Synesthesia

Sometimes, you really do eat your words

By **John Wilhelm**

As far as State of the Union speeches go, you have a few clear favorites. In short, Harry Truman's 1946 address was cogent—he balanced partisan tensions and maintained a lighthearted, likable demeanor. Franklin Delano Roosevelt's 1941 address on the immediate cusp of WWII was no less impressive; you might argue it formed the backbone of modern liberalism. But nothing compares to Abraham Lincoln's speech on December 1st, 1862. When the country needed it most, Lincoln stepped in to announce the emancipation proclamation. His writing was eloquent, his delivery was immaculate—or so say the first-hand accounts. The most impressive, though, beyond all of Lincoln's talents, was his ability to write a speech that tasted just like a home-cooked thanksgiving dinner. He was great at keeping consistent taste throughout his speeches. FDR, on the other hand, while his verbiage wasn't bad, he could never keep his flavors cohesive. When he discussed international relations, you couldn't help tasting overdressed salad, excess bleu cheese, and flour. While Truman's commentary on military management was great by all accounts—it just tasted like onions, onions, onions.

If nothing struck you as odd halfway through that last paragraph, then congratulations—you might be a lexical-gustatory synesthete! It is not often that words carry a palpable flavor, but this is nothing out of the ordinary in lexical-gustatory synesthesia—a condition where written or spoken words elicit an involuntary association with a specific taste.[1] Of course, this is not limited to food-related words; if I said 'delectable filet mignon,' I would not blame you for getting a hint of tender steak—but any lexical-gustatory synesthete could feel the same way about the word 'bunion.' It is also worth noting that, in reality, it would be quite rare for an entire speech to taste so cohesive to a lexical-gustatory synesthete. Often, words have very distinct, disparate tastes; the word 'woman' might taste like potato chips, where something as innocuous as the word 'by' could taste like sewage gas.[1] In that case, a single one of FDR's sentences in a State of the Union address

Type of Synesthesia	Lexical-Gustatory	Grapheme-color	Ordinal Linguistic Personification	Mirror-touch	Spatial Sequence	Tone-color (Chromesthesia)
What neural pathways are combined?	Words & taste	Words & color	Words & sense of identity	Vision & touch	Temporal & spatial	Sound & color
How does the synesthete experience it?	Synesthete tastes words, either spoken or read aloud	Synesthete sees letters as colored	Synesthete sees individual letters as having personalities	Synesthete feels physical touch that they observe	Synesthete sees time as a spatial construct	Synesthete sees music notes as having a specific color
How common is it?	Very rare, *far* less than 1% of population	Common; roughly 1% of population	Often co-occurs with grapheme-color synesthesia, fairly common	Second most common type of synesthesia, 1.6%	Prevalence unknown; few studies	Rare; under 1% of population; but more common in musicians

could jump from completely palatable words to absolutely repulsive ones in a matter of seconds; but, in my defense, this makes for a more confusing introduction.

Lexical-gustatory synesthesia is far from the only condition of its type. Broadly, synesthesia is a phenomenon in which two neural pathways form a "long-distance relationship"—stimuli of one perceptual pathway elicit a response in another.[1] There are more than 60 documented types of synesthesia.[1] For example, of a word or letter might provoke the feeling of a certain color (grapheme-color synesthesia), as could hearing a specific music note (tone-color synesthesia). The associations in synesthesia tend to be bidirectional, so for a tone-color synesthete, musical tones elicit colors and colors elicit musical tones.[3] Previously, synesthesia was thought to be an incredibly rare condition affecting less than 1 in 2000, people, but it is now known that roughly 4% of the population has some type of synesthesia.[4] Though they are grouped under the same name, types of synesthesia can look very different. For example, visualization of time as a spatial construct around the synesthete (Spatial Sequence Synesthesia), and associating concrete personalities with letters and numbers (Ordinal Linguistic Personification) are also considered synesthesia.[5,6] Types of synesthesia also vary greatly in how common they are, and how much scientists understand about them. So, how does synesthesia work? What is going on in the brains of synesthetes?

Lexical-gustatory synesthesia

As types of synesthesia go, lexical-gustatory is on the uncommon side, affecting very few people—less than 1% of the population.[4] Lexical-gustatory synesthesia is so scarce that there are next to no aggregate studies of individuals with the condition; all of them take the form of case studies—or long-term, in-depth analyses of a particular individual. While a case study might not have the explanatory power of a hundred-participant meta-analysis, they provide a detailed picture of the individual in question. The major risk of a case study is generalizing the results beyond the appropriate context, so it is important to be measured when extrapolating from case studies.

At this point you might be wondering how researchers verify that a person has lexical-gustatory synesthesia in the first place. It is hardly as simple as putting up a "volunteers wanted" sign at your local community center. This is a concern when studying any type of synesthesia—verifying that an individual is indeed a synesthete can be a difficult task, since synesthesia is an internal, perceptual phenomenon. Nonetheless, synesthesia researchers have developed many paradigms to this end, which vary widely between types of synesthesia. In the case of lexical-gustatory, researchers verify an individual's synesthesia by a months-long 'pop quiz' model.[7,8] They begin by establishing a list of ~100 word-taste associations with the synesthete. Months later, they quiz the synesthete on the same associations without prompting—the synesthetes are almost always 100% accurate, except in cases of synonyms (e.g. the synesthete might claim the word 'table' elicits the taste of 'biscuits' instead of 'wafers'). Researchers have extended this paradigm by decades. In one case, a lexical-gustatory synesthete had 100% consistent answers 27 years after the initial study.[8]

It is difficult to generalize the nature of lexical-gustatory synesthesia from any individual

"Word cloud of apple." Pixabay, 23 June 2015, cdn.pixabay.com/photo/2015/06/22/15/38/tag-817712_960_720.jpg.

case study, but most have a few things in common. For instance, lexical-gustatory synesthetes' tastes tend to be quite distinct, including texture and temperature sensations—e.g. a synesthete would not just taste "beer," they would taste "bitter, flat beer."[7] Most lexical-gustatory synesthetes also have "tasteless" words, though the amount of tasteless words varies between synesthetes—one synesthete might "taste" every word in a 100-word sample, but another might only taste 44%.[7] Additionally, the semantic meaning of the word seems to influence taste associations for most synesthetes. Generally, food-words taste like the food they describe ('cabbage' tastes like cabbage), but this extends to indirect semantic associations ('newspaper' tasted like 'chips' to a UK synesthete, where chips are often eaten out of newspaper.[8]

The actual sound of the word appears to influence taste association, as well. For lexical-gustatory synesthetes, the taste sensation provoked by real words ('beach') can also be provoked by similar-sounding 'non-words,' ('keach'). Additionally, lexical-gustatory synesthetes seem to link specific individual sounds to specific flavors.[1] A case study of synesthete "JIW" demonstrated that his synesthetic flavors were connected to specific phonemes (indivisible units of sound, like the /t/ in table). Of the 17 words which elicited the taste of 'cake,' 10 of them contained the /m/ phoneme. This means that words containing the sound /m/ (as in 'mice') were highly associated with the taste of cake for JIW, significantly more so than any other individual sound. Other tastes were linked to sounds in the same manner—for example, the taste of 'yogurt' was highly linked to the sound /g/ (as in gosh) and the taste of 'egg' was linked to the sound /k/ (as in 'key').[8] The reason for these associations is unclear, but it is peculiar that words containing /m/ taste like cake, but the word "cake" does not contain /m/—this holds true for most lexical gustatory associations.

Because of the scarcity of lexical-gustatory synesthetes, little is known about the neural basis of the condition. Of the few neuroimaging studies available, preliminary evidence suggests that the "taste" experienced by synesthetes has a different neural basis than the taste experienced by eating food. When observing the neural activity of a synesthete in response to taste-inducing words, researchers did not see activity in the orbitofrontal cortex or anterior cingulate cortex, regions responsible for processing "normal" taste.[9] The researchers did observe that displeasing synesthetic tastes induce activity in the left anterior insular cortex—a region associated with emotional responses to sensory experiences, particularly smell and taste.[9,10] This could indicate that while the neural basis of synesthetic taste is not the same as "normal" taste, the disgust experienced upon hearing the name Derek[1] is just the same as an individual tasting earwax.

1 "Derek Tastes of Earwax" (September 2004) is a BBC horizon documentary about a lexical-gustatory synesthete - apologies to all the Dereks out there.

Culture and upbringing are two additional but poorly understood factors of lexical-gustatory synesthesia. Synesthete PS, a native English and French speaker, experienced gustatory sensations in both languages, but not in Spanish, which she picked up at the age of 9.[11] On one hand, this could support the idea that synesthesia arises due to associations formed in childhood. On the other hand, perhaps her lack of synesthesia was due to her level of fluency; after enough Spanish work, "Otorrinolaringólogo" might start to taste like pizza. Likewise, the exact stimuli required to elicit a gustatory response are ambiguous—for instance, PS did not experience taste when listening to an individual read words in quick succession, but other synesthetes experience taste from spoken words, written words, and even ambient noise. As fascinating as the condition is, much remains to be discovered about lexical-gustatory synesthesia.

Grapheme-color Synesthesia & Ordinal Linguistic Personification

"'One day,' I said to my father, 'I realized that to make an 'R' all I had to do was first write a 'P' and then draw a line down from its loop. And I was so surprised that I could turn a yellow letter into an orange letter just by adding a line.'"[39]

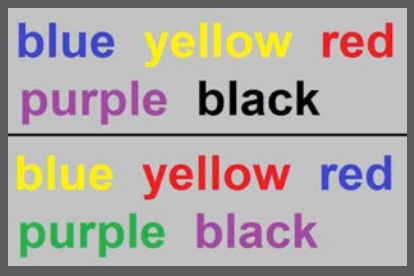
Patricia Lynne Duffy, both a researcher and synesthete herself, remembers discussing her synesthesia with her father at the age of 16. Her father was completely

baffled by Duffy's account of her synesthesia—and she was equally baffled that he did not see letters as colored. While it would be unlikely for a lexical-gustatory synesthete to spend decades of their life without realizing they have synesthesia, it isn't uncommon for grapheme-color synesthetes.[1] Grapheme-color synesthetes associate graphemes (the smallest units of written language, e.g. letters, numbers, symbols) with a distinct color, regardless of the physical color of the grapheme.[1] These colors are quite specific to the synesthete with the exception of a few letters—across synesthetes, "A" is often red, "B" is often blue, and "C" is often yellow.[12] Grapheme-color synesthesia affects 1% of the population, making it one of the most common types of the condition.[4] Like most versions of visual synesthesia, grapheme-color synesthetes can be broken down into two categories: "projective" and "associative." When viewing a grapheme, associative synesthetes have a strong internal feeling of a particular color, but projective synesthetes see the color physically represented on the grapheme. Associative synesthesia is much more common than projective.[13] Grapheme-color synesthesia frequently co-occurs with a type of synesthesia called "ordinal linguistic personification" (OLP). To an OLP synesthete, graphemes have distinct personalities, identities, and motivations—for example, "3" might be a concerned businesswoman working hard to support her child's education, while "5" is a young, bright-eyed rock musician and "Q" is a kindly grandmother.[1]

"ABC-Kids." Public Domain Pictures, www.publicdomainpictures.net/pictures/210000/velka/abc-kids.jpg.

To verify that an individual has grapheme-color synesthesia, researchers employ an altered version of the Stroop task (depicted below) which you can try now, for yourself.

For most individuals, reading the color of the ink in the incongruent condition (below the black line) is harder than reading the color of words in the matching condition. This occurs because of "semantic interference," where the semantic meaning of the word makes naming the physical color more difficult.[14] In an altered Stroop task, synesthetic participants name the synesthetic color of the individual graphemes in the word.[15] This is easier if the graphemes in the word match its semantic meaning (e.g. a synesthete who sees "e" and "l" as blue reads the grapheme colors of "blue") and harder if they are inconsistent (the same synesthete reads the grapheme colors of "yellow"). For an OLP synesthete, an altered Stroop task consists of quickly stating the gender of names, in rapid succession.[6] A synesthete who considers "J" a female letter is quicker to identify "Jillian" as a female name than "James" as a male name. While the altered Stroop paradigm serves to verify synesthesia, it can also demonstrate its intensity. Recording the change in participants' response time between normal and altered Stroop tasks provides a picture of how much synesthesia interferes with participants responses—a high level of interfer-



1) Read the words above the black line
2) Read the words below the black line
3) Read the colors of the ink above the black line
4) Read the colors of the ink below the black line

"Stroop Test 2." Wikipedia, the Free Encyclopedia, 18 Nov. 2012, en.wikipedia.org/wiki/File:Stroop_Test_2.jpg.

ence indicates strong synesthesia.[15]

Owing to its commonality and long history (descriptions of grapheme-color synesthesia date as far back as 1812) most neuroimaging research on synesthesia has been carried out in grapheme-color synesthetes.[16] Unfortunately, meta-analyses show that the lion's share of neurophysiological studies have been inconclusive, inconsistent in methodology, or statistically erroneous.[17] As a result, it remains impossible to conclusively define any neural correlate of synesthetic color. Despite this, there is one peculiar result—research has shown that the synesthetic colors evoked by graphemes do not change activation of the visual cortex. One explanation for this is that real and synesthetic colors are processed differently altogether, similar to how the synesthetic taste of lexical-gustatory synethetes differs from "normal" taste. This could also be explained by a difference in connectivity, e.g. in a grapheme-color synesthete, the regions responsible for color processing have a stronger connection to word-processing areas than in a normal individual.[1]

Mirror-touch Synesthesia

"...[She] has a form of synaesthesia in that she experiences touch from purely visual input. She experiences tactile stimulation on the part of her body that mirrors the body part she observes being touched. [She] has spent the whole of her life experiencing touch when she observes touch on others, unaware that the vast majority of the population do not experience similar sensations."[20]

On the list of "Top 10 Types of Synesthesia That Make it Difficult To Watch An Action Movie," Mirror-touch synesthesia clocks in at #1. Mirror-touch is a variant of synesthesia in which watching another person being touched—tapped on the shoulder, poked in the cheek, punched in the face—elicits a similar tactile feeling for the synesthete in the same area. Unsurprisingly, mirror-touch synesthetes tend to score higher than controls on tests of empathy.[18] Researchers have tried to elicit tactile sensations from mirror-touch synesthetes in various ways, but it seems mirror-touch synesthesia is highly specific to observation of physical touch on another human.[19] Flashes of light on an individual do not elicit tactile sensations, nor does observed touch on an inanimate object.

The first formal study of a mirror-touch synesthete occurred in 2005; this makes it one of the more recently characterized variants.[20] Despite this, mirror-touch is among the most common types of synesthesia. A study of more than 500 people at University College London revealed a prevalence of 1.6%.[19] Much like a Stroop task, researchers verify mirror-touch synesthesia by examining response time on a test where two neural pathways are concurrently activated: researchers have synesthetes report the location of touch on their own face while observing touch to another person's face. Specifically researchers look for "mirror-touch errors" (e.g. a synesthete is poked

"Hand in Mirror." Pxhere, 22 Mar. 2017, pxhere.com/en/photo/1229143.

in one cheek while watching someone be poked in the other cheek, and they report a sensation in both cheeks) which are unique to mirror-touch synesthetes.[19]

Now, imagine yourself as a mirror-touch synesthete. You are facing someone who is tapped on their right shoulder—do you feel the sensation on your right shoulder, or your left shoulder? As it turns out, either answer is correct. There are two categories of mirror-touch synesthesia: "specular" and "anatomical."[19] Specular synesthetes feel a sensation as though they are looking in a mirror—a tap on someone's left shoulder elicits a feeling in their right shoulder; while anatomical synesthetes feel a sensation on the observed side. The specular subtype is roughly four times more common; researchers hypothesize that this choice of mental frame may be driven by individuals viewing their own reflections.[19,20]

Unlike other types of synesthesia, the neural basis of

mirror-touch synesthesia may lie in a recently discovered type of neuron, a "mirror neuron." Completely independent of synesthesia, mirror neurons were first discovered in Macaque monkeys, when researchers noticed a peculiar pattern of neuronal firing.[21] Mirror neurons are understood to fire both when an observer watches an action being performed, and when they perform the action themselves.[22] It has been hypothesized that over-activation or an abnormally high amount of mirror neurons could account for mirror-touch synesthesia.[23] While appealing, this explanation incorporates two poorly understood concepts, and mirror neurons are a topic of heated debate in the neuroscience community. A great deal of further research is necessary to support a hypothesis linking these two phenomena.

Origins & Neural Basis of Synesthesia

Beyond those that we have briefly discussed, dozens of synesthesia variants exist. Other prominent types include tone-color synesthesia, where music notes have a specific color, day-color synesthesia, the most common type of synesthesia (prevalence of 2.8%), and auditory-tactile synesthesia, where sounds result in a feeling of touch on the body.[1,4,24] The vast and varying types of synesthesia make it a difficult condition to study. Currently, a major question for researchers is whether or not the varying types of synesthesia are caused by similar mechanisms.

Broadly, proposed mechanisms of synesthesia all suggest that synesthetes have atypical connectivity between brain regions associated with their synesthesia. Though this is the prevailing mentality in the literature, there has yet to be conclusive evidence in this regard. Despite claims of individual studies, a 2015 meta-analysis of neuroimaging literature concluded that "most published studies to date show, in fact, that the brains of synesthetes are functionally and structurally similar to the brains of non-synesthetes."[17]

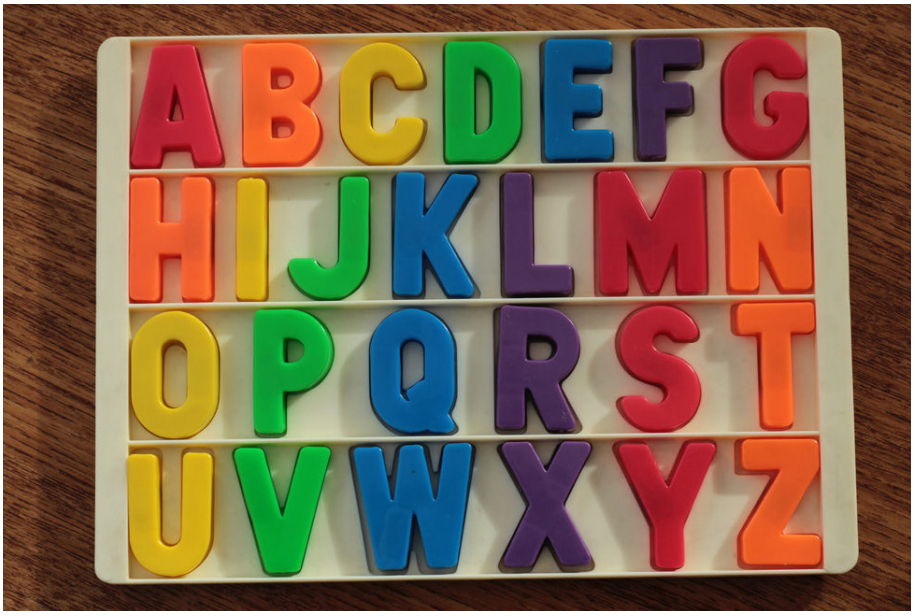
The origins of synesthesia are not completely ambiguous, though. There is a clear genetic component to the condition, multiple studies have found that roughly 40% of synesthetes have another synesthete as a first-degree relative.[25,26,27] Specific types of synesthesia do not appear to be genetically linked. Having a relative with grapheme-color synesthesia makes you more likely to be a synesthete, but not a grapheme-color synesthete; this could support the idea of a shared neural basis between types of synesthesia.[27] Of course, it is also possible that the familial synesthesia reflects a cultural influence, owing to a shared upbringing, or even knowledge of the existence of synesthesia.

Additionally, the evolutionary advantage conveyed by synesthesia may indicate a genetic basis. If synesthesia is an evolutionarily advantageous trait, then it should be preferentially selected for, which could explain the genetic origins of synesthesia. So, what advantages are conveyed by tasting words, hearing colors, and seeing sounds? As it turns out, quite a few. Multiple studies of grapheme-color synesthetes indicate that they have superior color discrimination than non-synesthetes.[28,29] Tone-color synesthesia often co-occurs with perfect pitch, and the prevalence of synesthesia among artists and musicians is at least twice as high as in the normal population.[4] But the benefits of synesthesia aren't limited to creativity. From a very young age, synesthetes tend to have superior memories than non-synesthetes, even if the topic has nothing to do with their synesthesia.[29,30] In particular, spatial-sequence synesthesia—where time is visualized as a spatial construct, normally around the synesthetes' heads—has been studied as the basis for remarkable memories.[31,32] Researchers at the University of Edinburgh propose that spatial-sequence synesthesia is linked to "hyperthymestic syndrome"—an incredibly rare condition where an individual can recall every day of their life in perfect, excruciating detail.[31] Since many individuals with hyperthymestic syndrome are also spatial-sequence synesthetes, it may be that the extra memory cue of spatial-sequence synesthetes' mental maps allows them to remember far more about their lives.

Of course—if synesthesia is governed strictly by genetics, and conveys creative, artistic, and memory benefits, we ought to all be synesthetes by now, surely. But it is unlikely that genetics are the only component of synesthesia. Considering cases of identical

twins where only one twin was a synesthete, it is clear that synesthesia has a social component.[28] In particular, the individual differences in synesthetes—the specific color of their letters, sounds, tastes—seems to be greatly influenced by experiences early in life.[33] For instance, many lexical-gustatory synesthetes' taste associations are foods which were commonplace in in their childhood.[1] Colored alphabets from early childhood also seem to influence the letter-color associations of many synesthetes. In one intriguing case, a grapheme color synesthete's associations were traced back to a Fisher-Price™ magnetic alphabet set, recovered from her parents attic. Her associations almost perfectly matched the color of the magnetic letters, with the exception of the letter "B," which happened to be missing from the set during her childhood.[34] Interestingly, when the same individual moved to Russia at a young age and learned the cyrillic alphabet, she developed synesthetic associations based on her prior associations in the latin alphabet. Cyrillic characters which closely resembled latin characters took on the same color as their latin counterpart ("Б" and "b" were both blue).[34] This was the same for characters with phonetic counterparts ("Ф" makes the same sound as "F", they were the same shade of purple).[35] The fact that old colors were mapped onto new graphemes—rather than new graphemes inducing new colors—strongly supports the idea that synesthesia reflects unique memories developed during early childhood.*

"Fisher-Price Magnet Set." Flickr, 20 Jul. 2015, https://www.flickr.com/photos/joybot/19150803152.



Much of the secrets of synesthesia have yet to be uncovered. Though culture and upbringing are important aspects of the condition, scientific understanding of synesthesia across cultures is quite limited. Despite years of effort, structural and neuroimaging studies have not discovered a neural basis for synesthesia. Nevertheless, a great deal of progress has been made in understanding the behavioral correlates and internal experience of synesthesia. The condition is absolutely intriguing, and provides a unique opportunity to study perception. Some researchers posit that the study of synesthesia will help to discover the neural correlates of consciousness.[37,38] Regardless, synesthesia research will certainly continue to reveal more about this unique condition. Perhaps the researchers will arrive at an earth-shattering conclusion about consciousness; perhaps they will shape cognitive neuroscience for years to come. Or maybe they'll end up eating their words.

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