachandran, 2005). As more research is done, this could mean that some of the theories may be combined, or that specific types of synesthesia might need their own theories instead of one theory to explain the various perceptions synesthetes experience.

ACQUIRED SYNESTHESIA

One interesting line of research in this ever-growing field is acquired synesthesia. Acquired synesthesia is a term that is used to describe synesthesia-like events that might occur in non-synesthetes, but these events do not occur because of genuine synesthesia; acquired synesthesia is sometimes referred to as “secondhand synesthesia” or “induced synesthesia.” Sensory deprivation is currently the only comparable way to induce acquired synesthesia events in non-synesthetes. Sensory deprivation has been shown to sometimes cause synesthesia-like experiences, possibly because of connections that exist between sensory systems. For example, the monosynaptic connection between auditory and visual areas of the brain as well as the indirect connections through the thalamic, temporal, and parietal regions (Nair & Brang, 2019). These existing connections allow for the possibility for one sensory perception to influence or alter another sensory perception. One study looked at the relationship between visual deprivation and auditory primary sensations leading to concurrent visual perceptions (Nair & Brang, 2019). Participants were kept in a dark room and told to keep their eyes closed for 30 minutes. Throughout the 30 minutes, they would hear different frequencies and were told previously to press a button if they experienced any visual concurrent perceptions. The study found that 57% of participants experienced synesthesia-like events, and most of these experiences started happening after just five minutes of visual deprivation. One issue with the study is that participants were told beforehand they may experience visual perceptions along with the frequencies they heard. Participants may have thought they were expected to report visual experiences so they may have reported more than they experienced. While this study supports the finding that non-synesthetes can experience concurrent sensational perceptions, at least in the case of visual and auditory events, sensory deprivation does not lead to the development of synesthesia (Nair & Brang, 2019).

Other methods have been studied to trigger acquired synesthesia such as drug usage and hypnotism. However, it was concluded that acquired synesthesia from drugs and hypnotism is not comparable to true synesthesia (Sinke, et al., 2011; Anderson, et al., 2014). It is important to note that in genuine synesthesia, synesthetes' concurrent perception does not change or deteriorate with time, but in studied cases of acquired synesthesia these perceptions do appear to deteriorate (Sinke, et al., 2011). Considering how little is known about synesthesia, there is even less known about drug-induced synesthesia. Most often drug-induced synesthesia is caused by hallucinogens, such as LSD (Sinke, et al., 2011). Drug-induced synesthesia is not automatic, and the same stimulus may not always elicit the same concurrent perception, which is not what occurs in genuine synesthesia. The only main similarity between drug-induced synesthesia and genuine synesthesia is that primary sensation perceptions can cause concurrent sensation perceptions to occur. There is virtually no documented research that has been done in regard to how drugs may affect synesthetes and how that might affect their synesthetic perceptions (Sinke, et al., 2011).

Hypnosis is a third way that has been studied to see if it can trigger acquired synesthesia. A study was done to see if grapheme-color synesthesia could be induced by hypnosis. Participants were given hypnotic color suggestions that were paired with images. Then those images were embedded, and participants were asked to detect the paired embedded images. The hypnotic color suggestions were only perceived after the embedded images were detected so the researchers concluded that hypnosis could cause a variation in sensory perceptions. However, the variation it created was not comparable to genuine synesthesia (Anderson, et al., 2014).

CONCLUSION

While current theories and research on synesthesia are still developing, much information about how sensory systems are associated together can be gleaned from this psychological phenomenon. In general, a lot more research needs to be done on synesthesia, specifically on types of synesthesia that are less prominent than grapheme-color synesthesia, such as sequence-personality synesthesia. More studies also need to be done to investigate the role that emotions play in synesthetic perceptions. With advances in technology and a better understanding of the human brain, synesthesia research is getting closer to understanding the mechanisms involved in synesthesia. Advances in technology may help in understanding the genetic basis of synesthesia. It is possible that researchers will decide synesthesia needs to be broken down into multiple different conditions or classifications as there is currently no one theory that can explain why all current types of synesthesia occur.

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