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Brief article

Synesthesia and number cognition in children

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Abstract

Grapheme-color synesthesia, when achromatic digits evoke an experience of a specific color (photisms), has been shown to be consistent, involuntary, and linked with number concept in adults, yet there have been no comparable investigations with children. We present a systematic study of grapheme-color synesthesia in children aged between 7 and 15 years. Here we show that such children (but not children with phoneme-color synesthesia) experience involuntary difficulties in numerical tasks when digits are presented in colors incongruent with their photisms. Synesthesia in children may thus have important consequences for certain aspects of numerical cognition.

Keywords: Synesthesia; Grapheme-colour; Number processing

1. Introduction

Synesthesia, the involuntary multi-modal perception of objects or events that are usually perceived unimodally, has greatly interested neuroscientists. For example, seeing a digit like 5 may automatically elicit a simultaneous color percept or "photism" (grapheme-color synesthesia), whereas a taste may evoke a tactile sensation. Current prevalence estimates suggest that around 4% of the population have some

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form of synaesthesia and that between 1% and 2% of the population experience the grapheme-colour form (Simner et al., 2006). Scientific investigation of synesthesia is expected to yield important clues to the neural mechanisms that underlie the integration of sensory information (Rich & Mattingley, 2002). However the study of synesthesia has so far focused exclusively on adults. This research strategy can only throw light on the end state of sensory integration. It cannot show whether synesthesia affects the development of sensory systems in ways that perturb the end state, or whether synesthesia has effects on cognitive developments that depend on sensory integration.

Although widely assumed to be present from early childhood (Rich & Mattingley, 2002), studies examining synesthesia in children are limited to case studies from the late nineteenth and early twentieth centuries (Riggs & Karwoski, 1934). It has been suggested that synesthetes are simply reporting idiosyncratic childhood associations between colors and numbers (Calkins, 1895). If it can be established that children experience grapheme-color synesthesia consistently (Baron-Cohen, Harrison, Goldstein, & Wyke, 1993; Baron-Cohen, Wyke, & Binnie, 1987) and automatically (Mattingley, Rich, Yelland, & Bradshaw, 2001; Mills, Boteler, & Oliver, 1999; Odgaard, Flowers, & Bradman, 1999) as adults do, one obvious developmental question concerns potential effects on the acquisition of culturally-acquired cognitive skills such as numeracy and literacy. If grapheme-color photisms for numbers are involuntary, this could affect the development of certain aspects of number cognition. For example, if a young child automatically experiences the digit 1 as having the color green, will this affect her ability to learn that 9 is a larger count number if 9 is printed in green in her maths book? In other words, will color interfere with conceptual understanding of magnitude relations? Somewhat analogous confusions have been noted in the domain of literacy. One adult reported 'I may call someone ''Debbie'' when she is really ''Paula'', because D and P are more or less the same color green' (Rich & Mattingley, 2002).

Grapheme-color synesthesia has been associated anecdotally with deficient mathematical ability (Cytowic, 2003). In a recent large-scale survey, reports of weakness in the area of mathematics were significantly greater among synesthetes compared to a control group (Rich, Bradshaw, & Mattingley, 2005). Interestingly, however, the percentage of synesthetes who reported mathematics as an area of *strength* was also significantly greater than that of controls, although the number of synesthetes reporting an advantage for mathematics was much smaller. It is not clear whether and how the mathematical difficulties or advantages experienced by grapheme-color synesthetes might be impacted by the experience of color itself. While it is accepted that photsims are triggered automatically, it is not yet known how synesthetic color might affect the way numerical information is processed in the brain. However research with adult synesthetes suggests that the concept of a number alone can elicit photisms (Dixon, Smilek, Cudahy, & Merikle, 2000; Jansari, Spiller, & Redfern, 2006). Subjects presented with single digit sums (e.g. $5 + 2$) followed by color patches were slower to name the color of the patch when it was incongruent to the photism elicited by the solution (Dixon et al., 2000). Additionally, while synesthesia was at first thought to occur in only one direction (e.g. numbers evoke colors, but colors