Unraveling the Links Between Synesthesia and Autism

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Abstract

While synesthesia and autism may not appear to be related at the surface level, they share common features such as hypersensitivity and enhanced perception, increased attention to detail, and atypical neural connectivity. Synesthesia was found to be more common in autism and oddly not schizophrenia, another disorder of altered perception; however, this increased prevalence does not generalize to all forms of synesthesia and autism, and studies suggest that synesthesia is more common when autism co-occurs with savant skills. Although more research needs to be conducted on whether there is a biological link, similarities between the two conditions could be explained by similar underlying neural mechanisms. As synesthesia and autism share similar theoretical models in terms of hyperexcitability and perception of the world, there may be a link between the two that makes them often co-occur.

Introduction

Do you often associate sounds with different colors? Or perhaps different textures trigger different tastes? If an association is strong enough between inducing stimuli and concurrent sensations and exhibits high consistency throughout life, you may be described as a synesthete. Synesthesia is a neurodevelopmental condition in which specific sensory inputs such as letters, sounds, tastes, or smells automatically and involuntarily trigger additional sensations such as texture, color, or shape (van Leeuwen et al., 2020). Although any combination of inducing inputs and concurrent sensations is hypothetically possible, the most common inducers are linguistic while the most common concurrents are visual, such as colors or shapes; overall, the most common type is grapheme-color synesthesia, where letters or numbers trigger color sensations (Simner et al., 2006).

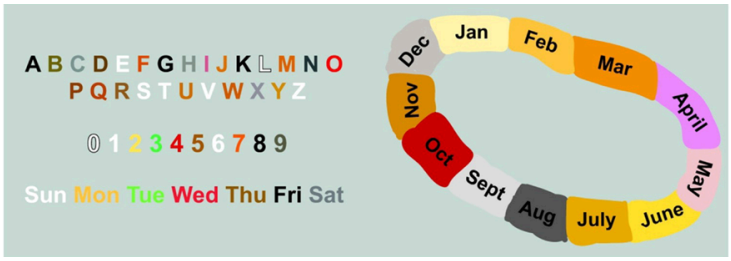

Figure 1. Examples of how letters, numbers, days of the week, and months may induce different color sensations in synesthetes (van Leeuwen et al., 2020).

Although synesthesia is a relatively rare condition, research has shown that it is more prevalent in individuals with autism spectrum disorder. Autism is a neurodevelopmental condition characterized by difficulties in social interaction and communication as well as patterns of restricted and repetitive behaviors, interests, or activities (van Leeuwen et al., 2021). 10% of autistic individuals also have savant abilities or skills that are exceptionally above average, and 50% of those with savant skills have autism (Treffert, 2009). While the relation of autism to synesthesia may not be clear at first, another diagnostic criterion for autism is altered sensory perception—which can be either hyposensitivity or hypersensitivity—and many autistic individuals pay increased attention to details. Hypersensitivity and enhanced perception are also traits of synesthesia, and there are similarities between autism and synesthesia regarding atypical neural connectivity and preference for local (detail-oriented) over global (big picture) visual processing (van Leeuwen et al., 2020). It is also hypothesized that the presence of savant skills plays an important role in determining the presence of synesthesia in autistic individuals (Hughes et al., 2017).

Though further research needs to be conducted to confirm whether there are underlying biological mechanisms connecting synesthesia and autism, the shared features and increased co-occurrence of the two conditions indicate that there may be a link between them. This paper will discuss precisely how much overlap there is between synesthesia and autism, theories as to why this overlap occurs, and the implications of these findings.

Is Synesthesia More Prevalent in Autism?

As a general estimate, synesthesia occurs in 4% of the population and autism occurs in 1% of the population. If these two neurodevelopmental conditions were to be independent of each other, the chance of them co-occurring would be about 0.04% or 4 in 10,000 people. Given how incredibly rare that is, it would be unlikely to ever meet someone with both synesthesia and autism. Baron-Cohen et al. (2013) conducted a study to investigate whether this base rate is accurate or if synesthesia is more common in autism.

After exclusions, 164 adults with professionally-diagnosed autism and 97 controls completed a synesthesia questionnaire, the Autism Spectrum Quotient (AQ), and the Test of Genuineness-Revised (ToG-R), which is used to validate self-reported synesthesia. It was found that the rate of synesthesia in autistic adults is 18.9%, almost three times greater than the rate of 7.22% in the control sample.

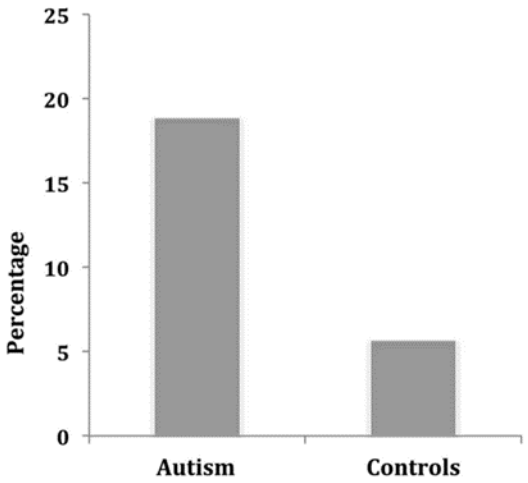

Figure 2. The percentage of people with synesthesia in the autism and control groups (Baron-Cohen et al., 2013).

The significant difference between the rate of synesthesia in autistic adults and the general population indicates that something is linking these two conditions and making them interdependent. This could perhaps be because they share underlying biological factors, such as enhanced local visual processing and hypersensitivity. There is also evidence that suggests synesthesia and autism are connected at multiple levels. A study by Gregerson et al. (2013) found a significant phenotypic and genotypic overlap between synesthesia and absolute pitch, which is the ability to identify or re-create a note on demand. This trait also has a higher prevalence in people with autism, suggesting that synesthesia and autism share several characteristics that result in the two often co-occurring.

However, there are issues of reliability and validity to be considered with any finding based on self-reported measures. The increased presence of synesthesia in autistic adults may be explained by individuals with autism being more likely to report abnormal sensory and perceptual experiences than those without autism. There were also three autistic participants who claimed not to have synesthesia, yet they were determined to be synesthetes based on their results on the synesthesia questionnaire; however, they were considered as non-synesthetes because they reported themselves as such. Because these participants declared they did not have synesthesia because they were unsure if their experiences counted, it is possible that the resulting rate was not an over-estimate, but instead an under-estimate. This study also has several limitations, the most critical one being that researchers were unable to collect complete consistency tests to validate the results. The sample also only included high-functioning autistic adults, and it would be interesting to see if these findings generalized to autistic children and more impaired autistic individuals.

Comparing Synesthesia in Autism and Schizophrenia

It is also worth questioning whether this increased prevalence of synesthesia is observed in other neurodevelopmental disorders or if it is specific to autism. One way to study this is by looking at relatives of synesthetes and whether certain disorders have a significantly higher chance of running in the family. Nugent & Ward (2022) investigated whether there is a familial aggregation between synesthesia and two disorders —autism and schizophrenia—as well as Type 1 diabetes as a control predicted to have no link to synesthesia. Both autism and schizophrenia were hypothesized to have a familial connection to synesthesia due to their shared features of altered sensory perception. After exclusions, 282 synesthetes and 281 non-synesthetes completed an online questionnaire, which resulted in collecting information about 1114 first-degree relatives of synesthetes and 1130 controls. Individuals were subsequently sorted into one of three groups: diagnosed autism, probable autism, and possible autism. Among participants, it was found that autism was more common in synesthetes (3.93% diagnosed, 3.57% probable, 2.14% possible) than in non-synesthetes (0.38% diagnosed, 0.38% probable, 1.91% possible). Among relatives, autism was also more common in first-degree relatives of synesthetes (2.98% diagnosed, 1.08% probable, 0.72% possible) than first-degree relatives of non-synaesthetes (1.68% diagnosed, 0.18% probable, 0.71% possible).

While an association between synesthesia and autism was observed, the results failed to indicate any link between synesthesia and schizophrenia at the individual or familial level. This finding was surprising considering that altered neural connectivity is also a characteristic of schizophrenia, like autism and synesthesia, and schizophrenic hallucinations and synesthetic experiences may both be explained by inflexible frameworks of sensory perception; that is, both groups are likely to distort sensory input to fit their internal models of the world even when faced with contradictory evidence. The key difference here may be that synesthetes are aware their sensory experiences are false.

However, this study has certain limitations, the most significant one being that there is no way to verify the truthfulness of the responses. The inclusion of a “prefer not to respond” option may be masking positive cases as well. Even assuming that all participants responded truthfully, there may still be intergroup variability in diagnosis-seeking behavior: synesthetes and their relatives may be more proactive in seeking an autism diagnosis than non-synesthetes. However, other evidence shows that high levels of autism are observed in synesthetes even without a formal autism diagnosis (van Leeuwen et al., 2019).

Considering Savant Skills’ Role in Synesthesia

One final thing to consider when measuring this co-occurrence is that it does not generalize to all types of synesthesia and autism. Considering that both conditions are conceptualized to lie on a spectrum with different characteristics across individuals, there may be an increased prevalence of certain types of synesthesia among certain types of autism. A study on this investigated whether synesthesia is indeed more common in autism or only when autism co-occurs with savant skills (Hughes et al., 2017).

Researchers tested three groups: 40 autism-savants, 34 autism-non-savants, and 29 controls without autism. Participants were asked whether they had a formal diagnosis of autism and completed a questionnaire on savant skills. Then, they were tested for grapheme-color synesthetes in total: one was a control, one was an autism-non-savant, and four were autism-savants. The prevalence of synesthesia in the autism-savant group (10%) was over seven times higher than the general population (1.4%) and held statistical significance, while no significant difference was observed for the control and autism-non-savant groups.

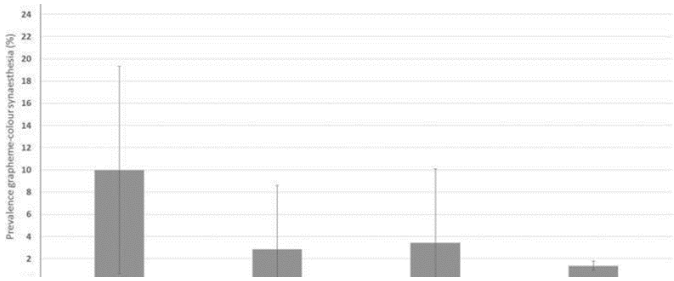

Figure 3. The prevalence of grapheme-color synesthesia in autism-savants, autism-non-savants, the control group, and the general population (Hughes et al., 2017).

A primary limitation of this study was that there is no objective test to assess for savant skills and the questionnaire involved self-reporting savant skills. It is likely that participants vary in how they perceive their own talents compared to the general population without an objective standard. Factors such as overestimating and under-estimating one's abilities as well as personality traits like modesty come into play. However, it is still worth questioning why synesthesia was more common in autism-savants and what the implications of these results are.

The first possible explanation is that synesthesia leads to savant skills because synesthetes are known to have improved memory. For example, if digits are encoded as both numbers and colors, they will have richer memory representations. This improved memory could then reach savant levels. Another possible explanation is that hyper-systemizing and veridical mapping are common in autism. Systemizing is the drive to identify patterns in rule-based information, and veridical mapping is the related ability to match two systems by their shared traits. In synesthesia and types of savant skills that require mapping two things, veridical mapping may then independently lead to both conditions, explaining why the two often co-occur with autism.

Shared Traits Between Synesthesia and Autism

Now that it is clear that synesthesia is more prevalent in autism, the next step is to ask why. What are the underlying mechanisms and shared characteristics that lead to this increased prevalence? Van Leeuwen et al. (2019) conducted a study to test the hypothesis that synesthesia and autism share atypical sensory sensitivity and perception. 76 synesthetes and 43 non-synesthetes completed a synesthesia screening questionnaire, the Autism Spectrum Quotient (AQ), and the Glasgow Sensory Questionnaire (GSQ), which assesses hypersensitivity and hyposensitivity across seven sensory modalities. Individuals with autism typically score higher on the GSQ than the general population, and it was hypothesized that synesthetes would score higher as well. Participants also completed a motion coherence task to assess for global motion processing and an embedded figures task to assess for local visual processing. The hypothesis was partially confirmed. Synesthetes scored higher than non-synesthetes on AQ-attention-to-detail, but not AQ-total. Synesthetes also showed GSQ scores positively correlated with AQ-attention-to-detail and higher scores on hypersensitivity subscales, but not hyposensitivity. Lastly, synesthetes performed poorer on detecting the global motion of direction in the motion coherence task and performed better on the most difficult level of local processing in the embedded figures task. High attention to detail, hypersensitivity, and bias towards local perception are all common characteristics of autism, and these findings suggest that synesthetes share these atypicalities.

These similarities between the two conditions could be explained by a shared underlying neural mechanism. There is evidence of local hyperconnectivity and reduced long-range connectivity in both synesthesia and autism, which would explain why both excel at tasks where global context, including long-range feedback, must be ignored. Another similarity lies in both groups showing atypical responses in the parvocellular system, which is the system responsible for processing spatial details and colors. This would explain why synesthetes and autistic individuals both exhibit enhanced perception of details and colors at the cost of reduced global motion processing.

Similar Theoretical Models of Synesthesia and Autism

Though little research has been done to conclude whether there is a clear biological explanation, Van Leeuwen suggests that there are possible theoretical models of perception in synesthesia and autism that account for their similarities (Van Leeuwen et al., (2020)). In autism, there is an imbalance between excitation and inhibition in the brain that leads to excitation not being met with sufficient inhibition (Orekhova et al., 2007). In synesthesia, the balance between excitation and inhibition has not been specifically measured, but there is evidence for hyperexcitability in the visual cortex for individuals with grapheme-color synesthesia (Terhune et al., 2011).

Predictive processing models of perception involve comparing "priors", or top-down knowledge based on one's past experiences, against incoming sensory information. A prior can be any knowledge structure that influences how sensory input is perceived, such as associating red with danger. If one has an over-reliance on priors, they may wrongly interpret every red item they see as dangerous. One version of this model proposes that people with autism have weaker priors and are therefore more likely to see the world as it is. This is especially interesting because synesthesia resembles the antithesis of this.

Rather than the hyper-real perception of the world in autism, synesthesia appears to be an over-reliance on priors similar to hallucinations in schizophrenia. So, how is it that synesthesia and autism co-occur so commonly? There is an alternative model of perception in autism that suggests that their priors are specific, narrow, and inflexible; therefore, a lot of incoming sensory information that contradicts their worldview is treated as surprising and unpredictable. This model is potentially more compatible with synesthesia, as autism and synesthesia may be similar in demonstrating excessively strong priors that lead to altered perception. Specific and inflexible priors are consistent with the imbalance between excitation and inhibition as well. If priors are too narrow to accurately predict incoming sensory signals, the brain will make more errors in predicting them. So, the different theoretical models of synesthesia and autism converge in this sense.

Conclusion

The shared features of hypersensitivity, enhanced perception, heightened attention to detail, and atypical neural connectivity suggest a link between synesthesia and autism. While studies indicate higher rates of synesthesia in individuals with autism, there are nuanced distinctions to be made when considering different manifestations of the two conditions, one particularly being the presence of autism with savant skills. However, the absence of a similar association with schizophrenia underscores the specificity of synesthesia and autism frequently co-occurring.

Evidence for a definitive biological link between synesthesia and autism still remains elusive, and these preliminary findings prompt a call for more research. As the complexities of neurodiversity are further explored, unraveling the links between synesthesia and autism will hopefully allow for deeper insights into the intricacies of the human brain and the diverse ways in which it perceives and interacts with the world.

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