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Mental imagery and synaesthesia: Is synaesthesia from internally-generated stimuli possible?

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ABSTRACT

Previous studies provide empirical support for the reported colour experience in grapheme-colour synaesthesia by measuring the synaesthetic experience from an externally presented grapheme. The current study explored the synaesthetic experience resulting from a visual mental image of a grapheme. Grapheme-colour synaesthetes ($N = 6$) and matched controls ($N = 10$ per synaesthete) completed a visual mental imagery task that involved visualising a letter and making a size-based decision about it. The background colour that the grapheme was visualised against was manipulated so that it was congruent or incongruent with the synaesthetic colour for the grapheme being visualised. Compared to matched controls, an effect of colour condition was found for four of the six synaesthetes, although importantly the direction of the effect varied between synaesthetes. In addition, a significant effect of group was found, as the synaesthetes were all faster than the matched controls at the imagery task, regardless of background colour. We conclude that there is some support for subjective reports of imagery-induced synaesthesia, but there are important individual differences. These findings are discussed in relation to both the visual imagery and synaesthesia literature.

1. Introduction

A growing number of studies have provided empirical support for grapheme-colour synaesthetes' claim that they experience colours when they see or hear a letter, digit or word. These colours are highly consistent over time, difficult to suppress, and share many qualities with 'real'/perceived colours (Ward & Mattingley, 2006). Neuroimaging studies have shown activation of colour processing regions of the visual cortex upon hearing words or viewing achromatic graphemes (Hubbard, Arman, Ramachandran, & Boynton, 2005; Nunn et al., 2002). In neuropsychological models of this phenomenon, the stimulus ("the inducer") for the process is typically an externally-presented visual or auditory grapheme (Grossenbacher & Lovelace, 2001; Rich & Mattingley, 2002). However, whether a synaesthetic experience can arise from an internally-generated visual mental image has yet to receive much attention.

There are several reasons for hypothesising that a mental image of an inducer could elicit a synaesthetic experience. First, synaesthetes often subjectively report that this is the case (Grossenbacher & Lovelace, 2001; Ramachandran & Hubbard, 2001). Second, researchers working on mental imagery have proposed that veridical visual perception and visual mental imagery share many neural substrates. Several neuroimaging studies support this premise, suggesting that regions of the extrastriate cortex activated during mental imagery are content-dependent (Ishai, Ungerleider, & Haxby, 2000), and that the content-dependent areas activated during imagery of an object (such as a house, face or place) match those activated during perception of that same object (O'Craven and Kanwisher, 2000). Further support comes from studies reporting activation of the early visual cortex during generation and inspection of a visual mental image (Kosslyn, Ganis, & Thompson, 2001). An fMRI study (Klein et al., 2004) found support for

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the retinotopic organisation of visual mental images in the early visual cortex, suggesting that visual mental imagery shares functional processes as well as anatomical substrates with visual perception. Therefore, activating the same early areas of the visual pathway with a mental image will allow a similar progression through the visual areas as would visually perceiving that image. Klein and colleagues speculated that one of the many functions of the primary visual cortex may be to link together the fine spatial features of a 'mental object' (what they refer to as 'spatial binding'), allowing aspects of the mental image to be kept as a whole, and for this object to then be processed as a unit by cortical regions further along the pathway. It could therefore be argued that the activation of the early visual cortex by a mental image would make it highly likely that for a synaesthete forming and inspecting a mental image of an inducer would elicit a synaesthetic experience, due to elicitation of the *percept* of the grapheme. Indeed, in their description of inducers, Grossenbacher and Lovelace (2001) suggested that synaesthetic experiences could arise from 'voluntary imagery of an inducer' (p. 37) as imagery is known to involve areas of the brain involved in perception: "synaesthesia can occur with incomplete activation of the entire cascade of sensory signalling normally propagated during perception" (p. 38).

The third reason for hypothesising that a mental image could elicit a synaesthetic experience is that recent studies using a modified Stroop task have shown that eliciting a number *concept* (without an externally presented inducer) is associated with a synaesthetic experience (Elias, Saucier, Hardie, & Sarty, 2003; Jansari, Spiller, & Redfern, 2006; Smilek, Dixon, Cudahy, & Merikle, 2002). In these studies, participants were given a simple arithmetical sum (such as 4 + 5) but before stating the answer were asked to name the colour of a patch presented on a computer screen. Whether or not the colour of the patch matched the 'synaesthetic' colour for the answer digit (9, in this example) had a significant effect on colour-naming time for the synaesthetes but not the non-synaesthete controls. If the colour patch was incongruent with the colour for the answer digit, synaesthetes' response latencies were significantly longer than when the colour was congruent. Therefore, in the same way as naming the ink colour of a visually presented digit is slowed if that colour is incongruent with their synaesthetic colour for that digit, the *concept* of a digit without an external presentation can also affect colour naming speed.

Given the above, the current study was an attempt to measure a synaesthetic experience from a visual mental image. Although previous studies show it is possible to measure a synaesthetic experience from an external visual percept of an inducer, and from the concept of an inducer, further objective evidence is needed on whether a visual mental image can elicit a synaesthetic experience. Combining methods from the imagery literature and the synaesthesia literature, we hope to fill this gap, by addressing the effects of an internally-generated mental image, which is neither a concept nor a percept. The data might have important implications, for both our understanding of synaesthesia, and for elucidating the relationship between visual perception and visual mental imagery.

Many studies exploring synaesthesia have used the 'congruency effect' to measure the experience of synaesthesia. A single-case study, using a modified visual search paradigm, found that manipulating the background colour of the search area, so it was either congruent or incongruent with the synaesthetic colour of the target digit, had an effect on search efficiency (Smilek, Dixon, Cudahy, & Merikle, 2001). When the background was congruent (with the synaesthetic colour of the target digit) it was more difficult for the synaesthete to locate and identify the target, than when the background was incongruent. No such difference was found for non-synaesthete controls. Based on these findings the authors concluded that synaesthetic colours can influence visual perception of black digits. The current study has also made use of this background colour manipulation, but to see whether changing the background colour would influence perception of visual mental images of graphemes.

To be confident that participants were forming mental images of the letters whilst looking at the different coloured backgrounds, a behavioural task was chosen that required participants to form a mental image of an upper case letter and to then make a size based decision about the letter (see Section 2.3). A similar paradigm has been used within the mental imagery literature, and it is argued that successful task performance necessitates the internal generation and inspection of a visual mental image (Ganis, Thompson, & Kosslyn, 2005; Kosslyn et al., 2004; Mast, Ganis, Christie, & Kosslyn, 2003; Mast & Kosslyn, 2002). Furthermore, there are a number of studies that provide strong support for the idea that visual mental images share very similar depictive representations as a perceptual representation (Thompson, Kosslyn, Hoffman, & van der Kooli, 2008). In the current study, the background colour for the visualisation was either congruent or incongruent with the synaesthetic colour for that letter, or it was white (for a 'no colour' comparison baseline condition). The occurrence of a synaesthetic experience was measured by comparing performance (response time for accurate responses) on this task under the different colour conditions. For synaesthetes the background colour was predicted to result in a significant difference in performance between the two colour conditions. Based on the findings of Smilek et al. (2001) it was hypothesised that synaesthetes would take longer to make an accurate decision when the background colour was congruent with the grapheme being visualised. However, for non-synaesthete controls no such difference across conditions was predicted.

2. Method

2.1. Participants

Six grapheme-colour synaesthetes (four female) participated in this study. The internal reliability of their synaesthetic colour responses to each letter of the alphabet and digits 0–9 was tested using a modified version of the Test of Genuineness (ToG) (Baron-Cohen, Wyke, & Binnie, 1987). This compares the similarity of each synaesthete's colour responses to given stimuli over two points in time. For this study the test and re-test stages were between 6–