Colours and Category learning

Implications for Grapheme-Colour Synaesthesia

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Published in:
Sálubót: Afmælisrit til heiðurs Jörgen L. Pind

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

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ÚTDRÁTTUR

Í nýlegri grein lýsa Pinna og Deiana (2018) hvernig litur getur hjálpað lesblindum börnum og fullorðnum við að greina í sundur orð. Hér fjöllum við um hvernig þessar niðurstöður kunna að styðja við hugmyndir um að samskynjun, þar sem grafem leiða til ósjálfráðrar skynjunar á lit, geti þróast sem svar við þeim áskorunum sem fylgja lestrarnámi barna. Að auki fjöllum við um hvaða ljósi þetta varpar á þau ferli sem liggja að baki samskynjun.

Efniorð: samskynjun, flokkanám, læsi

ABSTRACT

In their recent publication, Pinna & Deiana (2018) describe the significant benefits of colour as a word segmentation tool for both adults and children with dyslexia. Here we describe how these findings may support work claiming that synaesthesia, a neurological phenomenon where graphemes elicit an automatic, involuntary experience of colour, may develop in response to the cognitive demands of gaining literacy in childhood (Watson, Akins, Spiker, Crawford & Enns, 2014; Watson, Chromý, Crawford, Eagleman, Enns & Atkins, 2017). We further describe how this may reflect on the underlying mechanisms of synaesthesia.

Key words: synaesthesia, category learning, literacy

Synaesthesia is a neurological phenomenon that occurs in a small percentage of otherwise neurotypical observers (2–4%; Simner, Mulvenna, Sagiv, Tsakanikos, Witherby, Fraser, Scott, & Ward, 2006, however, see also Baron-Cohen, Johnson, Asher, Wheelwright, Fisher, Gregersen, & Allison, 2013). Synaesthetic individuals exhibit atypical perceptual associations, where experience of one sense automatically and involuntarily triggers experience of a secondary, unrelated sense (Grossenbacher & Lovelace, 2001). Synaesthesia is a diverse phenomenon, and various types have been reported from more exotic associations between taste and geometric shapes (Cytowic, 1995), to more common associations between graphemes and colours (e.g. Ásgeirsson, Nordfang, & Sørensen, 2015). In grapheme-colour synaesthesia, an experience of a grapheme automatically and involuntarily elicits an experience of colour, and these associations seem surprisingly robust over time (Witthoft & Winawer, 2006). Some grapheme-colour synaesthetes may report colour associations for all, or only specific letters or numbers, others may only report associations for other categorical concepts that have graphic representation. These may include months, days of the week, seasons or time, with many synaesthetes reporting an unpredictable combination (however see also Witthoft, Winawer, & Eagleman, 2015). Despite this diversity, grapheme-colour synaesthesia has a common thread in that it almost invariably occurs within categories that are complex and meaningfully organised, and consequently require significant cognitive effort to master. This has become an increasingly important consideration for those looking to answer why some individuals develop synaesthetic associations.

Although many assume that perception is similar between individuals, synaesthesia hints to the degree of variation that exist. There are a range of phenomena that reveal large differences in perceptual processing. A common example of this would be colour blindness, where individuals are unable to distinguish between specific colours when they are presented in close proximity. Other less common examples include phonagnosia, where people are unable to identify familiar individuals from the sound of their voice (Shilowich & Biederman, 2016), or developmental prosopagnosia, a condition where an individual is unable to recognise faces (McConachie, 1976).

These perceptual differences may be reflective of differences in perceptual strategies that are developed in our interaction with the environment. Such differences are often seen in the processing of other objects that require complex categorisation, such as in face processing, where some have less developed strategies for processing facial feature cues than others (Sørensen & Overgaard, 2018). Alternative strategies for face recognition become apparent in many instances following a change of environmental circumstance that causes them to be limited or eliminated entirely, for example the case of patient AB (McConachie, 1976), who only experienced problems when she changed to a school that used uniforms, presumably because she had developed a preference in perceptual features of clothing over facial features. Similarly, several studies demonstrate that synaesthetic associations are influenced by the environment, apparent in the famous example where coloured refrigerator magnets were shown to influence some colour associations (Witthoft & Winawer, 2006; Witthoft, et al., 2015).

Support for a theory of learning as a potential cause for synaesthesia has seen a recent revival, with many researchers now conceding that even if it is the case that an individual is biologically predisposed to the condition, learning is at the very least in an ongoing reciprocal relationship with synaesthetic experiences (Blazej & Cohen-Goldberg, 2016; Mroczko-Wasowicz & Nikolic, 2014; Simner & Bain, 2013; Sørensen, Nordfang, & Ásgeirsson, 2016). The very fact that synaesthesia is invariably connected to some form of complex category, where objects and their associated concepts share a high degree of similarity and require a high degree of expertise to discern, would imply that synaesthetes are able to understand and discriminate within that category. Efforts are now being made to examine the extent to which learning is a part of synaesthesia. Recent work by Watson and colleagues (2017) reported that incidents of synaesthesia were positively correlated with higher degrees of difficulty in childhood language learning. Results of their investigation demonstrated greater instances of synaesthesia in cases where individuals typically learn non-native second languages, while in countries with an opaque native language the number cases of synaesthesia were doubled in comparison to those with a transparent native language. In an opaque language, a grapheme can potentially correspond to multiple phonemes, such as in English where 'ough' can make different sounds depending on the word context, as in "cough" or "through". Conversely, in a transparent language the grapheme consistently corresponds to a phoneme and is consequently written as it is read. This makes opaque languages significantly more cognitively taxing to learn in written form. Watson and colleagues (2017) conclude that the more cognitively taxing learning is, the more likely synaesthesia is to develop, thus supporting the claim that synaesthesia is intrinsically linked to learning.

Like graphemes, colours are in and of themselves a complex category, albeit lacking the abstract nature inherent to graphemes as arbitrary symbols. We begin learning to distinguish colours from an early developmental stage, typically at around 18 months (Luinge, Post, Wit, & Goorhuis-Brouwer, 2006). They are discerned not only via obvious differences in their visual attributes, but are frequently taught alongside commonly associated objects (e.g. a red apple, a yellow sun, etc.). Colours develop to become an overt attribute of many objects we encounter in day to day life and can often be utilised to provide information about a specific object – for example, to judge the temperature of an object, or the ripeness of a fruit. The importance of colour in identifying and categorising objects is reflected in synaesthesia, where Japanese synaesthetes using Kanji, a written language dictating whole words with single characters, often report the character to be the colour of the object (e.g. the symbol for bamboo is green, the symbol for blood is red, and so on) (see Yokosawa & Asano, 2011; Asano & Yokosawa, 2012). In the vast majority of circumstances, colours become a well-established and frequently used category long before an individual begins the arduous task of learning to read.

Recently Pinna and Deiana (2018) described the positive influence colour distributions can have on dyslexic individuals' ability to read – more specifically, the influence of the colours on word segmentation were shown to be highly beneficial to both reading speed and accuracy. This positive effect was found to be most prominent in conditions whereby an entire word was allocated a monochrome colour distribution that varied from its neighbour. The authors argue that benefits were mostly derived from this condition as individual word colour distributions assisted participants in word segmentation.

Thus in a reading task, the application of monochromatic colours to words enables the reader to exploit an already established mental category (colours) for the purposes of discriminating within new complex categories, meaning that they are no longer entirely reliant on the features of the new category (letters) to distinguish words from one another. Interestingly, previous work by Pinna & Deiana (2014) has demonstrated that the positive influence of colour on reading ability is significantly greater than other tools for segmentation in this context, including italicising, font variations and bold text. We would argue that this greater benefit is derived from the fact that colours provide pre-established categorical information, making their ability to define objects as different superior to other purely perceptual effects.

These results highlight the significant benefit of colour as a supplementary categorisation tool, and as such may lend support to the notion that grapheme colour synaesthetes establish colour associations in response to the cognitive challenge of literacy. This is not to imply that synaesthesia is comorbid with dyslexia or other literacy disabilities, but rather that dyslexia research has provided evidence for colour attribution as a successful tool in facilitating reading (Pinna & Denna, 2018). It may be the case that during critical learning periods, synaesthetic individuals naturally adopted this perceptual strategy in response to the difficulties of categorising and segmenting graphic items as has been previously suggested (Watson, Akins, Spiker, Crawford, & Enns, 2014).

Some of our previous studies investigating the relationship between expertise and cognitive components such as attention and short-term memory (e.g. Sørensen & Kyllingsbæk, 2012) may provide supporting evidence as to the mechanism behind this categorical encoding. Short-term memory has been described as limited to 3–4 objects at a time (Cowan, 2001), and is surprisingly robust across stimuli (Luck & Vogel, 1997). Nevertheless, it has previously been demonstrated that short-term memory capacity is influenced by the degree of expertise with a given stimulus category (Dall, Watanabe, & Sørensen, 2016; Sørensen & Kyllingsbæk, 2012). One theoretical interpretation of this expertise modulation is that representing an item in short-term memory is equivalent to making a categorisation between perceptual sensory evidence and a mental template (Bundesen, 1990), where the item is then retained in memory through reverberant feedback loops (Sørensen & Kyllingsbæk, 2012; Usher & Cohen, 1999). Presumably the total amount of available reverberant loops within the system remain constant over time, however, as perceptual categories are trained, they will become stronger and more specific, requiring fewer resources and effectively resulting in an increase in short-term memory capacity.

In essence, simpler featured categories can be combined in order to make new more complex category templates which retain their association to simple feature categories (e.g. colours). In line with this reasoning we suggest that simple feature categories like colours may be recruited initially when learning novel abstract categories such as graphemes, and as this new perceptual category builds, colour associations initially assist in grapheme segregation.

With time these either wither away as they lose their relevance as grapheme categories establish themselves through training or they may persist and become integrated perceptual aspects of the grapheme processing we recognise as synaesthesia. This would be in line with evidence that synaesthesia seems to develop during early school years (Simner & Bain, 2013), and suggestions that synaesthesia may be more prevalent in children (Simner et al., 2009).

The notion of recruiting established categories to build or help establish novel ones would also provide circumstantial intimations to some of synaesthesia's unusual characteristics. For example, it is reasonable to assume that the specification and degree of difficulty experienced by a person in learning graphic concepts would vary significantly between individuals, and we would suggest that this may go some way towards accounting for the heterogeneity observed in synaesthesia.

Where Watson and colleagues (2017) have demonstrated a positive influence of increased learning difficulty on the prevalence of synaesthesia, Pinna and Deiana (2018) provide compelling evidence of colour attribution as a positive influence on task efficiency in literacy. Combined, these works show reciprocal support for recruitment of colours in cases of novel graphic categorisation, implicating a potential reason for why some individuals develop grapheme colour associations.[1]

1 The authors would like to thank the Independent Research Fund Denmark for funding the project "Synaesthesia – the Roles of Association Learning and of Differential Brain Development".

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