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Synesthetes show normal sound-induced flash fission and fusion illusions

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ABSTRACT

Idiopathic synesthesia, a neurological condition in which a stimulus in one sense generates a concurrent experience in a different sense, is often considered an example of multisensory integration. Consequently it has been suggested that synesthetes should experience multisensory illusions more consistently and compellingly than typical participants. To test this we measured the sound induced flash fission and fusion illusions in 22 coloured hearing synesthetes and 31 control participants. Analysis of the data using signal detection analysis, however, indicated no difference between the groups, either in perception or response bias, but a secondary analysis of the data did show evidence of a decline in the illusions for synesthetes with increasing age.

1. Introduction

Idiopathic synesthesia, a neurological condition in which a stimulus in one sensory modality generates a concurrent experience in a different sensory modality, is often considered an example of enhanced multisensory integration (Goller, Otten, & Ward, 2009; Maurer & Mondloch, 2006; McCormick & Mamassian, 2008; Spector & Maurer, 2009).

In this paper we test the hypothesis that idiopathic synesthetes are more susceptible to multisensory illusions by testing coloured hearing synesthetes and controls using the sound induced flash illusion (SIFFI) (Shams, Kamitani, & Shimojo, 2000). Several researchers have linked synesthesia to the SIFFI implying that the illusion may detect differences between adult synesthetes and controls in cross-sensory processing (Goller, Otten, & Ward, 2009; Hubbard, 2008; McCormick & Mamassian, 2008; Spector & Maurer, 2009). The "Failed Differentiation" model of synesthesia Maurer and Mondloch (2005) for example argues that adult synesthesia may be a remnant of the undifferentiated cortex of infants, possibly due to a failure of neural pruning or inhibition in development. This lack of differentiation consequently makes it difficult for young children to disambiguate a multimodal event into its separate modalities (Spector & Maurer, 2009). The argument posits that failed differentiation results in direct multisensory pathways. Similarly, Hubbard and Ramachandran (2005) and Hubbard et al. (2005) argue on the basis of both psychophysical and fMRI studies, that synesthesia is the result of cross-activation between different cortical areas. Hubbard et al. (2005) attribute this to "a failure of pruning of peri-natal connections". There is also some support from ERP studies for the hypothesis that there are differences in early stage processes of sensory integration between synesthetes and controls. Beeli, Esslen, and Jancke (2008), for example, show differences in the ERP waveforms of synesthetes and controls to words, pseudo words and letters as early as 122 ms after stimulus onset in both auditory and colour areas. Barnett et al. (2008) have also shown that there are early ERP waveform differences in linguistic colour synesthetes at 65–85 ms after the onset of non-inducing stimuli. The pattern of data is particularly compelling because it suggests that there are differences in the visual processing of synesthetes in areas such as V1 and V2. Finally, Goller, Otten, and Ward (2009) presented brief tones to auditory-visual synesthetes (those who experience synesthesia for non-linguistic auditory stimuli) and controls and found that differences in auditory evoked potentials between the groups emerged as early as 100 ms after the onset of the tone. Taken together these results suggest that synesthesia can be the result of early processing differences related to multimodal integration. If synesthesia then is

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the result of failed differentiation for example, then synesthetes, like children, would be more susceptible to the SIFFI than controls.

However, there is contradictory evidence which supports the theoretical position that synesthesia requires later stage sensory integration. A number of studies have shown that synesthesia requires attention to the synesthetically inducing stimuli or is influenced by attending to the synesthetic inducer (Dixon et al., 2006; Rich & Karstoft, 2013; Sagiv, Heer, & Robertson, 2006; Smilek et al., 2002). In one of the first multisensory integration studies of synesthetes, Bargary et al. (2009) used the McGurk effect in linguistic synesthetes to investigate the multisensory nature of synesthesia. In the McGurk effect, visual cues (lip movements) affect the perception of words or phonemes when spoken. Using this phenomenon, Bargary and colleagues demonstrated that the colours elicited by the heard words were determined by the perceived words, not spoken words. They concluded that synesthesia is elicited by late perceptual processing and that coloured speech synesthesia occurs only after "a significant amount of information processing has occurred". This finding supports the earlier work of Dixon et al. (2006) who showed that the meaning (not the physical form) of a graphemic stimulus is pivotal in determining its colour. Synesthetes themselves report that attention often influences their experience. For example, a synesthete may report a certain colour for a piece of music when played by another (passive listening), but may report a different colour if they are playing that piece of music themselves. Further, a piece of music, may be one colour when heard, but when identified as being played in a particular key (such as the key of C) moves to the colour usually belonging to the letter of that key when listening (e.g. C). This suggest that higher level multisensory integration may be required to elicit synaesthesia, or at the very least that synesthesia as experienced, can be attenuated by late stage attentional processes.

Multisensory illusions such as the SIFFI, which occur early in perception, provide a unique opportunity to further interrogate the debate surrounding the locus of synesthesia. The sound induced flash illusion is a simple cross sensory illusion. It is produced by presenting tones and flashes simultaneously. In contrast to the McGurk effect, audition biases vision. One flash accompanied by two tones but perceived as two flashes is termed a fission illusion – in essence, one flash splits into the perception that there are two flashes. Conversely, two flashes accompanied by one beep but perceived as one flash is termed a fusion illusion – the 2 flashes fuse into the perception of one flash (Andersen, Tiippana, & Sams, 2004, 2005; Mishra, Martinez, & Hillyard, 2008; Shams, Ma, & Beierholm, 2005; Watkins et al., 2006). These illusions can be tested together in the same experiment by manipulating the number of flashes and beeps presented on each trial within a block. In this paper, the illusions are jointly referred to as the sound induced fission and fusion illusions (SIFFI).

Two studies have used the SIFFI to examine differences between synesthetes and controls. Brang, Williams, and Ramachandran (2012) found that synesthetes report the presence of the SIFFI more often than controls. With a sample of 7 grapheme colour synesthetes, using a variation of the traditional SIFFI experiment in which a temporally different control condition is used to measure differences in response accuracy and a reduced set of stimuli than that reported in this paper, the authors found that synesthetes had reduced accuracy in only the fission illusion condition of their experiment. Contrary to this, Neufeld et al. (2012) examined a larger number of synesthetes ($n = 18$) and age matched controls and found the reverse situation in the fission illusion condition. Synesthetes perceived fewer fission illusions compared to controls. Neufeld et al. (2012) found that both groups experienced the fusion illusion equally. A set of explanations for the conflicting results across both studies were offered by Neufeld et al. (2012). These included different synesthesia subtypes being tested between the studies, different types of synesthetes (associators vs. projectors), differences in study design and instructions and age differences between the samples in the respective studies. Each is worth considering. It is well known that group effects in synesthesia research are subject to confounds introduced because of heterogeneity across synesthetes – even within the same type of synesthesia (Hubbard et al., 2005). This is difficult to control for between studies. Moreover many synesthetes have more than one form (Day, 2005) making exclusion of one type or selection for only one type difficult in a larger sample. There are likely to be differences across these studies, attributable to participant level variations, (including our own) that limit the generalizability of results or the comparability between them.

The possibility of differences in study design and instructions is also a viable explanation, however the SIFFI has been shown to be reliable across many different methods and many different types of instructions for example: (Andersen, Tiippana, & Sams, 2005; Apthorp, Alais, & Boenke, 2013; Shams, Ma, & Beierholm, 2005; Zhang & Chen, 2006). It is difficult to conceive of a situation where minor variations in instructions would give completely opposing results.

A compelling explanation offered by Neufeld et al. (2012) is that the age of participants is driving the differences between results – specifically that reporting of the illusion decreases with age in synesthetes. The Neufeld et al. (2012) sample shows a mean age of 34.8 years whereas the Brang, Williams, and Ramachandran (2012) sample shows a mean age of 20.1 years which is a considerable difference. In general, increased multisensory integration is seen in older people over younger ones (Laurienti et al., 2006), such that we could expect a decline in sensitivity to the illusion with age, and one in which idiopathic synesthetes, who are likely to be more sensitive to the illusion, would show a marked decline compared to controls. Idiopathic synesthesia is considered to be a developmental condition and if age is a factor, plasticity would be the likely underlying explanation. There are no studies specifically examining age effects on the fission and fusion illusion conditions in either control or synesthete samples. It is therefore of interest as a secondary analysis in our study.

Finally, it is also possible that different types of analysis could account for differences between studies. Concerns that the illusions are the result of criterion shift (response bias) rather than any actual effect of the illusion have been expressed by researchers previously (McCormick & Mamassian, 2005). Brang, Williams, and Ramachandran (2012) argue that their use of the double flash control condition (two beeps followed by a flash after 300 ms) controls for response bias. Neufeld et al. (2012) argue similarly that since there were no group differences in their 1 flash 0 beep condition that there was no response bias. Signal detection theory (SDT) offers us an alternative approach to resolving this criticism; it measures the responses of participants in both baseline and illusion conditions. Measures of subjective signal strength and any response bias which may be present are inferred. We utilise both the traditional SIFFI method and SDT in our methodology to be certain that any effect we see in response accuracy is not a result of response bias. SDT analysis of the SIFFI in normal populations has been previously conducted by Andersen, Tiippana, and Sams (2004) and our study makes use of the same criterion for analysis while providing a useful replication and comparison.

Our hypotheses therefore are: that synesthetes will be more susceptible to the SIFFI than controls as measured by subjective signal strength (d') rather than average response accuracy and that our secondary analysis investigates whether the number of reported illusions decreases with age, particularly for the synesthete group – in line with the suggestion of Neufeld et al. (2012), and by inference as expected from the arguments espoused by Spector and Maurer (2009).