WEDNESDAY IS INDIGO BLUE

Discovering the Brain of Synesthesia

Richard E. Cytowic, M.D., and David M. Eagleman, Ph.D.

A Bradford Book

The MIT Press
Cambridge, Massachusetts
London, England

This book was set in Stone Sans and Stone Serif by SNP Best-set Typesetter Ltd., Hong Kong and was printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data
Cytowic, Richard E.
Wednesday is indigo blue : discovering the brain of synesthesia / Richard E. Cytowic and David M. Eagleman.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-262-01279-9 (hardcover : alk. paper) 1. Synesthesia. 2. Emotions and cognition. I. Eagleman, David. II. Title.
RC394.S93C964 2009
612.8'233—dc22

2008029814

10 9 8 7 6 5 4 3 2 1

1 What Color Is Tuesday?

Most people have never heard of synesthesia.

Yet everyone knows the word "anesthesia," meaning "no sensation." Rhyming with it and sharing the same root (Greek *syn* = union + *aisthaesis* = sensation), "synesthesia" means "joined sensation," such that a voice or music, for example, is not only heard but also seen, tasted, or felt as a physical touch. Some individuals with synesthesia are shocked to discover as children that the rest of the world does not experience things as they do. Many other synesthetes reach adulthood completely unaware that their experience is in any way unusual.

"I thought everybody—!" they exclaim.

It is often by accident that synesthetes discover that their way of perceiving is not the norm. As a seven-year-old, for example, synesthetic artist Carol Steen once said to a schoolmate, "The letter 'A' is the most beautiful pink I've ever seen."

Thinking she must be crazy, Carol's classmate gave her a withering look. After that, Carol never mentioned her colors to anyone until she was twenty, when, as she and her family were sitting around the dinner table one evening, she told them that the number 5 was yellow—whereupon her father startled her by insisting, "No, it's yellow ochre!" and then refused to say anything more about it. Later, when she was in her thirties and teaching art at the University of Michigan, a psychology colleague revealed that this experience of colored letters had a name: synesthesia.

At the time, all Carol could uncover about synesthesia was a dictionary definition, and then it only mentioned colored music. She went twenty more years starved for information until she happened to hear one of the authors of this book, Richard Cytowic, explaining synesthesia on National

Public Radio.[1] Only then did she learn that her experience was not only genuine but also scientifically important. Forever grateful, she now says, "The knowledge he shared gave me my freedom after fifty years of isolation."

Another woman with what are called "number forms" reached college before realizing that most people do not sense numerals along a three-dimensional line that twists and zigzags in space. She complained to her math professor of having difficulty with the equations "because the digits keep going up to their places." Sensing something significant in her offbeat remark, the professor handed her a length of stiff wire and asked her to indicate where along it the figures were located. He then watched as, without the least hesitation or surprise, "she took the wire and bent it here and there in three dimensions until it looked like a tortured thing. A number of times, she returned to previously made bends, correcting the angles precisely."[2]

"Is anything odd about it?" the student asked in all seriousness. "Everybody sees numbers like that, don't they?"

She was stunned to learn that they did not.

Some synesthetes live a very long time before discovering their exceptional ways. Jean Milogav, a Swiss synesthete, reached her sixties before realizing that sensing the alphabet and numerals as colored was rather unusual:

> I only became consciously aware of it after reading Vladimir Nabokov's autobiography *Speak, Memory* in which, to my great surprise, he describes exactly the same type of synesthesia as mine: i.e., "seeing" every letter of the alphabet and every number in a specific color. . . . My colors are not the same as his.
>
> I too never talked about it, not out of shyness but because I always thought all people were like that. Only after reading Nabokov's description of his synesthesia did I realize this was rather unusual. . . . I enjoy it very much and would be hard put if these colors would suddenly vanish. I don't think they will; I am 61 now and had it all my life.[3]

Jean speaks German, Italian, French, and Spanish, and because her colors are determined by the physical appearance of each letter rather than by their sound, it is the spelling that determines the color of a word no matter which language she speaks.

As noted above, accident is how synesthetes often first learn about their astonishing gift, and accident also lay behind Richard's rediscovery of

Figure 1.1
In Michael Watson, taste and smell triggered tactile sensations of contour, texture, weight, and temperature.

synesthesia in February 1980. His dinner host delayed their seating with the apology that there weren't "enough points on the chicken." Michael Watson, literally *The Man Who Tasted Shapes* in the book of that title that Richard would later write, felt taste and smell as a physical touch on his face and in his hands.

"With an intense flavor," he explained, "the feeling sweeps down my arm into my hand and I feel shape, weight, texture, and temperature as if I'm actually grasping something" (see figure 1.1). He had wanted the chicken to be a prickly, pointed sensation, "like laying my hand on a bed of nails." But it came out all round.

"I can't serve this," he insisted, embarrassed at having roasted the wrong shape. Michael enjoyed cooking, but rather than flavor being his gourmet guide he liked to conjure up dishes that evoked particular shapes, textures, and other tactile sensations.

"They're Just Looking for Attention"

At that time, no one in Richard's academic circle had ever heard of synesthesia, and science had lost interest in it for many decades because it couldn't explain it or even verify someone's subjective experience. Richard only knew the term because he had read a translated book called *The Mind of a Mnemonist* by the famous Soviet neuropsychologist A. R. Luria, describing a memory expert named Sheresevsky, who remembered limitless amounts thanks to a fivefold synesthesia that spanned his senses. For example, a bell triggered seven simultaneous perceptions for Sheresevsky:

> I *heard* the bell ringing . . . a *small, round* object *rolled* before my eyes . . . my fingers sensed something *rough* like a rope . . . I experienced a *taste* of salt water . . . and something *white*.[4]

Richard's neurology colleagues joked that his subject, Michael, had to be either crazy or on drugs, insisting that synesthesia could not be a real perceptual phenomenon because it contradicted standard notions of separate sensory channels in the brain. They warned him not to pursue it scientifically because it was "too weird, too New Age," and "would ruin" his career. In other words, they had the typical reaction of orthodoxy to something it cannot explain: deny it and sweep it under the carpet.

Thanks to Richard's pioneering work, however, the paradigm has shifted, and today young researchers around the world are writing articles, Ph.D. theses, and scholarly books and papers about synesthesia and are having to think about the brain in ways they have never had to think about it before. You will meet many of them in these pages.

For a long time, though, it was typical to dismiss synesthesia with glib or even hostile assertions. "They're just imagining it," skeptics claimed, writing synesthetes off as needy exhibitionists with overactive imaginations who simply want to call attention to themselves. One feature that skeptics grabbed onto in support of their contention that synesthetes were just "making it up" is the fact that synesthetic associations are idiosyncratic. That is, no two synesthetes, not even identical synesthetic twins, experience the same colors if given the same stimulus. And the assertion that synesthetes were "on drugs" was not entirely arbitrary, because LSD and mescaline sometimes *do* cause synesthesia, both during the high and

afterwards. However, drug-induced synesthesia is a different experience from the naturally occurring state. (Yet the fact that drugs can induce a similar state only makes the naturally occurring kind more intriguing.) When other excuses failed, critics ultimately dismissed synesthetes as "crazy artists."

Many in the scientific establishment rolled their eyes at the notion of synesthesia and tried to explain away a very common type—namely, sensing letters and numbers as colored even though they are printed in black ink—by arguing that synesthetes were just "remembering" childhood associations from coloring books or refrigerator magnets, and that is why the letter A was red or D was green, for example. But synesthesia runs strongly in families, a fact Sir Francis Galton noted more than a century ago in Britain. It would be an implausible coincidence if subsequent family generations all happened to "remember" color associations from magnets handed down. Moreover, almost all of us played with coloring books and refrigerator magnets as youngsters, but for the majority a particular color "memory" does not become irreversibly bound to digits or letters. Finally, each synesthete's palette of color pairings is quite idiosyncratic—a fact true even between family members. Therefore, a privileged memory is likely not the explanation for synesthesia.

What Galton astutely noted, actually, is that otherwise normal people saw colors whenever they *looked* at numbers or letters. That is, it was the visual appearance of the written grapheme that triggered an experience of color. By contrast, we note that the sounds of language, called *phonemes*, tend to trigger synesthetic tastes. For James Wannerton, the word "village" tastes like sausage, as do words with the same /idg/ sound such as "college" and "message." The name "Derek" tastes like earwax, and "safety" like lightly buttered toast. It further turns out that phonemes triggering tastes tend to be present in the word for that taste. Thus, "April" tastes of apricots, "Barbara" like rhubarb, and "Cincinnati" like cinnamon rolls. Childhood food names apparently act as templates for other words triggering synesthetic tastes, a finding whose importance we elaborate in chapter 6.

A remarkable observation is that once a synesthetic link is established, it seems to remain stable for life. That is, for a given individual, the letter A is always cobalt blue or "Derek" always tastes like earwax. Once established, the association becomes locked in. Most fascinating, synesthesia is genetically inherited and thus a function of nature but also requires

interaction with nurture in the form of early life exposure to culturally learned artifacts such as letters, numbers, and food categories. In fact, permanent links get established between aspects of sensation and a whole range of concepts as shown by the many varieties of synesthesia—because basically the gene confers increased cross talk between different brain areas. Whether the cross talk results from extra wiring or more activity in the normal wiring is the subject of chapter 9.

In the case of colored letters and numbers, the brain area crucial for recognizing letter and numeral graphemes (the green area in figure 1.2) is positioned in the left hemisphere just next to the color perception area (the red area in figure 1.2) called V4. Because of increased cross talk, the appearance of a letter triggers activation in the V4 color area. It is interesting that despite having normal color vision, synesthetes commonly say they experience "weird" or "ugly" colors they would not deliberately choose. Even Steven S., a partially color-blind synesthete, speaks of seeing "Martian colors."[5] Some of his photoreceptors are abnormal, restricting the range of colors he can see, but the color areas in his brain appear to be driven by alternate nonoptical inputs. Cases like this rule out the argument that synesthesia is nothing more than childhood memories, because how could someone remember colors he or she has never seen or is incapable of seeing?

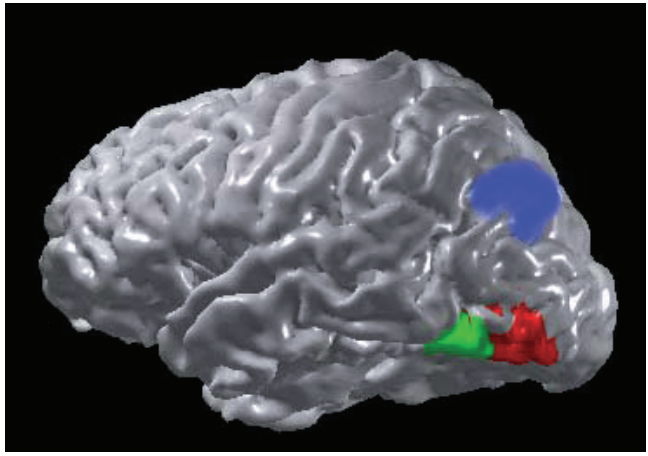

Figure 1.2
The brain area for recognizing letter and numeral graphemes (green) is positioned in the left hemisphere just next to the color perception area (red) called V4.

A recurrent criticism of skeptics is that synesthetes are simply speaking metaphorically, the way someone might speak of a "loud tie."[6] But think a minute—isn't a tie visual instead of auditory? And why do people use a taste adjective to describe a person, as in "she's so sweet?" What is going on with terms like "sharp cheese" and "cool jazz"? There is a circular logic in saying synesthetes are just being metaphoric because we do not yet understand how metaphor is represented in the brain. Rather, the argument should perhaps go the other way around: perhaps common metaphors stem from synesthesia. Our hope is that understanding the concrete sensory phenomenon of synesthesia will give us a handle on the neurological basis of metaphor and even artistic creativity. We explore this relationship in chapter 8.

More Common than Originally Suspected

Given that most people have never heard of synesthesia, one of the first questions tends to be "How common is it?"

In 1880, Sir Francis Galton[7] assumed the prevalence of synesthesia to be 1 in 20 based on his observations of individuals with "visualized numerals." His contemporaries came up with similar estimates ranging from 1 in 4 to 1 in 10.[8] By contrast, Richard studied numerous varieties of perceptual synesthesia and, in 1989, estimated synesthesia in general to be quite rare at 1 in 25,000. He extrapolated from known cases in North America. An informal follow-up survey of two million online individuals in 1994 agreed with that figure.[9]

A drawback of the survey method is that it is far from the ideal of a random sample of the population. All survey samples are prone to bias. For example, while two million individuals is an impressive pool of candidates, it includes only people who own computers and subscribe to a particular Internet provider. This methodology further skews results by selecting only those who read the survey and by depending on individuals to come forward and identify themselves as synesthetes rather than having a researcher systematically examine each one to ascertain who really has the trait.

As synesthesia gradually became a respectable topic for scientific study again, other researchers aimed to pin down its prevalence more rigorously. In 1993, Simon Baron-Cohen and colleagues in London surveyed two nonrandom populations and came up with estimates of 1 in 2,000 and 1

in 2,500.[10] They derived their estimates from the number of respondents to newspaper advertisements in campus and town papers, basing their calculations on the papers' circulation. Although also depending on self-referrals, the team did personally evaluate positive responses to determine whether those individuals truly were synesthetic. Because the entire participant pool was not questioned, however, no conclusions could be drawn about those who did not respond. Thus, the estimate of 1 in 2,000 was conservative.

As synesthesia became more widely known among neuroscientists, it also drew increasing attention in the popular press. Accordingly, synesthetes began to read about themselves in newspapers and magazines or hear about themselves on radio programs, and they eagerly contacted the researchers being interviewed. More estimates of the prevalence of synesthesia became available based on populations who came forward as self-identified synesthetes available for study. In Germany, Hinderk Emrich and colleagues estimated synesthesia to occur in between 1 in 300 and 1 in 700 individuals,[11] whereas in the United States, Vilayanur Ramachandran and Edward Hubbard put the prevalence at 1 in 200 based on classroom surveys.[12] Since these estimates were again based on self-report, they shared the same shortcomings as earlier ones.

Finally, in 2005, Julia Simner and colleagues in Edinburgh tested two populations, one at a university and another visiting a large science museum. Her team overcame earlier shortcomings by individually assessing a large random sample of people and verifying their self-reports with objective tests. The university study tested for all known types of synesthesia, whereas the museum study asked only about colored letter synesthesia. Their calculation is therefore the most sound to date because of its sampling methods, the use of objective tests, and the agreement of both estimates using two different populations and testing methods.

The results confirmed that synesthesia is far more common than originally assumed: 1 in 23 for any type of synesthesia, and 1 in 90 for grapheme → color synesthesia. It was also determined that the most common type of synesthesia was experiencing color for days of the week, followed by grapheme → color synesthesia. Previously, the latter was widely believed to be the most common manifestation.

We relate this history to illustrate how scientific "facts" shift based on new information. Typically, answering one question raises others. Some-

times a shift occurs as a result of better methodology or accuracy. Other times it results from asking different questions. Often, we are left with loose ends or even data that conflict.

A good example of this is the striking observation in the earlier studies of a strong-overrepresentation-of-females bias among synesthetes: in the past, three to six times as many women reported having synesthesia as men. This finding seemed to have strong theoretical implications, suggesting a mode of genetic inheritance that is linked to the X chromosome. That is, mothers (who possess two X chromosomes) can pass an X gene on to either sons (XY) or daughters (XX), while fathers (having XY chromosomes) can transmit the gene only to daughters. People therefore began to suspect that the genetic basis of synesthesia would be associated with the X chromosome.

However, that hypothesis was still not enough to explain the massive outnumbering of women to men. The problematic observation of a ratio as high as 6 to 1 was addressed by appealing to a genetic event known as "male lethality." The idea was that genes associated with synesthesia were deadly to half of male embryos, who would accordingly miscarry, leaving an excess of female synesthetes among live births. Thus, the excess number of female synesthetes seemed accounted for.

It was therefore a surprise when Julia Simner's randomly sampled population showed no female bias. Instead, she found roughly equal numbers of synesthetic men and women. The conclusion is that the strong female biases detected by earlier studies were all likely due to sex differences in self-disclosure. That is, women are far more likely than men to come forward and report interesting and unusual experiences such as synesthesia. As a result of Simner's study, we can drop the need to hypothesize maternal inheritance and male lethality.[13] One of us, David, has for years been studying synesthetic families and their DNA, and in chapter 9 we turn in detail to the genetic findings and what they teach us about the neural basis of synesthesia.

An Early Family Affair

Synesthesia is usually evident at an early age. Individuals invariably claim to have had it as far back as they can remember and cannot recall ever not having it. Indeed, a childhood assumption is that everyone is like them.[14]

When they realize this is not the case, the pendulum may swing the other way, making individuals then believe they are the only person in the world who perceives as they do. For example, Bruce Brydon, who has emotionally mediated synesthesia causing him to see colored auras around objects, felt isolated:

> I have never communicated to anybody of seeing additional colored light. For one, I have failed to understand it myself, and to try to explain it to somebody else would leave me no better off. I was so happy to see that my experience is shared and acknowledged by others. I'm 35 years old and work in the construction industry. Fear of ridicule has held my secret.

Unfortunately for young synesthetes, disbelief and ridicule are real possibilities. Deni Simon has three types of synesthesia, hearing → color, grapheme → color, and emotion → color. She recalls:

> My parents thought I was very strange. They thought I was making it up to get attention. Everyone was always jumping in with psychological explanations: I had an overactive imagination, I was spoiled and wanted attention, a whole slew of things. My mother was the only person that believed me, and I'm not sure she was truly convinced that what I experience is real.

Sometimes, untoward results occur. For example, a baby-sitter alarmed a four-year-old's parents by insisting, "Schuyler is psychotic!" He had told her that "colored straws" were floating in his apple juice (possibly indicating smell/taste causing an experience of color + shape). He further made endless crayon drawings of sounds such as a "helicopter sound" or the "cuckoo clock sound" (possibly indicating colored hearing). Fortunately, both parents were Ph.D. students, and neither gave in to the sitter's excitement. Rather, they scoured their university's library for alternative explanations and eventually rang up Richard to inquire whether their child might be synesthetic.

As Galton had noted, synesthesia tends to run in families.[15] When it does, otherwise odd remarks are thankfully recognized for what they are. For example, when Vladimir Nabokov, as a toddler, complained to his mother that the colors on his alphabet blocks were "all wrong," she understood him to mean that the colors painted on the blocks did not correspond with his idiosyncratic letter–color perceptions. Nabokov's mother

readily understood because she too had colored letters as well as colored hearing,[16] demonstrating that while synesthesia is inherited, parent and child can have different types. In later years, Nabokov's son Dmitri would turn out to have grapheme → color and sound → color synesthesia.[17] Interestingly, Nabokov's wife Vera was also synesthetic, making it impossible to determine in retrospect from whom Dmitri inherited his synesthesia.

Susan Osborne escaped ridicule as a child because her father and sister also had grapheme → color synesthesia. To pass the time on automobile trips in the 1950s, they would play a game that involved calling out the corresponding colors of numerical sequences on roadside signs. For example, "Route 206" might make one of them sing out "sparkly blue, pale orange, and pink," whereas "Scranton 87 miles" might bring forth an assertion of "red and lime green." Of course, each player saw his or her own hues, and the fun part of the game was standing up for one's unique color combinations. Her mother, who was not synesthetic, never could make heads or tails of her family's strange pastime.

Given recent advances, synesthesia may be the first *perceptual* condition for which a gene can be discovered. It appears that synesthetic perception results from a heritable overinteraction between different areas of the brain. We explain these theories in chapter 9.

Nineteenth and early twentieth century reports emphasized that synesthesia appears to be common in childhood.[18] In 1883, the eminent psychologist G. Stanley Hall found that twenty-one of fifty-three children (40%) described musical instrument sounds as colored.[19] Thus, the overall impression is that synesthesia is several times more common in children than adults.[20] Because most synesthetes claim to remember having synesthesia far back in childhood, a plausible conclusion is that a proportion of childhood synesthetes lose their synesthesia as they grow up.

Consistent with this conjecture are a small number of our own case histories in which individuals claim to have lost their synesthesia around the time of puberty. For example, one man with a synesthetic brother recalls his own synesthetic childhood well but reports "by the time of my bar mitzvah it was gone." The time frame here is noteworthy, because puberty is a time of enormous physical change not only in outward appearance but also in brain reorganization. Juvenile brains are constantly changing and reorganizing themselves as they develop through childhood, but a big push comes during the concentrated secretion of sex hormones during

puberty. Brain maturation then slows down dramatically until subsiding to a steady level in the early twenties.

In our experience, the number of people who claim to lose synesthesia is small compared to that of Riggs and Karwoski, who in 1934 wrote, "frequently synesthesia disappears in adolescence. . . ." As we do not have the benefit of having objectively evaluated their subjects, such evidence must be considered anecdotal. Shedding some light on this, a recent study[21] finds no difference in adults compared with children ages six to seven in the incidence of grapheme → color synesthesia. Either individuals with this kind of synesthesia tend not to lose it once it is established, or else if they do, the loss occurs before the age of six or seven.

Even less common in our experience than losing synesthesia around puberty are anecdotal reports of first gaining it. We know of two women with colored hearing who insist the trait was not present before thirteen years of age. Hinderk Emrich in Germany also cites anecdotal reports wherein synesthesia has either intensified or vanished at puberty.

Such observations have theoretical importance. A widely agreed upon idea among synesthesia researchers is that learning is involved in establishing synesthetic links at an early age. Once learned, however, the links appear to become fixed and remain stable for life. That at least appears to be true for the overwhelming majority of synesthetes. For example, Vladimir Nabokov jotted down Dmitri's letter–color pairs when the son was eight or ten. In his late thirties Dmitri chanced across his father's notebook and retested himself. The colors were all the same.[22] However, pubertal changes, no matter how seemingly rare with respect to synesthesia, suggest that the brains of synesthetic youngsters may actually be in a state of flux.

Early literature supports this notion. In 1917, Stanford psychologist David Starr Jordan, himself synesthetic, took note of the colored letters experienced by his eight-year-old synesthetic son.[23] Five years later, and without mention of the matter during intervening years, the father had the boy repeat his color list. Eleven of twenty-six (42%) of the boy's color–letter associations had changed somewhat.[24] A useful direction for future studies would therefore be to prospectively examine childhood color associations and see if they change over time during adolescence.

We can only speculate as to why synesthesia might be widespread in childhood but be lost with age as juvenile brains mature. Because it is invariable and overly inclusive as a mode of thinking, it may be that

Table 1.1
A possible cognitive continuum

Perceptual → similarities	Synesthetic → equivalences	Metaphoric → identities	Abstract language

Note. On a line of increasingly complex cognition, perceptions that are synesthetically "the same" fall between perceptions that are alike in some way (e.g., "bright" is "high") and those that are metaphoric (e.g., "loud color").

synesthesia is simply replaced by a more flexible mode of cognition, namely, abstract thought and language. As such, there may be a cognitive continuum beginning with perception, reaching to perceptual similarities, then to synesthesia, next to metaphor, and finally to abstract language (see table 1.1). In other words, synesthetic perception may be a normal stage of brain development that consciously persists in a minority of adults. We have more to say about synesthesia's fundamental importance to cognition in chapter 8.

What Synesthesia Isn't

There is confusion about the word "synesthesia" given that it has been used over a 300-year period to describe vastly different things ranging from poetry and metaphor to deliberately contrived mixed-media applications such as psychedelia, son et lumière, odorama, and even cross-disciplinary educational curricula. Therefore, we have to carefully separate those who use synesthesia as an intellectual idea of sensory fusion—artists such as Georgia O'Keeffe, who painted music,[25] or the composer Alexander Scriabin who included light organs[26] in his scores—from individuals with genuine perceptual synesthesia. This latter group of real synesthetes includes famous artists such as novelist Vladimir Nabokov, composers Olivier Messiaen and Amy Beach, and painters David Hockney and Wassily Kandinsky. Perhaps the observation that synesthesia appears to be more common among creative people fueled the dismissal that synesthetes were just being artistic rather than having a genuine sensory experience.

Synesthesia is not metaphoric language. If it were, we would expect the associations to change according to context rather than be stable as they are over a lifetime. We would further expect to find common expressions

among different synesthetes instead of the highly idiosyncratic associations that are observed. Synesthesia is also not poetry, even though synesthetic-like associations are widely found in literary tropes. Poets commonly fuse different senses and employ cross-sensory adjectives to induce a compound aesthetic experience.

Another thing synesthesia is not is vivid imagination. What synesthetes see is not pictorial and elaborate but rather simple and elementary. For example, a common type of synesthesia is *colored hearing*, or the activation of color, shape, and movement by everyday environmental sounds, voices, and, especially, music. For synesthetes, these sounds trigger an experience something like fireworks: colored moving shapes that rise into existence then fade away. That is their perceptual reality. Whereas nonsynesthetes might picture a pastoral landscape while listening to Beethoven, for example, synesthetes will see colored lines or moving geometric shapes. Deni Simon describes her experiences this way:

> When I listen to music, I see the shapes on an externalized area about 12 inches in front of my face and about one foot high onto which the music is visually projected. Sounds are most easily likened to oscilloscope configurations—lines moving in color, often metallic with height, width and, most importantly, depth. My favorite music has lines that extend horizontally beyond the "screen" area.

Deni's synesthesia is particularly vivid as evidenced by her perceptions' appearing to exist in a well-defined location. It is important to emphasize that synesthetes do not substitute or confuse one sense for another. That is, when seeing with their ears they do not *mistake* a sound for a sight. Rather they perceive both sensations simultaneously. In philosophers' terms, they have "extra" qualia, where qualia are defined as the subjective aspects of sensation such as redness, sweetness, or pain, for example.

Objective evidence that synesthesia is not imagination comes from brain scanning, which shows that brain activation patterns during synesthetic experience are not similar to those seen when subjects visualize in their mind's eye. Rather, the activations more closely match the patterns observed during actual perception. The idea that synesthetes have hyperactive imaginations and simply want to call attention to themselves is further contradicted by the fact that they do not buttonhole people to tell them how special they are. Rather, they often do the opposite,

sharing their experiences only rarely either because they assume everyone has similar experiences or else because they have been ridiculed and subsequently keep their experiences private and hidden. Despite their reticence, synesthesia remains vivid and insuppressible throughout their lifetimes.

Studying Subjective Experience

Convention holds that *symptoms*—such as pain, dizziness, or forgetfulness—are subjective states "as told by" patients, whereas *signs*—such as inflammation, paralysis, or language errors—are objective, outwardly observable facts.

Historically, a long-standing problem with synesthesia was its lack of objectively observable signs. That is, reports of synesthesia relied entirely on subjective first-person statements by individuals claiming to have it. There is a long history in modern science of regarding self-reports and reference to mental states as unfit for investigation. As a methodology, introspection was considered scientifically unreliable because it was supposedly unverifiable. Such a stance against first-person accounts did not exist in the nineteenth century and earlier, when introspection was a popular experimental technique.

Not surprisingly, then, the late nineteenth century coincides with synesthesia's peak popularity as evidenced by the number of papers written on the topic (see figure 1.3). For example, during the fifty years between 1881 and 1931, seventy-four publications appeared, compared to only twenty-three in the fifty years between 1932 and 1982. The rise of behaviorism—a school of psychology that regarded behavioral observation (as opposed to investigation of conscious experience) as the correct approach to psychological inquiry—during the latter period is largely responsible for banishing mental states from scientific study. However, as the figure indicates, synesthesia is currently undergoing a renaissance.

Synesthesia was forgotten after its original heyday because science could not explain it. Simply put, psychology and neurobiology were premature disciplines at the time. Psychological theory relied on countless associations, and concepts of nervous tissue were paltry compared to today's understanding. What we consider modern neurology was still in its infancy, and neuroscience as we now practice it had not yet been invented. Just as

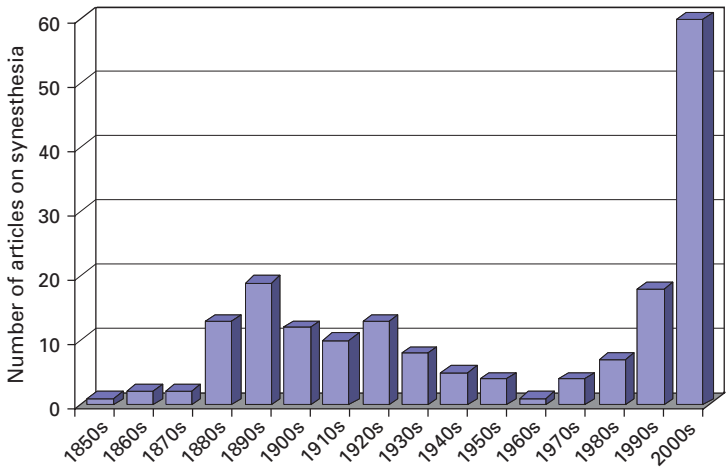

Figure 1.3

Peer-reviewed papers on synesthesia by decade from 1850 through 2006. There was considerable interest at the turn of the twentieth century, followed by a marked dropping off during the decades that behaviorism held sway as the dominant psychological paradigm. (Its height of popularity was between 1920 and 1940.) Increasing interest characterizes recent decades, indicating a second renaissance of synesthesia study.

concepts of how the brain was organized became recognizably modern, behaviorism appeared on the scene with such draconian restrictions against subjective experience that even acknowledging the existence of an inner life was taboo for a long time. In the eyes of the establishment, synesthesia was no longer a respectable topic of inquiry.

Believe it or not, relating conscious experience to brain function is also a relatively recent notion: neurology was overwhelmingly indifferent to mental life during the bulk of its history.[27] Rather, it concerned itself with movement, spinal reflexes, and other physical functions while leaving mental life to the realm of psychiatry and philosophy. Literature of the 1950s expressed considerable ambivalence about the status of the cerebral cortex in mental functioning,[28] an attitude finally swept away in the 1990s when the Decade of the Brain was ushered in.

How does science approach the distinction between a first-person understanding of experience and a third-person one that is supposedly objective? The lack of obvious agreement among synesthetes compounds the apparent difficulty. Indeed, the fact that two individuals with the same sensory

pairings do not report similar, let alone identical, synesthetic responses has sometimes been cited as proof that synesthesia is not real. But this stems from a misunderstanding of both the neural mechanisms and the phenomenon itself and underscores the deeper issue of "Real to whom—to the questioner or the person who has it?"

While an inspiring knowledge base has arisen through physical investigation of the brain, it has proven harder to get a grip on mental life. Perhaps we can turn to the multiply talented nineteenth-century physician and physicist Gustav Fechner for guidance, because it is precisely physical absolutism that he meant to transcend. He articulated something that every nineteenth-century physiologist knew but that was gradually lost in the twentieth century's zeal to decipher the nervous system: namely, that a mental world exists. Then, as now, the question is how to do science in such an arena. In a fundamental sense, Fechner's psychophysics—relating physical stimuli to perceived sensation—has no substitute: no amount of brain imaging or analyzing nerve impulses can substitute for an introspective report. Even modern neuroimaging starts with the subject's state of mind.

How do we get an objective handle on a state of mind? Different kinds of scientists favor different kinds of data. Psychologists generally prefer to measure behavior, what people do, whereas biologically oriented types favor physical evidence, especially pictures of the brain. Synesthesia happily puts us smack in the middle of this dilemma by showing the necessity of using both first- and third-person accounts. It also shows how both kinds of observations are theory laden and how each kind biases conclusions.

An experimenter may observe, but only the subject has access to experience. Subjects, however, are prone to interpret their self-observations rather than give a straightforward description. It is not just that people ordinarily have no need to describe their conscious experience and thus do not pay attention to its subtle features. It is also that any description of experience contains implicit theoretical assumptions.[29] As they are based on what is called "folk psychology," meaning common sense, such assumptions often differ radically from those of the neuroscientist, who usually breaks experience into components and does care about its many subtle features.

For example, consider the experience of drug-induced visual hallucinations—a variety of "seeing things." Starting in the 1920s, the German

psychologist Heinrich Klüver wanted to better understand them. He induced hallucinations with mescaline and quickly discovered that subjects were awed and overcome by the "indescribableness" of what they saw. They gave cosmic interpretations instead of straightforward descriptions, poetically embroidering their sensory experience. Once Klüver trained subjects to introspect carefully and hone descriptions down to essentials, he succeeded in identifying three categories of visual experience. We discuss one of these, the "form constants," in chapter 2 when we illustrate perceptual similarities that different synesthetes share.[30]

Just as subjects interpret or rationalize their experiences based on assumptions that are often very different from those of neuroscience, so too experimenters make assumptions when translating introspective reports into scientifically useful characterizations. Investigators do this either individually or as members of a collective neuroscience community. What they often fail to recognize, however, is that their assumptions and interpretations are just as theory laden as their subjects'. As a corollary, scientists cannot accept introspective reports literally, but subjects' biases can be addressed by training them to observe, and both subject and investigator bias can be minimized by using a script. Other sources of so-called objective data (e.g., brain metabolism as measured by scans) are also biased by investigators' assumptions. It follows that introspective reports—not accepted literally but properly guided and interpreted, and revised by investigators as necessary—are legitimate sources of data. Some years ago Richard cautioned, "though synesthetes are often dismissed as poetic, it is *we* who must be cautious about unjustifiably interpreting their comments."[31] Training ourselves is the flip side of training self-observers.

The opportunity to embroider is especially ripe in synesthesia because the experience is so ineffable. Because it is quite difficult to convey, subjects often resort to metaphor when describing "what it is like." For example, Michael Watson described the taste of spearmint as "cool glass columns." Was he being metaphoric, or verbally interpreting a sensory experience by couching tactile sensations in terms of images the investigator could understand? The distinction was teased out by asking him to focus on and describe the exact sensations he felt, rather than painting verbal pictures or "explaining" his experience. When given the spearmint stimulus, Michael rubbed his fingertips together and moved his hands through the air as if palpating an actual object:

I feel a round shape. There is a curvature behind which I can reach, and it's very, very smooth. So it must be made of marble or glass, because what I'm feeling is this incredible satiny smoothness. There are no ripples, no little surface indentations, so it must be glass because if it were marble I'd be able to feel the roughness of the stone or the pits in the surface. It's also very cool so it has to be some sort of glass or stone material because of the temperature. What is so wonderful is the absolute smoothness of it. I can run my hand up and down, but I can't feel where the top ends. I feel that it must go on up forever. So the only thing I can explain this feeling as is that it's like a tall, smooth column made of glass . . . there is a funny sort of feeling of being able to reach my hand into this area. It's very, very pleasant.[32]

It quickly became evident that Michael experienced elementary tactile qualities that he sensed as identical over time if given the same stimulus. Questioning other synesthetes about their experience and retesting them at later dates subsequently confirmed this stability, leading to one of the five diagnostic criteria for the trait, namely, that synesthetic percepts are generic and consistent. "Generic" means that what is experienced is not complex or pictorial but elementary—blobs, lattices, cold, rough, sour, zigzag, or geometrically simple. "Consistent" means the experiences are largely (but not totally) invariable through time. Teasing out these phenomenal features therefore contributed to synesthesia's classification as a real condition.

Had Richard accepted Michael Watson's descriptions at face value or as metaphoric, rather than probing to tease out the sensory qualities Michael struggled to convey, synesthesia might have remained relegated to a mere curiosity rather than being recognized today as a striking anomaly with important implications for concepts of how the brain is connected. Rather than second-guessing experiential reports, the focus of those who currently explore the phenomenon has been on trying to understand synesthetes' reports and seeking behavioral correlates of their subjective claims. This requires interplay between first-person and third-person accounts. A dialogue or structured questioning between clinician and subject constitutes a second-person relation between shared knowledge about experience. This kind of feedback sometimes leads to further self-observations from synesthetes and the subsequent invention of additional third-person tests by the investigator.

Theoretical constructs constituting investigator biases, though evidently derived from objective third-person observation, nonetheless have

historically shortchanged first-person accounts. For example, Richard first became aware of the mismatch between subject and examiner during his ophthalmologic training in the 1970s. He was struck by how often patients spoke of "seeing things" they could describe in detail sufficiently nuanced so as to sound similar to "things" other patients saw, yet the medical exam revealed nothing amiss despite using plenty of special equipment. Faculty and trainees assumed that every optical symptom had a physical correlate they could observe through their lenses. The conceit never had to be taught explicitly because it was just taken for granted, deeply embedded.

Looking back, that level of confidence is breathtaking, but many assumptions investigators make appear so "obvious" that their bias is never questioned. Patients did not want to hear "I don't see anything wrong with your eyes," because it left their questions unanswered, and their persistent asking left physicians frustrated. Each side had different expectations. Perhaps Richard's sensitivity to the mismatch between subject–observer expectations left him open to Michael Watson's experience instead of dismissing it as impossible, or Michael as crazy, as his medical peers automatically had. Investigator bias toward or against something can therefore influence the very kind of data one takes up as interesting.

A Different Texture of Reality

Imaging being able to see into the ultraviolet part of the electromagnetic spectrum the way birds and bees do—or into the infrared or X-ray range the way machines can. You would literally perceive the world differently from other individuals and have a different texture of reality than other people. This is similar to the situation of a synesthete, who experiences the world more richly.

Often nonsynesthetes imagine that sensing nonpresent colors, textures, and configurations must somehow be a burden. "Doesn't it drive them crazy having to cope with all the extra bits?" they ask. But this is no different than a blind person telling you, "Oh you poor thing. Everywhere you look you're always seeing something. Doesn't it drive you crazy always having to see everything?" Of course not, because seeing is normal to us and constitutes what we accept as reality. Synesthetes simply have a different texture of reality.

This fact brings us back to a central point—namely, that reality is much more subjective than most people suppose. Far from being objectively fixed "out there" in the physical world[33] and passively received by the brain, reality is actively constructed by individual brains that uniquely filter what hits the outside senses.

In this light, synesthesia catalyzes a paradigm shift by highlighting the dramatic differences in how individuals objectively see the world. It illuminates a broad swath of the mind and forces fundamental rethinking about how brains are organized. Over a quarter of a century ago, neurologists insisted that synesthesia could not be real because it contradicted accepted theory; today, synesthesia's undeniable reality is forcing theory to change. Understanding this strange and delightful way of perceiving can help us understand how all our brains operate.