

A developmental theory of synaesthesia, with long historical roots

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One small addition to the comprehensive survey of "the existing state of affairs" of synaesthesia by Hochel & Milán (2008) may be interesting. In a fascinating theory Maurer & Maurer (1988) suggested that normal infants are typically synaesthetic, with subsequent neural and synaptic pruning leading to more segregated senses in most of us (see also Maurer & Mondlach, 2005). Those few who are synaesthetic as adults are, then, those whose cross-modal connections do not wither in the same way. This theory provides a developmental mechanism and behavioral correlate for the hyperconnectivity proposed in a number of the theories discussed by Hochel & Milán.

Thanks to the efforts of Peter Huttenlocher and his colleagues, we have direct anatomical evidence that the number of synapses in sensory and association cortices peaks in childhood and declines thereafter (Huttenlocher, 1979; Huttenlocher & Dabholkar, 1997). The possibility that synaesthesia in adults results from a failure to prune some of these connections is mentioned by Hochel & Milan and consistent with the recent evidence that adult synaesthetes have greater white matter connectivity between certain brain regions than have normals (Rouw & Scholte, 2007).

If adult synaesthesia is caused by extra connections, then we should take seriously the Maurers' idea that the extra connections that children have gives them some form of synaesthesia. To account for what we know from studying adults with synaesthesia, such connections should be present between perceptual cortices, either via direct connections - "crossed-wire theories" in the terminology of Hochel & Milán - or indirect connections possibly through disinhibition of top-down connections. Intriguing evidence consistent with the existence of such connectivity in babies comes from Kennedy et al. (1997), who document projections from auditory cortex to visual area V4 in fetal macaque monkeys, projections that apparently are normally subsequently pruned. Aside from this study, there is not much consistent evidence available, but then most studies of neural connectivity between modalities have been done only in the last decade or so. This decade has seen an explosion of behavioral and neuroscientific studies of intersensory connections (e.g., Shams, Kamitani, & Shimojo, 2000; Amedi, Stern, et al., 2007; Hubbard & Ramachandran, 2005). Immediately prior to this, it was thought that early cortical processing of information from each sense proceeds largely independently of the others. Modern researchers are to be congratulated for overturning this doctrine. However in full historical context the doctrine, and resulting preconception against the infant synaesthesia hypothesis, may be an aberration. In the Enlightenment era when neuroscience was just beginning and experimental psychology yet to begin, thinkers speculated that the senses at the beginning of life are unified and only later segregate.

The influential eighteenth-century philosopher Jean-Jacques Rousseau described his theory of child development in his book *Emile* (1762) and hypothesized that if "a child had at its birth the stature and strength of a man, that he had entered life full grown like Pallas from the brain of Jupiter... all his sensations would be united in one place, they would exist only in the common 'sensorium.'" A few decades later, this idea captured the imagination of Mary Shelley, in spite of her mother, who condemned Rousseau's doctrines in a very early work of feminist philosophy (Wollstonecraft, 1792).

Although Mary Shelley was only nineteen when she wrote her timeless novel, *Frankenstein* (1818), she combined contemporary philosophical and moral issues with a vision of the danger of emerging sciences that still has relevance today. The specific idea of early unity of the senses, very likely inspired by Rousseau, was articulated by Frankenstein's creation in his first-person account of his early experiences:

It is with considerable difficulty that I remember the original era of my being: all the events of that period appear confused and indistinct. A strange multiplicity of sensations seized me, and I saw, felt, heard, and smelt, at the same time; and it was, indeed, a long time before I learned to distinguish between the operations of my various senses.

-Mary Shelley, *Frankenstein* (1818), chapter 11

Shelley goes on to present the creature as very humanlike, and it appears here that she wished to show that this extended to the earliest moments of his mental life. With the publication of *Frankenstein*, the unified senses idea was thus brought into the popular culture, and Shelley's words were probably read by some cognitive neuropsychologists in grade school, even if they paid little heed to the sentiment. The idea also lived on within philosophy and, later, the science of psychology.

In their professional career, very many cognitive neuropsychologists become acquainted with William James, and indeed the majority should recognize the phrase "one great blooming, buzzing confusion". Most also recognize this as referring to the world of the infant, but few are probably aware that James was writing about his view that information from different senses are first fused in a child before later segregation. In the quotation below, the emphasis including capitalization is James' own:

...the undeniable fact being that any number of impressions, from *any number of sensory sources, falling simultaneously on a mind WHICH HAS NOT YET EXPERIENCED THEM SEPARATELY, will fuse into a single undivided object for that mind.* The law is that all things fuse that *can* fuse, and nothing separates except what must. What makes impressions separate we have to study in this chapter. Although they separate easier if they come in through distinct nerves, yet distinct nerves are not an unconditional ground of their discrimination, as we shall presently see. The baby, assailed by eyes, ears, nose, skin, and entrails at once, feels it all as one great blooming, buzzing confusion...

-William James, *The Principles of Psychology* (1890), chapter 13

We have seen that although at first the theory of infant synaesthesia may seem strange to the modern researcher, in fact the bias towards senses as segregated would be surprising to a founder of American psychology. It is particularly ironic that part of James' statement on the subject is very frequently quoted, although usually in a way that obscures the meaning. The sensory fusion that James and Rousseau were thinking of is different from the adult synaesthetic experience of specific mappings between certain percepts in different senses (Hubbard & Ramachandran, 2005). Here we have pointed out that while modern synaesthesia researchers tend to begin with the idea of independent

senses and then seek to explain the synaesthetic connections, earlier thinkers would have assumed intermixed senses and sought to explain why specific connections sometimes persist. Hochel & Milán have given an accurate survey of predominant opinion by omitting the infant synaesthesia theory, but as cross-modal research accelerates, the discarded and forgotten perspective of our founders may become mainstream again.

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