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Psychophysiological evidence for the genuineness of swimming-style colour synaesthesia

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ABSTRACT

Recently, swimming-style colour synaesthesia was introduced as a new form of synaesthesia. A synaesthetic Stroop test was used to establish its genuineness. Since Stroop interference can occur for any type of overlearned association, in the present study we used a modified Stroop test and psychophysiological synaesthetic conditioning to further establish the genuineness of this form of synaesthesia. We compared the performance of a swimming-style colour synaesthete and a control who was trained on swimming-style colour associations. Our results showed that behavioural aspects of swimming-style colour synaesthesia can be mimicked in a trained control. Importantly, however, our results showed a psychophysiological conditioning effect for the synaesthete only. We discuss the theoretical relevance of swimming-style colour synaesthesia according to different models of synaesthesia. We conclude that swimming-style colour synaesthesia is a genuine form of synaesthesia, can be mimicked behaviourally in non-synaesthetes, and is best explained by a re-entrant feedback model.

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1. Introduction

Synaesthesia is characterized by extraordinary experiences in response to ordinary stimuli. Several forms of this condition have been documented, such as 'colours' to graphemes (Grossenbacher & Lovelace, 2001; Simner et al., 2006), 'tastes' to words (Ward & Simner, 2003; Ward, Simner, & Auyeung, 2005), and 'shapes' to tastes (Cytowic, 1993). Many other forms exist and recently, we have provided evidence for a new form of synaesthesia, swimming-style colour synaesthesia, in which the conceptual representation of swimming in a particular style (i.e., breast, backstroke, crawl, butterfly) triggered highly specific colour photisms (Nikolić, Jürgens, Rothen, Meier, & Mroczko, 2011). Given the limitations of this previous study and the far-reaching theoretical implications for the nature of synaesthesia in general, the main goal of the present study was to seek further and stronger evidence for the genuineness of this new form of synaesthesia.

Over the last 15 years, evidence for a strong conceptual component to synaesthesia has accumulated. For instance, synaesthetes were faster at naming a colour patch when a preceding arithmetic problem (i.e., 5 + 2) lead to a solution for which synaesthetic colour was congruent rather than incongruent (Dixon, Smilek, Cudahy, & Merikle, 2000). Context dependent

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interpretation of ambiguous stimuli was also shown to play an important role in the specific synaesthetic experience (Dixon, Smilek, Duffy, Zanna, & Merikle, 2006; Ramachandran & Hubbard, 2001). Moreover, synaesthetic experiences can occur for imagined synaesthetic inducers (Frith & Paulesu, 1997; Grossenbacher, 1997; Ramachandran & Hubbard, 2001; Rich, Bradshaw, & Mattingley, 2005). Importantly, for all these experiences the format of the synaesthetic inducer (e.g., 5 + 2) was present at the same level (i.e., in the same task set) as the synaesthetic inducer is present typically (e.g., as numbers). Thus, a conceptual representation of a *grapheme* was activated by presenting, thinking about, or imagining *graphemes*, thereby probably still activating a perceptual representation of the inducer (e.g., Grossenbacher & Lovelace, 2001; cf. also, D'Esposito et al., 1997; Kosslyn, Thompson, Kim, & Alpert, 1995). In contrast, in a study by Nikolić et al. (2011), synaesthetic colour experiences for swimming-styles were elicited by a photograph of the inducer and thus presented in a completely different task set than that in which the inducer typically occurs (i.e., as proprioceptive input of swimming). Hence, perceptual representations were even less likely to be activated, suggesting that the constitutional property of an inducer is its semantics and not its sensory input (cf. also, Mroczko-Wąsowicz & Werning, 2012).

Specifically, in the study of Nikolić et al. (2011), during a test of consistency and a synaesthetic Stroop task, the synaesthetes and non-synaesthetic controls were presented with different photographs of a person swimming in one of the four main swimming-styles. The synaesthetes were more consistent than the controls in choosing a colour associated with the different swimming-styles in a test and retest several weeks later. In the Stroop task, the synaesthetes showed significantly shorter reaction times for photographs presented in the colours congruent with the depicted swimming-style in comparison to photographs in colours incongruent with the depicted swimming-style. Such interference effects were not present in the controls.

However, the test of consistency and the Stroop effect are not entirely conclusive regarding the genuine nature of swimming-style colour synaesthesia. Tests of consistency rely on synaesthetic colour matching. Crucially, there is evidence that the precision of synaesthetic colour matching resembles that of recollected colours rather than physical colours (Arnold, Wegener, Brown, & Mattingley, 2012). Hence, overlearned and recollected colour associations are sufficient to pass a test of consistency. This is not problematic for most forms of synaesthesia where the sets of inducer-concurrent associations are large enough to prevent pure recollection of these associations. Even so, since only four different swimming-styles exist, high consistency does not provide conclusive evidence for the genuine nature swimming-style colour synaesthesia. Similarly, Stroop effects can be detected for any type of overlearned associations (Nikolić, Lichti, & Singer, 2007) and hence, can never provide sufficient evidence that an association is synaesthetic. Notably, studies with sample sizes as large as 20 and 40 participants, respectively, provided evidence that even synaesthetic Stroop effects and inverse Stroop-like priming effects can be mimicked in non-synaesthetes after several days of training grapheme–colour associations (Meier & Rothen, 2009; Rothen, Wantz, & Meier, 2011). However, trained participants did not report colour *experiences* in response to associated graphemes in follow-up questioning (for similar findings cf. also, Elias, Saucier, Hardie, & Sarty, 2003; Hancock, 2006). Critically for the purpose of the present study, Meier and Rothen (2009) also demonstrated that grapheme–colour pairings, simply associated through training, are not sufficient for a synaesthetic conditioning effect, as is the case for genuine synaesthetes (Meier & Rothen, 2007; Rothen, Nyffeler, von Wartburg, Müri, & Meier, 2010). That is, a startle reaction to a loud sound repeatedly coupled with a colour does not generalize to the associated grapheme in the case of trained non-synaesthetes, where the grapheme does not elicit a synaesthetic colour *experience*. Hence, in contrast to synaesthetic inducers, synaesthetic concurrents seem to be more than a mere semantic representation of colour information in real synaesthetes.

The present study was conducted with several aims. The first was to demonstrate strong evidence for the genuine nature of swimming-style colour synaesthesia. The second was to provide further evidence that Stroop-like synaesthetic priming effects can occur simply due to trained synaesthetic associations and without genuine synaesthetic *experiences*, even for swimming-style colour synaesthesia Therefore, we presented a swimming-style colour synaesthete and a non-synaesthete who was trained on swimming-style colour associations, with the synaesthetic conditioning paradigm (Meier & Rothen, 2007, 2009) and a synaesthetic priming paradigm (Gebuis, Nijboer, & van der Smagt, 2009; Rothen et al., 2011). In both tasks, we used pictograms of swimming-styles to trigger synaesthetic colour experiences. Note, pictograms are likely to act at a higher level of abstract conceptual representation than photographs as used in the previous study (Nikolić et al., 2011) and thus, they are even less likely to trigger brain activation representing perceptual aspects of swimming (i.e., proprioceptive input). We hypothesized that the swimming-style colour synaesthete and the trained control would both show a synaesthetic priming effect, but that only the swimming-style colour synaesthete would show a synaesthetic conditioning effect. The third aim was to elaborate on the theoretical relevance of swimming-style colour synaesthesia with respect to three basic models of the genesis of synaesthetic experiences (i.e., cross-activation model, disinhibited feedback model, re-entrant feedback model).

2. Methods

2.1. Participants

H.T. (25 years, right-handed, male) already participated in our previous study (Nikolić et al., 2011). He has colour experiences for digits, but not for letters. More interestingly, H.T. involuntarily experiences vivid and highly specific colours for swimming-styles (i.e., butterfly, breaststroke, backstroke, and crawl). He started swimming early in childhood and began

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