COGNITION

THE ROLE OF MEANING IN GRAPHEME-COLOUR SYNAESTHESIA

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Abstract

When the synaesthete, J, is shown black graphemes, in addition to perceiving the black digits or letters she also experiences highly specific colours that overlay the graphemes (e.g., 5 is pink, S is green). We used ambiguous graphemes in a Stroop-type task to show that the exact same forms (e.g., 5) can elicit different synaesthetic colours depending on whether they are interpreted as digits or letters. J was shown strings of black digits (e.g., 3 4 5 6 7) or words (e.g., M U S I C) for 1 sec. All but one of the graphemes then disappeared and the remaining grapheme changed to a colour that J had to name as quickly as possible. The key trials involved coloured graphemes that were ambiguous (e.g., the 5 in the strings above could be interpreted either as a digit or as a letter). On congruent trials, the colour of the ambiguous target grapheme was the same as J's photism for the digit or letter interpretations of the grapheme. On incongruent trials, the colours of the ambiguous target graphemes were different than the colours of J's photisms for the digit or letter interpretations of the graphemes. On digit-context incongruent trials, the ambiguous graphemes were presented in J's colour for the letter-interpretations of the graphemes, whereas on letter-context incongruent trials, the ambiguous graphemes were presented in J's colours for the digit-interpretations of the graphemes. Thus the same ambiguous grapheme (e.g., a pink 5) served as a congruent stimulus in one context and an incongruent stimulus in another context. J's response times showed that ambiguous graphemes elicited different photisms depending on whether they were interpreted as digits or letters. This finding suggests that it is not the form but the meaning of graphemes (whether they are interpreted as digits or letters) that determines the colours of synaesthetic photisms.

Key words: grapheme-colour, synaesthesia, digits, letters, meaning

Introduction

For people with grapheme-colour synaesthesia, viewing digits or reading text can be a colourful experience. When J is shown a string of black digits (e.g., 2, 3, 4, 5, 7) each grapheme consistently induces a conscious experience of a highly specific colour. For J, a 4 is a "semi-dark, sky blue" colour, and a 5 is "medium-dark pink". Letters too, induce highly specific colour experiences for this 22-year old female synaesthete. H is a "slightly dark, melon brown" colour, and S is "medium-dark green". The specific synaesthetic colour experience associated with each grapheme does not change over time (Baron-Cohen et al., 1993; Svartdal and Iversen, 1989), and numerous studies have found that when synaesthetes view graphemes, their photisms are elicited independent of their intentions, or in other words, "automatically" (Dixon et al., 2000, 2004a, 2004b; Mattingley et al., 2001; Mills et al., 1999; Odgaard et al., 1999; Wollen and Ruggiero, 1983). For some synaesthetes, whom we refer to as *associators*, the synaesthetic colour is experienced in their "mind's eye" and for other synaesthetes, whom we call *projectors*, the synaesthetic colour is experienced as a colour overlay that sits atop the visually presented grapheme (Dixon et al., 2004a, 2004b).

In the present experiment, we explored the nature of projected synaesthetic colours by evaluating whether such synaesthetic colour experiences depend primarily on the *meaning* of graphemes or whether they depend primarily on the *visual form* of the graphemes. On the one hand, certain lines of evidence suggest that projected synaesthetic colour experiences may depend primarily on the visual form of graphemes. For instance, projector synaesthetes can perceptually group stimuli together using photisms (Ramachandran and Hubbard, 2001a) and photisms can aid in the identification of graphemes when there is perceptual crowding (Ramachandran and Hubbard, 2001b). Also, projected photisms can improve the efficiency of visual search (Smilek et al., 2001, 2003; Palmeri et al., 2002). Such findings suggest that synaesthetic colours might arise relatively early in perception. Because the form of a grapheme is processed earlier in the perceptual system than is the meaning of a grapheme, one can argue, as did Ramachandran and Hubbard (2001b, 2003), that synaesthetic colours are determined primarily by the visual form of a grapheme and that the identity of a grapheme (i.e., the meaning) is not essential for activating its synaesthetic colour.

On the other hand, several aspects of the subjective reports of synaesthetes are consistent with the idea that the meaning of a grapheme plays a critical role in determining the colour of the synaesthetic experience. First, synaesthetes who we have interviewed typically report that for any given letter, their synaesthetic colours are unaffected by variations in either the size or the font of the graphemes. The fact that a myriad of graphemic forms can elicit identical colours is consistent with the idea that it is the identity or, in other words, the meaning of a grapheme that activates the colour, rather than the specific form of a grapheme. Second, synaesthetes report that ambiguous graphemes (e.g., a 5 that can be interpreted as either the digit 5 or the letter S) induce different synaesthetic colours depending on whether they are interpreted as digits or letters (Smilek et al., 2001). For example, we recently asked a mother to show her five-year old synaesthetic son two separate displays: a string of digits (e.g., 37564) and a string of letters (HPSOA). She asked him to name the colours that he experienced for the graphemes in each display. Even though the middle grapheme in each display was exactly the same, he reported experiencing different colours for this grapheme in the digit and letter context. Importantly, he did not report any oscillations between colours; rather he consistently reported one colour in the digit context and a different colour in the letter context. Likewise, when the synaesthete C (c.f., Dixon et al., 2000) was asked to describe her colours for ambiguous graphemes embedded in different contexts, she said "If I definitely know it's the number 5, then it's immediately green, and if I definitely know it's the letter S, then it's immediately fuchsia". Similar anecdotal reports of top-down colouring of ambiguous graphemes have also been reported by Ramachandran and Hubbard (2001b). Anecdotes such as these suggest that the meaning of the graphemes might play a primary role in determining the colours of photisms.

Whether synaesthetic colours are primarily determined by the form of a grapheme or by the meaning of a grapheme has important implications for the types of neural architectures that can be proposed to explain how synaesthetic colours arise in synaesthesia. If synaesthetic colours depend primarily on form, then it would be reasonable to surmise that synaesthetic colours result primarily from cross activation between the areas of the brain that process form and the areas of the brain that process colour, with minimal or no influence from areas of the brain that process the meaning. Such a cross-talk model has been proposed by Ramachandran and Hubbard (2001a, 2001b, 2003). In contrast, if synaesthetic colours depend primarily on the meaning of graphemes, then feedback from areas of the brain that process meaning to areas of the brain that process colour would be essential to any model of grapheme-colour synaesthesia. Such feedback or reentrant models have been proposed by Grossenbacher and Lovelace (2001), as well by our research group (Smilek et al., 2001; Smilek and Dixon, 2002; Dixon et al., 2004a, 2004b).

Even though a number of researchers have discussed the possible roles of form and meaning in the generation of synaesthetic colours (Ramachandran and Hubbard, 2001b; Smilek and Dixon, 2001), to date, there has been only one study in which this issue was investigated directly. Myles et al. (2003) used Stroop methods to test PD, a projector synaesthete, who experiences photisms for both digits and letters (for PD, a 2 is green and a Z is brown). PD was asked to name the colours of ambiguous graphemes (e.g., a green 2) embedded in lists of sequentially presented digits or letters. When the green 2 appeared within a list of digits, PD was faster to name its colour (green) than when the same stimulus appeared in a list of letters. Myles et al., attributed this Stroop-like interference to PD's photisms. When she was biased to interpret this stimulus as a digit, the green 2 induced a green photism that speeded colour naming, but when she interpreted it as a letter, the green 2 induced a brown photism that interfered with colour naming. It should be noted that only three ambiguous graphemes were tested, and only two of these graphemes elicited these context-dependent Stroop effects.

Although the study reported by Myles et al. (2003) constitutes a first step towards demonstrating that meaning plays a critical role in determining the colour of synaesthetic experiences, there are two limitations to the study that need to be addressed before strong conclusions are made. First, the study reported by Myles et al. (2003) involved only a single synaesthete and therefore, it remains unclear to what extent these findings generalize to other synaesthetes. Second, the study used only three ambiguous graphemes and failed to find evidence for conceptual influences for all of the graphemes that were used. That only two of the three graphemes showed the predicted context dependent Stroop effects indicates either that the conceptual influences were not particularly strong or that the manipulation of meaning by context used in this study was not maximally effective.

In the present experiment, we extended the findings reported by Myles et al. (2003) by addressing the limitations described above. First, to establish the generality of context-dependent Stroop effects, we replicated the findings with a different projector synaesthete. Second, to establish the robustness of the findings, we used a larger set of five ambiguous graphemes (see Table I). Third, to establish the reliability of these context-dependent Stroop effects we attempted to elicit these effects in two different conditions (one in which digit and letter context trials were presented in blocks and another in which they were intermixed). Finally, we used a more salient manipulation of context than used by Myles et al. (2003). Specifically, rather than using sequences of unambiguous digits or letters to bias interpretation of the ambiguous graphemes we increased the salience of the context by directly embedding the ambiguous graphemes either within strings of digits or within strings of letters forming words. J was shown strings of black digits (e.g., 3 4 5 6 7)