

Synaesthesia: reconciling the subjective with the objective

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Coloured hearing synaesthesia (from the Greek *syn* (union) and *aisthesis* (sensation)), has been known to the scientific community for over 300 years and yet has gone relatively uninvestigated. This review charts recent progress in the investigation of synaesthesia and discusses the consequences of this research for our understanding of the condition.

When I see equations, I see the letters in colors — I don't know why. As I'm talking, I see vague pictures of Bessel functions from Jahke and Emde's book, with light-tan j's, slightly violet-bluish n's and dark-brown X's flying around. And I wonder what the hell it must look like to the students;

This quotation, taken from the Nobel prizewinning physicist R. Feynman's book *What Do You Care What Other People Think?* [1, p. 59] suggests that he may well have experienced coloured-hearing synaesthesia, a condition in which a sensation in one modality gives rise to sensations in another. His account of the condition is curiously similar to that given by the author Vladimir Nabokov in his autobiography, *Speak, Memory* [2, p. 58]:

I present a fine case of coloured hearing. Perhaps 'hearing' is not quite accurate, since the colour sensation seems to be produced by the very act of my orally forming a given letter while I imagine its outline. The long *a* of the English alphabet (and it is this alphabet I have in mind unless otherwise stated) has for me the tint of weathered

wood, but a French *a* evokes polished ebony. This black group also includes hard *g* (vulcanised rubber) and *r* (a sooty rag being ripped). Oatmeal *n*, noodle-limp *l*, and the ivory-backed hand mirror of *o* take care of the whites.

These accounts have presented neuroscientists with a fascinating problem — how might we give a satisfactory theoretical account of a condition such as synaesthesia, whose primary source of data is the entirely subjective account of the experience of seeing colours when hearing words? In the following review we shall give an account of how we have sought to provide a scientific account of the condition by using a combination of experimental psychology and neuroimaging, but also with reference to the phenomenological accounts of the condition given to us by subjects with synaesthesia.

A brief history of synaesthesia

A review of the literature reveals that while during the last 20 years research into synaesthesia has experienced something of a renaissance, the condition has been known to science for well over 250 years (an early account is given by John Locke [3]). However, it is in the closing decades of the nineteenth century and early twentieth century that synaesthesia seems to have enjoyed most interest. One of the most notable individuals to devote attention to the condition during this period was Sir Francis Galton in his *Inquiries into Human Faculty and its Development* [4]. Galton gives an account of several individuals with the condition, even going to the trouble of reproducing some of his subjects' 'coloured alphabets'. Galton's commentary prefigures many of the more contemporary accounts. For instance, he informs us that 'seers are invariably most minute in their description of the precise tint and hue of the colour. They are never satisfied, for instance, with saying "blue", but will take a great deal of trouble to express or to match the particular blue they mean', an observation that echoes our own experience of synaesthetes' colour descriptions. Galton makes two further

points: first, 'that no two people agree, or hardly ever do so, as to the colour they associate with the same sound' and, secondly, 'that the tendency is very hereditary', observations that find support in our studies [5,6].

Such was the interest in synaesthesia during Galton's time that a review by L. Marks [7] reveals that between 1881 and 1931 more than 70 papers were published on the condition. These accounts depended almost entirely upon the subjective reports of individuals with the condition, a form of data entirely reliant on the subject's ability to accurately 'introspect'. Unfortunately, introspection proved to be a most unreliable method of uncovering the nature of human cognition, in that subjects tended to give accounts of their mental processes that were found to be inconsistent with more objective data. A response to this concern with the quality of phenomenological data was the emergence of behaviourism as the dominant psychological paradigm. Behaviourism effectively precluded reference to mental states in its bid to bring psychology into the fold of the natural sciences, instead insisting that psychologists should concentrate only upon observable behaviour. Research into synaesthesia, which could be defined only by self-report and with references to mental state, appears to have been an early casualty of behaviouristic thinking, as evidenced by the fact that in the 42-year period from 1932 to 1974 Marks reports only 16 published papers on the topic.

Behaviourism is generally acknowledged to have failed to provide the general laws of learning it was expected to yield. Following Chomsky's [8] damning indictment of the inadequacy of B.F. Skinner's [9] account of language acquisition, a shift to cognitivism began. Behaviourism had banished reference to mental states from scientific language, but, with the rise of cognitivism, mental phenomena once more became legitimate targets for scientific study. As a probable consequence, within the last 20 years, research into synaesthesia has enjoyed something of a renaissance and recent developments have led for the first time to the condition's being widely recognized as

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having a 'neurological reality', thereby moving it beyond the romantic neurology categorization given it by G. Humphreys [10]. In this article we provide an account of recent work into the condition and hope to use the example of synaesthesia as a way of illustrating how neuroscience might seek to reconcile subjective experience with objective analysis.

Testing for synaesthesia

Currently, no consensus exists regarding an objective test for confirming the presence of synaesthesia. Our own attempts have relied upon performance on a test that gauges a subject's consistency at relating colour descriptions triggered by words across two or more occasions [5,6]. R.E. Cytowic [11,12] has relied upon a set of diagnostic criteria of 'clinical' symptoms as opposed to signs of the condition. A possible weakness of this latter approach is that once again it is entirely reliant upon the individual's subjective account of the condition. Diagnosis on the basis of subjective symptoms rather than objective signs increases the likelihood of making false positive declarations. Our own view is that in order to ensure a suitable baseline for testing and experimentation it is essential to establish the presence of synaesthesia. We have traditionally sought to do this using the test described above, though we are aware

of possible difficulties with relying solely on consistency as the criterion of genuineness. The study of the subject Elizabeth Stewart-Jones reported by Baron-Cohen *et al.* [5] reported that the colour percept for each word seemed unpredictable on the basis of the colour correspondence for each of the component letters. This was in contrast to the later study reported by Baron-Cohen *et al.* [6] in which it appeared that the word-colour correspondence was highly dependent upon the colour association of a dominant letter within the word. For example, for subject RY the colour for the word 'speak' was found to be blue, a correspondence chiefly due to the letter 'S' having a blue percept. It would in principle be possible to score 100 per cent on our test by learning to associate a colour with each letter of the alphabet and using the first letter of the word to establish the appropriate response.

A new and more objective method for establishing the presence of idiopathic synaesthesia exists in that, with the advent of neuroimaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), it has been possible to image the brain *in vivo*. R.E. Cytowic and F.B. Wood [13] used the xenon¹³³ inhalation technique to image the brain of a single subject and our own group has used PET [14] and more recently fMRI (S. Williams, J. Harrison and

S. Baron-Cohen, unpublished manuscript). The results of the experiment by E.J. Paulesu *et al.* showed that subjects with synaesthesia exhibited increased regional cerebral blood flow (rCBF), as compared with control subjects, in two visual association areas (posterior infero-temporal cortex (PIT) and the junction of the occipital and parietal cortices) when listening to words (see Figure 1). Scanning for activation in these areas provides a possible test for synaesthesia.

What is 'idiopathic synaesthesia'?

Much of the literature on synaesthesia has tended to deal with instances of cross-modal stimulation that has been induced, acquired or contrived. For instance, there are a number of accounts of individuals reporting synaesthetic percepts as a consequence of neurological disorder or as a result of the use of psychoactive drugs (see [11,12]). It is important to note that the subjects upon whom we have reported exhibit a natural, idiopathic form of the condition, which is, in all cases, an automatic experience.

Many writers (for example, [11,16]) on the topic of synaesthesia have been drawn into discussing the possibility that a number of authors, poets, artists and musicians may have had synaesthesia. A typical list of these individuals would include the composers Liszt, Rimsky-Korsakov, Messiaen and

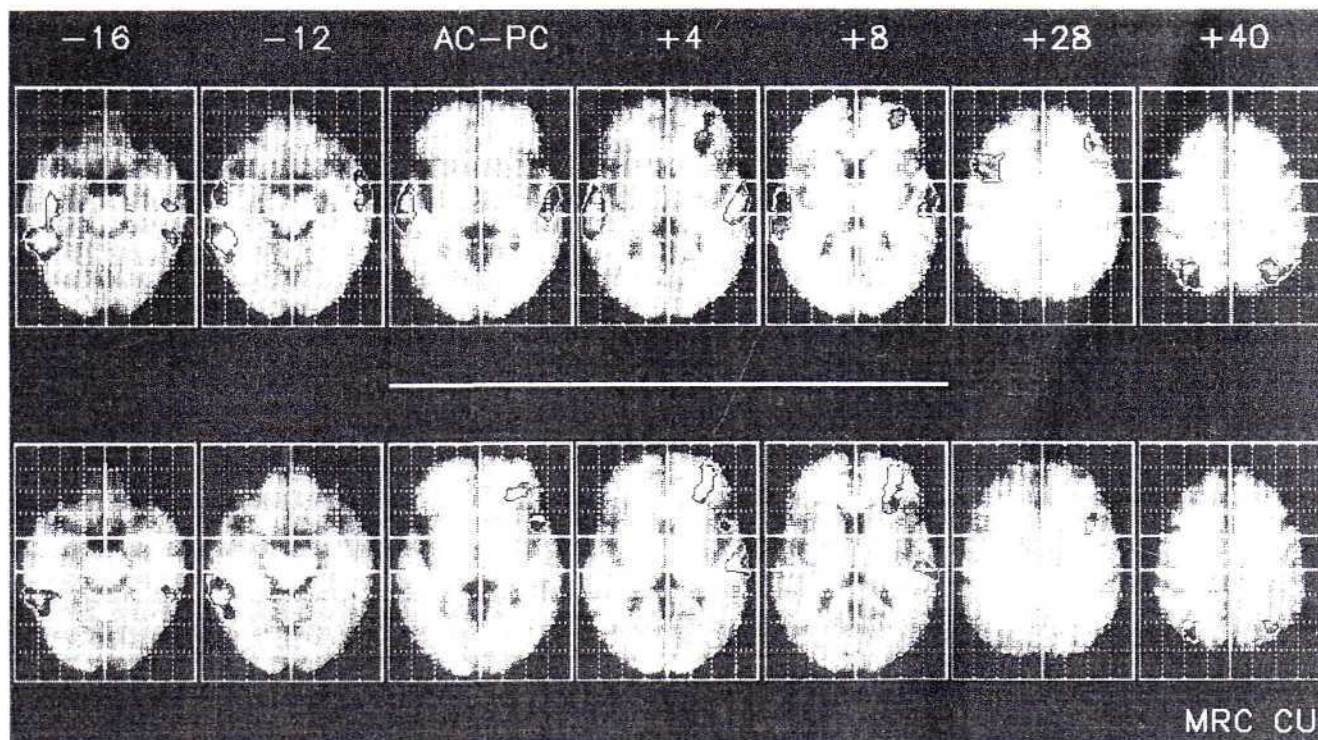


Figure 1 Activations during colour-word synaesthesia. The top part illustrates the location of the rCBF increases induced by word perception in synaesthetes. Areas of significant rCBF increase have been plotted on averaged MRI images transformed into the stereotactic space of Talairach and Tournoux [15]. The activated areas are shown in colour. The lower part illustrates the locations where subjects with synaesthesia showed significantly greater activation than controls in response to the same word stimuli. These areas include the left inferior temporal cortex, the right prefrontal, insular and superior temporal cortex, and the parieto-occipital junctions bilaterally. AC-PC signifies the plane corresponding to the anterior commissure-posterior commissure (bicommissural) line. Distances (in millimetres) refer to the AC-PC plane. (Reproduced from [14] by permission of Oxford University Press.)

Seriabin; the poets Basso, Rimbaud and Baudelaire; the artists Kandinsky and Hockney; and, finally, the novelist Nabokov, already mentioned. We are unaware of evidence of these individuals having been formally tested for synaesthesia and so have no direct objective data upon which to make a firm 'diagnosis'. We have recently reviewed the literature in these cases and have concluded that in almost all instances these individuals have been using metaphor rather than exhibiting idiopathic synaesthesia. A notable exception to this appears to be the case of Nabokov who gives an autobiographical account of his synaesthesia. On p. 59 of *Speak, Memory* [2] he discusses the nature of his mother's synaesthesia as well as his own:

The confessions of a synesthete must sound tedious and pretentious to those who are protected from such leakings and drafts by more solid walls than mine are. To my mother, though, this all seemed quite normal. The matter came up, one day in my seventh year, as I was using a heap of old alphabet blocks to build a tower. I casually remarked to her that their colours were all wrong.

Much of Nabokov's account of his synaesthesia shows a marked similarity to those given by subjects with synaesthesia reported by Baron-Cohen *et al.* [6]. Subjects in this study confirmed that they too had possessed synaesthesia for as long as they could remember and also reported synaesthetic relatives. However, Nabokov appears to have been fortunate as compared with many synaesthetes we have interviewed in that he recalls revealing his synaesthesia to his mother, who shared the condition. A number of the synaesthetes who have contacted us have confessed to having remained silent on the topic for fear of ridicule by others who either do not understand, or share, the condition.

A further questionnaire item [6] dealt with the extent to which the synaesthetes tested dreamt in colour. We have invariably found that the answer to this question is that such individuals claim 'always' to dream in colour. Received wisdom in psychology is that most people, when asked this question, will either deny dreaming, be unsure as to whether they dream in colour, or say that they dream in colour occasionally. Consistent dreaming in colour may mark out people with synaesthesia from the 'normal' population. This possibility is made more interesting by 'The case of the colour-blind painter', reported by O. Sacks and R. Wasserman [17]. The subject of their study, JI, suffered brain injury as the result of a car accident and as a consequence became cortically colour-blind (achromatopsic). However, when JI lost his ability to see colour, he also lost his coloured-hearing synaesthesia as well as his ability to dream

in colour. JI presents us with a neuropsychological dissociation in that, as a result of brain damage, he has lost the ability to see or dream in colour, as well as losing his synaesthesia. Such a pattern of dysfunction opens up the possibility that these capacities may share a common neural substrate.

What are synaesthetic percepts 'like'?

Cytowic [12, pp. 118–19] has suggested that synaesthetic percepts constitute an ineffable experience which, to understand, one must experience first-hand. We have encouraged synaesthetes to try to explain, as precisely as possible, the nature of their experience. One way in which we have sought to do this is to ask subjects to make graphic representations of their synaesthetic percepts. A synaesthetic painter's attempt to depict the percept experienced is shown in Figure 2. This piece represents the percept experienced by Elizabeth Stewart-Jones whenever she hears the names 'Harold

Pinter' and 'Alan Ayckbourn' [5]. She claims, consistent with Cytowic's notion of the ineffability of synaesthetic percepts, that while this is the best she can achieve, it does not perfectly capture the exact nature of her experience. It would appear that synaesthetes have a great deal of difficulty satisfactorily explaining the nature of their experiences. For example, a question designed to establish 'where' the percepts occur yielded a consistent account with all but two of the subjects reported by Baron-Cohen *et al.* [6], confirming that the colour was not in their visual field. Subsequent questioning has established that the percept is not an imagined visual image.

It would seem that synaesthetic percepts are neither imagined nor retinally derived, the two sources of visual experience in non-synaesthetes. A possible third source of visual experience has been suggested by the work of G. Beckers and K. Beckers [18] who have used transcranial magnetic stimulation (TMS), a technique that stimulates

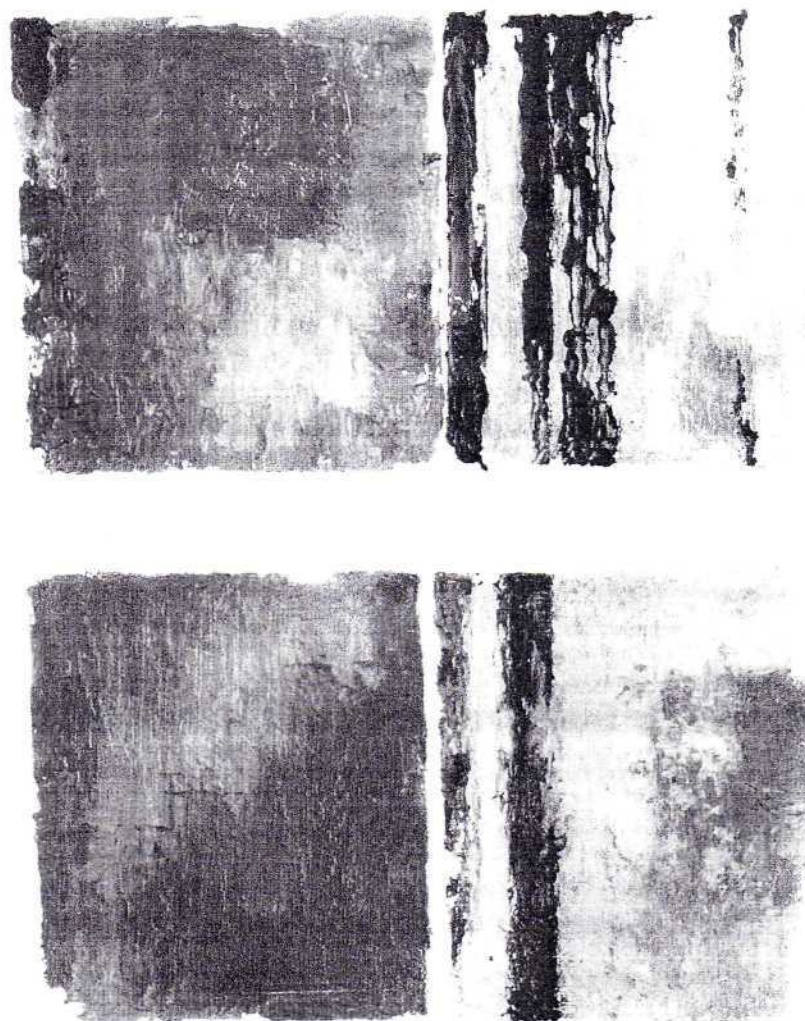


Figure 2 Representations painted by Elizabeth Stewart-Jones of the synaesthetic percepts triggered by 'Harold Pinter' (top) and 'Alan Ayckbourn' (bottom).

the brain by the application of a magnetic pulse. They elicited coloured, visual percepts (chromatophenes) from subjects by stimulating areas of the occipital lobe. TMS might be used in future as a method of eliciting chromatophenes in synaesthetes in order to establish whether they constitute a similar visual experience to that of coloured-hearing synaesthesia.

The biological basis of synaesthesia

Cytowic has argued for the importance of emotion for synaesthesia and has suggested that the limbic system may have ascendancy over the cortex. In this respect it is important to point out that Paulesu *et al.* [14] found no increase in rCBF to limbic areas in synaesthetes, shedding doubt on the importance of the limbic system. In any case, we would not argue for synaesthesia being rational rather than emotional and in fact regret the adoption of this rather polarized dichotomy. Neurons within the limbic areas use the same electrochemical coinage of information exchange as those in cortical areas, and the imposition of emotionality rather than rationality upon them seems to us inappropriate. In any case, substantial areas of the limbic system (that is, the cingulate gyrus, hippocampus) contain cortical areas, so suggesting that either a 'cortical' or a 'limbic' explanation of the biological basis of the condition is logically unsound.

In order for us to 'know' that a percept is visual, auditory, olfactory, etc., we must have developed a method for identifying information as being derived from one sensory modality or another. There is, presumably, a structure to sensation which allows for discrete identification of information as being specific to a sensory system. We have previously provided a functional account of synaesthesia [6] which suggests that the condition may provide us with a model of how a breakdown in this modularity may yield a percept which, while auditory in origin, has a visual quality to it. D. Maurer [19] has suggested a biological correlate of this breakdown in modularity by proposing that neonatal pathways between auditory and visual areas of the brain are, in individuals with synaesthesia, perpetuated beyond the neonatal period (three to six months) in which they are found in normal individuals. The consequence of this activity is that auditory information (in some cases exclusively linguistic) is carried beyond those areas of the brain concerned with auditory information and on to those dealing with visual information.

Conclusions

The PET study reported by Paulesu *et al.* [14] has provided us for the first time with objective information about differences in brain activity in subjects with synaesthesia. However, this study does not allow us to choose between the competing hypotheses that the differences in rCBF are due to (i)

hardwired neurobiological differences, or (ii) differences in strategy. In any case, the use of PET, as well as experimental psychological methods, has allowed us to seek to reconcile the 'subjective' experiences of synaesthetes, with the 'objective' view of science.

The problem of providing scientific explanations of subjective experience was famously and eloquently stated by C.F. Sherrington who traced the light from a star through the visual system. He suggested that the mechanics by which data about the star reached the visual cortex were relatively well understood, but that we had no explanation of the subjective experience of seeing the star: 'At this point the scheme puts its finger to its lips and is silent' [20]. Reconciling the first- and third-person views of human cognition has proved to be a difficult enterprise and for many years personal experience was not seen as the proper domain of science. This perspective seems to be the legacy of Galileo's notion that the universe was made up of (i) matter and (ii) energy, the first dealing with primary qualities (velocity, weight, mass, etc.), the second with those of subjective experience (smell, vision, truth, etc.). For Galileo, only the former was properly the domain of science. Descartes appears to have taken a similar view, suggesting that *res extensor* (the physical world) was the domain accessible to science, whereas *res cogitans* (the mental world) remained inaccessible. As a result of Einstein's reconciliation of mass and energy, we are left with a one-stuff universe, thereby allowing, at least potentially, for scientific explanations of Galileo's secondary qualities and Descartes' *res cogitans*.

Psychological thought has sought to accommodate this perspective, swinging from concern with inner mental life to placing a premium on observable behaviour, and back again, while never achieving a consensus view concerning the reconciliation of phenomenology with objective data. In this context synaesthesia makes an interesting topic of investigation in that the subject matter is necessarily an internal, mental state whose existence we can only infer from the findings of behavioural testing. Cytowic has tended to rely almost entirely upon the subjective self-reports given him by his subjects with synaesthesia. We have sought to rely primarily upon objective quantification of data according to the traditional methods of experimental psychology, but have allowed room for including what synaesthetes tell us about their experience in the form of questionnaire data.

Acknowledgements

We thank Ian Miller of the Massachusetts Institute of Technology for drawing the example of Richard Feynman's coloured letters to our attention. Parts of this review will appear in a forthcoming book on synaesthesia, edited by the authors.

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