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Synaesthesia in Chinese characters: The role of radical function and position

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ABSTRACT

Grapheme-colour synaesthetes experience unusual colour percepts when they encounter letters and/or digits. Studies of English-speaking grapheme-colour synaesthetes have shown that synaesthetic colours are sometimes triggered by rule-based linguistic mechanisms (e.g., B might be blue). In contrast, little is known about synaesthesia in logographic languages such as Chinese. The current study shows the mechanisms by which synaesthetic speakers of Chinese colour their language. One hypothesis is that Chinese characters might be coloured by their constituent morphological units, known as radicals, and we tested this by eliciting synaesthetic colours for characters while manipulating features of the radicals within them. We found that both the function (semantic vs. phonetic) and position (left vs. right) of radicals influence the nature of the synaesthetic colour generated. Our data show that in Chinese, as in English, synaesthetic colours are influenced by systematic rules, rather than by random associations, and that these rules are based on existing psycholinguistic mechanisms of language processing.

1. Introduction

Synaesthesia is an inherited condition, in which stimuli are experienced with unusual secondary sensations. For example, synaesthetes might experience colours in addition to sounds when listening to music (Ward, Huckstep, & Tsakanikos, 2006), or they might feel tactile sensations on the hand triggered by the flavours of food in the mouth (Cytowic & Eagleman, 2009). Around 80–90% of known synaesthesias involve colour triggered by language (Simner, Glover, & Mowat 2006a); for example, in *grapheme-colour* synaesthesia, sensations of colour are triggered by letters or digits. During the last decade, the neural basis of synaesthesia has been examined in both functional imaging studies (e.g., Aleman, Rutten, Sitskoorn, Dautzenberg, & Ramsey, 2001; Hubbard, Arman, Ramachandran, & Boynton, 2005; Hubbard & Ramachandran, 2005; Nunn et al., 2002; Sperling, Prvulovic, Linden, Singer, & Stirn, 2006; Tomson, Narayan, Allen, & Eagleman, 2013) and in structural imaging studies (e.g., Hanggi, Beeli, Clechslin, & Jande, 2008; Hupé, Bordier, & Dojat, 2012; Rouw & Scholte, 2007; Weiss & Fink, 2009). Together these show that synaesthetic experiences are characterised by atypical patterns of brain activity when compared with non-synaesthetes, and differences in white matter and grey matter structure.

In behavioural terms, some researchers have hypothesized that synaesthetic experiences are not the idiosyncratic, random associations they were once believed to be. Instead, the particular nature of the synaesthetic experience often appears

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influenced by 'rules' which govern how particular triggers (known as *inducers*; Grossenbacher, 1997) come to be paired with particular synaesthetic sensations (known as *concurrents*; for review, see Simner, 2013). For example, people with *grapheme-colour* synaesthesia tend to share preferences for the colours of letters (e.g., *A* is often red from synaesthete to synaesthete) and that these preferences may have a structure behind them. For example, across large groups of synaesthetes, the linguistic frequency of letters correlates with the linguistic frequency of the concurrent's colour term (e.g., high frequency *A* often pairs with high frequency 'red'; Simner & Ward, 2008; Simner et al., 2005). The linguistic frequency of the letter inducer also tends to correlate with the concurrent's luminance and saturation (Beeli, Esslen, & Jaencke, 2007; Smilek, Carriere, Dixon, & Merikle, 2007). In the current study we look at synaesthesia in non-alphabetic languages, asking whether rule-driven influences can also be detected in the colouring of Mandarin Chinese.

Our study is one of the first to examine the colouring of words in Chinese, and for this reason we briefly review what is known about synaesthetic word-colouring in other languages, looking first at English (the most studied language in synaesthesia research) and then at other languages – both European and non-European. English-speaking synaesthetes who experience coloured words are often grapheme-colour synaesthetes whose words come to be coloured by their constituent letters. This letter-to-word colouring tends to happen in systematic ways. For example, it is often the case that one particular letter within the word will dominate the colour of the word overall, and this tends to be the word's initial letter (e.g., *cat* is the colour of the letter *c*) or its initial vowel (e.g., *cat* is the colour of the letter *a*; Barnett, Feeney, Gormley, & Newell, 2009; Baron-Cohen, Harrison, Goldstein, & Wyke, 1993; Mills et al., 2002; Simner et al., 2006a,b; Ward, Simner, & Auyeung, 2005). It has been suggested that this special status for word-initial letters/vowels could stem from the fact that initial letters/vowels have a special status in psycholinguistic processing more generally: they are visually less crowded, and they are usually processed first in lexical access for reading (Simner et al., 2006a,b; Ward et al., 2005).

Word-colouring might also be influenced by certain phonetic (prosodic) qualities and, again, this may reflect more general psycholinguistic principles of language processing. Simner et al. (2006a,b) found that for some grapheme-colour synaesthetes, words tend to be coloured by their stressed vowels (e.g., *'con-vict* would be the colour of the letter *o* while *con-'vict* would be the colour of *i*). Stressed vowels have a special status in spoken word recognition because they are used by listeners of English to parse the speech stream into words (Colombo, 1991). Other influences on synaesthetic word-colouring come from morphological considerations. In studies with German-speaking synaesthetes, for example, compound words tended to trigger more than one dominant colour, directly reflecting their lexical/morphological makeup. Interestingly, this was more likely for low-frequency compounds (*Fährmann* = *ferry* + *man*) than for high-frequency compounds (e.g., *Bahnhof* = *station*; Kubitza, unpublished, in Simner, 2007) and this suggests that high-frequency compounds are lexicalised as single units in German.

The studies above suggest that the synaesthetic colouring of English and other European languages is not random, but instead is influenced by psycholinguistic processes used elsewhere in normal language comprehension. Recent studies in non-European languages have drawn similar conclusions. For example, Simner, Hung, and Shillcock (2011) found a small influence of alphabetic/phonological features in the synaesthetic colouring of Chinese characters – the basic linguistic constituents of Chinese. Although characters are logographic (i.e., not composed of alphabetic units) they can be transcribed using alphabetic/phonetic spelling systems (e.g., Pinyin or Bopomo) which are taught alongside characters in literacy development. Simner et al. (2011) showed that the synaesthetic colouring of characters is influenced by these phonetic spellings, as some Chinese-speaking synaesthetes coloured their characters according to the initial Pinyin letter. For example, the character 湯 is transcribed segmentally in Pinyin as [tang], and this character's synaesthetic colour tended to be the same as other characters also transcribed with an initial [t]. Asano and Yokosawa (2012) showed that synaesthetic colouring for Japanese Kanji characters also arises to some extent from their corresponding phonetic spellings. For example, for their Japanese synaesthete SA, homophonic Kanji characters such as 甲, 肯 and 講 (all spelled as 'こう' in Hiragana and pronounced /kou/) all shared a similar shade of yellow with the first letter of the Hiragana spelling (in this case, 'こ'; see also Asano & Yokosawa, 2011). However, for the study in Chinese at least, alphabetic influences were found only for non-native (i.e., second-language) speakers with alphabetic mother-tongues (e.g., English), or for Chinese speakers who had moved from China to a Western culture at a young age. Because we did not find the same effect for native Chinese speakers more generally, this leads us to question what other mechanisms might be in operation to govern synaesthetic colouring in Chinese. We tackle this question in the current paper, and preface our study with a very brief overview of Chinese orthography.

1.1. Overview of Chinese

As noted above, the basic writing unit in Chinese is the Chinese character. Characters have a non-alphabetic, square-like configuration composed of strokes (e.g., 家 'home') which never function as sound units. Instead, their configuration is thought to have evolved from ancient pictographs, whose iconicity has since been lost except in relatively rare cases (e.g., 木 'tree'). Characters are assigned one of four tones: 'high', 'rising', 'falling-then-rising', and 'falling' tone, and these tones are transcribed in phonetic spelling systems with the digits 1–4, respectively (e.g., 木 = [mu4] 'tree'; 湯 = [tang1] 'soup'). Simner et al. (2011) found no influence of tones in synaesthetic colouring, and so we consider here another feature of Chinese characters. The majority of Chinese characters are compounds composed of two sub-components known as radicals (Hsiao & Shillcock, 2006; Li & Kang, 1993). Typically, the *semantic radical* provides information about the meaning of the compound whilst the *phonetic radical* gives clues to its pronunciation. For example, in the character 櫻 ('cherry blossom', pronounced [ying1]), the semantic radical (木) means 'tree' and the phonetic radical 嬰 (pronounced [ying1]) indicates the pronunciation of the whole character. The semantic radical most commonly appears on the left, and the phonetic radical on the right (e.g.,