editorial

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Synesthesia and mapping of subjective sensory dimensions

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The word "synesthesia" comes from the Greek *"syn,"* meaning union, and *"aisthesis,"* meaning sensation. Found predominantly in women, synesthesia is a rare condition in which stimulation of 1 sense produces an involuntary perception in another sense. While synesthesia can combine any or all of the 5 senses, the most common is sight with sound, or "colored hearing." This occurs when sounds such as music, voices, or environmental noises cause the synesthete to see moving colors and shapes externally projected. For synesthetes, the phrase, "I see what you're saying," could be taken literally. For example:

> What first strikes me is the *color* of someone's voice. [Name] has a crumbly, yellow voice, like a flame with protruding fibers. Sometimes I get so interested in the voice, I can't understand what's being said.
>
> Spearmint tastes like cool, glass columns. Lemon is a pointed shape, pressed into my face and hands. It's like laying my hands on a bed of nails.
>
> The name Paul is such an ugly color, it's gray and ugly. I told her, "Name the baby anything but Paul." She couldn't understand why, and I said, "It's such an awful color, that name Paul." She thought I was out of my mind.

What is a neurologist to make of this?

Synesthesia has been known to the medical and psychological communities for over 200 years. Curiously, neurologists have taken no interest until quite recently. The current paper by Rizzo and Eslinger (see page 781 in this issue) is an example of the late-found interest in a subject that would seem to be natural territory for neurologists. But neurologists have characteristically been hesitant to study whole-brain functions and often run the other way from subjectivity. We have instead become used to single-electrode penetrations and similar analyses that claim to be totally objective. Many believe that subjective phenomenon can be approached just like anything else, except that there is no shared referent. Rizzo's case contains many characteristic features of synesthesia and is subjected to a well-thought-out battery of psychophysiologic tests. His investigation shows that synesthesia is not learned and that there are no direct linkages between auditory and visual systems in his subject.

I could also add that language has nothing to do with it. Synesthesia is *not* just a more intense form of cross-modal metaphor, although for years psychologists pursued this mistaken path. The arguments against language being "the link" between senses—which, by definition, would make synesthesia one of the highest of higher cortical functions—are presented elsewhere.[1] Being a vivid cross-modal association, synesthesia is obviously a higher cortical function. It's just that it isn't that high a function. In this context, one is reminded of the anecdote of Hans Lucas Teuber who, rolling his eyes upwards, said he didn't mind discussing "higher" functions as long as by "higher," one didn't mean extracranial. There is considerable evidence that synesthesia is perceptual and brain-based, and not mind-based as is the case of imagery.

The first medical reference to synesthesia was circa 1710, when an English ophthalmologist, Thomas Woolhouse, described the case of a blind man who perceived sound-induced colored visions. In 1704, Sir Isaac Newton tried mathematically to correlate the energy of sound and color, and the first practical application of this appears to be the *clavecin oculaire*, an instrument that plays sound and lights simultaneously. Erasmus Darwin achieved the same effect with a harpsichord sometime later (1790). Correspondences with color are noted by Goethe in *Zur Farbenlehre (Theory of Color*, 1810). Thus, great minds have turned their attention to synesthesia, and we should note that many had either an artistic or naturalistic disposition.

Historically, however, there were great problems in explaining synesthesia. At the height of its interest in the 19th century, psychological theories were so conflated and jam-packed with associations that they couldn't handle the seemingly idiosyncratic responses of a synesthete's perceptions. Likewise, conceptualization of nervous tissue and neuroanatomy was inadequate to provide any physiologic mechanism. No wonder synesthesia was placed on the back burner and regarded as a mere psychological quirk. Review of the subject had been published in 1890 in French by Suarez de Mendoza (*L'Audition Colorée*) and in 1927 in German by Argelander (*Das Farbenhoren und der synasthetische Faktor der Wahrnehmung*), but neither was able to approach the subject from a neurologic basis. But we have learned more about the brain in the past 10 years than in the previous entire history of neuroscience. We have changed both the conceptualiza-

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tion of nervous tissue as well as our conceptualization of cognitive psychology so drastically since the heyday of synesthesia that a coherent and convincing explanation of this remarkable condition is now possible.

Synesthesia is currently defined by 5 criteria that separate it from imagery or artistic fancy: (1) synesthesia is involuntary and cannot be suppressed; (2) the sensations appear not in the mind, but are usually perceived externally as real; (3) the synesthetic sensations are discrete (few in number and tend to be categorical or generic in nature); (4) they are highly memorable; (5) they are accompanied by strong emotion and a sense of conviction.

Next, one must separate idiopathic synesthesia from that arising from a known etiology or mechanism. Examples of the latter are as follows. *Epileptic synesthesia*, such as a gustatory-visual-tactile perception during a limbic discharge, occurs in less than 10% of temporal lobe-limbic seizures. There are persons with hippocampal epileptogenic foci who have synesthetic experiences relatable to a seizure, but who are not synesthetic otherwise. *Drug-induced synesthesia* occurs only infrequently (contrary to popular belief) with hallucinogens such as LSD, peyote, and mescal. An example of *synesthesia due to deafferentation*, or sensory deprivation, would be sound-induced photisms occurring in a blind hemifield. A few cases of synesthesia have been described with *gross brainstem lesions*. It is of interest that removal of a brainstem cystic tumor stopped that patient's synesthesia. Synesthesia can be *evoked* by electrical stimulation of the temporal cortex, as in Penfield's experiential responses. Lastly, about 2% of patients with *concussion* will develop a photo- or audio-algesic synesthesia in which sudden noises or bright lights produce momentary pain extending into the trunk or extremity. This condition is temporary.[2]

Idiopathic synesthetes appear normal in every sense, have normal neurologic exams, and are of normal intelligence. The trait appears in childhood, often as far back as the subject can recall. They are surprised to "discover" that others do not share their perceptions and nearly always suffer ridicule for disclosure. An exception to this is when the trait runs in families. When such is the case, it is seen in contiguous generations and may be transmitted in any sex combination, suggesting an autosomal dominant mode. Penetrance is incomplete. Six of the 42 subjects presented in my recent book have synesthetic relatives. One of them, to my great delight, is a professor of neuropathology. The trait runs for 3, possibly 4, generations in his family.

The trait is more common in women (2.5:1). Left-handedness or mixed dominance is found in 50% of patients or their first-degree relatives. Subjects claim to have exceptional memories, and testing proves this to be so. Indeed, it was Luria's famous mnemonist, who was also synesthetic, who suggested a link between hypermnesia and synesthesia.[3] I believe this link is real and points to the importance of limbic brain in fathoming the neural substrate of synesthesia.

It turns out that there are so many possibilities for the neurologist to consider in trying to identify this neural basis that only a book-length treatment can suffice. Herewith are a few conclusions of that analysis. Multiple sources of evidence suggest that synesthesia "resides" only in the left hemisphere and that the hippocampus is an important node in the neural machinery that generates the parallel perception. Some of the evidence comes from close neuropsychological study, which finds synesthetes' cognitive skills uneven. As a group, they have dyscalculia, right-left confusion, and difficulty with spatial relations. Their sense of direction is dismal, particularly for vector maps. The synesthetic percept is never elaborated, but always simple and generic, certainly never pictorial. In other words, synesthetes don't see pastoral landscapes while listening to Beethoven, nor taste clam chowder when touching wood. Rather, they see blobs, spirals, cross hatchings and moving lines; taste salty or metallic tastes; feel cold, prickly, or rough textures. Color and geometry are prominent. These are elementary sensations, the building blocks, one might say, of more elaborate ones.

At present, after 9 years of thought on the subject, my simplest explanation is that synesthesia represents a pre-object or, in the language of microgenetics, a preliminary display of a *normal* cognitive process. While we easily know that what we see and hear are distinct events, a moment's reflection shows that identification between the senses occurs regularly. The mapping of disparate sensory dimensions is a topic of great current interest. In subhuman primates, we now find some 2 dozen overlapping neuronal representations of the visual world which are defined in terms of the different ways they process visual information. Yet as the avalanche of facts about the detailed working of the brain—in vision, somasthesis, and movement—threaten to overwhelm the neuroscientist, we still have no understanding of integration at the highest level, no place to which we can point and say, "Is this how we come to understand?"

It is as if each sense samples an event, if only just a little, and that in synesthesia some of these sensory samplings become bared to consciousness. What synesthesia can provide is a rich stimulus to the imagination in pondering how it all comes together.

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