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# Synesthesia

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Synesthesia is a trait in which one sensory input elicits an unusual secondary experience that is not typically associated with that input. For instance, the letter A printed in black may trigger a red color experience. Synesthetic experiences are automatically triggered, idiosyncratic, and unidirectional (i.e., a letter that triggers a color experience is usually not triggered in response to the respective color). It is well established that synesthesia is neither imagination nor metaphorical thinking but has a neurophysiological basis integrating the perceptual aspects of the inducing stimulus with the resulting concurrent synesthetic experience. Prevalence studies estimate that approximately 5% of the general population have one or several types of synesthesia. Beyond being an example of human perceptual diversity, it provides an opportunity to explore links between perceptual functioning and higher cognitive processing from a healthy special population perspective.

## History

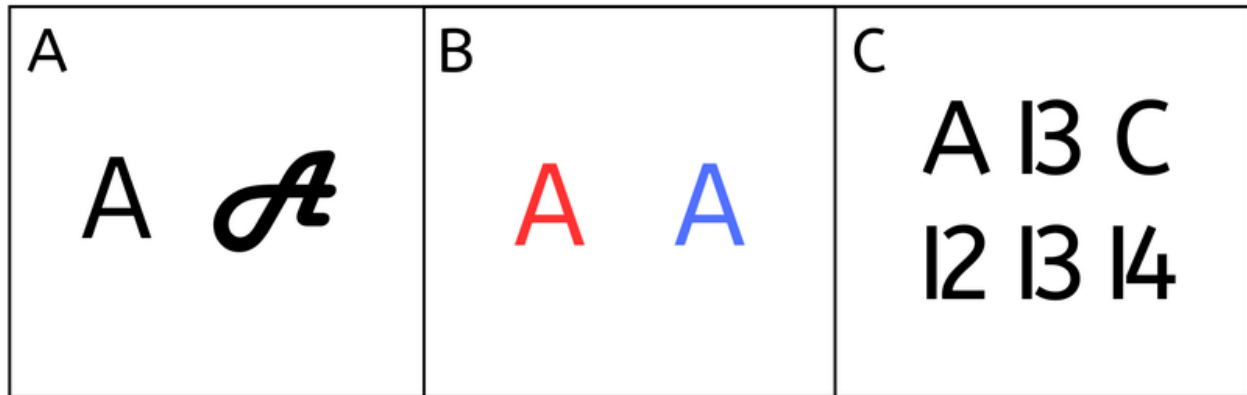
The term synesthesia is of ancient Greek etymology: syn-aisthēsis, which means “together” and “sensation.” Reports of synesthesia date back to the 18th century, although under different names. The term in its current meaning was only introduced in the late 19th century ([Jewanski et al., 2020](#)) when the subject started to receive systematic attention, for instance, in publications by Francis Galton and Gustav Fechner. The reports that described cases of synesthesia were often dismissed or pathologized, partly because synesthetic experiences could not be objectively verified.

Interest in synesthesia faded for much of the 20th century, as the burgeoning behaviorist approach discouraged the study of subjective experience. It resurfaced in the 1980s and 1990s as cognitive science and neuroscience advanced, with researchers demonstrating that synesthesia can be studied objectively (e.g., [Ramachandran & Hubbard, 2001](#)). Early studies were based on single cases and small samples. Over time, the field has grown into a vibrant, interdisciplinary area of research spanning psychology, neuroscience, philosophy, and the arts.

## Core concepts

### *Inducer and concurrent*

Synesthesia is not understood as a disorder but as a neurodivergent human trait. The stimulus that triggers a synesthetic experience is called an *inducer* (e.g., the letter A). The synesthetic experience is called the *concurrent* (e.g., a red color experience). The inducer can be presented in different formats and elicit the same concurrent (e.g., [Figure 1A](#); [Ward, 2013](#)). The best-studied forms include grapheme–color, sequence–space, and lexical–gustatory synesthesia. In grapheme–color synesthesia, letters or numbers evoke specific colors; in sequence–space synesthesia, sequences such as weekdays or months appear in spatial layouts; and in lexical–gustatory synesthesia, words trigger distinct taste sensations.

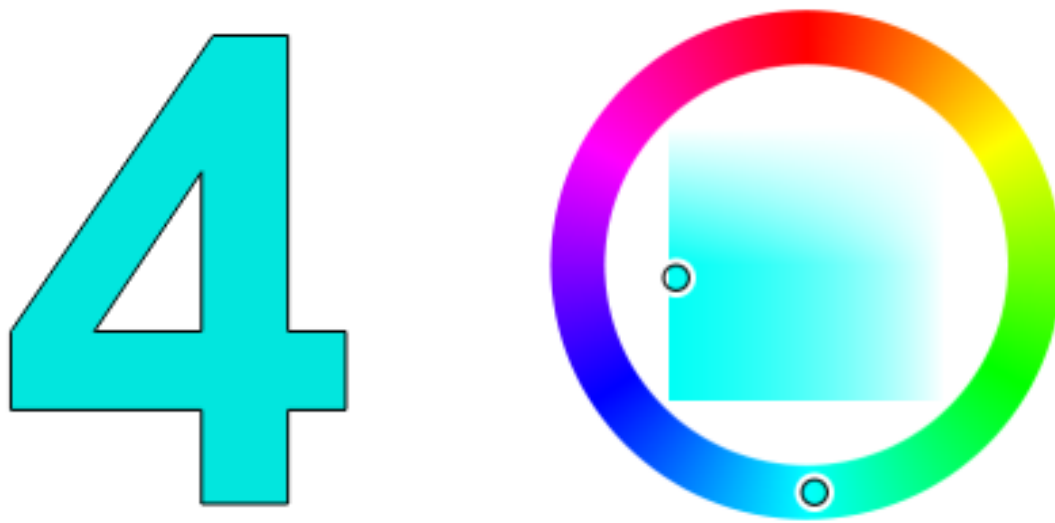


**Figure 1**

(A) The inducer can be presented in different formats and elicit the same concurrent. (B) In a synesthetic Stroop task, participants are presented with inducers which are either consistent or inconsistent with the concurrent experience. (C) “I3” might elicit different colors depending on whether it is interpreted as “B” as in “A I3 C” or “I3” as in “I2 I3 I4.”

## Consistency

Synesthetic experiences are consistent over time. To diagnose synesthesia, this feature is verified by means of consistency tests ([Figure 2](#)). Participants must repeatedly determine their concurrent experience in response to potential inducers. Synesthetes are highly consistent in these tests because they can rely on their experiences while nonsynesthetes must memorize random associations ([Eagleman et al., 2007](#); [Rothen et al., 2013](#)).



**Figure 2**

An example of consistency test, with the presentation of a potential inducer (i.e., grapheme) and potential concurrent experiences (i.e., color palette). Note that in this specific version, the outline of the inducer is filled with the selected concurrent color.

### ***Automaticity***

Synesthetic experiences are automatically triggered and not under voluntary control. This is demonstrated with synesthetic Stroop tasks, in which participants are presented with inducers that are either consistent or inconsistent with the concurrent experience (e.g., “A” in red text or “A” in blue text; [Figure 1B](#)). Synesthetes are faster when the color matches their synesthetic experience in comparison to when the color conflicts with the synesthetic experience. No difference is observed for nonsynesthetic individuals ([Dixon et al., 2004](#)).

## ***Idiosyncrasy***

Synesthesia is generally very heterogeneous. The experiences are highly specific (e.g., eggshell white instead of just white) and idiosyncratic, but systematic patterns can be observed on a larger scale (e.g., A is often red). The phenomenology can differ considerably across individuals. For instance, some grapheme–color synesthetes report seeing the colors in front of their mind’s eye (i.e., *associators*), and others report seeing the colors projected onto the surface where the inducer is located (i.e., *projectors*; [Dixon et al., 2004](#)). Moreover, there are more than 75 different types of synesthesia known today, but not all have been objectively confirmed ([Day, 2022](#)).

## ***Neural basis***

Neuroimaging studies suggest that the neurophysiological basis of synesthetic concurrents involves activation in sensory brain areas responsible for processing the relevant physical properties, such as area V4 of the visual cortex, which is specialized in color perception. The parieto-occipital junction appears to play a key role in binding the *inducer* and the *concurrent* into a unified, integrated perceptual experience ([Hubbard et al., 2005](#); [van Leeuwen et al., 2010](#); but see [Hupé & Dojat, 2015](#)).

## **Questions, controversies, and new developments**

### ***Is synesthesia a categorical trait or a continuum?***

Traditionally synesthesia has been regarded as a rare categorical trait ([Simner et al., 2006](#)). However, there are individuals who report less consistent synesthetic experiences or synesthetic experiences for a very limited subset of inducers (e.g., a small number of letters). Moreover, weaker crossmodal associations apply to the general population (e.g., higher tones are generally associated with lighter colors). Hence, synesthesia might be a somewhat exaggerated form of general multisensory integration ([Martino & Marks, 2001](#)).

### ***Is synesthesia innate or learned?***

Synesthetic traits tend to run in families, suggesting a genetic basis ([Barnett et al., 2008](#); [Tilot et al., 2018](#)). By contrast, synesthesia is often triggered by cultural artifacts, depending on context and interpretation rather than low-level visual perceptual features, suggesting a learning component in its development. For instance, “13” might elicit different colors depending on whether it is interpreted as “B” as in “A 13 C” or “13” as in “12 13 14” ([Figure 1C](#)). Further evidence for learning is based on studies suggesting that exposure to educational materials may determine synesthetic associations ([Witthoft & Winawer, 2006](#)).

### ***Can synesthesia be acquired?***

Most of the studies seem to suggest that it is not possible to acquire synesthesia ([Rothen & Meier, 2014](#)), but more recent studies including more extensive training regimes suggest that it might indeed be possible to acquire synesthesia later in life ([Bor et al., 2014](#); [Rothen et al., 2018](#)).

## Broader connections

Synesthesia offers a window into broader questions in cognitive science. It is a tool to study individual differences from a healthy human special population perspective. It informs how perceptual diversity may support mental imagery ([Price, 2009](#)) and creativity ([Ward et al., 2008](#)) [see [Mental Imagery](#)]. It offers insight into how language interacts with perceptual systems ([Mankin, 2019](#)) [see [Language](#)]. It also challenges assumptions about the boundaries between perception and memory ([Ovalle-Fresa et al., 2021](#)) [see [Memory](#); [Visual Memory](#); [Working Memory](#)].

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