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Enhanced semantic priming in synesthetes independent of sensory binding

Stephanie C. Goodhew *, Melissa R. Freire, Mark Edwards

Research School of Psychology, The Australian National University, Australia

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ABSTRACT

Synesthesia is the phenomenon in which individuals experience unusual involuntary cross-modal pairings. The evidence to date suggests that synesthetes have access to advantageous item-specific memory cues linked to their synesthetic experience, but whether this emphasis on item-specific memory cues comes at the expense of semantic-level processing has not been unambiguously demonstrated. Here we found that synesthetes produce substantially greater semantic priming magnitudes, unrelated to their specific synesthetic experience. This effect, however, was moderated by whether the synesthetes were projectors (their synesthetic experience occurs in their representation of external space), or associators (their synesthetic experience occurs in their 'mind's eye'). That is, the greater a synesthetes's tendency to project their experience, the weaker their semantic priming when the task did not require them to semantically categorize the stimuli, whereas this trade-off was absent when the task did have that requirement.

1. Introduction

There is a subset of the population, called synesthetes, who appear to have a qualitatively richer experience of the world around them. Synesthesia is defined as the involuntary experience of largely idiosyncratic cross-modal bindings, where a particular stimulus ('inducer') evokes a given sensory experience ('concurrent') for that individual. For example, an individual with grapheme-color synesthesia can experience the color forest-green as a consequence of reading the letter 'A', an individual with music-color synesthesia may experience a distinct shade of purple in response to the note F#, and an individual with sound-taste synesthesia can experience a salty taste in response to the sound of a friend's voice (e.g., Galton, 1880; Mattingley, Rich, Yelland, & Bradshaw, 2001; Ramachandran & Hubbard, 2001; Simner, 2007; Watson, Akins, Spiker, Crawford, & Enns, 2014). The purpose of this study is to elucidate the nature of the semantic processing of individuals with synesthesia.

A substantial body of evidence demonstrates that synesthetic sensations are genuine experiences that are involuntary consequences of perceiving the inducing stimulus. A given individual's synesthetic associations tend to be highly reliable over time (Edquist, Rich, Brinkman, & Mattingley, 2006). Moreover, adaptations of classic cognitive interference tests, such as the Stroop test (Stroop, 1935), demonstrates the involuntary nature of these bindings. For example, if a given synesthete associates the word 'May' with the color blue, then this synesthete will be faster to identify the physical color in which the word is presented when it matches their synesthetic experience (e.g., May in blue) compared with when it appears in a

* Corresponding author at: Research School of Psychology (Building 39), The Australian National University, Canberra 0200, Australia.
E-mail address: stephanie.goodhew@anu.edu.au (S.C. Goodhew).

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conflicting color (e.g., May in red). Such response-time congruity effects demonstrate that the synesthetic association is involuntary, in that it is elicited even when it is unhelpful to task at hand (Dixon, Smilek, Cudahy, & Merikle, 2000; Mattingley et al., 2001; Smilek, Dixon, Cudahy, & Merikle, 2001). Moreover, there is activation in areas of the brain that process color during synesthetic experience of color (Sperling, Prvulovic, Linden, Singer, & Stirn, 2006), and finally, the underlying brain anatomy of synesthetes differs from that of non-synesthetes, such that it is characterized by stronger and more diffuse connectivity (Bargary & Mitchell, 2008). Altogether, these imply that synesthetic experiences are genuine, involuntary experiences.

The most common forms of synesthesia reported are grapheme-color and lexical-color synesthesia, in which a particular grapheme (letter or digit) or words reliably elicits the experience of a particular color (Simner et al., 2006). But many other different forms of synesthesia have also been identified, such as music-shape synesthesia in which different musical instruments elicit the experience of particular shapes (Mills, Boteler, & Larcombe, 2003), and lexical-gustatory synesthesia in which reading or hearing words evokes the sensations of particular flavors (Jones et al., 2011), and person-color synesthesia in which a halo of color surrounds given individuals (Ramachandran, Miller, Livingstone, & Brang, 2012). In addition to the existence of many different forms of synesthesia, a core distinction among synesthetes is whether their synesthetic experience occurs in their external representation of space (*projectors*) or whether it occurs internally, in the individual's "mind's eye" (*associators*) (Dixon, Smilek, & Merikle, 2004). This categorization is not just one of conventional nomenclature. Instead, the evidence suggests that the functional consequences of synesthesia can be qualitatively different for these different forms of synesthetic experience. Dixon et al. (2004) investigated the synesthetic Stroop procedure described above in synesthetes identified as projectors versus associators, with one modification: in one condition participants' task was to identify the synesthetic color induced by the word presented, and in the other, their task was to identify the physical color in which the word was presented. Projectors were quicker to name the synesthetic color, and produced the greatest congruency effect when they were naming the physical color (interference therefore created by synesthetic experience of color), whereas associators were faster to name the physical color, and obtained the strongest congruency effect when they were naming the synesthetic color (interference therefore created by the physical color) (Dixon et al., 2004).

Further evidence that there are distinct perceptual consequences for projector versus associator synesthetes is that whether the synesthetic experience of color produces pop-out in visual search in the way of normal color (e.g., Treisman & Gelade, 1980) depends on whether the synesthete is a projector or an associator. That is, the concurrent experience of color appears to influence attention and speed visual search for a projector synesthete (Smilek, Dixon, & Merikle, 2003), but not in samples where the associator/projector distinction was not analyzed (Edquist et al., 2006). Moreover, in samples where the projector/associator distinction was not drawn, awareness of the inducing stimulus appears necessary for the synesthetic experience to be elicited, such that the concurrent experience does not survive masking of the inducer (Bacon, Bridgeman, & Ramachandran, 2013; Mattingley et al., 2001). In contrast, it has been reported that for one projector synesthete, their synesthetic experience of color protected against object-substitution masking (Wagar, Dixon, Smilek, & Cudahy, 2002), a form of visual masking in which target awareness is impaired due to object-updating processes (for a review see Goodhew, Pratt, Dux, & Ferber, 2013). This suggests that projector versus associator synesthesia has different perceptual consequences and that the associator/projector distinction is an important one for making sense of different patterns of results with synesthetes.

More recently, the research focus in the field has shifted from the perceptual consequences of synesthesia, to the condition's cognitive consequences, including the implications for language processing and memory. The evidence is accumulating to indicate that, consistent with their subjective reports of superior memory, synesthetes can strategically use their experience to facilitate objective performance on memory tasks (Gross, Neargarder, Caldwell-Harris, & Cronin-Golomb, 2011; Pritchard, Rothen, Coolbear, & Ward, 2013; Rothen & Meier, 2010; Rothen, Meier, & Ward, 2012; Watson, Blair, Kozik, Akins, & Enns, 2012; Yaro & Ward, 2007). For example, Radvansky, Gibson, and McNerney (2011) compared 10 grapheme-color synesthetes against controls on a series of memory tasks that indirectly measure semantic processing. The first of these tested the von Restorff effect, in which memory is enhanced for an item in a list when that item is presented in a distinctive way. For example, a word presented in red is likely to enjoy superior memory recall when it is embedded in a list of items presented in black, because the red item is uniquely defined along the given (color) dimension (Hunt, 1995). Radvansky et al. (2011) found that when the distinctiveness of the critical item was defined in terms of color in a word list, synesthetes showed a reduced von Restorff effect (i.e., reduced memory advantage for the critical item) compared to controls. As the authors pointed out, this is likely due to the fact that the synesthetes experienced color for some or all of the words in the list as colored, thus diluting the distinctiveness of the physically-colored item. However, a reduced von Restorff effect was also observed in these same synesthetes when the item's distinctiveness was manipulated by virtue of semantics. That is, the critical word belonged to a distinct semantic category compared with the other items on the list (Radvansky et al., 2011). This result could be interpreted as indicating a general reduced semantic processing capacity in synesthetes. Another possibility, however, is that the synesthetic surface features induced an item-specific mode of processing, that attenuated the depth of semantic processing for the synesthetes in this context. This would suggest a trade-off between item-specific and relational processing in synesthetes.

The second major test was the Deese–Roediger–McDermott (DRM) false memory paradigm. That is, non-synesthetes typically show a strong and reliable false memory effect, whereby after exposure to a list of semantically-related words, a critical lure that is semantically related to the presented words but was not actually shown, tends to be incorrectly identified as having been presented (Deese, 1959; Roediger & McDermott, 1995). This is a judgment that participants endorse with a high