WILL ALL SYNAESTHETES PLEASE RAISE THEIR HANDS?

Testing for Synaesthesia

In 1987 Elizabeth Stewart-Jones, a professional painter who trained at the Chelsea School of Art in the 1930s, placed an advertisement in the journal of the British Psychological Society, describing herself as 'an artist who has experienced the life-long condition of hearing words and sounds in colour'.

Simon Baron-Cohen answered her advertisement. In order to gauge her condition, he read out 103 words and letters and asked her to describe the colours they evoked. The word 'Moscow', she said, was darkish grey, with spinach-green and a pale blue in places. 'Daniel' was deep purple, blue and red and shiny. Baron-Cohen read out the same list to a control subject – a colleague who was not synaesthetic. The control gave the kind of simple, sometimes predictable responses anyone would give: 'fridge', unsurprisingly, was white.

Two weeks later, Baron-Cohen read out his list again. The control's answers were quite different: only seventeen responses matched.

Elizabeth Stewart-Jones, after ten weeks and with no prior warning, described every word exactly as she had the first time.[1]

1. Motluk, 1994. Motluk, A. The Sweet Smell of Purple. New Scientist 1938, 13 August.

Stewart-Jones's strangeness earned Baron-Cohen a spot on Radio 4's *Science on 4* – the programme whose listeners I will insult so egregiously later in this chapter. The 212 letters Baron-Cohen received after this programme formed the basis for a second, even more rigorous test of synaesthetic stability. This time, Baron-Cohen's list consisted of 130 items. He read them out to two groups: a group of non-synaesthetic controls; and synaesthetes identified from correspondence following the radio programme. He warned the control group that he would retest them a week later, and taught them mnemonic tricks to help them remember their responses. A week later, they scored 37%.

Baron-Cohen said nothing to the synaesthetes, then contacted them again after more than a year to arrange a retest. The synaesthetes scored 92%.[2]

Baron-Cohen's Test of Genuineness, with subsequent refinements, is considered part of the standard armoury of synaesthesia researchers, as they attempt to distinguish synaesthetes from the general population.

His 'TOGr' targets just one important aspect of synaesthetic experience: its stability. But how reliable an index is stability?

Researchers, explaining their work to often sceptical outsiders, make much of the stability of a synaesthete's inner world. One of the most interesting aspects of synaesthesia, however, lies in all the ways that it *isn't* stable.

Children outnumber adults about three-to-one in many early twentieth-century reports[3]. How some children may lose their synaesthesia as they grow up is still an area that needs work. At Dartmouth College in the 1930s, Professor Theodore Karwoski drew the young Lorrin Riggs – later a leading vision researcher – into a fascinating series of studies into how a child's perceptions develop. Their work very much advances the idea that synaesthesia is a normal part of development: 'frequently,' they add, synaesthesia disappears in adolescence.'[4] Hinderk Emrich, a

2. Harrison, 2001, p94. Harrison, John E. 2001. Synaesthesia – the strangest thing; Oxford: Oxford University Press.
3. Cytowic, 2002, p276. Cytowic, Richard E. 2002. Synaesthesia: a Union of the Senses. Second edition. Cambridge, Massachusetts: MIT Press.
4. Riggs & Karwoski, 1934. Riggs, Lorrin A., and Theodore Karwoski. 1934. "Synaesthesia." British

German psychologist with a particular interest in synaesthesia, has also noted some instances where synaesthesia either vanished or was intensified at puberty.'[5]

Twenty years' research has provided Richard Cytowic with only a handful of such cases.[6] On the other hand,they do include the surprising case of two women who *acquired* tone-colour synaesthesia around puberty!

Even if we admit some developmental role for synaesthesia, and accept that as we change, it changes (or disappears), we tend to assume that the experience of synaesthesia in adulthood is fixed. But this is certainly not the experience of Carol Steen, an artist who lives and works in New York City.

Steen has experienced synaesthesia for as long as she can remember, perceiving colors in numbers, letters and when hearing certain sounds. Acupressure and acupuncture also lead to the perception of both colors and shapes.

Carol Steen, 61, a New York City artist, works on a

Journal of Psychology; volume 25: 29-41.

5. Cytowic, 2002, p293. Cytowic, Richard E. 2002. Synaesthesia: a Union of the Senses. Second edition. Cambridge, Massachusetts: MIT Press.

6. Cytowic, 2002, p293. Cytowic, Richard E. 2002. Synaesthesia: a Union of the Senses. Second edition. Cambridge, Massachusetts: MIT Press.

painting inside her Manhattan studio. Steen's art is a reflection of the images she sees in her mind when she listens to music. (Richard Schapiro/CNS)

Steen is in no doubt that synaesthesia responds to practice: ‘Synaesthesia doesn’t come to you full-blown but develops over time… When I started getting really aware of synaesthesia, I was struck by the sense that the first colours that I saw for numbers and letters were the brightest ones – the reds, orange, and yellows. Green and blue came later, and there was confusion about it. I remember thinking to myself, if some of these letters and numbers have colours, then they all ought to have colour. Then I started to look, and the blacks came and the whites came, and then finally, the very last colours that I saw were the ones that could be considered low-value or subtle colours, dove-gray, for example…’[7]

The longer she has spent discussing her synaesthesia with researchers and other synaesthetes, the more elaborate Carol’s synaesthesias have become. Her photisms never used to have shape: now they do. She never used to hear music in colour: now she does.

While Simon Baron-Cohen’s test of genuineness is an excellent (and universally accepted) method of identifying synaesthetes, it cannot tell us a very great deal about their experiences. What we need is a means to test objectively the self-reports of synaesthetes – particularly synaesthetes like Steen, whose experiences challenge our day-to-day assumptions about the condition.

So how are we to measure the immediacy – one almost wants to say the *reality* – of the experiences of Steen and others?

7. Dann, 1998, pp5-6. Dann, Kevin T. 1998. Bright Colors Falsely Seen: Synaesthesia and the Search for Transcendental Knowledge. New Haven and London: Yale University Press.

John Ridley Stroop

The test most frequently harnessed to examine synaesthesias, the Stroop Test, has its origins in a classic introspectionist experiment. In 1886 at the University of Leipzig, the psychology pioneer Wilhelm Wundt set an interesting problem for his doctoral student James McKeen Cattell (later to become the United States' first professor of psychology). Cattell was to explore the time it took people to identify things by name. Three measures were taken. The time it took to name objects; the time it took to name the properties of those objects (for example, their size or colour); and the time it took to read aloud the words representing those objects or properties. Cattell found that coming up with the words to describe a red chair took longer than reading aloud the words 'a red chair'. In other words, our reading abilities tend to run ahead of our thought processes. This is an interesting enough result, and it did generate quite a lot of interest for about fifty years before John Ridley Stroop got hold of it.

Stroop was born in 1897 on a farm in Hall's Hill, in Rutherford County, Tennessee. He was the fifth of sixth children, a frail child who didn't start school until age seven. With money from the sale of a horse, two cows, and a crop of potatoes, and with a forty dollar loan from his father, Stroop moved to Nashville to complete his schooling. By working as a janitor and a librarian, he put himself through the last two years of high school and two years of college.

Religion was the greatest force in Stroop's life. Baptised into the Church of Christ in 1913, he was a devout Christian for his entire life. From his college days on, he preached every Sunday, often taking a train out into the country and being paid with a chicken or a bag of potatoes, if at all.

Stroop was also an extraordinarily promising psychologist. In 1928 he enrolled in a doctoral program at Peabody College. Peabody's Jessup Hall was the first building in the country built specifically for psychological research. Stroop's advisor, Joseph Peterson, was an eminent psychologist who did early work in auditory and visual perception, learning, and intelligence testing.

Under Peterson's supervision, Stroop toyed with Cattell's result, reasoning that if objects, properties and words took different times to process, ambiguously combining these elements might reveal how they were inter-related in the mind.

Stroop's PhD work formed the basis for his paper, first reported in the lead article of the December, 1935 issue of the *Journal of Experimental Psychology*[8]. At the time it had relatively little impact. The wealth of data then being generated by behaviorism far outshone a doctoral student's tinkering with an old introspectionist idea.

Stroop's paper has since become a classic: since 1965 it has been cited more than two and a half thousand times in scientific literature.[9]

For his experiment, Stroop printed the names of several colours onto card, each time using a differently coloured ink. The word 'red' might be printed in red ink at one location; in green ink at another.

In one set of tests, Stroop asked his subjects to read the words on the card. In another, he asked his subjects to announce the word's physical colour.

Reading what the words said was easy. And when the colours matched the words, stating the colour of the words was easy, too. When subjects attempted to state the colours of incongruent words, they burst into frustrated laughter. Try it yourself. You need to speak out loud to get the full effect.

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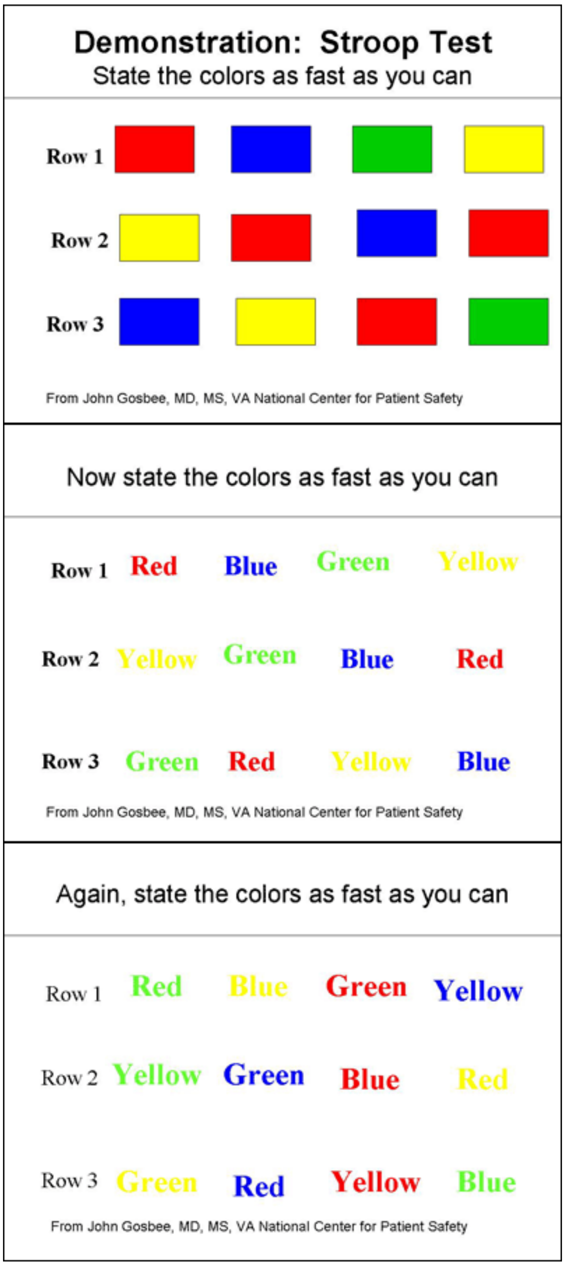
8. Stroop, 1935/1992. Stroop, J. R. (1935/1992). Studies of interference in serial verbal reactions. Journal of Experimental Psychology: General, 121, 15-23.
9. Salisbury, D F. 2002. Stroop effect helps put Vanderbilt on psychology map. The Daily Register (September 30). Vanderbilt University. Available at http://www.vanderbilt.edu/register/



Even with practice, stating out loud the colours of green 'RED's and yellow 'BLUE's is incredibly hard to do. Because reading races ahead of cognition, the mind has automatically determined the semantic meaning of the word before it runs up against actual sensory information. The mind has to override its first (semantic) impression with a new (sensory) impression. The result is a tongue-twister worthy of

Dr. Seuss.

John Stroop published only three other articles in experimental psychology, all in the six years between 1932 and 1938. His supervisor Dr Peterson offered to collaborate with him on further research – then, quite suddenly, Peterson died, and Stroop, without his mentor, lost his appetite for experimental psychology.[10]

Bible study consumed him. He became professor of biblical studies in the David Lipscomb University in Nashville. In the 1940s he began to write popular books with titles like *The Church of the Bible* and *Why Do People Not See the Bible Alike?* Every so often, someone would ask him why he had abandoned psychology for religion.

John Stroop's son Fred remembers his father's answer: 'He would explain that Jesus was the greatest psychologist on Earth.'

What if we adapted Stroop's test to synaesthesia?

Suppose you are a grapheme–colour synaesthete who experiences the digit '4' as red. A Stroop test featuring a blue '4' will trip you up, because of the incongruence between the digit's ink colour and its synaesthetic colour. The Stroop test shows that the perception of synaesthetic colours relies on the same mechanisms as the perception of real colours. In short, it demonstrates the *reality* of synaesthetic experience.

Although ideally suited to the study of grapheme-colour synaesthesia, Stroop's test can be adapted to demonstrate the reality of other forms of the condition. In one such variant, a music-colour synaesthete is asked to name a red color patch while listening to a tone that produces a blue sensation[11]; in another, a musical key–taste synaesthete is asked to identify a bitter taste while hearing a tonal interval that induces a sweet taste[12].

To assess the reality and behaviour of synaesthetic experiences, we require little

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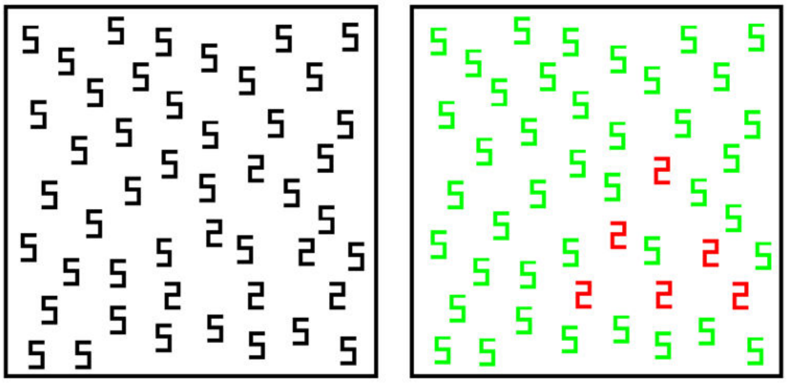
10. MacLeod, 1991. MacLeod, C. M. (1991). John Ridley Stroop: Creator of a landmark cognitive task. Canadian Psychology, 32, 521-524.
11. Ward et al, 2006. Ward, J., Tsakanikos, E., & Bray, A. (2006). Synaesthesia for reading and playing musical notes. Neurocase, 12, 27-34.
12. Beeli et al, 2005. Beeli, G., Esslen, M., & Jancke, L. (2005). When coloured sounds taste sweet. Nature, 434, 38.

by way of expensive hardware, but rather more by way of invention. In 2001, it dawned on the neurologist Vilayanur Ramachandran and his former PhD student Edward Hubbard that colour-blindness tests could be harnessed to study grapheme-colour synaesthesias. On hearing of this idea – so obvious with hindsight – not a few hands were slapped to foreheads.

Ramachandran and Hubbard presented synaesthetes and controls with displays composed of a number of 5s, with some 2s embedded among the 5s. For a synaesthete who sees 2s as red and 5s as green, their synaesthetic colors help them to find the "embedded figure".[13]



No doubt there are other innovations to come. Now that simple tests can demonstrate, to every reasonable person's satisfaction, synaesthesia's reality and (relative) stability, it is a relatively easy business to employ these tests to identify genuine synaesthetes. From that, it is natural enough for us to assume that the business of counting synaesthetes is therefore made a great deal easier.

And we'd be wrong.

13. Ramachandran, V. S. & E. M. Hubbard (2001), "Synaesthesia: A window into perception, thought and language", Journal of Consciousness Studies 8 (12): 3-34

How many synaesthetes are there?

Let's begin our search for an answer by consulting two senior researchers. Richard Cytowic's pioneering work in the 1980s made synaesthesia scientifically respectable again after a fifty year haitus. In 1987, John Harrison helped Simon Baron-Cohen develop the first rigorous tests for the condition.

According to Cytowic, one in twenty of us are synaesthetic. Harrison, on the other hand, reckons synaesthetes are more rare: about one in 200,000. Two contemporary researchers, each with a list of peer-reviewed publications as long as your arm about synaesthesia – and their estimates vary by more than three orders of magnitude.

The problem is not in the figures. It's in the question. We have to say what synaesthesia is before we can ask how many synaesthetes there are. A merely arbitrary or conventional definition won't do, because no one knows yet how the synaesthetic pie divides. We have to keep our options open. Is synaesthesia one condition, or many? Is it an underlying brain anomaly with multiple, variable symptoms? Or is it a set of symptoms common to a far greater number – perhaps an uncountable number – of idiosyncratic conditions?

Is there anything in common between people who see coloured letters and people who see coloured sounds? Are people who see coloured letters 'in their mind's eye' the same as people who see coloured haloes around letters on a printed page? These are some of synaesthesia's most interesting questions, and every one of them makes a complete mockery of attempts to arrive at a simple tally.

Here's another example, again involving John Harrison. In *Synaesthesia: The Strangest Thing* Harrison claims that the most common form of synaesthesia is coloured hearing[14], and he cites a study of 270 synaesthetes by Dr Sean Day. More than nine out of ten of Day's cases enjoyed *audition colorée*.

Now visit Sean Day's extensive and influential website, The Synaesthesia List[15]. You will discover that coloured-hearing synaesthesias are outnumbered by grapheme-colour synaesthesias six to one. Is Harrison misrepresenting Day? Not at all: he just happens to be excluding so-called cognitive synaesthesias (synaesthesias that involve graphemes and abstract concepts) from his account. Synaesthesia research is a small world; the people involved in it know each other's work; and no-one is confused. For the rest of us, looking in from the outside, this tolerance of apparent contradiction is the stuff of migraine.

Sean Day is more sensitive to the problem than most, and does not offer a single figure for the prevalence of synaesthesia. Instead, he offers three: one in 500 for cognitive synaesthesias like coloured letters and musical pitches, one in 3000 for 'proper' synaesthesias (for example, coloured or flavoured music) and one in 25,000 or more – maybe much more – for rare synaesthesias.[16] (Day knows one woman who, uniquely, tastes the things she touches.)

These figures sound reassuringly conservative. And after all, synaethesia is supposed to be rare. Were it common, it would probably have inspired no more intellectual interest than any other quirk of the subjective life – for example, the sensation of falling that often precedes sleep.

How, then, did Richard Cytowic, writing in 1997, arrive at the uncommonly high prevalence rate of one in twenty?

It used to be thought that such rates were artefacts of a problem that has beset

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14. Harrison, 2001, p183. Harrison, John E. 2001. Synaesthesia: The Strangest Thing . Oxford: UP.
15. http://home.comcast.net/~sean.day/html/the_synesthesia_list.html
16. Day, S. (2005). Some demographic and socio-cultural aspects of synesthesia. In L. C. Robertson & N. Sagiv (Eds.), Synesthesia: Perspectives from cognitive neuroscience. Oxford: Oxford University Press. p12

synaesthesia research from the beginning. Synaesthetes are a self-selecting group. They are otherwise healthy people who *want* to be examined by doctors. How is one to extrapolate from this handful of articulate, confident, fairly extrovert people, the prevalence of their condition in the population at large? This is the statistical equivalent of herding cats. Let's be blunt here: most people thought Cytowic was wrong.

Of course, only the sure-fire way to know the prevalence of synaesthesia in the population at large is to ask them. Since that is not practicable, a true randomized trial would be a good second bet.

In 2006, Julia Simner, a research fellow at the University of Edinburgh, led a team conducting the first such study. At last, a figure was to be secured from the general population. The true rarity of the condition would now be unveiled. According to Simner and her colleagues, writing in the journal *Perception,* the proportion of synaesthetes to general population was – one in 23![17]

This recent figure, which flies in the face of every other recent study, and comes close to confirming Richard Cytowic's anomalously high estimate *circa* 1997, suggests nothing so much as the swirling futility of the entire exercise. What is going on?

17. Simner et al, 2006. Simner, J.; C. Mulvenna & N. Sagiv et al. (2006), "Synaesthesia: The prevalence of atypical cross-modal experiences", Perception 8 (35): 1024-1033.

Girls and Boys

Numbers are only ever as interesting as the patterns they make. The more numbers we can gather about a phenomenon, the more interesting and exciting will be the patterns we will find hiding inside them.

Why was it, for instance, that for every twenty correspondents who got in touch with Simon Baron-Cohen and John Harrison, following a radio science programme, nineteen were women?[18]

The literature is fairly consistent on this point: women synaesthetes really do outnumber the men. ‘The larger number of the subjects are women,’ wrote the Ohio psychologist W. O. Krohn in 1892, ‘who as a class can hardly be called introspective; at least, they are less so than men – but they are more observant.’

Set aside any mild affront this statement might occasion, and you will notice that Krohn, writing at the end of the nineteenth century, has touched upon a real and still present difficulty. How do we measure the relative prevalence of synaesthesia between men and women, given that men and women have very different relationships to medicine? It is generally accepted that some of the imbalance between men and women with synaesthesia (early studies suggested ratios of between 3:1 and 8:1) is due to the fact that women are more likely to talk about themselves. Men generally don’t make time for all that touchy-feely stuff.

18. Harrison, 2001, p178. Harrison, John E. 2001. Synaesthesia: The Strangest Thing . Oxford: UP.

Next, Baron-Cohen and Harrison sent each of their correspondents a questionnaire. Among other things, they asked about relatives with the same or a similar condition. Nearly a quarter of replies mentioned a female relative with synaesthesia. Not one mentioned a male relative.

Suspicion that there might be a genetic component to synaesthesia arose very soon after the condition was identified. In 1883, Francis Galton, describing the condition for the first time in Nature, remarked that it was it 'very heritable'.[19] Baron-Cohen and Harrison's studies certainly agreed with Galton's on this point. Indeed, they were able to put figures on that 'very'. According to Harrison, the chances are about even that a synaesthete will know of a synaesthetic relative. The daughter of a synaesthetic mother has an excellent chance (nearly three in four) of being synaesthetic. A son has a one-in-four chance.

Synaesthesia is heritable. This is powerful news. It suggests that synaesthesia is, for all its psychedelic variety, a single, discrete condition. Identify the gene responsible for synaesthesia, and *voilá*, you can say where synaesthesia comes from.

The hunt for a single gene

The idea that there may be a single 'synaesthesia gene' is, of course, naive. Three hundred genes are implicated in the regulation of blood pressure alone. What makes us think there might be only one gene responsible for such a subtle warping of

19. Galton, 1883/1997. Galton, F. (1883, 1997). Colour Associations. In S. Baron-Cohen & J. E. Harrison (Eds.), Synaesthesia: Classic and Contemporary Readings. Oxford: Blackwell.

subjective experience?

The idea is not altogether daft. Differences in a single gene can generate exotic effects. Gilles de la Tourette syndrome is caused by the malfunction of a single gene. Single bad genes have been implicated in a number of sex chromosome-linked mental retardations. It only takes one bad gene to cause colour blindness.[20]

For analysts wanting to see if any simple models of genetic transmission can explain the incidence of synaesthesia, there is, to date, only one port of call. Because they were tested in the same way by a single team, the six families studied by Simon Baron-Cohen and his team in 1996 provide us with our only good, robust data set.[21]

From their study of six families, Baron-Cohen's team were not only able to say how likely it was that a child of either sex would be born to a synaesthetic mother: they were also able to say something about the proportion of girl synaesthetes to boy synaesthetes. And this is where it gets curious. If you've a one in four chance of being the synaesthetic son of a synaesthetic mother, and a three in four chance of being the synaesthetic daughter of a synaesthetic mother, then it stands to reason that there must be three times as many women with synaesthesia around as men. The figures from Baron Cohen's cohort told a different story: the female/male affected ratio here was 7.7:1.

What simple genetic mechanism could explain a heritability pattern that produced 7.7 affected girls to every affected boy?

The simplest form of heritance is called Autosomal Dominant transmission. Autosomes are the name we give to all the chromosomes that aren't to do with sex. (That is, all of them but two, chromosome X and chromosome Y.)

In Autosomal Dominant transmission, the presence of mutated copy of the gene in each cell is sufficient to cause a genetic condition. If both parents have the condition, then all their children will have the condition. If only one parent has the

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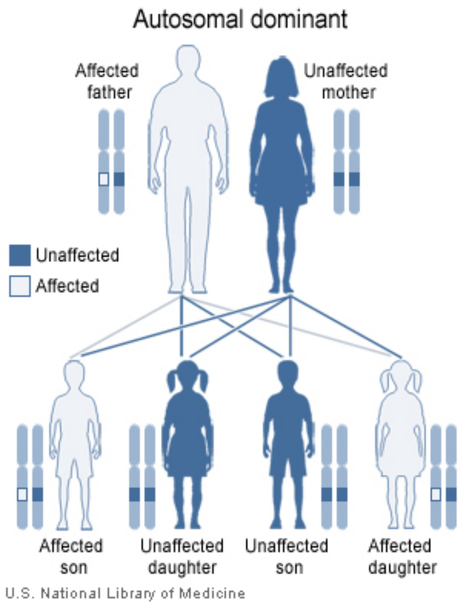
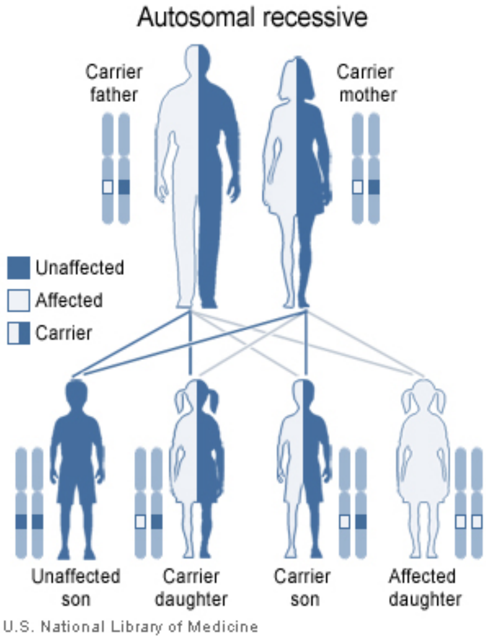
20. Cytowic, 2002, p58. Cytowic, Richard E. 2002. Synaesthesia: a Union of the Senses . Second edition. Cambridge, Massachusetts: MIT Press.
21. Baron-Cohen et al, 1996. Baron-Cohen, S., Burt, L., Smith-Laittan, F., Harrison, J., & Bolton, P. (1996). Synaesthesia: Prevalence and familiality. Perception, 25, 1073-1079.

condition, then the odds are even that a child will inherit it. In either case, boys are as likely to inherit it as girls – a sex ratio of 1:1 – so autosomal dominant transmission is not, at first glance, a great model for the heritability of synaesthesia.



Autosomal Recessive transmission is no better. In this case, *two* mutated copies of the relevant gene – one from each parent – are required to cause a genetic condition. Chromosomes come in pairs and recombine at fertilization to form an individual's unique genetic make-up. This means that both father and mother must carry at least one copy of the mutated gene, if any of their children are to inherit the condition. Most usually, the father and mother each carry one copy only of the mutated gene. Though they carry the gene, they do not express it. Their children have an fifty per cent. chance of carrying the condition, the way their parents did, and only a one-in-four chance of expressing it. For synaesthesia, this is a non-starter already. Synaesthesia is more easily inherited than that. Even worse, being a boy or a girl doesn't make any difference to your chances of expressing the gene. The sex ratio is, again, 1:1.

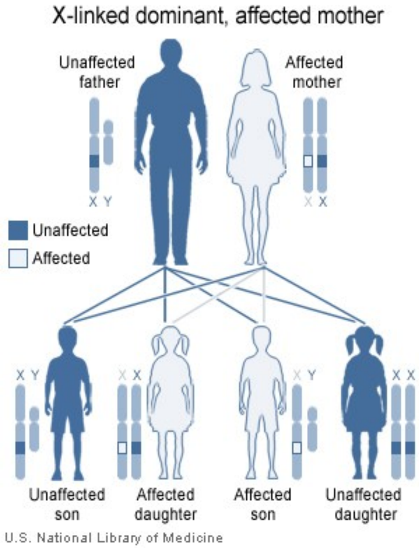


What if our hypothetical synaesthesia gene sat on a sex chromosome?

In mammals there are two sex chromosomes, labelled X and Y. The X chromosome is full of good things and those of us who inherit two X-chromosomes grow up female. The Y chromosome is a bizarre runt which does little more than induce half of us to grow up male. Synaesthesia can't be Y-linked because only boys have Y chromosomes. Transmission can only pass from father to son. That there are female synaesthetes at all (let alone a preponderance of them) is enough for us to dismiss Y-linked transmission out of hand.

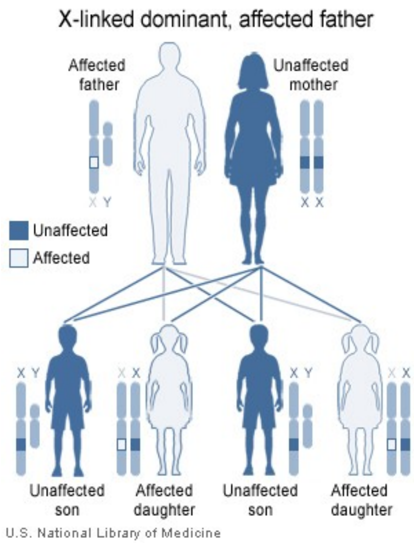
This leaves us with X-chromosome transmission, Now things begin to look more promising.

Women have a pair of X chromosomes. Men have an X chromosome paired with a Y chromosome. If one of a woman's pair of X chromosomes contains the mutated gene, she will have the condition, and there is an evens chance that she will pass that condition on to her children. Boys are as likely to be affected as girls.



If a man has a mutated gene on one of his X chromosomes, he will have the condition. He will not be able to pass the condition on to his sons, however, because sons inherit only Y-chromosomes from their fathers. (Their X-chromosomes come from their mothers.)

A man with the condition will, however, be able to pass the condition on to his daughters. Indeed, since every daughter will inherit a copy of his X-chromosome, every daughter *will* inherit the condition.



Assume that all affected families are made up of equal numbers of males and females – a reasonable starting assumption, since the number of boys and girls in the world is roughly the same. Say each family has four children: two girls and two boys. A family with a synaesthetic father will have two synaesthetic girls. A family with a synaesthetic mother is likely to have one synaesthetic boy and one synaesthetic girl. Add the figures together. Synaesthetic families, taken as a whole, are likely to produce three synaesthetic girls, for every synaesthetic boy. A sex ratio of 3:1.

This is better – a lot better. But it's still nowhere near Baron-Cohen's figure of 7.7:1.

I've already mentioned that boys in Baron-Cohen's study had a one in four chance of acquiring synaesthesia from a synaesthetic mother. Those odds fits the model quite neatly. Only the half of boys who inherit the mutated gene from their mother's X-chromosome stand a chance of being affected, and only half of them will inherit the condition. Half of half is a quarter: a chance of one in four.

But I also mentioned that daughters of synaesthetic mothers have a *three-in-four* chance of being synaesthetic themselves. This doesn't match the model at all. According the model, the chances should be evens. What improves the chances of synaesthetic daughters being born to synaesthetic mothers?

Are there any other simple genetic mechanisms we can look at? No. (The only other easy mechanism is sex-linked recessive transmission, which never gets expressed in women.) X-linked dominant transmission remains our best bet. But we still have to explain the awkward preponderance of synaesthetic girls.

Two easy explanations leap to mind. It could be that some of the menfolk in the study have skewed the figures by keeping their condition to themselves. Or it could be that synaesthesia is a condition that expresses itself less well in males.

There is a third possibility along the same lines, which until recently was generating a lot of interest. What if synaesthesia killed half of all males in the womb?

We have a pair of Glasgow researchers, Mark Bailey and Keith Johnson, to thank for this rather macabre idea. They first suggested it back in 1997.[22] And it is by no means a bad suggestion. This sort of thing does happen. Consider Rett syndrome, a serious disorder of development which prevents cell division. Rett syndrome prevents male brains from developing, and baby boys with Rett syndrome inevitably die. Females are not so badly affected, and survive with often crippling handicaps.

Women are generally less affected by X-linked conditions because they have two X-chromosomes. Each cell in a woman's body only gets to express one X-chromosome, and it chooses at random which one to listen to. This means that a faulty or disease-carrying X chromosome has a fifty-per cent chance of being expressed – and if the fault acts by killing the cells in which it is expressed, then either healthy cells will take their place, or there will be enough of healthy tissue around anyway for things to function normally. (This is especially true of the brain, which can survive astonishing losses of material with no apparent ill-effects. Consider the way Alzheimer's disease turns the brain to Swiss cheese long before actual dementia sets in.)

Bailey and Johnson suggested that the presence of one normal X-chromosome in females might prevent the full, lethal expression of a synaesthesia gene. They predicted that synaesthetic mothers would give birth to many more girls than boys, and that synaesthetic mothers would experience more miscarriages than the rest of the population.

We don't have any miscarriage statistics for synaesthetic mothers, and given that most miscarriages happen too early in development for the mother ever to realise she is pregnant, it's unlikely that gathering such statistics would serve much purpose.

It is an easy business, however, to compare the number of boys and girls born to synaesthetically gifted families. Baron-Cohen's six families, examined by Bailey and Johnson in their 1996 paper, together produced 18 female and 9 male offspring: exactly what the male-lethality hypothesis predicted. If twice as many girls are born

22. Bailey & Johnson, 1997. Bailey, M. E. S., & Johnson, K. J. (1997). "Synaesthesia: Is a genetic analysis feasible?" In S. Baron-Cohen & J. E. Harrison (Eds.), Synaesthesia: Classic and Contemporary Readings . Oxford: Blackwell pp182–207

to synaesthetic families as boys, and if girls are three times as likely to be synaesthetic, then we can expect six synaesthetic girls to be born for every boy – respectably close to Baron-Cohen's observed girl-boy ratio of 7.7:1.

Five years later, the idea of male lethality was still very much alive when a young Canadian researcher, Dr Daniel Smilek, came across identical twin girls, only one of whom was a synaesthete. For her, numbers had colours.[23]

At first glance, the existence of genetically identical twins, only one of whom has synaesthesia, appears to contradict the idea that there may be a simple genetic basis for the condition. If one of the girls has it, why not the other? Among the explanations offered by Smilek and his colleagues, one dovetailed neatly with the male lethality hypothesis.

If the mutation that causes synaesthesia lies on the X-chromosome, then each identical twin would have inherited one mutated X-chromosome, and one normal X-chromosome. Each cell in their bodies would have read one X-chromosome at random, and ignored the other. So, over the course of development, it was not only possible but quite likely that the twins would express their X-chromosomes in different proportions. By harnessing this process, to their argument– a process called called X-inactivation – Smilek and his colleagues seemed to have further circumstantial evidence to support the idea of male lethality.

Three years later, Smilek heard about another pair of identical twins. Again, only one of them was synaesthetic. This time though, there was a problem, big enough to blow the earlier study – and many other ideas of synaesthetic transmission – clean out of the water. The twins were boys.

Boys inherit only one X-chromosome, from their mother. This is paired with a Y-chromosome from their father. This is what makes them boys. Every cell in their bodies must read their mother's X-chromosome. If synaesthesia was produced by a mutation on the X-chromosome, then both boys had to be synaesthetes. They

23. Smilek et al, 2002. Smilek D, Moffatt BA, Pasternak J, White BN, Dixon MJ, Merikle PM. (2002) Synaesthesia: a case study of discordant monozygotic twins. Neurocase. ;8(4):338-42.

weren't. Only one of the ten-year-old twins saw colours for letters and numbers.[24]

X-inactivation had turned out to be a red herring. Some other, more complicated mechanism had to be responsible for the uneven expression of the synaesthesia gene – assuming, of course, that there was just one gene. Smilek was no longer so sure: 'In general, the findings raise serious questions regarding whether it is possible at this time to establish the genetic contribution to synaesthesia.'

This was a setback, but not a shocking one. Already evidence had begun to emerge that the synaesthesia gene, even if it existed, could not be relied upon to turn up regularly in the genome. Work on synaesthesia by Ramachandran and Hubbard centres around grapheme–colour synaesthesia (seeing coloured numbers and letters). An important early subject for their work was JC who, it turned out, has a synaesthetic mother and cousin. The mother of his cousin, his maternal aunt, does not have synaesthesia. Neither does his uncle. In that side of JC's family, synaesthesia has skipped a generation.[25]

Equally curious in its way is the variation in synaesthesias experienced by an affected family. Your mother might see coloured music, but that does not mean that you will. You might see coloured letters instead. Synaesthesia the condition may be heritable, but its particular sensory manifestation isn't. Maybe developmental factors, including the environment, have a role in determining which types of synaesthesia an individual will experience.[26]

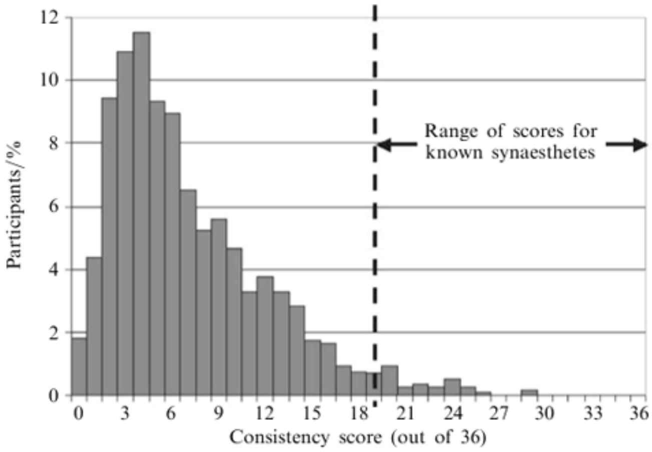
If the genetics of synaesthesia has become an altogether more complex and uncertain recently, there is one bit of good news: that awkward sex ratio of 7.7:1 may not need explaining after all.It may be a simple anomaly. In 2005 – the same year Smilek's twin boys study was published, young British researchers Jamie Ward and Julia Simner totted up the female-male ratio of an unprecedentedly large group of

24. Smilek et al, 2005. Smilek, D.; M.J. Dixon & P.M. Merikle (2005), "Synaesthesia: Discordant male monozygotic twins.", Neurocase 11 (5): 363-370.
25. Hubbard & Ramachandran, 2003. E.M. Hubbard and V.S. Ramachandran Refining the Experimental Lever A Reply to Shanon and Pribram. Journal of Consciousness Studies, 10, No. 3, 2003, pp. 77–84
26. Ward & Simner, 2005. Ward, J. & J. Simner (2005), "Is synaesthesia an x-linked dominant trait with lethality in males?", Perception 34 (5): 611-623

synaesthetic families. By concentrating on grapheme-colour synaesthesia – the most common and most easily tested form of the condition – Ward and Simner had been able to identify and analyze the histories eighty-five families. The results broadly fit the idea that synaesthesia is transmitted on the X chromosome. But the ratio between synaesthetic females and synaesthetic males wasn't nearly so high as that in Baron-Cohen's study: in fact, it came in at 2:1 – actually rather low for X-chromosome transmission.[27]

A year later, the same researchers called X-chromosome transmission itself into question, with experiments on passers-by at London's Science Museum, and on the undergraduate population in Edinburgh. Simner and Ward devised a computer test in which black letters and numbers were flashed on a screen, and people had to pick a colour as quickly as possible as a black letter or number was flashed on a screen. Most people chose randomly but those with synaesthesia were very reliable in their choice of colours. A few months later, people who had done particularly well on the original tests were invited back, to see if the answers they gave now would match their original responses.

27. Ward & Simner, 2005. Ward, J. & J. Simner (2005), "Is synaesthesia an x-linked dominant trait with lethality in males?", Perception 34 (5): 611-623



The results of Julia Simner's survey of synaesthesia among students at the Universities of Glasgow and Edinburgh in 2006.

Subjects had to duplicate at least 19 responses in order to be considered synaesthetic. About 1 percent of those completing the study succeeded and were classified as grapheme-colour synaesthetes.[28]

One out of a hundred of us is a grapheme-colour synaesthete. This lends weight to Cytowic's prevalence figure (of one in twenty for all types of synaesthesia). More significant by far, however, is the way these experiments demolish a key assumption about synaesthesia: that women are about six times as likely to experience synaesthesia as men. Simner and Ward found that their female to male ratio was quite different: about 1.1 to 1!

What conclusions can we draw from the study of synaesthesia's genetics? In as much as we can spot a pattern, synaesthetes are born into synaesthetic families. The talent appears – or appeared until very recently – to be passed down the female line. Exotica like X-chromosome inactivation and male lethality seemed to offer a window into the condition – but recently it has turned out that these mechanisms are not involved. The statistic they were invoked to explain looks increasingly anomalous.

More troubling, recent surveys by Simner and Ward call into question the very

28. Simner, J., Mulvenna, C., Sagiv, N., Tsakanikos, E., Witherby, S. A., Fraser, C., et al. (2006b). Synaesthesia: The prevalence of atypical cross-modal experiences. Perception, 35, 1024-1033.

idea of female-line transmission. It may be that synaesthetic men are reluctant to discuss and advertise their condition. Or they may be simply unaware of it. Either way, their silence may have skewed the figures so badly that we have been sent off on a complete wild goose chase. Instead of looking at the X-chromosome, we should have been looking at the twenty-two pairs of autosomal chromosomes. Ironically, Richard Cytowic suggested that synaesthesia was an autosomal dominant condition back in 1989!

Of course, none of the studies to date give us very big numbers on which to draw firm conclusions. The bigger the numbers, the more reliable the statistics, so there is always an appetite among researchers for bigger, better surveys. Were an even bigger study to throw up a sex ratio close to 3:1 – ideal for X-chromosome transmission – then many researchers would take heart. Confirmation of a straightforward sex ratio of 1:1 would, conversely, suggest that a lot of good work has been misdirected.

These remarks summarize our knowledge to date. Nothing is certain. After one hundred and twenty years, we are barely able to add anything to Francis Galton's remark that synaesthesia is 'very heritable'.

How many synaesthesia genes are there?

Genetic errors get a bad press because strenuous efforts are made to identify the ones that cause us problems. But what about the ones that don't? What about the errors that enhance our lives? What is an 'error', anyway?

Some people have eidetic or 'photographic' memories – and pass this peculiar, cinematic style of recall to their children. Some people see flicker in a light where most of us see a steady source of illumination. Studies of families and twins shows that this talent is heritable, too. Some people, listening to a musical tone, can tell you straight off whether it's C-sharp or B-flat, and when the piano needs tuning. Most people with perfect pitch are women. Their talent appears at an early age, and around ninety per cent of them know about their ability by age ten. They don't need to practise: this unusual gift will stay with them for life. It seems reasonable to assume that perfect pitch has a genetic basis, too. We're unlikely ever to know for sure, because no-one is going to pay for a study into the genetic basis of something that doesn't do anybody any harm.[29]

Studying the genetic basis of gifts and talents is difficult. Part of this difficulty is practical: the funding is hard to come by. But the real problem is much more interesting, and cuts to the heart of our ideas about cultural value, heritance, and even evolution.

If we define talent narrowly as giftedness – 'that which does not require practice' – then the ground stays fairly firm under our feet. Perfect pitch is a talent of this sort. It cannot be acquired by practice. You're either born with it, or you aren't.

The trouble is, this definition of talent is so narrow as to exclude most of the interesting phenomena we might want to sink our teeth into. It prohibits any discussion of general musical talent, for example, because while musical gifts certainly run in families, there is no question that early exposure, encouragement, familiarity, and hours of practice do make huge differences in how an individual expresses that gift.

Let's expand our definition of talent, then, to include noteworthy early aptitude. Richard Cytowic did just this, mining numbers gathered from the records of the Julliard School of Music to show that between half and three quarters of the school's opera singers, instrumental virtuosos, and music students came from musically

29. The only downside to perfect pitch I know of involves listening to Yehudi Menuhin. The great violinist's cavalier approach to tonality has driven at least one person to screaming hysterics.

gifted families.

Before we get too carried away, however, I should point out that the ground beneath our feet has become distinctly spongy. To start with, how are we to separate the influences of nature and nurture in the development of a virtuosic musician? The plain answer is, of course, that we can't. Genes only ever get expressed in an environment. So children brought up in a musical households will get more opportunities to express their innate musical gifts.

What if the number of musical households declines? This is certainly the case in the last hundred years, as recorded music has replaced the piano as the primary source of popular musical entertainment.

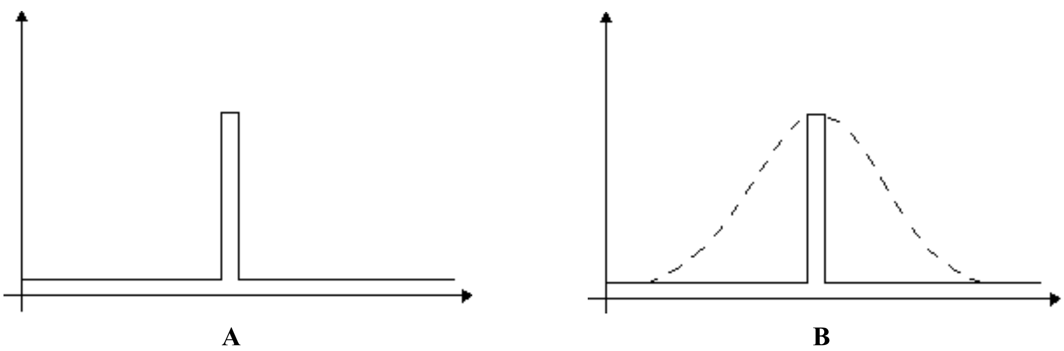
When most everybody played piano (badly), the talent of those who played it well seemed less remarkable and less in need of a fancy explanation. When most everyone played piano, you found, for every brilliant pianist, a handful of excellent pianists. For every excellent pianist you turned up, you also, in passing, came across a roomful of good ones. And so on, the numbers travelling more or less tidily along the slope of the Bell curve that describes normal distribution.

More significant still: when most everybody played piano badly, more people played piano *well*. This is the insight contained in a paper, crucially important to the development of evolutionary theory, written by James Mark Baldwin in 1896. 'A New Factor in Evolution', Baldwin called it. We call it the Baldwin Effect.

Imagine a monkey is born with a genetic predisposition towards playing with sticks. Junior likes poking things with sticks. He likes poking sticks down cracks and crannies. (His parents are in despair. What's with this stick business? Which side of the family did *this* come from?) Then, one day, an ant crawls onto Junior's stick. Junior eats the ant. How many ants will Junior have to eat, over what period, before the extra food source makes him fitter than his fellows? How reliably will that extra fitness be reflected in better mating opportunities? How many more children and grandchildren and great-grandchildren must be sired before Junior's talent with sticks becomes established in the monkey troupe's gene-pool?

Baldwin, contemplating this fairly tortuous sequence of difficult questions, decided there had to be an easier way to consolidate good tricks in the gene pool of a species. He realised that the key was imitation. Sticking with our example, let's say a neighbouring monkey happened to see Junior in action; she might be able to copy his trick with the stick. She might not have much native stick talent to begin with, but – especially if she was a relative – she might have just enough to be able to copy the trick once it had been demonstrated to her. Over the course of a few generations, monkeys that fished for ants fairly well would fare better, and breed more, than monkeys with no fishing aptitude at all. Eventually, the ability to fish for ants out of little holes would become virtually universal – and, hey presto, this is why the wallplugs in our house have these plastic inserts in them. My one-year old son, little monkey that he is, keeps trying to fry himself.

So: back to our starting question. Is the talent for fishing ants out of holes with sticks genetic, or cultural? Remember, our original monkey *did* have a genetic quirk that made him clever with sticks. Thanks to the Baldwin effect, however, spreading this talent no longer requires that the original genetic quirk be passed down to every individual of the species. An individual may harness quite unrelated quirks in an effort to emulate Junior's talent. A talent for imitation *itself* would allow even the most hamfisted monkey to fish for ants with above average success. So the chances that such a talent is dependent on one gene are vanishingly small.



The Baldwin effect. The vertical axis represents fitness. The horizontal axis represents genetic variation. A: Without the Baldwin effect, only an animal that hits upon a particular genetic mutation will acquire a 'good trick' and thrive. B: With learning, animals can try to emulate a good trick. As emulators interbreed, the population capable of good tricks expands, and a hill of increased fitness forms around the original mutation.

Fishing ants out of holes with sticks is a good, stable example of a talent. The trouble with studying human talents, is that we are generally talking about things that are good tricks *in a certain context*. When we say that Judy Wilson has a talent for swimming, we don't mean that she has never been known to sink to the bottom of the pool. We mean that she is fast in the water; that she has good action; that she wins races. In fact, Masters champion Judy Wilson has broken over 35 World Masters Records. In other words, Judy's talent is expressed *culturally*. And that culture is not old. Woodcock Street Baths in Birmingham is the oldest operational swimming pool in Great Britain. It was opened in 1860, less than 150 years ago.

The problem with mapping the heritability of a human talent of this sort is the sheer speed at which the expressing environment changes. In the space of a hundred and fifty years, we have become a nation of swimmers. In even less time, we have gone from a culture of music-makers to a culture of music-consumers. Any new ideas about musical heritance are likely to be painfully simplistic, because these days, musical prodigies are the only musicians we know. (Cytowic didn't simply pop round to his local music hall: he visited the Julliard!) The silent majority of people who might play music with middling ability, were cultural circumstances a bit different, simply don't get considered.

I am reminded of Woody Allen's gag about his celebrity. If he had been born a Sioux, he would have been a nobody, since Sioux culture doesn't do stand-up. When it comes to music, it is as though we have become Sioux Indians, puzzling over the mechanisms of stand-up, and with only Woody Allen to study.

What about synaesthesia? It is, after all, a sort of talent. (It's certainly not a pathology.) What sort of talent is it? Is it like perfect pitch – a pure gift? Or does it respond to practice, encouragement, and a sympathetic cultural environment?

If it's a pure gift, it might well have a simple genetic basis. If it's a culturally valued talent, the course of evolution, iterating the Baldwin Effect again and again, will have rendered its genetics hugely complicated and tangled. If the cultural value is high enough, genetics may simply not come into the picture at all. Our propensity to imitate each other may be explanation enough. Year on year, PlayStation games get more difficult – because more people play them better. There is no PlayStation gene.

What if synaesthesia is a pure gift for some, and in others, it is something that responds to encouragement? This certainly seems to be the case with musical ability. Regardless of whether the rest of us play piano or not, there are always a handful of prodigies in every generation, and if we could get them all in the same room for long enough, we probably could ferret out a simple, common, genetic basis for their prodigious abilities. But what would be the point of this exercise – the equivalent of gathering together a room full of monkey stick-prodigies, a whole cage full of stick-wielding Juniors?

We could certainly describe the *simplest* model of heritability. The danger is, though, that we would then claim to understand musical talent *in general*. If we allow the anomalous prodigy to be the yardstick against which we measure all musical talent, suddenly musical talent is considered *rare*.

Could something similar have happened to our ideas about synaesthesia? Julia Simner's graph of her 2006 survey results (page 21) makes the point quite eloquently. Everyone to the right of the dotted line is considered synaesthetic. Look behind the line, however, and you will see that the survey results describe a smoothly rising curve, representing the ever-more-modest synaesthetic abilities of ever greater numbers of people. These are synaesthesia's silent majority. The thumbfumblers and the flubbers. The ones who can't hack Chopin, but can pick out a tune now and then. Now that researchers like Simner are providing us with bigger numbers and better surveys, the time nears when we must stop drawing dotted lines on our graphs. We have been concentrating hard on spectacular cases – but missing a world of middling synaesthetic talent.

The Trouble with Volunteers

When we count synaesthetes, whom, exactly, are we counting? Who are these people? What, apart from synaesthesia, do they have in common? Actually, they have quite a lot: awareness of the condition, a willingness to share their experiences, confidence enough to discuss these matters with strangers, not to mention a certain amount of free time.

Synaesthetes – at least, those synaesthetes known to us – are a self-selecting group. They each responded to an advertisement in a newspaper or a college newsletter, or called into a radio programme, or they joined Sean Day's Synaesthesia List on the World-Wide Web. They haven't been *rounded up*. They want to be counted.

Chances are, the invitation they are responding to made synaesthesia sound at least mildly enticing. Apart from anything else, the researcher will have wanted to demonstrate goodwill. If you want people to take time out of their day to talk about themselves, you will tend, out of simple politeness, to couch their condition in positive terms.

It is frighteningly easy to let this sort of thing run away with itself. In 1892, an early attempt to estimate the frequency of synaesthesia in the population was made by Mary Whiton Calkins, at Wellesley College, Massachusetts. Of the 525 college students questioned by Calkins, 25 people (6.7 per cent.) claimed to experience 'pseudochromasthesia'. Calkins continued to monitor successive intakes at the college. Remarkably, the figure of 6.7 per cent. for 1892 more than doubled to 16.82 per cent. in 1893 and then rose to 23.3 per cent. in 1894. What explains this pandemic? Most likely, Professor Calkins' students had heard about her research. Presumably it sounded attractive (synaesthesia always attracts attention, amazement, even envy). Who wouldn't want to be part of such research? Who, anyway, would want to go out of their way to disappoint a well-regarded teacher?[30]

Interviewed by the *Independent* newspaper on June 30, 1992, Simon Baron-Cohen mentioned that the synaesthetes he was working with were mostly 'bright and artistic'. Now, it so happened that the people he was talking about had contacted him following a piece on the Radio 4 programme *Science on 4*. Bright and artistic they may have been – but this may have been in no small part due to the fact that they were already, by their choice of radio station, a self-selected group of well-educated listeners who enjoyed listening to complex subjects on talk radio. The implication, however, as it appeared in the *Independent*, was that being synaesthetic meant you were bright and artistic. After the article appeared, Simon Baron-Cohen heard from many more synaesthetes and, lo and behold, most of these people were bright and artistic, too. Baron-Cohen had inadvertently made bright and artistic synaesthetes feel especially welcome.[31]

Sometimes instances of sampling bias are easy to spot. An on-line survey of synaesthesia in 1994 elicted email responses from equal numbers of men and women – but at a time when many more men than women used home computers.[32] Other biases reveal themselves over time. Before Ward and Simner analyzed their 2005 study, they totted up the letters they had received. Women volunteering family information outnumbered men nearly fourfold. Detailed study of actual family histories halved the difference, revealing a sex ratio of only 2:1.

30. Harrison, 2001, pp38-40. Harrison, John E. 2001. Synaesthesia – the strangest thing; Oxford: Oxford University Press.
31. Harrison, 2001, pp86-87. Harrison, John E. 2001. Synaesthesia – the strangest thing; Oxford: Oxford University Press.
32. Cytowic, 2002, p53. Cytowic, Richard E. Synaesthesia: a Union of the Senses. Second edition. (New York: MIT 2002).

Some biases are revealed only years after the event. Over the years, Richard Cytowic has noticed the following about synaesthetes: they have artistic ability, they are more likely to be homosexual, they have more profound feelings of clairvoyance than other people, their math is generally poor, they tend to be left-handed, and many of them have a lousy sense of direction.

These observations were made in the certain knowledge that many would prove ephemeral – artefacts of chance or sampling bias. To date, only poor maths and poor direction-finding have been identified by others as possible synaesthetic traits.

For most of its history, synaesthesia has lacked any objective measure. This has made it particularly vulnerable to accusations of sampling bias. You say a few words on *Science on 4* and suddenly your office is deluged with letters. For every letter from a man, there are nineteen from women. Who are these women? Are they synaesthetes? Or are they lonely middle-class housewives with too much time on their hands? Let's say they're both, and that you conduct some sort of survey or experiment with them. How are you going to convince people that your results are to do with synaesthesia? Why can't your results be explained by life as a lonely middle-class housewife?

We'll see how Simon Baron-Cohen actually handled his problem in a minute. Right now, let's throw some more crude accusations around. There are plenty to choose from. At one time or another, synaesthetes have been accused of being crazy, stoned, or just too 'arty' for their own good.

Our first response to such devastating, levelling accusations is to insist upon synaesthesia's specialness. We exclude from our studies people who are easy targets for such scepticism. The mad and the stoned are relatively easy to spot, and we rarely let them enter the literature on synaesthesia. This in itself may be a problem. Are we sure we want to disregard the many valuable insights that may come from the study of mental illness and pharmaceutical medicine?

Critics of synaesthesia studies tend to harbour a suspicion that synaesthetes have an ulterior motive for announcing their special gifts to the world. Their criticisms are not without foundation. In fact, they have helped shape the course of synaesthesia studies from their very beginning. Here are four of the more important hostile criticisms[33]:

1. 'Synaesthetes are just crazy'

When it comes to our subjective experiences, we are not just different from each other: we are wildly different. Contrary to the impression given by *One Flew Over the Cuckoo's Nest,* we pathologize only a tiny fraction of our weirdnesses. Experiencing *dejá vu* will not land you on a gurney; neither will a tendency to see visions in pools of still water. Both conditions are 'normal'. *Deja vu* happens to almost all of us at one time or another. The imagery associated with crystal gazing is more rare – but harmless.

Were this the whole story, then accusations of synaesthetic 'craziness' would be so much water off a duck's back. Some schizophrenics report having synaesthetic experiences, and we have no way of telling whether their experiences are sensory or delusional. But why should this matter? The fabulations of schizophrenics may make them difficult for us to study, and for that reason we may want to exclude them from

33. This list was originally formulated by Ramachandran and Hubbard in Ramachandran, V. S. & E. M. Hubbard (2001), "Synaesthesia: A window into perception, thought and language", Journal of Consciousness Studies 8 (12): 3-34

our experiments, but no one is seriously suggesting that all synaesthetes are schizophrenics – are they?

In 2005, Sean Day, who founded the popular and valuable Synaesthesia List on the World-Wide Web, had this to say about schizophrenia:

'In the past six years, I have also received urgent e-mail messages from synaesthetes in Chile, Peru and Italy. In each of these cases, the synaesthete had sought out doctors to get more information about their synaesthesias, only to get caught in a complex web where one or more doctors, plus various family members, wanted to institutionalize them, or at least perform a series of quite potentially harmful tests involving drugs.'[34]

When synaesthesia is missed in adolescents, they are frequently misdiagnosed with schizophrenia: an error which is as absurd as it is distressing. The charge that 'all synaesthetes are crazy' is no less damaging for having no rational basis, and synaesthesia researchers are consequently keen to emphasize the mental health and fitness of their subjects.

When I mentioned to an acquaintance of mine that I was planning a book about synaesthesia, her first reaction was to take a step backwards: 'Ah,' she said – and I steeled myself for some half-baked comment about schizophrenia. I had misjudged her. Her misinformation was much more up-to-date. 'Isn't that to do with autism?'

Her choice of words is revealing. Note how it implies causality. Synaesthesia is a little-understood mental quirk. Autism is a heavily researched, serious mental and physical condition. The implicit assumption is that autism somehow *underlies* synaesthesia. It doesn't, of course. We generally assume that if one phenomenon is related to another, then the relationship must be causal. In reality, and particularly in the sciences of mind, such causal relationships are very rare indeed and very hard to demonstrate.

Synaesthesia is, as it has always been, a victim of fashion and fads. For every

34. Day, 2005. Day, S. (2005). Some demographic and socio-cultural aspects of synesthesia. In L. C. Robertson & N. Sagiv (Eds.), Synesthesia: Perspectives from cognitive neuroscience. Oxford: Oxford University Press.

synaesthete who rings up Baron-Cohen's office, mildly encouraged by hints of artistic promise, how many others are mildly put off to discover that Baron-Cohen's most recent work has been into… autism?

A more cogent criticism of synaesthesia might be that it is 'just one of those things': a real enough phenomenon in its way, but not nearly distinctive or special enough to justify serious dedicated study. Buzzing sounds are real enough, but were you to agitate for a Department of Buzzing Research, you wouldn't get very far. Buzzing is already dealt with, in passing, by existing institutions, including musicology and physics and physiology. Indeed, buzzing is so well taken care of 'in passing' that it is hardly a subject at all.

There are, in fact, whole categories of anomalous sensations that resemble very closely the experiences of synaesthetes. It is not unusual for people to experience sensations in amputated limbs, or following the loss of sensory organs. Anatomical or spinal synaesthesia was a term current at the turn of the twentieth century to describe various abnormal sensations associated with spinal injury and 'phantom limbs'.[35] Vilayanur Ramachandran and Carrie Armel have worked with one subject, PH who, two years after going completely blind, began to experience photisms while reading Braille and brushing against corners.[36] Sean Day mentions that one of the subscribers to The Synaesthesia List is a teenaged girl who was involved in a car accident when she was 14. She lost her sense of taste and smell, but now 'smells' music.[37] Eye disease, brain damage and migraines also induce synaesthetic sensations. So can depression, according to Baron-Cohen's colleague John Harrison.

35. Critchley, 1997. Critchley, E. M. R. 1997. Synaesthesia: possible mechanisms. In S. Baron-Cohen and J. Harrison (Eds.); Synaesthesia: Classic and Contemporary Readings; Oxford, England: Blackwell. pp. 259-268.

36. Armel & Ramachandran, 1999. Armel, K.C., and V.S. Ramachandran. 1999. "Acquired Synesthesia in Retinitis Pigmentosa" Neurocase; volume 5.4: 293-296.

37. Day, 2005. Day, S. (2005). Some demographic and socio-cultural aspects of synesthesia. In L. C. Robertson & N. Sagiv (Eds.), Synesthesia: Perspectives from cognitive neuroscience. Oxford: Oxford University Press.

E.M., a 42-year-old woman with massive post-natal depression, developed varieties of synaesthesia. She said she could 'hear her taste' and said her senses were 'all mixed up'.[38]

Obviously it is not enough to say that synaesthesia is 'crossed sensation' or 'anomalous sensation', since by that token any migraine sufferer is an occasional synaesthete. The point is that for a handful of people, some underlying mechanism gives them synaesthetic experiences all life long. This mechanism is our proper area of study.

In extremis, we might even want to focus entirely on those forms of synaesthesia which cannot be acquired except by accident of birth. Cognitive synaesthesias are never the product of medical assault. No one has woken up after a car crash to find the days of the week have sprung funny colours. This is just one of a number of factors that have made the study of grapheme-colour synaesthesia increasingly popular among researchers, at the expense of work that explores synaesthesia's variety and idiosyncrasy.

2: Synaesthetes spend their lives stoned

When Richard Cytowic mentioned to colleagues in the early Eighties that he was looking into synaesthesia, there were not a few in-drawn breaths. Indeed, he was repeatedly cautioned against studying anything so 'New Age'.

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38. Harrison, 2001, p205. Harrison, John E. 2001. Synaesthesia – the strangest thing; Oxford: Oxford University Press.

A list of common synaesthesia-inducing substances reads like the contents of Dennis Hopper's bathroom cabinet *circa* 1970. There's LSD, of course. But let's not forget mescaline, hashish, peyote, fly agaric, MDMA and dimethyltryptamine (DMT). No wonder so many researchers steered clear of synaesthesia for fear of being tarred with the psychedelic brush.

Explorations of the relationship between synaesthesia and drugs are as old as the study of synaesthesia itself. In 1843 the French Romantic poet Théophile Gautier reported that he had been able to produce 'pseudo sensations of colour' by the use of hashish. Not long after, at Union College in Schenectady, New York, the undergraduate FitzHugh Ludlow experimented with hashish and discovered 'what it is to be burned by salt fire, to smell colours, to see sounds, and much more frequently, to see feelings. How often do I remember vibrating in the air over a floor bristling with red-hot needles, and, although I never supposed I came in contact with them, feeling the sensation of their frightful pungency through sight as distinctly as if they were entering my heart.'[39]

A century after Gautier, the Swiss chemist Dr Albert Hoffman, working in the pharmaceutical-chemical department of Sandoz Laboratories, accidentally absorbed through his fingertips the lysergic acid that he had first synthesized five years before, and had then forgotten about. His diary entry for that day – April 16 1943 – describes how he fell into a synaesthetic swoon in which sounds created optical effects and visual images conjured sounds. Three days later, he swallowed 250mg of the stuff – LSD-25 – and wrote of the experience: 'It was particularly striking how acoustic perceptions such as the noise of a passing auto, the noise of water gushing from the faucet or the spoken word, were transformed into optical illusions.'[40]

When it comes to inducing full-flown synaesthesias, LSD's efficacy is actually quite modest.[41] That, and the variable quality of street-grade acid, means that, for all

39. Ludlow, 1857. Ludlow, F. 1857: The Hasheesh Eater. New York, Harper. pp149-150
40. Quoted in Ward, on-line. Ward, Jamie. Synaesthesia Research: questions and answers. Available from http://www.syn.sussex.ac.uk/
41. Cytowic, 2002, p103. Cytowic, Richard E. 2002. Synaesthesia: a Union of the Senses . Second edition. Cambridge, Massachusetts: MIT Press.

the verbiage surrounding the stuff, we have no really good accounts of the drug's synaesthetic mechanism: nor are we likely to get any, given the current the ethical climate – a situation Hoffman himself deplores.

All this talk about drugs leaves one very pertinent question hanging in the air. It is quoted here in the form given it by the vision researcher Christopher Tyler, formerly of Moorfields Eye Hospital, now working in the United States:

'Is it really possible that a sensory effect that is so readily evoked by a small dose of hallucinogen would be so sparsely represented in the population?'[42]

Obviously not all synaesthetes are pot-heads. But if an occasional spliff can induce synaesthesias, are we wise to study just a handful of self-proclaimed synaesthetes? Should we not be looking for synaesthesia in the population at large?

Actually, this is a surprisingly easy criticism to answer. Although drugs can generate sensations reminiscent of synaesthesia, there are clear and telling distinctions between idiopathic synaesthesias and drug-induced synaesthesias. The cross-modal sensations of synaesthetes are not accompanied by feelings of ego loss. Neither are they accompanied by numinous, recurring feelings of intense novelty or significance. Synaesthesia is not 'trippy'. Synaesthetes can always tell you what modalities are involved in their sensations. They are always able to say whether a particular sensation was a sight or a sound. Such confusions are fairly common under the influence of LSD. Synaesthetic associations are quite specific (for example, the letter *A* might look *crimson*). Drug-induced synaesthesias do not have such specificity or longevity.

The mechanism of LSD is too crude to serve as a model for synaesthesia. Its wholesale suppression of the brain's serotonergic function decreases the filtering of cognition, perception and feeling, so that *everything* is experienced in a novel and less mediated manner. (This may explain why LSD users feel like they are experiencing things for the first time.) LSD's excitation of pyramidal cells in the

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42. Tyler, 2005. Tyler, C. 2005. Varieties of Synesthetic Experience. In L. C. Robertson & N. Sagiv (Eds.), Synesthesia: Perspectives from cognitive neuroscience. Oxford: Oxford University Press.

cerebral cortex may cause synaesthesia-like sensations, but synaesthesia is more than sensation. It is a system, a mechanism, as stable as it is idiosyncratic, and far more nuanced than anything afforded by an acid trip.

3: Synaesthetes are being pretentious

Of all the hostile criticisms directed at synaesthesia studies, the accusation that synaesthetes are simply using vague, tangential, 'poetic' speech is the easiest to demolish. It is also the most cogent criticism, the most radical, and the one most likely to transform our understanding of synaesthesia in the coming years.

Language is tangential. It proceeds by metaphor and analogy. In a moment I'll be quitting my keyboard to pick my children up from nursery. I'll take a sandwich to eat on the way because I skipped lunch. There's some in the fridge: a sharp cheddar. I'd better dig out my warm jacket because the weather's turned bitter. I make that four metaphorical expression: 'pick up', 'skip', 'sharp' and 'bitter'. The second two are uncontestably synaesthetic. Why is the cold 'bitter'? Cheese is soft to the touch, so why do we say 'sharp'? Obviously, I mean that the taste is sharp, but why is a tactile adjective being applied to taste?

It is worth trying to answer these questions because synaesthetic metaphors are not local idiosyncracies: they are a common feature of every language, ancient and modern. Aristotle himself, writing at about 350BC, noted 'a sort of parallelism between what is acute or grave to hearing and what is sharp or blunt to touch.'[43]

Aristotle's 'metaphors transferred from their proper sphere' are a commonplace in all languages, and there is a great deal of cross-cultural consistency. White is good and black is evil the world over. The Yale psychologist Charles Osgood, writing in 1960, noted how Anglos, Navajos and Japanese all agreed that white was 'thin and calm'; fast was 'thin, bright and diffuse'; heavy was 'down, thick, dark and near.'[44]

What distinguishes the reports of synaesthetes from the linguistic synaesthesias employed by the rest of us? Most obviously, synaesthetes do not agree with each other about their experiences. No two synaesthetes are alike. Synaesthetic metaphors used by the rest of us are, on the other hand, universally comprehensible, and even cross language boundaries.

Nothing here suggests that synaesthetes are any more than poetic try-hards. To prove otherwise, we will have to prove that synaesthetes really are experiencing something novel (they are not just 'talking fancy'), and their experiences are consistent over time (they are not just 'tripping').

4. Synaesthetic perceptions are just memories

The idea that synaesthetes may simply have learned their associations was put forward by Mary Calkins in 1893. It is an idea that can certainly be recommended on

43. O'Malley, 1957. O'Malley, G., 1957. Literary Synesthesia. The Journal of Aesthetics and Art Criticism, Vol. 15, No. 4 (June), pp. 391-411
44. Osgood, 1960. Osgood, C. E. (1960). The Cross-Cultural Generality of Visual-Verbal Synesthetic Tendencies. Behavioral Science, 5, 146-169.

grounds of economy. Why hypothesize abnormal brain function, when a good memory will do as well to explain a synaesthete's experiences? The suggestion that synaesthesia is merely associative recall sounds like a cheap dismissal. Calkins certainly didn't mean it in that spirit. In its detail, the idea is actually rather ingenious. Take, for example, the most notorious shaggy-dog story in the literature of synaesthesia: The Blind Man Who Heard Red Trumpets.

This man may have been Professor Nicholas Saunderson (1682-1739), who held the Lucasian Professor chair (Newton's chair, more recently held by Stephen Hawking) in the Mathematics Department at Cambridge from 1711 to 1739. Or it may not: Locke mentions a blind man who declared that the sound of trumpets seemed crimson – but he was writing his Essay Concerning Human Understanding around 1690, when Saunderson would have been only eight years old.

Whoever it was, he certainly attracted a lot of attention. After Locke came Leibniz, who mentioned him in 1704. Then came Shaftesbury (1712); Diderot (1749); the empiricist philosopher Etienne Condillac (1749); Adam Smith (1757) and the romanticist philosopher I.G. Herder (1772)! Every one of them took the gentleman's 'scarlet' comment literally, even though Locke's account contains no assertion regarding the immediacy of the blind man's experience. This is even more surprising, given that, far from noting a fascinating synaesthesia, used the story dismissively. Locke was making the point that a trumpet blast is a really *lousy* description of the colour red. Words cannot ever replace perceptions, and the blind man who considered that he knew what red was by associating it with a trumpet blast was at best deluded; at worst, a pretentious fool.

It is rather delightful, I think, that the first full statement in English concerning synaesthesia comes from Locke, whose snide definition of it – 'that we might taste, smell, and see by the ears' is almost as devastating as his *coupe de grace*: he considers it 'a sort of philosophy worthy only of Sancho Panza, who had the faculty to see Dulcinea by hearsay.'

The British neurologist Macdonald Critchley, who died in 1997, looked somewhat more kindly on the reality of synaesthetic experience, but saw no reason to invoke anything more than memory to explain it. To make his point, he reached for synaesthesia's hoariest cliche, the blind man who heard red trumpets, explaining, with devastating insouciance, how such a 'photism' might arise.

> 'The familiar story of trumpet blasts provoking a photism of red, may stem from the fact that such a sound immediately culls up in some persons an imagery of soldiers on parade. Ordinarily they shall be in dress uniform. This evokes a mental picture of scarlet. Should the middle part of this notion eventually become submerged, there will remain a synaesthetic linkage of trumpet-calls with redness.'[45]

This is not an explanation we can dismiss lightly. Some synaesthetes have somewhat better recall than the rest of us. It is very unlikely that such modest improvements in memory can be responsible for all the very precise, very stable sensations of the average synaesthete. This, unfortunately, is an argument from incredulity. (*Surely* memory cannot be responsible!) In other words, barely an argument at all.

In one justly celebrated case, memory might actually be sufficient explanation for a man's experiences of synaesthesia. The man in question is Solomon Shereshevsky, a stage memory-man whose tragic gift was his inability to forget. Shereshevsky would write things down on a paper, and then set light to it, in the desperate hope that seeing the words turn to cinders would help him forget them. It didn't work. Shereshevsky's recall was so total that he really could have remembered lists of random sensory associations. Indeed, he would have found it hard to forget them.[46]

Most synaesthetes concede that they find their associations handy when it comes to performing certain mental tasks, including memory tasks. So: is a good memory a product of synaesthesia, or is synaesthesia a manifestation of an exceptional

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45. Harrison, 2001, p209. Harrison, John E. 2001. Synaesthesia – the strangest thing; Oxford: Oxford University Press.
46. Luria, 1968. Luria, A. R. & Lynn Solotaroff (trans.) 1968. The Mind of a Mnemonist. London: Jonathan Cape.

memory?

Even without Shereshevsky, we would have to admit that there has to be some connection between learned associations and synaesthesia. We are not born with a knowledge of letters and numbers, yet many synaesthetes – the majority – enjoy grapheme-colour synaesthesia. The propensity to synaesthesia may be innate, but many synaesthetic operations must involve associations and memories.

This leaves researchers in something of a bind. They want to distinguish synaesthesia from mnemonic tricks. At the same time, they do not want to completely disregard the important connection that must exist between synaesthesia and memory.

You too can be a synaesthete!

Synaesthesias. Associations. Memories. Linguistic regularities. Even physical constants. At the beginning of study into synaesthesia, there were no walls between these categories. In 1876, the German psychologist Gustav Theodor Fechner asked whether there were regularities between our experiences of auditory and visual spectra. His subjects reported the colours which accompanied certain sounds. Fechner does not say whether his subjects saw the colours, or whether they simply conjured them 'in their mind's eye.' The distinction is not important to him.

If we are the answer the charge that synaesthetes are 'making it all up', or 'tripping', this distinction must matter to us. But where the devil is it?

Research into grapheme-colour synaesthesia has revealed two kinds of synaesthetes. Both are true synaesthetes, in that their experiences are idiosyncratic, reliable, and stable over time. Still, one group report that they see coloured letters; the other group say that when they see letters, they 'imagine' or 'call to mind' colours. (The distinction between 'projectors' and 'associators' almost certainly applies to other forms of synaesthesia as well.) The difference between the experiences of projectors and associators certainly reminds us of the range in intensity of synaesthetic experiences. However, as an idea, it may turn out to be more trouble than it is worth. This is because, the closer you look at the difference between these groups, the vaguer it becomes.

Jessica Edquist is a researcher at the Australian National University and a music-colour 'associator'. 'It's not like I see colours out there in the real world,' she told ABC's science programme *Catalyst* in 2002, 'like I'm seeing the beach or anything. It's just that there's an association between certain sounds and certain colours. I can't really think of a better way to explain it.'[47] In 2006 she put a team together to explicitly test for differences between projectors and associators. They couldn't find any. Projectors and Associators did well or badly in visual research in ways that made a nonsense of the hypothesized distinction. Worse, individuals who described themselves as one thing, later described their experiences in terms that suggested they belonged to the other group![48]

Synaesthetes are clearly different from other people, but are these differences of kind, or differences of degree? We know that mental associations and learning must play some role, at least in the cognitive synaesthesias. We know also, thanks to Pavlov's early conditioning experiments, that mental associations can be learned.

What if we were able to train people to be synaesthetic?

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47. Catalyst: Synaesthesia. ABC TV Science. 11 April 2002. Transcript available at http://www.abc.net.au/catalyst/stories/s528838.htm
48. Edquist et al, 2006. Edquist, J., Rich, A. N., Brinkman, C., & Mattingley, J. B. (2006). Do synaesthetic colours act as unique features in visual search? Cortex 42, 222-231.

Can synaesthesia be learned? Alfred Binet certainly thought so. The French psychologist – inventor, in 1905, of the first usable intelligence test – argued that synaesthesias were learned in childhood. To prove his point, he paired colours and sounds and taught himself the pairings. His proficiency at naming the colours became great – as good as the results he got from a synaesthetic subject.[49]

A more convincing attempt at conditioning synaesthesia was made in 1941 – this time, ironically enough, by a figure at the very heart of the behaviorist project: Douglas Ellson. A colleague of B F Skinner at the University of Indiana, Ellson eventually succeeded Skinner as department chair of the Indiana psychology department. During World War 2, Ellson was employed on government contract to research gunfire control at the University of Wisconsin.

Ellson, a specialist in learning theory and its applications, conducted experiments into cross-sensory conditioning. In one such experiment, he seated a volunteer in a comfortable reclining chair that had a small light bulb fitted to its left armrest. Immediately after the light went on, a sound began to build in the room from a concealed location. The tone, about two octaves above middle C, built to a crescendo, then faded steadily away. When it petered out altogether, the bulb went out.

After pairing the light and the tone for some time, Ellson's subjects found that they hallucinated the tone whenever the light came on. Eighty percent of his subjects could not tell the difference between a bona fide sound and their own hallucinations. These included two out of four psychologist colleagues who were familiar with the procedure and purpose of the experiment. Foreknowledge did not prevent them from hallucinating.

Clarence James Leuba, a leading authority on hypnotism achieved similar results

49. Binet, 1893. Binet, A. (1893). L'Application de la Psychométrie a l'Étude de l'Audition Colorée. Revue Philosophique, 36, 334-336.

at around the same time, with subjects were under hypnosis. He also managed to induce sensations of touch and smell conditioned to sound.[50]

These experiments get fairly short shrift in the literature on synaesthesia, and it is easy to see why. Experiences closely analogous to synaesthesia can be triggered by all manner of things, from a migraine to a sneaky spliff. When experimental psychologists get in on the act and induce synaesthesias, this is not headline news. In fact it only serves to further cloud an already muddy picture.

On the other hand, very little research has been done into how synaesthesia and memory are related. So these experiments may yet be remembered as the foundations of a new and fertile line of enquiry.

One reason for the unpopularity of the Binet-Ellson-Leuba approach may be historical. Claims that synaesthesia is teachable are characteristic less of the laboratory than the literature of 1960s counterculture. The people who sucked their teeth when Richard Cytowic went off to study synaesthesia surely had conniptions when considering claims made by LSD apologists Robert Masters and Jean Houston. In their 1972 book *Mind Games,* Masters and Houston assert that synaesthesia offers 'education, ecstasy, entertainment, self-exploration, powerful instruments of growth.' for all.[51]

What if they're right?

Synaesthesia is considered rare, and incapable of cultivation, but meditators report the experience quite commonly, In 2005 Roger Walsh[52] a professor of psychiatry, philosophy and anthropology at the University of California, Irvine, developed a questionnaire for meditators at different levels of aptitude and engagement. 35 per cent. of people on a meditation retreat said they experienced synaesthesias. In a group of regular meditators, that figure went up to 63 per cent. 86

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50. Marks, 1975/1997. Marks, L.E., 1975/1997. On Colored-Hearing Synesthesia: Cross-Modal Translations of Sensory Dimensions. In S. Baron-Cohen and J. Harrison (Eds.); 1997. Synaesthesia: Classic and Contemporary Readings ; Oxford, England: Blackwell.
51. Dann, 1998, p167. Dann, Kevin T. 1998. Bright Colors Falsely Seen: Synaesthesia and the Search for Transcendental Knowledge. New Haven and London: Yale University Press.
52. Walsh, 2005. Walsh, R, 2005. Can Synaesthesia Be Cultivated?: Indications from Surveys of Meditators, Journal of Consciousness Studies, Volume 12, Numbers 4-5, pp. 5-17

per cent. of advanced teachers said they experienced synaesthesias.

Several Eastern philosophies regard mental objects as sensory ones and vice versa, and have recognized synaesthesia for over two thousand years. In Indian philosophy, for example, the senses are not only interrelated; they are combined with colour, gender, and the devnagari alphabet. (The word for the alphabet itself, translated literally, is ‘colour-garland’.)

If synaesthesia is cultivated by meditation, then laboratory studies of meditators could open up promising new intellectual territory. More important, attempts to identify synaesthetes through their bloodline, or even through their special abilities, may be missing the point entirely.

What if we were all synaesthetic – and simply hadn’t noticed?