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Synesthesia: Is F-Sharp Colored Violet?

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> The violins, the deep tones of the basses, and especially the wind instruments at that time embodied for me all the power of that pre-nocturnal hour. I saw all my colors in my mind; they stood before my eyes. Wild, almost crazy lines were sketched in front of me.
> Vassily Kandinsky (1913, p. 364)

It is generally agreed that synesthesia occurs when an individual receives a stimulus in one sense modality and experiences a sensation in another. Historical difficulties of subjecting cross-modality to rigid scientific analysis, however, has led commentators to cast the phenomenon in terms of abnormality, philosophy and metaphor. Clearly discernable patterns of correspondence were not obvious and the often contradictory historical data were comprised of lists of stimuli and synesthetic responses. For example, accounts such as those attributed to Scriabin and Rimsky-Korsakov equated colors with given musical notes and keys (e.g. see Cytowic 1995; Harrison, 2001). Yet, reportedly, Scriabin claimed the key of C-Minor was red, while Rimsky-Korsakov perceived it as white (Harrison, 2001).

This confusing and haphazard body of work is now being re-visited as researchers design studies capable of examining cross-modal sensation from a neural perspective. Although exciting findings have reinvigorated synesthesia research, of greater interest is that many documented accounts that were perceived as incoherent now appear to be essentially correct in light of what laboratory experiments are revealing (Harrison, 2001; Mattingly et al., 2001; Ramachandran & Hubbard, 2001). Moreover, the validation of older accounts complements a long historical literature on sensory inter-relationships that is robust and cross-cultural. The range is particularly thought-provoking when contrasted with current research findings regarding the phenomena.

One of the earliest efforts to make sense of these relationships was the Pythagorean quest to assign a particular color to each musical note, about the 6th century BCE. In more recent times, the list of famous figures who were involved with the synesthetic experience includes Charles Baudelaire, Arthur Rimbaud, Nikolai Rimsky-Korsakov, Alexander Scriabin, Vassily Kandinsky, Vladimir Nabokov, Sergei Eisenstein, Oliever Messiaen, David Hockney and Richard Feynman. These attributions are based on some of the intriguing comments we find in their writings or remarks they have made about their own work. In

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his *What Do You Care What Other People Think?*, Feynman (1988, p. 59) claimed, "When I see equations, I see the letters in colors." To composer Alexander Scriabin the key of F# major appeared violet in color (Myers, 1914). Writer Vladimir Nabokov noted in his autobiography *Speak, Memory* (1947, p. 21), "[t]he long "aaa" of the English alphabet has for me the tint of weathered wood, but a French "a" evokes polished ebony." And composer Oliever Messiaen waxed lyrical about "the gentle cascade of blue-orange chords" in one of his pieces (Bernard, 1986).

Historical documents also show that synesthesia has long been seen as neurologically abnormal, because it was at odds with the idea that we have five distinct senses, as codified by Aristotle. It is also at variance with the *Law of Specific Nerve Energies* formulated by Johannes Müller (1826), following the earlier insights of Charles Bell (1811). The law implies that each sense modality has its characteristic sensory quality, regardless of the physical means by which the peripheral nerve was stimulated. Thus, signals traveling up the optic nerve are always experienced as visual activation, whether stimulated by optical, tactile, sonic or electrical activation of the photoreceptors. Müller's concept is deeply embedded in the analysis of brain function, and seems to negate the possibility of cross-modal activation in the cortex. How could the nerve energy be specific if it activated more than one sense modality? On the other hand, the physical energy that activates the nerve has a synesthetic quality, in that we can feel as well as hear a strong sound vibration. There seems to be implicit agreement that this kind of cross-modal activation of the peripheral nerve does not qualify as synesthesia.

In sum, the emphasis in synesthesia has been on cross-modal interactions within the brain rather than the peripheral nerves. The particular manifestation of the cross-modal interaction is idiosyncratic, however, for one synesthete might always see a number or a letter as a particular color while another might associate a taste with a sound. Historically, the first bona fide report of synesthesia seems to have been a medical treatise in Latin published by Dr. G.T.L. Sachs in 1812 (see Dann, 1998). The title of his treatise in English may be rendered "The natural history of two albinos, the author himself and his sister" (Sachs, 1812). Although there is no known association between albinism and synesthesia, in this case both siblings had extensive synesthetic color associations with sounds, digits and other numerical data. In fact, they reported highly specific and invariant color sensations evoked by vowels, consonants, musical notes, the sounds of instruments, numbers, dates, days of the week, city names, periods of history and the stages of human life. The work attracted substantial interest in the medical community, and was soon translated into German. Indeed, it must have provoked substantial debate in relation to the Bell and Müller championing of the separation of the sense modalities, particularly as this was the era of romantic experimentation with new musical and poetic forms to evoke a greater wealth of sensory and emotional experience. It would be interesting to know whether there was discussion of such issues in the post-Napoleonic salons, since Romantic poetry of the 19th century is replete with synesthetic metaphors (Siebold, 1919; Ruddick, 1984).

At about the same time, Johannes Purkinje, the physician who investigated numerous aspects of human biology, published a series of papers devoted to subjective visual sensations-hallucinations, afterimages and a wide variety of visual phenomena derived from the eye (Purkinje, 1819). In fact, this investigation represents the fullest treatment of the topic to this day, in which he developed a classification system of 28 categories of entoptic and related phenomena. Although it seems closely related, he did not include synesthesia in this classification, however.

A scientific approach to color-sound associations was carried by the poignant figure of Gustav Fechner, a physicist who fell ill with a brain fever for a year and then recovered with the idea of resolving the mind-brain dichotomy with the science of psychophysics, the direct measurement of sensation. Fechner (1876) tabulated the color-tone associations of 347 individuals as part of this effort to find regularities in the domain of the mind, but he did not emphasize the specificity of the sensory quality as true synesthesia.

The first comprehensive investigation of synesthesia seems to have been carried out by the notable professor of psychiatry Eugene Blueler during his medical studies. He later tried to integrate Freudian psychoanalytic theory with Wilhelm Wundt's new field of experimental psychology, introduced the term "schizophrenia" to describe the fractured mental state of this condition, and gave Carl Jung his early training. The synesthesia study was prompted by his student, Karl Lehmann, who had synesthesia, and found that about 12% of a sample of nearly 600 people reported sensations of color-vowel associations, although there is some question about whether metaphorical associations were also included in the reports (Bleuler & Lehmann, 1881). Since vowel have no common associations with colors in the language in general, however, the occurrence of metaphorical associations would in itself seem to imply some degree of synesthesia.

In the last two decades the ability to probe intersensory relationships has been given a boost by new technologies of brain imaging. The results have been counterintuitive in some respects. For example, Frith and Paulescu (1997) evaluated the change in local cerebral blood flow in a group of six female synesthetes listening to color-evocative words, in comparison to the response to pure tones. Increased blood flow (implying increased neural activity) was seen in many more brain areas of the synesthetes in comparison to the change in a matched group of nonsynesthetic controls. All participants showed greater activation to the words in traditionally linguistic brain areas in the inferior frontal cortex and in the temporal cortex. The synesthetes also showed bilateral increased activation in two visual brain areas – dorsally at the junction of the occipital and parietal lobes, and ventrally at the junction of the occipital and temporal lobes. These two areas correspond to the principal brain regions activated specifically in tasks of the naming of colors associated with common objects shown without their colors (Martin et al., 1995). Their function therefore seems to be associated with the 'conception' rather than direct perception of colors.

An important aspect of this enhanced activation is that it was not seen in the primary visual projection area V1, or in the subsequent projection areas V2, V3 or V3A. These are all areas with color-selective cells that could have supported the enhanced color perception of the synesthestes, but any change in cellular activation was below the resolution of the methods used. An additional surprise was that there was no significant change in the brain area most strongly associated with color processing, area V4 on the ventral surface at the back of the brain. The areas where increased activation showed up were later visual processing regions commonly associated with object and space perception, despite the fact that the synesthetes did not report any special enhancement of object awareness beyond the associated color, and that the colors were related to purely formal aspects of the word, such as their first letter, rather than object-relevant properties.

The other brain regions that were differentially activated in the synesthetes in the Frith and Paulescu (1997) study were two non-visual areas on the right side of the brain – the middle frontal gyrus and the insula, a deep cortical region lying just below it. The insula on the left side showed a pronounced deactivation complementary to activation on the right side. These brain areas are typically associated with functions of complex motor control and decision making, but Frith and Paulescu offer no interpretation of either the activation or the deactivation of these frontal regions. One might speculate that they represent a control mechanism by which the synesthete brain switches from a predominant left-hemisphere activation of speech (since five of the six synesthetes tested were right-handed, and therefore would have had left-hemisphere dominance) to a right-hemisphere activation of verbal associations not normally accessible in non-synesthetes. This kind of attentional switch could help to explain how the synesthetic colors were brought to consciousness without enhanced activation of the early color processing areas. Indeed, Frith and Paulescu reported that the color experiences of their synesthetes were evoked only when attention was drawn to the sound of the words by subvocalizing during reading, but not during normal reading.

These tools also make it possible to design experiments to evaluate whether synesthesia might be an innate condition in some, or show evidence of brain plasticity in others. We can now compare the neural functioning in innate synesthesia and in synesthesia of those affected by life-altering neurological events. One case of note was reported by Vike et al. (1984). This subject saw kaleidoscopic and spiraling lights in his left eye when stimulated with clicks of 65 decibels. His synesthesia stopped with the removal of a large cystic mass extending from his left medial temporal region to the midbrain. Similarly with Jonathan I., a colorblind artist made famous by the neurologist Oliver Sacks, we find a life-altering neurological event brought about a loss of synesthesia along with his loss of color perception in general. Mr. I. also illustrates that grappling with this phenomenon underscores there are diverse, complex variables related to the senses that scientific research has yet to resolve. Briefly, Jonathan I., who died in the late 1980s, had been a painter who had always relished color before an automobile accident left him unable to see color at all. Although no reliable anatomical information is available about this patient, who died about three years after his accident, John Harrison concludes that the achromatopsia was most likely damage to the lingual and fusiform gyri of the brain (2001). Before his accident, his work was abstract, colorful and highly non-representational. After his accident, he found he had an achromic condition that left him unable to work effectively with color. In addition, prior to the accident Jonathan I. experienced the form of synesthesia in which one sees colors when presented with musical tones. After the accident he lost this synesthesia along with all other color experience.

This loss is particularly intriguing when the case is considered in its full context, for it demonstrates that the history of an artist and of an individual has a tremendous impact on how the brain develops (Sacks, 1995). Blind to color relationships in his general environment and in conceiving his artwork, Mr. I's entire life changed. For a painter, no doubt, this change was devastating and it required him to develop a totally new approach to his life and his profession. Mr. I. began to prefer to venture outside when the light made it easiest for him to distinguish forms in his 'gray' world and changed his diet, preferring foods he 'knew' were 'naturally' black and white. Although Mr. I. became totally colorblind, these losses did not keep him from painting. In fact, after a year or more of experiment and uncertainty, he moved into a strong and productive artistic phase, as evocative as anything in his long artistic career. Looking at the monochromatic paintings he produced at this time (see Fig. 1), it

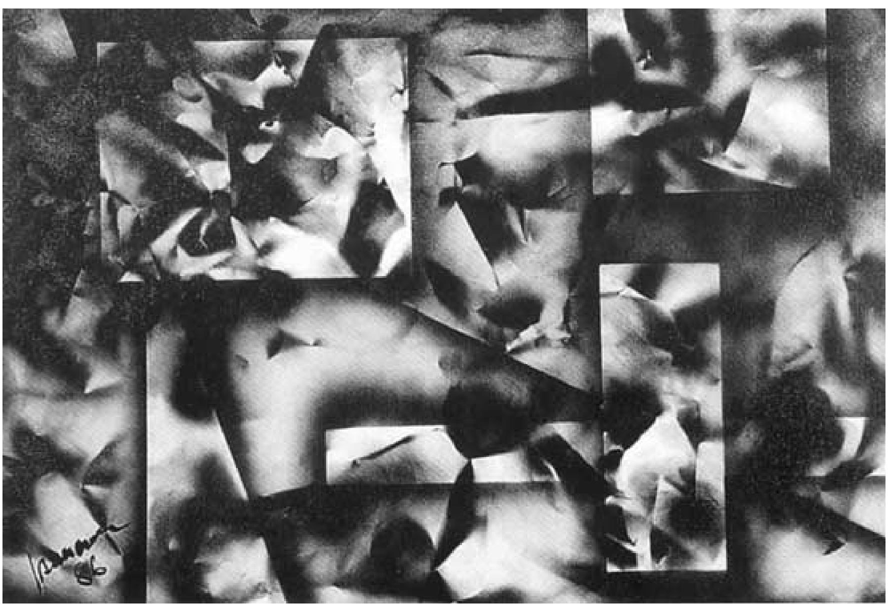

Fig. 1. Monochromatic painting by Jonathan I., a colorblind artist who lost his synesthesia when he lost his ability to perceive color. ©1995 Oliver Sacks. Reprinted with permission of The Wylie Agency, Inc.

is important to keep in mind that the accident only damaged the section of his brain specialized for color (designated as visual area V4 in the occipital lobe), and yet the depth of the overall change altered his entire way of being. Perhaps of greatest importance to his life as a painter was that he did not lose just his perception of color, he also lost his sense of color imagery, the ability to dream in color and even his memory of color. Although he continued to paint monochromatic abstracts that portray a tonal, musical quality, these paintings derived from a different neurosensory foundation form earlier work. Nonetheless, the gray-tone paintings produced at this time were highly successful and people commented on his creative renewal when seeing this new 'phase' he had 'moved' into. The excitement people felt when seeing his monochromes is perhaps most meaningful when we reflect on the fact that very few people knew that this new phase was anything other than an expression of his artistic development. They failed to recognize that it was brought about by a calamitous neural loss (Sacks, 1995).

Two aspects of his case are particularly noteworthy neurologically. First, since he continued to paint, researchers were able to use his work to explore how a brain could adapt to radically new modes of expression and ways of seeing. Second, although Sacks believes this kind of case allows us to assess how the cerebral 'mapping' may be drastically reorganized and revised in cases of the special use or disuse of individual parts, we need not necessarily draw this conclusion. Clearly his brain did adapt in some ways. Yet, too, these adaptations did not bring color back into his memory or visual experience. He never recovered his synesthesia or any sensation of color.

As scientific studies proceed, many continue to debate about what, if anything, we can learn from artists who spoke about experience in terms we now characterize as synesthetic. Clearly, a strictly physiological evaluation of historical figures is impossible. Does this mean that historical cases should be interpreted metaphorically? Although the debates are complex, some have pointed out that the conclusions applied to historical accounts are often limited by more than the contradictions evident in the literature. Another area of concern is that current interpretations of synesthetic tend to follow trends in brain research, where studies concentrate on a search for the organic basis for the experience. Artistic projects, however, stress experimentation. Whether innately synesthetic or not, artists are likely to gravitate toward projects that enhance sensory interchange. Further investigation into historical cases of artists developing techniques to investigate perceptual and emotional mechanisms, might contribute to developing more foundation for contemporary neurological research into synesthesia. The difference between contriving metaphors and developing techniques to explore perceptual and emotional mechanisms is as relevant as the ability to distinguish an innate synesthesia from one developed through focused endeavors.

One painter who explored synesthesia extensively was Vassily Kandinsky (1866–1944), who had striven to enhance his cross-modal capabilities from childhood. His writings make a strong case that he was a true synesthete (Ione & Tyler, 2003). Stimulated to develop a sensory unification of color and music, Kandinsky systematically devised dynamic painted compositions (see Fig. 2) that are difficult to perceive in terms of static representation. Rather the concrete painted forms evoke a visceral language that entices the

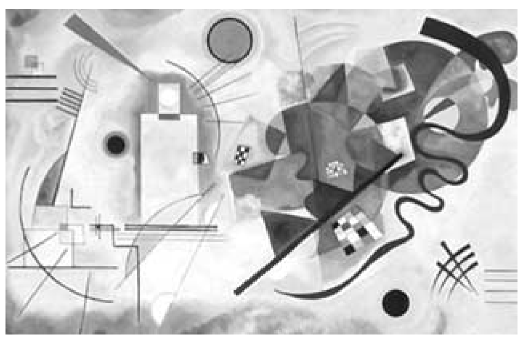

Fig. 2. Kandinsky's Yellow-Red-Blue (1925) is from his period of totally non-representational works, but this particular painting seems evocative of the concept of a person experiencing vivid 'synesthetic' imagery. Oil on canvas, Musée National d'Art Moderne, Centre Georges Pompidou. Reprinted with permission: Réunion des Musées Nationaux/Art Resource, NY. © 2003 Artists Rights Society (ARS), New York/ADAGP, Paris.

colors to sway to unheard music. The viewer immediately senses that each point seen is moving toward the evocation of its counterpoint, just as each series of lines appears to correlate with a sonic form. Kandinsky's writings support the viewer's reaction, often stating his longing to provide painting with the independence from nature that he felt in music. He frequently spoke of how an understanding of art and music can expand the value of using associative techniques aimed at enhancing sensory exchange. In addition, the idea that he developed his innate capabilities is supported indirectly by our knowledge of how he worked as well as the circumstantial evidence contained in his writings (Kandinsky, 1912, 1913, 1947; Lindsay & Vergo, 1982).

Although we are unable to test him, we do know that when he lived there was a great interest in synesthesia. This interest is recorded in Figure 3, where von Campen's chart shows that the number of synesthesia publications per decade peaked during Kandinsky's most productive years. No doubt interest early in the 20th century was enhanced by the publicity that Kandinsky and his colleagues gave to synesthesia. Finally, we know that Kandinsky penciled notes in his books that spoke of exercises one could do to enhance synesthesia. He also desired to bring the essence of cross-modal experience to a wider audience, asserting that "one can feel the multi-sensory consonances and dissonances in simultaneously performed color movements, musical movements and dance movements" (Van Campen, 1997).

Ironically, although it continues to be debated whether Kandinsky was actually a synesthete, the foundational issues became somewhat moot with the advent of LSD (the hallucinogenic drug *lysergic acid diethylamide*) in the 1960s. Multimodal synesthesia is experienced by most who take LSD, revealing that it is a latent facility that takes only the specific effects of the miniscule dose of this drug to release (see Marks, 1978). Such releasers imply a kind of neural plasticity in which the latent synesthesia can be triggered and, presumably, developed by appropriate forms of stimulation. Cytowic (2002) points out, however, that the effect is not universal and that LSD does not produce synesthesia every time the drug is ingested.

Finally, all of these points suggest that broadening our understanding of synesthesia will require we broaden our view of historical cases without losing sight of their inaccessibility to

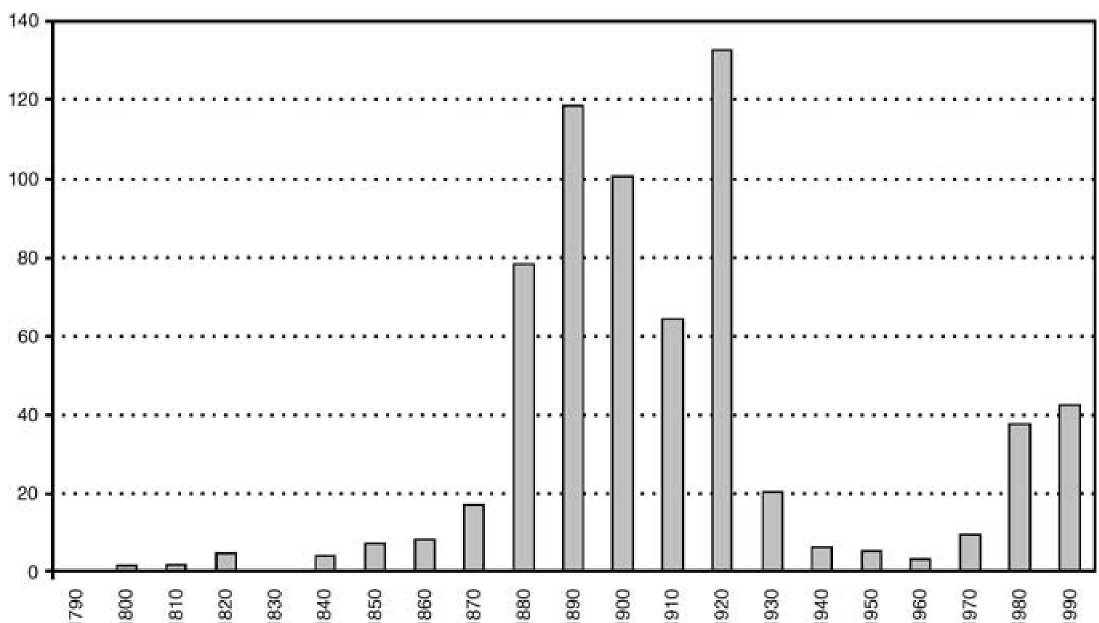

Fig. 3. Number of publications on synesthesia per decade. Source: Crétien von Campen (1999).

direct study. Understanding their merits is aided by the work of contemporary teams who are now identifying which neural correlates appear to be 'cross-wired' in synesthetes, and are comparing synesthetes' brains with those of non-synesthetes. Ramachandran and Hubbard (2001), for example, have proposed that cross-wiring in the fusiform gyrus is the neural basis of grapheme-color synesthesia. Ramachandran has even suggested that synesthesia may form the basis of primordial color perception. In one case, a subject who was genetically color blind reported that numbers evoked sensations of "Martian colors" that he had never seen with direct vision. The implication is that the synesthesia activated color-coding circuitry within his brain that could not be reached through the defective wiring from his photoreceptors.

Indeed the work of a number of scientists (e.g. see Marks, 1978; Cytowic, 1989, 2002; Baron-Cohen & Harrison, 1997; Ramachandran & Hubbard, 2000, 2001) is involved in exploring the neural mechanisms of synesthesia. These neurologists are removing this sensation from the taint of charged terms such as 'abnormal' or 'aberrant'. Surveying the research that now challenges Aristotelian notions of five distinct senses, we find studies of letter confusions that have shown that the colors seen by synesthetes can be so vivid that they interfere with the identification of colored numbers (Mattingly et al., 2001; Ramachandran & Hubbard, 2001). Other studies show that the synesthetic colors may be used to penetrate the crowding effect of arrays of nearby shapes, letters and numbers (Ramachandran & Hubbard, 2001; Wagar et al., 2002). The synesthetic color provides a marker identifying particular numbers or objects under conditions when they are invisible to people without this special perception, who are unable to distinguish discrete numbers within the masking array. In addition, researchers such as Mills et al. (1999) are designing tests to determine that synesthete reports are accurate over time. In sum, with the current explosion of techniques to explore the brain, synesthesia, like other formerly misunderstood behaviors, is opening doors that allow us to re-evaluate art, neural wiring, and sensory relationships.

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