What is like being a research biologist in Singapore? Singapore is an extremely attractive place to live and work for both Asians and non-Asians. English is spoken by everyone and it has become a very appealing place for Asian (typically, but not exclusively, Chinese and Indian) and non-Asian (from North America, Europe, Australia and New Zealand) researchers trained elsewhere to move to. For the Asians, this is home or close to home, while non-Asians get to experience a different culture, by living and working here. There has also been a tremendous push to raise the profile of life sciences in schools and colleges. Various scholarship and fellowship schemes have been instituted by governmental and private agencies to encourage more Singaporeans to take up higher education in the life sciences.

By capitalizing on all these features, Singapore hopes to make life-science-based industry a major focus of its economy. The government, as well as other organizations have invested a great deal into the life sciences. The 'Agency for Science, Technology and Research' has been mandated with effecting the biomedical revolution and runs a number of institutes carrying out biomedical research. Then there are the universities, which are also involved in life science research.

I work in an exceptional institute — the Temasek Life Sciences Laboratory — run by *Drosophila* cell biologist Bill Chia. We broadly focus on cellular and developmental biology, where our investigators are involved in curiosity-driven-research using a variety of model organisms, covering plant, animal, fungi and bacteria. The majority of activity in all research organizations is in training manpower and in generating intellectual property. The impact of Singapore's life science investments on biotechnology industry and economy should come soon and this will make it satisfying for everyone involved. I certainly think we are moving in the right direction.

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Quick guide

Synaesthesia

Catherine Mulvenna and Vincent Walsh

What is synaesthesia? It refers to when an individual experiences a sense other than the one being stimulated. This unusual pairing is automatic, present since childhood and consistent across time. A specific experience will be activated by the same stimulus with a seemingly arbitrary connection. For example the sight of the letter 'q' may always activate the experience of a deep red colour; or a middle C played on a violin may always activate the experience of the taste of tuna. The pairings can be more complex for some synaesthetes; for example, a sequence of pitches may activate the sensation of "gold, yellow and white moving rapidly upwards and at an angle to the right, like a rippling stream". The condition is also referred to as 'sensory cross-activation'.

What isn't it? It does not apply to forced or acquired associations, such as the word Christmas having connotations with the colour red, the smell of mince pies or the general sound of Christmas carols. It also does not include sensations triggering memories, such as a song eliciting the memory of a person or place.

Who first discovered it? The first known reference to synaesthesia in scientific writing is John Locke's account of a blind man who described the colour scarlet as "the sound of a trumpet" in 1690. Similar isolated case-studies continued for some time, and it was described in detail by Francis Galton at UCL in 1883. Since then synaesthesia has suffered repeated waves of dismissal as a phantom condition, despite continual reports of its existence. It is only relatively recently, with the application of brain imaging techniques, that it has gained creditability in the scientific world as a genuine neurological condition, and this acceptance has led to the current surge in synaesthesia research.

How do we know it is real? Sensory cross-activation in the brains of synaesthetes has now been observed by positron-emission tomography (PET) and functional magnetic resonance imaging (fMRI). Activation of brain regions associated with visual perception was observed in blindfolded synaesthetes listening to words that evoked visual experiences. These activations were shown to be clearly different from those evoked in either non-synaesthetes or the same synaesthetes listening to tones that did not evoke visual experiences. Activation of areas strongly associated with the perception of colour was observed in a group of word–colour synaesthetes. This was not observed in non-synaesthetes, even after they were trained to associate pairings of words with colours. Current investigations are examining if this neurological trend is observable across subtypes involving other senses.

What causes it? One theory suggests that, rather than synaesthesia being caused by extra connections 'growing' between sensory areas, the apparent cross-activation could be a result of reduced apoptosis which aids differentiation of the sensory areas of the brain in the first months after birth. Because of this increased sensory connectivity, some experiences between certain senses in infancy may stay fixed in the brain. If this is the case, we were all synaesthetes at one stage, but sensory modularity developed more explicitly in non-synaesthetes.

Is it a help or a hindrance? It is very rare that synaesthetes' experiences are so strong they are problematic. Synaesthetes frequently report it as a pleasant experience that they would prefer to have, given the choice. They can find it difficult to accept how other people do not experience it, and do not think of it as surreal or unusual. The cross-activation often acts as

Some artists' work is in response to sound–colour associations. This painting by British artist Mark Rowan-Hull is in response to Messiaen's composition Turangalîla 3.

an additional cue in memory. For example, if you experience colours for specific months, you may not remember exactly when something happened, but you may remember it was, say, a light blue month so it must have been October. One frequently reported advantage is the use of activated colours to remember phone numbers by number-colour synaesthetes.

From case studies over the last two centuries, a profile of cognitive traits has emerged that is believed to be associated with having synaesthesia, but these require proper investigation. The traits include higher intelligence, left-right confusion, better spatial memory, poorer spatial navigation and higher levels of creativity.

How many types of synaesthesia are there? In theory, synaesthesia can occur between or within any of the senses. The most commonly observed atypical activation is colour, and the most common stimuli to cause it are days of the week or letters of the alphabet. Individuals may have several subtypes of synaesthesia — music-colour, letter-taste, day-colour, music-shape and so on — or just one. It is uni-directional, so if numbers activate colours, colours will not (necessarily, but see Cohen-Kadosh *et al.*) activate numbers.

How many people have synaesthesia? This is a controversial area of synaesthesia research. The first estimate in 1883 was that this affects 1 in 20 people, which fluctuated to 1 in 250,000 by the 1980s. A pioneering study by Baron-Cohen and colleagues in 1996 was the first to investigate this issue empirically, and found that at least 1 in 2000 people have synaesthesia. Following this, estimations have continually risen and current large-scale screenings of the populations indicate as many as 1 in 30 people experience at least one subtype of synaesthesia. It also shows a pattern of running in families and initial genetic investigations suggest in some cases at least it may be an X-linked trait.

Will I ever experience it? You either have synaesthesia or you do not. Similar states have been reported from users of hallucinogenic drugs such as LSD. But this is widely believed to have a different basis, as the apparent activation between senses changes from time to time across different uses of the drug. While different synaesthetes have different pairings from each other, one of the defining characteristics of the condition is that each synaesthete's own pairings remain the same over time.

What is the relationship between synaesthesia and creativity? It seems that synaesthesia is experienced disproportionately by artists, writers and musicians. The composer Olivier Messiaen (1908–1992), for example, described his experiences in detail: "Colours are very important to me because I have a gift — it is not my fault, it's just how I am - whenever I hear music or even if I read music, I see colours". The persistent connection with creativity is now being re-examined. Individuals identified as having synaesthesia are being compared to individuals without the condition on recognised psychological tests of creativity and initial results do indeed suggest that synaesthetes may have a greater aptitude for creative/abstract thinking. As a synaesthete might say, for further developments, "watch this space"

Where can I learn more?

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