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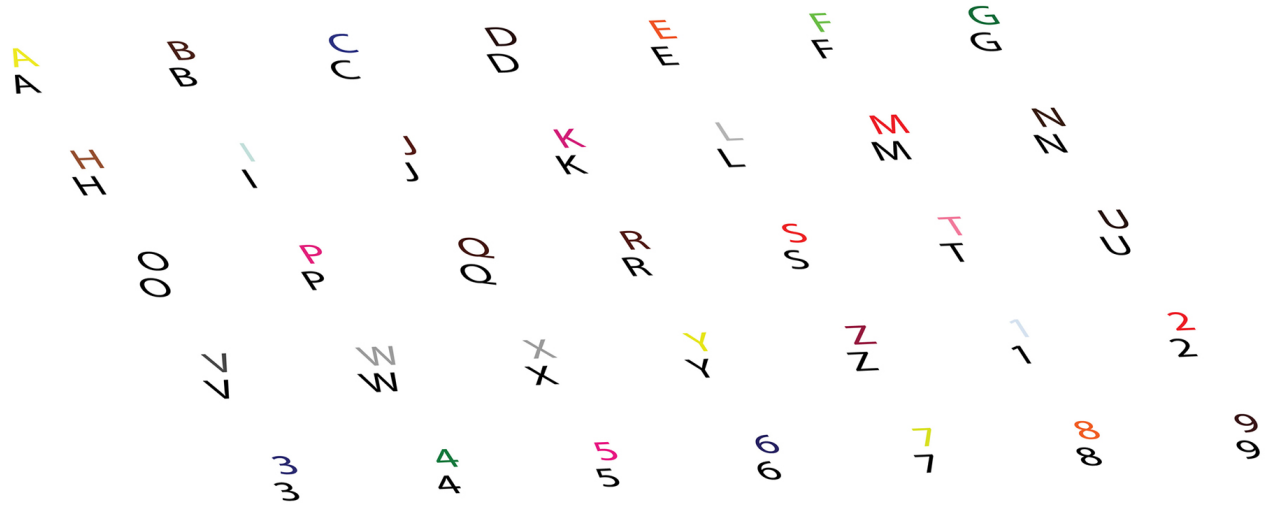
Hearing colours: On a remarkable phenomenon with philosophical implications

By Berit Brogaard and Kristian Marlow

Synesthesia is an unusual way of perceiving the world, in which stimuli provoke atypical phenomenology. For example, the number 3 may lead to a perception of copper green, the word "kiss" may flood the mouth with the flavor of tomato soup and the key of C# minor may elicit a slowly expanding purple spiral.

One of the best-known forms of color synesthesia is grapheme-color synesthesia, in which numbers or letters are seen as colored. But lots of other forms of color synesthesia have been identified, including week-color synesthesia, sound-color synesthesia, taste-color synesthesia and fear-color synesthesia.



Projector Versus Associator Synesthesia: "Projector" synesthetes experience colors as out in the world while "associators" experience colors in the mind's eye.

But there are also less known forms of synesthesia. Lexical-gustatory synesthetes experience taste sensations when they hear or think about words. Music-touch synesthetes claim to actually "feel" music. Such is the case with one of our lab's case studies, Megan. She feels the sounds of a piano literally "poking" at her face. String instruments vibrate in her chest. Waves from brass instruments pass in front of her, sometimes buzzing on her neck. Drums come up from below. Intensity increases with volume but these sensations are never unpleasant, as Megan feels like she is in the music.

It is still unclear what exactly underlies this extraordinary phenomenon. In fact, synesthesia may not be a single condition. The most widely discussed cases of synesthesia, such as grapheme-color and week-color synesthesia, are developmental. They start in early childhood, perhaps even earlier. But sometimes the condition is acquired after an accident, a stroke or a seizure, and it can also occur while under the influence of hallucinogenic drugs, such as LSD, magic mushrooms, and DMT. No one knows whether all conditions referred to as “synesthesia” have similar underlying causes. However, there appear to be commonalities among the cases.

One mark of color synesthesia is that the synesthetic colors are seen either as projected out onto the world (“projector synesthesia”) or in the mind's eye (“associator synesthesia”). Projection is experienced much like veridical perception, that is, the concurrent experiences are located in the visual scene outside of the synesthete’s mind. While some synesthetes who experience projection report seeing concurrents that float above their inducers, others describe experiences similar to seeing afterimages or phosphenes.

A second mark is that synesthetic experience is automatic, that is, synesthetes cannot help but experience a particular association once stimuli are interpreted. They cannot suppress the association between an inducer and its concurrent. Just as the smell of fresh baked cookies would bring on thoughts of the cookies themselves, synesthetes cannot help but experience a synesthetic concurrent when an inducer is presented to them.

A third characteristic of synesthesia is its test-retest reliability: Colors identified by the subject as representative of her synesthetic experiences relative to a given stimulus in an initial testing phase remain nearly identical to colors identified by the subject as representative of her synesthetic experiences relative to the same stimulus in a retesting phase at a later time. Reliability can be determined using the *Synesthesia Battery*, an online test developed by neuroscientist David Eagleman. The test doesn’t merely require that synesthetes pick among a simple list of colors - synesthetes are faced with a color palette with close to 17 million distinct color choices. Yet synesthetes are able to repeatedly choose very similar colors for particular graphemes.

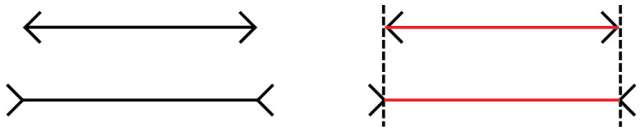
Synesthetic color experience typically is unique for each synesthete. For example, the letter A may trigger the color red in one grapheme-color synesthete but trigger the color blue in another. In fact, each grapheme has been found to trigger each of the 11 Berlin and Kay colors (red, pink, orange, yellow, green, blue, purple, brown, black, white, gray) in different synesthetes. Despite the uniqueness of synesthetic color experience, synesthetic colors sometimes fall into certain clusters. For example, grapheme-color synesthetes tend to associate A with red, E with yellow or white, I with black or white and O with white.

So what is this odd phenomenon called synesthesia, really?
But what exactly is this odd phenomenon called synesthesia? Is it a way of seeing the world? Or is it like visual images in your mind? One way to look at it is as a kind of misperception of the

world, an illusion or a hallucination. Cognitive neuroscientist Jamie Ward has argued that we should “distinguish synesthesia from seemingly similar phenomena such as illusions (in which the inducer is, in some sense, misperceived) and hallucinations (a concurrent without an inducer).” In synesthesia, unlike in ordinary illusions and hallucinations, the inducer is frequently perceived correctly, even if it also gives rise to a concurrent experience. However, while it is true that synesthesia typically differs from more well known illusions and hallucinations, synesthesia satisfies the normal philosophical characterization of these phenomena.

What we call an ‘illusion’ is not simply a failure of the perceptual system to precisely mirror the stimulus, as the perceptual system never completely mirrors the stimulus. Rather, it’s an *aberrant* (conscious) misperception of a trait of an actual object defined relative to normal veridical experiences of neurotypical perceivers. A hallucination, on the other hand, is an aberrant (conscious) misperception of an object that isn’t there. A grapheme-color synesthete who perceives a grapheme printed in black as black but also perceives it as green is misperceiving a trait of the grapheme in a way that is unusual compared to the general population. So her experience is illusory. A synesthete who experiences the time of day and the months of the year as being in a space around her body, on the other hand, is experiencing a space that doesn’t exist. So her experience is hallucinatory. Whether we choose to call synesthetic experiences ‘illusory’ or ‘hallucinatory’ or something else is a verbal issue.

Many synesthetes know that the world isn’t the way that they see it. This phenomenon is also called a “known illusion” or a “known hallucination.” The illusion is apparent in the Müller-Lyer figure. In this illusion you have a perceptual appearance of two line fragments being of unequal length despite the fact that you know they have the same length.



The Müller-Lyer illusion: In this illusion you believe the lines are of the same lengths but no matter how long you look, your continue to experience the bottom like as being longer than the top line. This illustrates a case in which perceptual information is encapsulated from belief influence.

This is called a “known illusion” because you know that what you experience isn’t so. But some synesthetes, particularly children, do not know that the world is not as they experience it. This is evident in an interview we conducted with one of our research participants RS (at age 5):

RS: Sometimes I see it. Sometimes it’s out in front of me.
E: Is it like seeing something or thinking that something is the case?
RS: It’s like seeing something, and my brain is telling me.
E: Is it exactly like seeing something?
RS: Both, you know...

E: Can everyone see the same colors as you can when they think about numbers?
RS: Not everyone, because not everyone thinks very well about numbers.
E: Are the colors in your head?
RS: Yes, and I am seeing them too.
E: Are numbers printed in colors?
RS: No, they are printed in black but that's because they don't know what colors they are.

So synesthetes are not always aware that their experiences are different from other people's. However, despite holding idiosyncratic beliefs about the world, they are not typically delusional, as they do not normally hold onto these beliefs once they realize that they see the world differently from most people. Synesthetic experience should also be kept apart from schizophrenic experience. A basic mark of schizophrenic experience is that the deluded attributes the thought or experience to a foreign agent. Unlike schizophrenics, however, synesthetes don't have the feeling that a foreign agent has planted the vision or sound in their head. Their synesthesia is merely a part of how they experience the world.

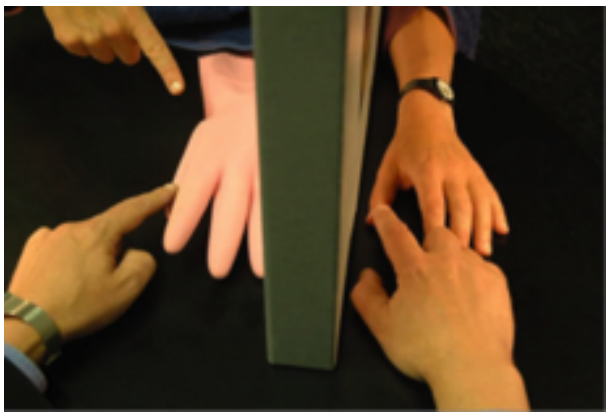
Synesthesia may cast light on other seemingly unexplained sensory phenomena, many of which are believed to be spiritual in origin. For example, one mystery is how some so-called healers and psychics are able to reliably describe people's auras. An aura is a supposed energy field of luminous radiation surrounding a person as a halo, imperceptible to most people.

At the 2011 *Toward a Science of Conscious Conference* in Stockholm, we stumbled upon Naama Kostiner, a self-proclaimed psychic and synesthete. Naama was able to provide descriptions of dozens of people's auras and then repeat every word a few days later. Her claim that she actually did see people's auras was very convincing. The reliability of her descriptions called for an explanation.

Recently Emilio Gómez Milán and his colleagues in Spain found that the ability to see people's auras probably is a form of synesthesia, which they call "emotional synesthesia." To carry out the study, the researchers interviewed synesthetes, including a "healer" from Granada, Esteban Sánchez Casas, known as "El Santón de Baza." The local people believe El Santón has paranormal powers but the researchers found out that what he has is a form of synesthesia. El Santón has face-color synesthesia and touch-mirror synesthesia. Face-color synesthesia arises when there is neural connection between face processing and color. For these synesthetes, different faces are associated with unique colors. Mirror-touch synesthesia is a phenomenon where a person feels the same as a person she can see being touched. For example, if a mirror-touch synesthete sees you being touched on the right shoulder, she too will feel a sensation of being touched on the shoulder.

The latter kind of synesthesia may be interestingly related to the *rubber hand* and *out-of-body* illusions. The rubber hand illusion is easy to generate. Put one of your arms behind a screen or

box on the table, so you can't see it. Put a fairly realistic rubber hand on the table in a position that will make it look like it's your hand. Then ask a friend to stroke both your real hand and the rubber hand in the same way while you look at it. In most cases people have the sensation that the rubber hand actually belongs to them. If the friend suddenly hits the rubber hand very hard, they jump.



The Rubber-Hand Illusion: In this illusion, watching a rubber hand being stroked while feeling your own hand being stroked temporarily causes you to experience the rubber hand as your own.

Swedish neuroscientist Henrik Ehrsson, the first to demonstrate the rubber hand illusion, managed to induce out-of-body experiences in normal individuals. Thirty-two participants were wearing a head-mounted display connected to video cameras in such a way that the images from the left and right video cameras of a life-sized mannequin were presented to the participants' left and right eyes. The two cameras were positioned in such a way that the images from each of them corresponded to the mannequin's eyes. The researchers would then stroke each participant's abdomen and that of the mannequin identically. After doing this for two minutes the participants perceived the mannequin's body as their own. The researchers then pretended to cut the mannequin's body with a knife. The participants showed much greater increase in anxiety compared to controls whose stomachs were not stroked in the same manner as the mannequin's.

The rubber-hand and out-of-body illusions illustrate how sight, touch and proprioception, or bodily sensations, combine to create a feeling of body ownership. In touch-mirror synesthesia, seeing someone else being touched apparently leads to a feeling of being touched in the same place. The illusion apparently is active in these synesthetes without conditioning by rubber hands and mannequins.

The Neural Mechanism of Color Synesthesia

The precise neural mechanism underlying synesthesia is unknown. Most hypotheses concern the most studied type of synesthesia: grapheme-color synesthesia. One theory is that

grapheme-color synesthesia arises due to cross-activation between color areas in the visual cortex and the adjacent visual word form area.

A second is that grapheme-color synesthesia may be due to disinhibited feedback from an area of the brain that binds information from different senses. The fact that synesthetic experiences can arise when subjects are under the influence of psychedelic drugs, such as LSD or psilocybin, provides further evidence for the disinhibited feedback hypothesis. The synesthetic effect of psychedelic substances may be due to an inhibition of feedback resulting in increased activity in the areas of information binding. It is unknown, however, whether drug-induced synesthesia and congenital synesthesia have the same underlying mechanism. Although the phenomenology might be similar, the way it's generated may vary.

The extent to which synesthesia is idiosyncratic has been a subject of much debate. It is possible that grapheme-color associations are learned during childhood. For example, some authors have suggested that grapheme-color associations often match the colors of the alphabet refrigerator magnets found in the homes of many children. Many researchers have responded that the evidence is nothing more than anecdotal and thus does not support the theory that these associations can be learned.

However, one recent study provides the evidence proponents of a memory model have been looking for. Researchers looked at the letter-color associations of 11 grapheme-color synesthetes that reported growing up with the same Fisher-Price refrigerator magnets. Using a standardized synesthesia battery that measures differences in color associations, the team found a striking similarity of letter-color associations among the synesthetes and nearly all color associations matched the colors of the Fisher-Price refrigerator magnets. This is an amazing result! The fewest matches among the 11 subjects was 14 letters. The chance that 11 synesthetes would choose the same color for 14 out of 26 letters of the alphabet is less than 1 in a billion! Such a striking result suggests that memory plays a crucial role in at least some cases of grapheme-color synesthesia.

Letter-Color Matching Data from the 11 Subjects: Letter-color pairs matched for 14 out of 26 letters of the alphabet. These results are impressive considering that the chance that 11 individuals chose 14 out of 26 possibilities in a particular order is less than 1 in a billion!

But how exactly is memory involved in forming grapheme-color associations? Our lab has proposed that the automatic association between graphemes and colors in grapheme-color synesthesia is much like the automatic association between smell and memories. For example, the smell of chlorine may automatically induce visual images of a particular pool party. In the case of smell, the tight association presumably is formed immediately as a result of the negative value of an event.

According to a recent model of memory, which we might call the ‘reactivation model’, the hippocampus is not a storage space for information but a region of the brain in charge of maintaining connections between neural networks located in different areas of the brain.

Working memory in the prefrontal cortex and hippocampus work in tandem. The hippocampus

guides the depositing of proteins at the synapses of neurons in areas that originally processed the information to be remembered. Together with neighboring hippocampal areas it also keeps track of the relative order of events and binds together events that belong together. Memory retrieval by working memory reactivates the original areas of information processing by interaction with the executive hippocampus.

On the memory model, synesthesia is the result of an indirect mechanism. The hippocampus would at some point have stored associations between information coming from the area of the brain responsible for generating visual color experience and the one responsible for interpreting symbols. After the formation of these associations, exposure to a black symbol-stimulus would trigger both recognition of the symbol's meaning as well as a memory retrieval of the associated synesthetic color. The retrieval of synesthetic color information from memory would require renewed activity in the visual color area which, in turn, might simultaneously give rise a conscious projection of synesthetic color.

In synesthetes in which graphemes and colors truly are bound together to the extent that graphemes literally are seen as having colors, the hippocampus may be treating the distinct neural networks the way it normally would with form and color that belong together (e.g., tomato and red). In cases in which the grapheme and color are not tightly bound together, the hippocampus must be treating the neural networks more like involuntary quick associations, such as the association between the striking of a match and its being lit.

It is plausible that different forms of color synesthesia proceed via different mechanisms. Cases of color synesthesia have been reported in which the visual cortex is not involved in generating synesthetic colors. None of the aforementioned hypotheses, despite their plausibility in run-of-the mill cases, can fully explain more unusual cases of color synesthesia.

Cognitive Advantages of Synesthesia

Having senses that collide can in rare cases be a debilitating condition, such as when all the rainbow's colors brutally penetrate the visual field of a particularly sensitive sound-color synesthete. Most synesthetes, however, describe their aberrant sensations as pleasant. Some experience the condition as an inner art exhibit or a natural wonder.

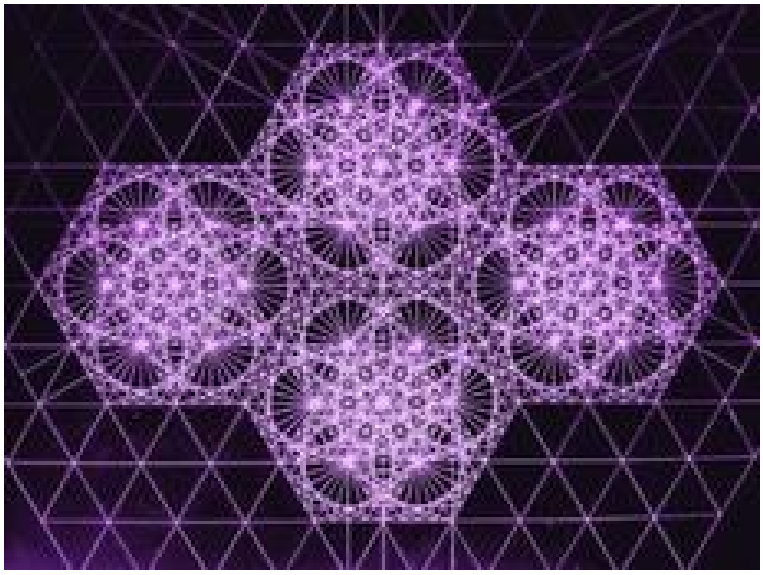
Synesthesia is not only aesthetically gratifying, it also helps the synesthetically gifted look inside the minds of others, see connections between seemingly unrelated ideas, and access parts of the brain that normally remain hidden from consciousness. Some synesthetes have apparent, superhuman insights into the thoughts and feelings of fellow humans, others are equipped with incredible memory skills or admirable artistic acumen, and yet others are able to influence stubborn minds by instantiating their atypical sensory connections in work environments or commercial settings.

Many synesthetes report that the condition can be helpful in day-to-day activities. For example, grapheme-color synesthetes may find it easier to recall phone numbers because the colors

associated with numbers provide an additional memory cue. Other synesthetes associate particular spatial locations with calendar dates, which can help these individuals remember certain events. In addition to these simple benefits, a small set of synesthetes can use their experiences to perform seemingly superhuman tasks.

Autistic savant and synesthete Daniel Tammet sees numbers as three-dimensional colored forms. His synesthesia gives him the ability to multiply high digits very rapidly. He reports that the product of multiplying two numbers is the number that corresponds to the shape that fits between the shapes corresponding to the multiplied numbers. Tammet's color synesthesia also gives rise to extreme mnemonic skills. Tammet currently holds the European record in reciting the decimal points of the number pi. A functional magnetic resonance imaging (fMRI) study comparing Tammet to controls while attempting to locate patterns in number sequences indicated that Tammet's synesthetic color experiences occur as a result of information processing in non-visual brain regions, including the temporal, parietal and frontal areas.

In previous work we have described the case of Jason Padgett, who has exceptional abilities to draw complex geometrical images by hand and a form of acquired synesthesia for mathematical formulas and moving objects, which he perceives as colored, complex geometrical figures.



One of Jason's Drawings: After his accident, Jason started to draw complex imagery using only a ruler and compass.

Jason's synesthesia began in the wake of a brutal assault that led to unspecified brain injury. A fMRI study contrasting activity resulting from exposure to image-inducing formulas and non-inducing formulas indicated that Jason's colored synesthetic images arise as a result of activation in areas in the temporal, parietal and frontal cortices in the left hemisphere. The image-inducing formulas as contrasted with the non-inducing formulas induced no activation in the visual cortex or the right hemisphere. These two unusual case studies suggest that at least some forms of color synesthesia can give rise to cognitive advantages in the area of

mathematics.

Another one of our case studies show that synesthesia may lead to enhanced musical abilities. Derek Amato started seeing little black and white squares that constantly flow across his field of vision after suffering a severe concussion in a pool accident. “It’s like a ticker tape rolling around my brain,” Derek explains. Three days after the incident he sat down and started playing the piano like a pro despite having no musical training. He explained that he merely follows the black and white blocks. They tell him where his fingers should go. It’s the endless flood of black and white squares that drives Derek’s compulsory movement of fingers and urge to get relief through playing. His hands interpret the squares one at a time. Each square is a musical note corresponding to a finger position on the piano. It may not be obvious that Derek’s visual imagery is a type of synesthesia. However, we believe it is a type of emotion-color/form synesthesia triggered by anxiety he developed after his accident.

Synesthesia remains of interest not only to neuroscientists and psychologists, but to philosophers as well. Philosophical theories of mind should be able to explain normal cases of consciousness or perception, but they should also be able to explain the unusual cases. In the wake of conditions like synesthesia we may find that some of our long-held theories are in need of revision. But there’s a long road ahead, for research on the condition is still in its infancy. It’s up to us philosophers to determine what sort of insights these conditions might provide.