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Synesthetic grapheme-color percepts exist for newly encountered Hebrew, Devanagari, Armenian and Cyrillic graphemes

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ABSTRACT

Grapheme-color synesthetes experience color, not physically present, when viewing symbols. Synesthetes cannot remember learning these associations. Must synesthetic percepts be formed during a sensitive period? Can they form later and be consistent? What determines their nature? We tested grapheme-color synesthete, MC2, before, during and after she studied Hindi abroad. We investigated whether novel graphemes elicited synesthetic percepts, changed with familiarity, and/or benefited from phonemic information. MC2 reported color percepts to novel Devanagari and Hebrew graphemes. MC2 monitored these percepts over 6 months in a Hindi-speaking environment. MC2 and synesthete DN, reported synesthetic percepts for Armenian graphemes, or Cyrillic graphemes + phonemes over time. Synesthetes, not controls, reported color percepts for novel graphemes that gained consistency over time. Phonemic information did not enhance consistency. Thus, synesthetes can form and consolidate percepts to novel graphemes as adults. These percepts may depend on pre-existing grapheme-color relationships but they can flexibly shift with familiarity.

1. Introduction

For most of us, the letter 'T' is not blue and happy, nor the number '7' shiny, yellow and good. Yet those with synesthesia reliably experience perceptual phenomenon absent in the stimulus. Although it sounds like a holdover from the psychedelic era, reports of synesthesia date back 200 years (reviewed in Jewanski, Simner, Day, & Ward, 2011). The most commonly studied form of synesthesia is grapheme-color synesthesia (Simner et al., 2006), in which a grapheme reliably elicits a color percept (reviewed in Hochel & Milan, 2008; Hubbard, 2007; Hubbard & Ramachandran, 2005; Mattingley, 2009; Rich, Bradshaw, & Mattingley, 2005; Sagiv, Heer, & Robertson, 2006; Ward, 2013; Ward & Mattingley, 2006). Synesthetes do not remember forming grapheme-color associations. Indeed, anecdotal reports describe synesthetes feeling frustration when encountering 'wrongly' colored alphabets in preschool (e.g. our participant MC2). Others discover their unique percepts later in life when they find that such percepts are not universal (e.g. our participant DN; see also Mills, Metzger, Foster, Valentine-Gresko, & Ricketts, 2009; Mills et al., 2002). Because synesthesia emerges early in childhood, it is difficult to definitively answer questions related to the development of synesthetic experiences. There are few papers describing the acquisition and stability of grapheme-color synesthesia. Simner et al. demonstrated that grapheme color synesthesia may be identified in children as young as 6 years of age (2009). Furthermore, testing children at the beginning and end of a year revealed significant improvements in the consistency of their synesthetic percepts (Simner, Harrold, Creed, Monro, & Foulkes, 2009). Spector

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and Maurer have worked with pre-literate and literate children to clarify effects of literacy on the development of synesthesia (2009, 2011). They demonstrated that toddlers made predictable color matches to letters and shapes ("O" and ameboids are white; "Z" and jagged shapes are black), but these were based on letter shape and not letter sounds; whereas they failed to make other associations commonly observed in literate children and adults ("B" is blue, "A" is red, etc.) (Spector & Maurer, 2009, 2011). Other findings show that grapheme-color synesthesia can exact a cost in task performance. Green and Goswami showed that children aged 7–15 years with grapheme-color synesthesia experience interference during numerical tasks if the digits were printed in color incongruent with their synesthetic percepts (2008).

One possibility is that an early sensitive period during development is essential for the formation of grapheme-color percepts. If true, novel graphemes encountered in adulthood might *not* produce synesthetic percepts. Alternatively, synesthetes may continually and automatically develop new grapheme-color percepts, especially for symbols similar to familiar graphemes. Another possibility is that there is an early sensitive period in which color associations are made, and that these associations may then map onto newly encountered graphemes later in life based on similarities in shape, name, meaning, use, etc. Indeed, support for the latter view comes from a recent finding demonstrating that some synesthetes can directly transfer one pre-existing synesthetic color percept onto a novel symbol. These authors presented words written in English but replacing the Latin letter 'A' with a novel Glagolitic grapheme and found that the new grapheme produced the same synesthetic color percept associated with the familiar letter 'A' (Mroczko, Metzinger, Singer, & Nikolic, 2009). This finding shows that an explicit transfer of synesthetic color to a novel grapheme serving as a placeholder can occur in as little as 10 min. Yet it remains unclear if or how quickly grapheme-color percepts arise for novel graphemes presented without a pre-existing context. Even if novel graphemes elicit a synesthetic percept, the *quality* of these adult-acquired synesthetic percepts may be different. Case studies of synesthetes describing their experiences with multiple learned alphabets (Mills et al., 2002, 2009; Rich et al., 2005; Witthoft & Winawer, 2006) show that adult synesthetes may overlay pre-existing percepts onto novel graphemes based on similarities between letter shape (Mills et al., 2002; Witthoft & Winawer, 2006) or phoneme (Mills et al., 2009; Witthoft & Winawer, 2006). In the other direction, Mills and colleagues reported that synesthete MLS associated new synesthetic colors with known graphemes, but these associations were temporary and qualitatively different from the synesthetic experiences associated with her native language (Mills et al., 2002). These findings point towards a flexible relationship between grapheme and synesthetic experience, but they do not clarify whether novel graphemes can produce synesthetic percepts independent of specific training or implied association or whether these percepts remain stable and consistent. Furthermore, these studies examined the color associations and consistency of grapheme sets that have already been learned at some earlier point, and thus cannot characterize the acquisition process of grapheme and color associations.

Here, we investigated the existence and consistency of grapheme-color associations for newly encountered novel grapheme sets in two grapheme-color synesthetes. In one unique case, we tested a synesthete before, during, and after she studied Hindi while abroad in India. Upon her return she and a second synesthete were trained in two new novel alphabets in a training study. In contrast to previous association forming studies (Mroczko et al., 2009) all graphemes were presented without any additional context, with the exception of Cyrillic characters, which were presented with an audio recording of their name. The present findings take advantage of two complementary approaches: one ecological and one laboratory based, to provide converging evidence regarding the consistency and quality of synesthetic percepts for novel graphemes as they become more familiar.

2. Experiment 1: Synesthetic color percepts to novel graphemes

Can novel graphemes elicit a synesthetic color percept? If acquiring color percepts for graphemes without additional context requires that they be encountered during a sensitive period over which grapheme-color links form in early childhood, there should be no synesthetic color percept to entirely novel graphemes. Alternatively, it may be the case that synesthetic percepts are automatically elicited for novel graphemes throughout the lifetime, or that previous color associations may map onto new graphemes. If true, novel graphemes should elicit a synesthetic color percept.

2.1. Method

2.1.1. Participant

MC2 (female, 26 years old) a psychology undergraduate at the University of Nevada, Reno participated. The University's Institutional Review Board approved this and all protocols. MC2 and all participants (participating in Experiment 3) signed informed consent documents. MC2's first language is English. MC2 reports taking four semesters of college Spanish, but does not claim fluency in any language other than English.

2.1.2. Synesthesia assessment

MC2 describes her synesthetic experience of graphemes not only in terms of color, but also in texture, personality, and emotional terms; we tested grapheme-color percepts. MC2 further reports that she has experienced these percepts for as long as she can remember, and does not recall a time before she had color associations. She reports that she first recognized that her experiences were not typical for everyone when she encountered an "inappropriately colored alphabet" in