Synesthesia: Phenomenology And Neuropsychology
A Review of Current Knowledge

Richard E. Cytowic
4720 Blagden Terrace, NW
Washington DC 20011-3720
USA

neuroman@glib.org

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ABSTRACT: Synesthesia (Greek, *syn* = together + *aisthesis* = perception) is the involuntary physical experience of a cross-modal association. That is, the stimulation of one sensory modality reliably causes a perception in one or more different senses. Its phenomenology clearly distinguishes it from metaphor, literary tropes, sound symbolism, and deliberate artistic contrivances that sometimes employ the term "synesthesia" to describe their multisensory joinings. An unexpected demographic and cognitive constellation co-occurs with synesthesia: females and non-right-handers predominate, the trait is familial, and memory is superior while math and spatial navigation suffer. Synesthesia appears to be a left-hemisphere function that is not cortical in the conventional sense. The hippocampus is critical for its experience. Five clinical features comprise its diagnosis. Synesthesia is "abnormal" only in being statistically rare. It is, in fact, a normal brain process that is prematurely displayed to consciousness in a minority of individuals.

1. Introduction

1.1 Although medicine has known about synesthesia for three centuries, it keeps forgetting that it knows. After decades of neglect, a revival of inquiry is under way. As in earlier times, today's interest is multidisciplinary. Neuroscience is particularly curious this time - or at least it should be - because of what synesthesia might tell us about consciousness, the nature of reality, and the relationship between reason and emotion.

1.2 The word *synesthesia*, meaning "joined sensation", shares a root with *anesthesia*,

meaning "no sensation." It denotes the rare capacity to hear colors, taste shapes, or experience other equally startling sensory blendings whose quality seems difficult for most of us to imagine. A synesthete might describe the color, shape, and flavor of someone's voice, or music whose sound *looks like* "shards of glass," a scintillation of jagged, colored triangles moving in the visual field. Or, seeing the color red, a synesthete might detect the "scent" of red as well. The experience is frequently *projected* outside the individual, rather than being an image in the mind's eye. I currently estimate that 1/25,000 individuals is born to a world where one sensation *involuntarily* conjures up others, sometimes all five clashing together (Cytowic, 1989, 1993). I suspect this figure is far too low.

1.3 It is aphorismic that nature reveals herself by her exceptions. Since our intellectual baggage includes deeply-ingrained historical ideas about normative concepts of mind, synesthesia not only flaunts conventional laws of neuroanatomy and psychology, but even seems to grate against common sense. Yet it should also be aphorismic (though never contemporaneously evident) that concepts which some souls now think of as clear, coherent, and final are unlikely to appear to posterity as having any of those attributes.

1.4 Since I have previously addressed synesthesia at book-length, and since my current task is to summarize rather than persuade, I have tried not to clutter up this review with references. Readers wanting further background or wishing to pursue a specific point should consult (Cytowic, 1989, 1993). Initialed examples in this review (such as JM or MW) refer to my subjects in the 1989 text.

2. General Features

2.1 No matter what senses are joined in a given synesthete, it is striking how similar the histories of all synesthetes are. One after another, they declare that their lifelong inter-sensory associations remain stable. (That is, if the word "hammer" is red with white speckles, it is always perceived thusly.) Synesthetes are surprised to discover that others do not perceive words, numbers, sounds, taste, and so forth as they do. Though they recall having always had their idiosyncratic perceptions as far back as they can remember, any mention of them at an early age characteristically prompted ridicule and disbelief. Despite keeping the experience private and hidden, it remained vivid and irrepressible, beyond any willful control.

2.2 We presently know the following:

2.3 Synesthesia runs in families in a pattern consistent with either autosomal or x-linked dominant transmission. (Either sex parent can pass the trait to either sex child, affected individuals appear in more than one generation of a pedigree, and multiple affected sibs can occur in the same generation. So far, I have encountered no male-to-male

transmission.) To give some flavor of the pedigrees I have encountered, one family has one synesthete in each of four generations, while another family has four synesthetes out of five siblings in the same generation.

2.4 Perhaps the most famous family case is that of the Russian novelist Valdimir Nabokov. When, as a toddler, he complained to his mother than the letter colors on his wooden alphabet blocks were "all wrong," she understood the conflict he experienced between the color of the painted letters and his lexically-induced synesthetic colors<1>. In addition to perceiving letters and words in color, as her son did, Mrs. Nabokov was also affected by music. (Parenthetically, Nabokov's son Dimitri is synesthetic. Unequivocal passing of the trait from father-to-son would eliminate the possiblity of x-linked dominant heritability. Unfortunately, Nabokov's wife was also aynesthetic, and it is not possible to determine from which parent Dimitri inherited the trait.)

2.5 Women synesthetes predominate. In the U.S. I found a ratio of 3:1 (Cytowic, 1989), while in the U.K. Baron-Cohen et al. (1993) found a female ratio of 8:1.

2.6 Synesthetes are preponderantly non-right-handed. Additional features (see below) are consistent with anomalous cerebral dominance.

2.7 Synesthetes are normal in the conventional sense. They appear bright, and hail from all walks of life. The impression that they are inherently "artistic" seems to me a sampling bias, given that famous synesthetes such as Valdimir Nabokov, Olivier Messiaen, David Hockney, and Alexander Scriabin are well-known because of their art rather than their synesthesia. Clinically, synesthetes seem mentally balanced. Their MMPIs are unremarkable except for non-stereotypical male-female scales. Standard neurological exams are also normal.

2.8 Not only do most synesthetes contend that their memories are excellent, but cite their parallel sensations as the cause, saying for example, "I know it's 2 because it's white." Conversation, prose passages, movie dialogue, and verbal instructions are typical subjects of detailed recall. The spatial location of objects is also strikingly remembered, such as the precise location of kitchen utensils, furniture arrangements and floor plans, books on shelves, or text blocks in a specific book. Perhaps related to this observation is a tendency to prefer order, neatness, symmetry, and balance. Work cannot commence until the desk is arranged just so, or everything in the kitchen is put away in its proper place. Synesthetes perform in the superior range of the Wechsler Memory Scale.

2.9 Within their overall high intelligence, synesthetes have uneven cognitive skills. While a minority are frankly dyscalculic, the majority may have subtle mathematical deficiencies (such as lexical-to-digit transcoding). Right-left confusion (allochiria), and a

poor sense of direction for vector rather than network maps are common<2>. A first-degree family history of dyslexia, autism, and attention deficit is present in about 15%. Very rarely, the sensual experience is so intense as to interfere with rational thinking (e.g., writing a speech, memorizing formulae). I have encountered no one whose synesthesia was so markedly disruptive to rational thought as it was in Luria's famous male subject, S.

2.10 As a group, synesthetes seem more prone to "unusual experiences" than one might expect (17% in my 1989 study, though if anyone knows what the general-population baseline for unusual experiences is, I should like to know). Qualitatively, one thinks of the personality constellation said to be typical of temporal-limbic epileptics. Deja vu, clairvoyance, precognitive dreams, a sense of portentousness, and the feeling of a presence are encountered often enough. Singular instances in my experience include empathic healing, and an explanans of psychokinesis for what was probably an explanandrum of episodic metamorphopsia. Unparalleled among my collection of other-worldly experiences is that of a woman who claimed to have been abducted by aliens, and to have enjoyed sexual congress aboard their space craft. Having experienced aliens, she confided, human males could no longer satisfy her. (My thanks to Larry Marks for this gem.)

2.11 From the above, it seems that for most people synesthesia is ineffable, that which by definition cannot be imparted to others or adequately put into words. It might seem impossible at first for science to scrutinize a phenomenon whose "quality" must be experienced first-hand.

3. History Of Synesthesia

3.1 Surprisingly, synesthesia has been known to medicine for almost three hundred years. After interest peaked between 1860 and 1930, it was forgotten, remaining unexplained not for lack of trying, but simply because psychology and neurology were premature sciences. Psychological theory was jam-packed with associations, and concepts of nervous tissue were paltry. Just as concepts became *recognizably modern*, behaviorism appeared with such draconian restrictions that even acknowledging the existence of an inner life was taboo for a long time. Subjective experience, such as synesthesia, was deemed not a proper subject for scientific study.

3.2 Synesthesia's history is intrinsically interesting but also important if we are to understand its neurological basis, because the word was used to describe diverse phenomena in different eras. Central to my initial approach in 1980 was a sharp demarcation of synesthesia as a sensual perception as distinct from a mental object like cross-modal associations in non-synesthetes, metaphoric language, or even artistic aspirations to sensory fusion. By contrast, the perceptual phenomenon is unheard-of in literary and linguistic circles, where the term "synesthesia" is understood to mean

rhetorical tropes (i.e. figures of speech) or sound symbolism (la Humboldt and Saussure). Whether such a demarcation remains warranted is considered below (see section 10).

3.3 Synesthesia attracted serious attention in art, music, literature, linguistics, natural philosophy, and theosophy. Two books were published: *L'Audition Colore* by Suarez de Mendoza in 1890, and *Das Farbenhren und der synsthetische Faktor der Wahrnehmung* by Argelander in 1927. Most accounts emphasized colored hearing, the most common form of synesthesia.

3.4 This disproportion in the types of synesthesia is itself intriguing. The five senses can have ten possible synesthetic pairings. Synesthetic relationships are usually unidirectional, however, meaning that for a particular synesthete sight may induce touch, but touch does not induce visual perceptions. This one-way street, therefore, increases the permutations to twenty (or thirty if you include the perception of movement as a sixth element), yet some senses, like sight and sound, are involved much more often than others. To persons endowed with colored hearing, for example, speech and music are not only heard but also a visual melange of colored shapes, movement, and scintillation.

3.5 It is rare for smell and taste to be either the trigger or the synesthetic response. Aside from my case VE, I have found no other in which sight evokes smell; and other than my index case MW, in which taste and smell evoked widespread tactile experience, I have found none in which smell itself is the trigger. In addition to MW, I am aware of only one other synesthete in whom taste induces a secondary sense, in this instance an experience of color.

3.6 Aside from MW's own geometric taste, perhaps the strangest synesthesia is "audiomotor," in which an adolescent positioned his body in different postures according to the sounds of different words. Both English and nonsense sounds had certain physical movements, the boy claimed, which he could demonstrate by striking various poses. By way of convincing himself of this sound-to-movement association, the physician who described it planned to re-test the boy later on without warning. When the doctor read the same word list aloud ten years later, the boy assumed, without hesitation, the identical postures of a decade earlier.

3.7 By mid-nineteenth century synesthesia had intrigued an art movement that sought sensory fusion, and a union of the senses appeared more and more frequently *as an idea*. Multimodal concerts of music and light (*son et lumiere*), sometimes including odor, were popular and often featured color organs, keyboards that controlled colored lights as well as musical notes. It is imperative to understand that such deliberate contrivances are qualitatively different from the involuntary experiences that I am calling synesthesia in this review.

3.8 The Russian composer Alexander Scriabin (1872-1915) specifically sought to express his own synesthesia in his 1910 symphony *Prometheus, The Poem of Fire*, for orchestra, piano, organ, and choir. It also included a mute keyboard, a *clavier a lumieres*, which controlled the play of colored light in the form of beams, clouds, and other shapes, flooding the concert hall and culminating in a white light so strong as to be "painful to the eyes."

3.9 Vasilly Kandinsky (1866-1944) had perhaps the deepest sympathy for sensory fusion, both synesthetic and as an artistic idea. He explored harmonious relationship between sound and color and used musical terms to describe his paintings, calling them "compositions" and "improvisations." His own 1912 opera, *Der Gelbe Klang* ("The Yellow Sound"), specified a compound mixture of color, light, dance, and sound typical of the *Gesamtkunstwerk.*

3.10 I will note that Kandinsky yearned to push aside analytic explanations and move himself and his audience closer to the quality of direct experience that synesthesia typifies. There is an important clue in his famous dictum, "stop thinking!" that relates to one of synesthesia's implications in reversing the roles of reason and emotion. Kandinsky grasped that creativity is an experience, not an abstract idea, and that a mind that incessantly analyzes what is there impedes that experience.

3.11 (Kandinsky's 1910 adjuration was, "lend your ears to music, open your eyes to painting, and . . . stop thinking! Just ask yourself whether the work has enabled you to 'walk about' into a hitherto unknown world. If the answer is yes, what more do you want?")

3.12 In such a climate, people were intrigued with the notion that synesthesia seemed to have a direct link to the unconscious. With time, however, attention turned to "objective" behavior that could be quantified or measured by machines. Humans became "subjects," the individual was abandoned, and the mind temporarily became a black box.

3.13 Mechanistic explanations have been plentiful throughout synesthesia's history. *The notion of crossed wires turns up repeatedly.* As early as 1704, Sir Isaac Newton struggled to devise mathematical formulae to equate the vibration of sound waves to a corresponding wavelength of light. Goethe noted color correspondences in his 1810 work, *Zur Farbenlehre*. The nineteenth century saw an alchemical zeal in the search for universal correspondences and a presumed algorithm for translating one sense into another. This mechanistic approach was consistent with the then-common view of a clockwork universe based on Newton's uniform laws of motion.

4. Clinical Diagnosis

4.1 The abundant confusion in synesthesia's history requires a clinical definition to distinguish it from superficially similar, but otherwise distinct, phenomena. Since the term "diagnosis" literally means "through knowledge," the criteria are wholly historical. (Some may find this a refreshing change from our reflexive and often unthinking use of technology.) Five diagnostic features are as follows:

4.2 Synesthesia is involuntary but elicited. It is a passive experience that happens to someone. It is unsupressable, but elicited by a stimulus that is usually identified without difficulty. It cannot be conjured up or dismissed at will, although circumstances of attention and distraction may make the experience seem more or less vivid.

4.3 Synesthesia is projected. It is perceived externally in peri-personal space, the limb-axis space immediately surrounding the body, never at a distance as in the spatial teloreception of vision or audition. My subject DS, for example, is a college teacher who, on hearing music, also see objects - falling gold balls, shooting lines, metallic waves like oscilloscope tracings - that float on a "screen" six inches from her nose. Her favorite music, she explains, "makes the lines move upward."

4.4 Distinguishing the experience of perception as "near" (e.g., chemosensation, touch, proprioception, body schema, the orientation of one's body within Euclidean space) or "distant" (e.g., seeing, hearing) is concordant with concepts of classical neurology and neuroanatomy. This idea was most clearly articulated by Paul Yakovlev (1894-1983) who mapped "three spheres of motility" onto three anatomical divisions of the neuraxis (Yakovlev, 1948, 1970).

4.5 Synesthetic perceptions are durable and generic, never pictorial or elaborated. "Durable" means that the cross-sensory associations do not change over time. This has been shown many times by test-retest sessions given decades apart without warning. "Generic" means that while you or I might *imagine* a pastoral landscape while listening to Beethoven, what synesthetes experience is unelaborated: they see blobs, lines, spirals, and lattice shapes; feel smooth or rough textures; taste agreeable or disagreeable tastes such as salty, sweet, or metallic.

4.6 Though synesthetes are often carelessly dismissed as being just poetic, it is *we* who must be cautious against unjustifiably interpreting their comments. For example, my index case MW described the shape of mint as "cool glass columns." On analysis, this turned out to be his shorthand way of trying to convey the quality of the tactile experience - "what is it like." When pressed to elaborate the sensations he felt, he said:
I can reach my hand out and rub it along the back side of a curve. I can't feel where the top and bottom end: so it's like a column. It's cool to the touch, as if it were made of stone or glass. What is so wonderful about it, though, is its absolute smoothness. Perfectly smooth. I can't feel any pits or indentations in the surface, so it must not be made of granite or stone. Therefore, it must be made of glass.
4.7 So, MW tells us that the sensory attributes of *curved + cool + smooth* "are like" rubbing a cool glass column. This is a third-person verbal description of a first-person sensory experience.

4.8 Seizure discharges in the hippocampus of the limbic system produce synesthesia in persons who are not otherwise synesthetic. An example is the sensation of flashing lights, a taste, a feeling of heat rising, and a high-pitched whine. Synesthesia is experienced in 4% of limbic seizures. Those that remain confined to the hippocampus produce an elementary experience - a taste, for example, is described as bitter, metallic, or merely unpleasant. Only when seizures spread to the *cortex of the temporal lobe* does the perception becomes more specific and elaborated - "rusty iron," "oysters," or "an artichoke."

4.9 *I believe that this distinction between elementary and elaborated experience is crucial if we are to craft a coherent neurological explanation of synesthesia.*

4.10 Synesthesia is memorable. At first, we are impressed by synesthetes' excellent figurative memory and taken with their anecdotes of how the "extra bits" help them to remember telephone numbers, appointments, and the like. It was Luria's *The Mind of A Mnemonist* (1968) that first suggested to me a link between synesthesia and hypermnesis. The apparently limitless memory of his subject, S, seemed due to the synesthesiae that accompanied his every experience. During recall, S described a replay of somatic feelings and "an overall sensation" during which "the thing remembers itself." By this, S meant that "he" exerted no effort to retrieve the desired information. He was merely a passive observer as the reminiscence unfolded itself.

4.11 On closer look, however, we note that what is even more memorable is the synesthetic perception itself. "She had a green name - I forget, it was either Ethel or Vivian." In this example, it is the synesthetic greenness and not the semantic label that is recalled. In other words, if Ethel is a green blob, the next time you see her you don't say, "it's Ethel," you say, "It's the green blob: therefore, it is Ethel." (It would take us too far afield to explore in this review the paradox regarding how the synesthesiae, which themselves are perceptually meaningful yet semantically vacuous, actually aid in recall. The mental gymnastics through which synesthetes go seem counterintuitively to contradict their claims that synesthesiae are "simple" and "natural" memory aids.)

4.12 That an experience rather than a thought is primary is illustrated by my subject JM, a Swiss polyglot in whom the spelling determines the perceived color of letters, words, and speech in any language. "You know how they have that electric band with the news in Times Square?" she asks. "That's how it is in my head. The color flows through me, and then I think of the thing. Somebody says to me, 'wie ist Ihr Hund?' First I have the color, and *then* I think of my dog."

4.13 Most of us have had a memory awakened by the smell of baked bread, flowers, or some other provocative fragrance. Yet while the context vividly returns to mind, few if any non-synesthetes assert that they can remember an actual odor or other episodic sensation, something that synesthetes routinely claim. My index case MW accidentally brought his synesthesia to my attention by apologizing for the delay in seating his dinner guests at table with the comment, "there aren't enough points on the chicken". Many

years later, MW and I were again dining on roast chicken. I pointed out the irony and misquoted him by saying something about "unwinding the curliques." He corrected me, noting that "I remember the *shape*, not the anecdote [unlike me, who recalled the anecdote but not the sensual details]. I was remembering that is was indeed uniformly round and it needed more points."

4.14 Synesthesia is emotional. The experience is accompanied by a sense of certitude (the "this is it" feeling) and a conviction that what synesthetes perceive is real and valid. This accompaniment brings to mind that transitory change in self-awareness that is known as ecstasy. Ecstasy is any passion by which the thoughts are absorbed and in which the mind is for a time lost. In *The Varieties of Religious Experience*, William James spoke of ecstasy's four qualities of ineffability, passivity, noesis, and transience. These same qualities are shared by synesthesia.

4.15 "Noetic" is a rarely used word that comes from the Greek *nous*, meaning intellect or understanding. It gives us our world "knowledge," and means knowledge that is experienced directly, an illumination that is accompanied by a feeling of certitude. James spoke of a "noetic sense of truth" and the sense of authority that these states impart.
Although so similar to states of feeling, mystical states seem to those who experience them to be also states of knowledge. They are states of insight into depths of truth unplumbed by the discursive intellect. They are illuminations, revelations, full of significance and importance, all inarticulate though they remain; and as a rule they carry with them a curious sense of authority for after-time <3>.

5. Lack Of Obvious Agreement

5.1 Its phenomenology makes clear that synesthesia is not an idea, but an *experience*. How does science approach this distinction between a first-person understanding of some experience and a third-person one that is supposedly objective? A lack of obvious agreement among synesthetes compounds the apparent difficulty. In fact, this rather glaring problem - that two individuals with the same sensory pairings do not report identical, or even similar, synesthetic responses - has sometimes been taken as "proof" that synesthesia is not "real."

5.2 Scriabin and Rimsky-Korsakov, for example, disagreed on the color of given notes and musical keys. "Researchers" from earlier centuries did little more than make lists of stimuli and synesthetic responses, followed by dismay that a pattern of correspondence was not obvious. I suspect that similarity was not apparent because they were looking at the terminal stage of a conscious perception itself, instead of some earlier neural process that led to that perception<4>.

5.3 We often think of the flow of neural impulses as linear, and emphasize its terminal locus - i.e., we classically think of perception, an action, or an utterance as the terminal stage of some process whose locus is somewhere in the cortex. We think of perception as

a one-way street, travelling from the outside world inwards, dispatching a linear stream of neural impulses from one relay to ever more complex ones, so that the process is metaphorically like a conveyor belt running through stations in a factory, until a perception rolls off the end as the *finished product*.

5.4 Instead of fixating on the terminal event, suppose we turned our attention to some earlier stage of neural transformation? When looking for relationships on any family tree, we find that members closer to the trunk resemble each other much more than members out on distal branches do. This is why family resemblances are more apparent in offspring when they are young children than when they are grown-up. For example, apes and humans are alike, although they hardly look it. Much of their anatomy is alike, their brains are very similar, and of course their DNA differs by only a few percent. But we need not go all the way back to DNA to see this similarity. Even in the case of different species, a human infant and a chimp infant look strikingly alike while the adult members call attention to their disparity (see Cytowic, 1993, p. 60 for an illustration). Regarding synesthesia, we conclude that all intervening transformations between the eye and the visual cortex are possible candidates for processes that are closer to the trunk of perception than a completed (and presumably cortically-situated) visual image is.

5.5 By analogy, the consensual image we see on the screen when watching television is the terminal stage of the broadcast. Someone able to intercept the transmission anywhere between the studio camera and the TV screen would be like a synesthete, sampling the transmission before it reached the screen, fully elaborated. Presumably, their experience would be different from those of us viewing the screen. We can similarly propose and test the concept of synesthesia as the premature display of a normal cognitive process.

5.6 This implies that we are all synesthetic, and that only a handful of people are consciously aware of the holistic nature of perception.

6. Neural Basis

6.1 Based initially on an analysis of phenomenology, and reasoning by analogy to more common phenomena that were qualitatively similar to the experience of synesthesia, I concluded that synesthesia was not a higher cortical function in the conventional sense. Momentarily disregarding what the *nature* of the link between a stimulating sensation and the synesthetically-perceived one might be, I further proposed that the *level* of this unknown link occupied a low to intermediate level of the neuraxis, rather than a higher level involving more mental mediation (Cytowic & Wood, 1982a; 1982b).

6.2 Experimental results were consistent with these suppositions. The five major probes were: (1) an examination of range and context effects during psychophysical sensory matching tasks between synesthetes and non-synesthetic controls; (2) the failure of Osgood's semantic differential to expose any linguistically-meaningful similarity between

stimuli and synesthetic responses (Osgood, 1957); (3) the manipulation of synesthetic perception by drugs that either stimulate or depress the cortex; (4) the comparison of regional brain metabolism, via the radioactive xenon method, during synesthetic, non-synesthetic, and adjuvant-enhanced states; and (5) the ability to induce perceptions that were qualitatively identical to the subject's idiopathic synesthesia during cerebral angiography, presumably by reducing oxygen substrate in the left hemisphere during both carotid and vertebral injections.

6.3 The detailed evidence and arguments appear elsewhere (Cytowic, 1989, 1993). In summary, synesthesia depends only on the left-brain hemisphere and is accompanied by large metabolic shifts away from the neocortex that result in relatively enhanced limbic expression. The hippocampus is an important and probably obligate node in whatever neural structures generate the synesthetic experience.

6.4 No matter what technology we use to make so-called "functional pictures" of the brain at work, we expect some cortical area(s) to "light up." We never expect a decline. It surprises many people - especially those waiting for a machine test before casting their vote whether synesthesia is real or imaginary - to learn that cortical metabolism plummets during synesthesia. MWs mean hemispheric flows are low and inhomogenous to begin with, yet drop a further 18% on average in the left hemisphere during synesthesia. Such a decrease is impossible to obtain in a normal person with, for example, a drug. Even during an *activation* trial with amyl nitrate, which subjectively intensifies the synesthetic experience, MWs regional blood flows are *decreased* compared to baseline. Normally, any physical or mental task, or any activation procedure (e.g., drug administration, carbon dioxide or oxygen inhalation), *increases* blood flow by five to ten percent.

6.5 MWs cortical metabolism dropped so low during synesthesia that he should have been blind, paralyzed, or shown some other conventional sign of a lesion. (Left hemispheric flows were nearly three standard deviations below our lab's acceptable limits of normal.) Yet his thinking and neurological exam were unimpaired. Such a depression of cortical metabolism during a distinct behavioral state disturbs traditionalists, who regard the more recently-evolved cortex as the seat of higher analysis and reason, while assigning the limbic system (the sub-cortical ring of tissue that encircles the brainstem and is much older in evolutionary terms) to handle the more "primitive" functions of emotion, memory, and attention.

6.6 I cannot enumerate here all the supporting reasons why I single out the hippocampus as being especially - but not solely - important for synesthetic experience. The hippocampus is also necessary for experiencing other altered states of consciousness that are qualitatively similar to synesthesia. For example, the perceptions during LSD-induced synesthesia, sensory deprivation, limbic epilepsy, release hallucinations, and the experiential responses during electrical stimulation of the brain all possess a generic,

elemental quality - just as they do in synesthesia (Cytowic, 1989, pp 91-146). This observation leads us to the topic of form constants, the enduring idea that elemental perceptual qualities exist.

7. Form Constants

7.1 The ineffable and indescribable nature of subjective experience is not unique to synesthesia. Heinrich Kluver faced the same difficulty when he tried, starting around 1930, to understand the experience of hallucinations. He was frustrated by the vagueness with which subjects described their experience, their eagerness to yield uncritically to cosmic or religious explanations, to "interpret" or poetically embroider the experience in lieu of straightforward but concrete description, and their tendency to be overwhelmed and awed by the "indescribableness" of their visions.

7.2 In explicating MW's description of mint (see 4.6), I distinguished between his factual description of curved, smooth, and cool tactile attributes and his analogical explanation of the taste as "cool glass columns." Similarly, once Kluver got his subjects past elaborating or, even worse, *explaining* what they saw, he identified four types of basic hallucinatory constants: (1) gratings and honeycombs, (2) cobwebs, (3) tunnels and cones, and (4) spirals. Kluver's work has been replicated and extended by others.

7.3 Variations in color, brightness, movement, perspective, symmetry, and replication provide finer gradation of the subjective experience. These are not just visual phenomena, but sensory form constants that are apparent in any spatially-extended sense. Initially, we thought these spatial configurations reflected some anatomic structure; then we tried mapping it to some prototypical function. Now, neuroscience is not sure what their physical correlates are, but many people do suspect that the form constants point to some deep, fundamental aspect of perception.

7.4 For example, few people claim to like explosions, yet everyone likes fireworks. Millions of pounds of entertaining explosives go up all over the world, with millions turning out to watch them. What are they, these colored lights, flashes, and bangs? They are not real things in nature, representations of anything else, and they don't remind us of anything at an intellectual level. They are as abstract as Piet Mondrian or Jackson Pollock - and yet they provoke a strong emotional reaction, inducing millions to watch and then walk away, highly satisfied, saying, "That was wonderful," without anyone being able to say exactly what "That" was. No other form of abstract visual expression is as popular.

7.5 The pulsation, flicker, drift, rotation, and perspective of fireworks of course remind us of the form constants. When we see fireworks, do we not get a feeling of salience, as if we recognize something? Isn't the "that" of, "That was great," an ineffable experience of recognition? I do not think it out of line to suggest that the satisfying appeal of something

so unnatural as a fireworks display lies in its astonishing similarity to an externalized catalogue of form constants.

8. The Implications Of Synesthesia Regarding The Primacy Of Emotion

8.1 Possibly because we have historically held a dichotomy between reason and emotion, we have misunderstood and even minimized the role that emotion plays in our thinking and actions. I want to make clear that the following comments are not a direct cause-and-effect of synesthesia, but an implication resulting from its physiologic basis. The two-fold key to this implication is: (1) appreciating the major role that the limbic brain plays in synesthesia; and (2) considering newer non-hierarchical models of brain organization.

8.2 The word "multiplex" is usually applied to contemporary concepts of brain organization that take into account volume transmission, distributed systems, non-linear dynamics, and the thermodynamic energy costs of any given biologic neural process. Such newer models remain largely unknown, a surprising unfamiliarity given their implications - for example, that we are irrational creatures by design and that emotion, not reason, may play the decisive role both in how we think and act. Additionally, our brains are not passive receivers of energy flux, but dynamic explorers that actively seek out the stimuli that interest them and determine their own contexts for perception. Ommaya (in press) has elegantly articulated a number of powerful contradictions in conventional models of brain organization that led to his reevaluation of the role of emotion in cognition and behavior. Indeed, he describes consciousness as "a type of emotion," and one of emotion's roles as a "cognitive homeostat".

8.3 The conventional hierarchical model implied that the limbic system was left behind as the neocortex burgeoned during evolution. If so, then human emotions are comparatively primitive, no more sophisticated than those of other mammals. Below the level of mammals, the limbic system is not seen in its developed form, but once we reach the mammalian line it undergoes robust elaboration. This development, however, occurs in tandem with that of the neocortex. Some mammals emerge higher in one dimension than another: rabbits, for example have well-develop limbic brains compared to their neocortical development, whereas monkeys show the opposite trend. Humans are unique among mammals in being well-developed in both limbic and neocortical dimensions. In humans, the relationship between cortex and subcortical brain is not one of dominance and hierarchy, therefore, but of multiplex reciprocity and interdependence.

8.4 Anatomically, the number of human limbic fibre tracts is greater both in relative size and absolute number compared to all other fibre systems. Thanks to new techniques, we have only recently realized that there are more projections from the limbic system to the neocortex than the other way around. In other words, we had the primary direction of flow backwards all these years. While we think that the cortex contains our

representations (or models) of reality - what exists outside ourselves - it is the limbic brain that determines the salience of that information. Therefore, I join Ommaya in arguing that it is an emotional evaluation, not a reasoned one, that ultimately informs our behavior.

8.5 I am hardly rejecting either reason or the role of the neocortex in objective assessment or assigning meaning. Though we quickly speak of reason dominating emotion, the reverse is actually true: the limbic brain easily overwhelms thinking. Let me give two clinical examples.

8.6 Limbic structures have a low threshold for seizures that produce both psychic and motor manifestations without spilling over to other brain regions. Most characteristic is a *qualitative alteration of consciousness*. Well coordinated involuntary actions, called automatisms, seem rational and purposeful to an uninformed observer, yet the patient has no awareness or recollection of them. Limbic seizures also cause compulsive thinking, psychosis, and episodes in which one cannot distinguish dreaming from waking reality. The overlap between limbic seizures and psychiatric disorders is a striking 50% compared to only 10% in all other kinds of epilepsy.

8.7 The second example concerns the emergence from coma. In recovering from coma, patients first manifest automatisms, then voluntary movements and speech that is childlike and emotionally childish. Behavior becomes more rational and adult-like if recovery continues. In other words, intellect cannot be reclaimed unless emotion recovers first.

8.8 Emotion did not get left behind in evolution. Reason and emotion evolved together and their neural substrates are densely interconnected. Yet each concerns itself with a different task. The word "salience", which means to "leap up" or "stick out", describes how the limbic brain alerts us to what is meaningful. We might say that the emotional brain deals with *qualitatively significant information.*

8.9 The limbic brain's use of common structures for different functions such as memory, emotion, and attention may partly explain why humans excel at making decisions based on incomplete information, "acting on our hunches." We know more than we think we know. And yet are we not always surprised at our insights, inspirations, and creativity? And do we not just as often reject our direct experience in favor of "objective facts" instead?

9. The Rejection Of Direct Experience

9.1 My usual response to those who ask if synesthesia is "real" is, "Real to whom? To you, or to those who experience it?" Questioning its reality without first having some

technological confirmation shows how ready we are to reject any first-hand experience. We are addicted to the external and the rational. Our insistence on a third-person, "objective" understanding of the world has just about swept aside all other forms of knowledge.

9.2 In the course of studying MW, for example, we came to a point of using invasive and rather sophisticated technology when he became frightened, not that we might uncover some medical abnormality, but because a machine might prove that his synesthesia wasn't real. MW was ready to accept the judgement of a machine over his lifetime of first-hand experience. This is a remarkable commentary.

9.3 When we think of our brains, we usually think of a computer, a reasoning machine in our heads that runs things. This is consistent with the hierarchical model. But emotion - which word I use to include irrational, a-rational, and non-verbal knowledge and cognition - is what actually directs our thoughts and actions. Like the Wizard of Oz, it is our a-rational inner life that pulls the levers behind the curtain. Our inner knowledge behind the curtain is largely inaccessible to introspective language, which means that what we feel about something is more valid than what we think or say about that something.

9.4 Reason is just the endless paperwork of the mind. The heart of our creativity is our direct experience and the salience that our limbic brain gives it. Allowing it to be that does not stop us from overlaying rational considerations on it - after which we can talk, recount, explain, interpret, and analyze to our heart's content.

10. Future Issues For Research

10.1 A number of tantalizing observations need to be systematically followed up, and other issues remain to be clarified, all of which can help address the overarching question of whether my sharp demarcation between synesthesia and other cross-modal associations remains justified. In addition to neuropsychologists, other professionals who can bring their expertise to synesthesia include anatomists, geneticists, linguists, and developmentalists.

10.2 Synesthesia embraces an unexpected constellation of features. Traits in which non-right-handers predominate customarily feature an excess of males. Yet synesthetes are predominantly women, and in commenting on synesthesia's heritability, Baron-Cohen (1993) notes that a preponderance of relatives who share the trait are also female. (Is this a sampling bias or not? Of my seven females who have a synesthetic relative, five are themselves female.) While mathematical and spatial (navigational) skills are said to be somewhat poorer in women than men in general, in synesthetes we find a strong tendency towards frank abnormality.

10.3 In the US, female synesthetes are 2.5 times more common than male synesthetes, while the ratio in the is much higher in the UK, a disparity that wants explaining. (Baron-Cohen reported a ratio of 4:1 in 1987, based on two independent samples). Some of the inequality may relate to the kind and number of synesthetes in our respective collections. While both of our subject populations are self-selected, mine (Cytowic, 1989) is smaller (N=42) and contains polymodal synesthetes whose experience is projected (i.e., experienced as outside of themselves). Harrison and colleagues have received inquiries from several hundred possible synesthetes, nearly all of whom manifest only colored letters and words (as in Valdimir Nabokov). Might this be a possible forme fruste? Or might it mark a realm where projected cross-modal experience merges into commonplace mental imagery? It is doubtful that transatlantic genetic differences contribute to this disparity.

10.4 Related to the above is the issue of synesthesia's incidence. Based on newly-encountered cases since *Synesthesia: A Union of the Senses* (1989), and especially since *The Man Who Tasted Shapes* (1993), which was written for a general audience, I have revised my initial approximation from 1/100,000 to 1/25,000. In the process of discerning its true frequency, we should also determine the relative incidence of different sensory combinations. Are smell and taste really less common, than sight and sound, and if so, why?

10.5 Further revisions are also possible in response to potential cases received via the Internet, either direct enquiries or those engendered by subscriber-based services such as Prodigy and CompuServe. The even sex ratio that I have ascertained in self-selected cases submitted electronically is likely because more men than women use computers with modems that are connected to on-line services.

10.6 Turning to the purely physical realm for a moment, I performed detailed Goldmann perimetric visual field testing in only two subjects (MW and LH). However, both showed a left monocular temporal field defect consistent with an abnormality in the left hemisphere optic radiation. Nowadays in clinical practice, such a lesion is rarely noticed because scanning has replaced careful but time-consuming hands-on examination. (Not only do patients usually fail to notice such small field cuts, but clinicians must deliberately hunt for them.) While I suggest that perimetry be systematically done on prospective synesthetes, I caution that it must be performed manually (not with automated octopus-type equipment), and with attention to color and motion defects.

10.7 Although my ascertainment is incomplete, at least ten percent of synesthetes are gay or lesbian, meaning that the actual incidence of homosexual synesthetes could be higher. Current research indicates that some part of human sexual orientation may be immutable, and that genes and other biological components play a significant role. The co-occurrence of a homosexual orientation and synesthesia (including its distinct cognitive profile and

gender distribution) would be most interesting, and broadly in agreement with Geschwind's controversial proposal that anomalous cerebral dominance underlies atypical cognitive talents and behavior (Geschwind & Galaburda, 1987; LeVay, 1993). This is obviously an early conjecture. Accordingly, detailed systematic sexual histories of synesthetes could prove or disprove what I have only surmised.

10.8 Learning disabilities seem more common in synesthetes and their first-degree relatives. What is the actual incidence of autism, dyslexia, and attention deficit disorder (ADD) among synesthetes? Do synesthetes themselves so afflicted differ from other synesthetes?

10.9 A young adult male recently phoned in to a radio program on which I appeared and recounted a typical story of colored hearing. He also had ADD, and mentioned being placed on Ritalin (methylphenidate) as a teenager. Instead of telling me that the stimulant attenuated his synesthesiae, as I fully expected, he related how it intensified the experience. This effect is the reverse of that demonstrated by my earlier drug experiments as well as anecdotal reports of synesthetes who have taken stimulants recreationally. Since individuals with ADD have a paradoxical response to stimulants, perhaps it is not surprising for that paradoxical response to carry over to those who have synesthesia as well.

10.10 Much can be learned from scrutinizing the effects of commonly-prescribed drugs on synesthesia. Because their psychopharmacology is usually known in depth, antidepressants, anti-migraine, and anti-epileptic medications come quickly to mind. For example, subject GG noted that her synesthesia was not as intense during the interval that she took Ludiomil (maprotiline, a norepinephrine reuptake blocker). One wonders about the effect of popular serotonin uptake inhibitors such as Prozac (fluoxetine), Zoloft (sertraline), and Paxil (paroxetine).

10.11 Whereas there are individuals with hippocampal epileptogenic foci who experience synesthesia during a seizure but are otherwise not synesthetic, there also exist synesthetes who are additionally epileptic and in whom the two phenomena are independent. A lifelong synesthete who developed temporal lobe seizures as an adolescent notes that the anti-epileptic Tegretol (carbamezapine) made her synesthesia less vivid (Cytowic, 1989, p 174).

10.12 Clinical skill and astute listening are mandatory if such experience is to be extracted from patients. Epileptics are frightened of a great many things, mostly irrational, and about which they *never* speak unless asked directly, without judgement and with compassion. It surprises many physicians to learn that epileptics are terrified foremost of dying during a seizure. If such an unfounded worry preoccupies their

thoughts, it is not hard to suppose that synesthetic experience might make them think that they are losing their mind.

10.13 Fourteen years ago, I conjectured that synesthesia was an all-or-nothing trait that did not disappear once it was manifest in childhood. Though aware of research showing that even newborns can make cross-modal associations (Meltzoff & Borton, 1979), or that cross-modal similarities in non-synesthetic children are stronger perceptually than verbally (Marks et al., 1987), I had found no clinical evidence to support the hypothesis that synesthesia might be more common in children as authors from earlier eras claimed. Only this year have (three) individuals remarked - with some amazement and in the context of my public appearance - that they vividly recall colored words, shapes, number forms and the like as children but no longer experienced these things as teenagers. "I haven't thought of this since I was a child," or "since my bar mitzvah," they typically volunteered.

10.14 So, do some children lose their synesthesia, and, if so, when? Do the hormonal storms of puberty play a role via modulation of cerebral organization? If some individuals indeed lose their conscious experience of synesthesia, do they retain any other common synesthetic features?

10.15 Related to this line of inquiry looms the disentanglement of phonemic from lexical stimuli, as well as issues centered on learning in those synesthetes who experience colored letters, numbers, and words. If the letter "M" is red, for example, there is something about its "M-ness" that makes it red, so some learning must be involved despite synesthesia being a relatively low-level higher function. But how much learning, when, and of what nature? Moreover, why do some synesthetes respond to the sound of a word while others are influenced by the spelling? Is there, as some developmentalists propose, a critical period of conceptual reorganization when children switch from speaking to reading? Could the details of such a switch explain the presumed retention of phonemic stimuli in some synesthetes and the progression to lexical triggers in others? Given synesthesia's heritability, one could possibly, though with effort, identify synesthetic offspring with colored hearing and see if the stimuli in fact do change after the acquisition of reading. Linguists no doubt could pose more sophisticated and probing experiments.

10.16 Stroop-type tests, and comparisons of homonyms, synonyms, and the like are additional probes that may answer some questions and raise others. For example a woman and her father both taste words. "Your name, Richard, tastes like a chocolate bar," she writes, "warm and melting on my tongue." "Some words are a complete 'experience' in that they have flavor, texture, temperature, and are sensed in a certain place in my mouth, i.e., back of throat, tip of tongue, etc. Often, the spelling affects the taste. 'Lori' tastes like a pencil eraser, but 'Laurie' tastes lemony. Go figure." In such a case, one might first verify whether the spelling or meaning determines the synesthesia.

Another concern is that there are innumerably more words than smells, so what eventually happens? (A similar case holds for those in whom sound rather than spelling determines colors.) Do tastes occur only for nouns, or concrete nouns? What about verbs, adjectives, and grammatical functors? What does the word "eraser" taste like? The questions go on.

10.17 Lastly, I did not mention cognitivists in the above list of professionals (10.1) who might help further clarify the brain basis of synesthesia. I generally take the view that clinical observation must drive theory rather than the reverse. I think this position is even more necessary with phenomena such as synesthesia that are largely experiential.

10.18 Just as I argued that our passion for a detached and "objective" point of view has diminished other kinds of knowing, so too I see that the experimental emphasis on deficits is gradually smothering the clinical method of symptom analysis. And herein lies the friction between cognitive scientists, who think abstractly and in terms of computation, and those scientists who think clinically and in terms of biology.

10.19 The experimental approach favored by cognitive science takes individuals with brain damage and focuses on deficits (what is missing) to infer the existence of underlying entities that are presumably linked into a computational network. The models of this abstract approach boil down to hypothetical components in box diagrams. In contrast, the clinical approach examines symptoms, positive errors rather than negative deficits. Because it focuses on how symptoms change over time rather than being interested in how network components interact at the same time at any given moment, clinical models are predominantly procedural and contextual.

10.20 Perhaps some distrust of symptom-based accounts lies in their aura of being more hermeneutic than scientific. That is, their validation is largely aesthetic, a theory's proof residing in the harmony of its elements, its coherence of ideas, and its explanatory power. Many scientists spurn this whiff of mysticism. Nonetheless, local cognitive models strike me as overly self-contained, the inevitable isolation of a model's elements artificially reifying them into real entities without an effort to say how everything comes together. Even then, "all together" doesn't mean how it relates to personality or the big picture, but only to other local models. Cognitive science can make a local model of anything, though the fact that it could make a model of synesthesia without needing a model of perception strikes me as odd. Being able to see the big picture requires an enormous understanding of myriad details.

10.21 If you think that the mind is some disembodied, abstract program that can be instantiated on any hardware capable of running it, then you can ignore the biological complexities of neural tissue. For those who think theoretically, this is both convenient and lazy. Cognitivists envision their negative deficits in terms of lesioning one or more

theoretically-assumed modules in the "system" underlying some behavior. Independent of any clinical evidence, computational models eagerly presume the existence of logically plausible but wholly abstract subsystems. Yet they seem to be able to say little about positive symptoms. At best, it can suggest that synesthesia represents a breakdown or unbinding of modularity (Baron-Cohen et al., 1993). While this seemingly may illuminate a single case report, no strategy exists for collapsing across cases, or different *kinds* of synesthesia.

10.22 I concur that the brain is representational, yet remain unsure (and unswayed) about its being computational. Our sensory input is digital, but our experience is analog. Yet hypothetical modules presently drive experiment instead of theory being driven by phenomenology. The Brodmann areas have conceptually metamorphosed into chips that serve distinct mental functions - grammar, syntax, color, contrast, or whatever. Behavior and perception are reduced to the inputs and outputs of a presumed central processor - a concept that divorces human experience from context, history, and environment. (This sounds like behaviorism revisited, although I grant that the behaviorists didn't care whether humans had a brain let alone a cognitive architecutre.)

10.23 Having said all this, let me ask you to cogitate whether microgenesis, for example, can explain synesthesia more satisfactorily than cognitive science can (Brown, 1988; Hanlon, 1991).

10.24 Do the elemental qualities of synesthesia, as partially represented by the form constants, represent "building blocks" or "modules" of cognitive science in which a perception is assembled like modeling a statue from bits of clay? Or is perception holistic, constrained by sensation as it unfolds from within? If so, then perception is like sculpting from a block of marble, exposing the statue within it by removing extraneous bits. In this view, synesthesia is the conscious awareness of a normally holistic process of perception that is prematurely displayed. That is, it is awareness before the terminal target, before the final stage of neural transformation and mental mediation. If this is correct, then we are all unknowingly synesthetic.

Notes

<1> See also the index under "color competition" in Cytowic (1989) for further examples of color conflict both in synesthesia and eidetic memory.

<2> See Cytowic, R.E. (1995) *The Neurological Side of Neuropsychology*, chapter 12 for the difference and for a discussion of geographical knowledge as a cognitive skill.

<3> James, W. (1901/1990) *The Varieties of Religious Experience*, p 343. New York: Vintage books.

<4> (Parenthetically, I have also approached the issue of non-universal responses via the well-known topics of color constancy and colored shadows.)

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