Consciousness and Cognition 20 (2011) 1816–1823

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Short Communication

Synesthetic colors are elicited by sound quality in Japanese synesthetes

Michiko Asano [a,b,*], Kazuhiko Yokosawa [a]

[a] Department of Psychology, Graduate School of Humanities and Sociology, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[b] Tamagawa University Brain Science Institute, 6-1-1, Tamagawa-gakuen, Machida-shi, Tokyo 194-8610, Japan

ARTICLE INFO

Article history:
Received 24 September 2010
Available online 11 June 2011

Keywords:
Indirect cross-activation models
Grapheme-color synesthesia
Japanese phonetic scripts
Phonology
Synesthesia

ABSTRACT

Determinants of synesthetic color choice for Japanese phonetic characters were studied in six Japanese synesthetes. The study used Hiragana and Katakana characters, which represent the same set of syllables although their visual forms are dissimilar. From a palette of 138 colors, synesthetes selected a color corresponding to each character. Results revealed that synesthetic color choices for Hiragana characters and those for their Katakana counterparts were remarkably consistent, indicating that color selection depended on character-related sounds and not visual form. This Hiragana–Katakana invariance cannot be regarded as the same phenomenon as letter case invariance, usually reported for English grapheme-color synesthesia, because Hiragana and Katakana characters have different identities whereas upper and lower case letters have the same identity. This involvement of phonology suggests that cross-activation between an inducer (i.e., letter/character) brain region and that of the concurrent (i.e., color) area in grapheme-color synesthesia is mediated by higher order cortical processing areas.

1. Introduction

Synesthesia refers to a condition in which certain stimuli ("inducers") trigger consistent, extraordinary experiences ("concurrents"). Grapheme-color synesthesia, in which a visual letter or character, i.e., a grapheme, induces a specific color sensation (e.g., red, yellow; Simner et al., 2006), is the most commonly described variant in literature on this phenomenon. This is characterized as idiosyncratic because graphemes do not elicit the same color across different individuals (Simner, 2007; Ward, Li, Salih, & Sagiv, 2007), Nevertheless, certain regularities appear in synesthetic perception (Beeli, Esslen, & Jäncke, 2007; Dixon, Smilek, Duffy, Zanna, & Merikle, 2006; Ramachandran & Hubbard, 2001; Rich, Bradshaw, & Mattingley, 2005; Simner, 2007; Simner et al., 2005; Ward, Simner, & Auyeung, 2005; Witthoft & Winawer, 2006). Most synesthetic experiences are triggered by a range of linguistic properties, such as visual form (graphemes), sound (phonemes), semantics (or concepts), and letter frequency (cf. Simner, 2007). Synesthetic colors for letters are usually determined by graphemes rather than phonemes (Simner, 2007; Ward et al., 2005). For example, the "c" in "cat" and in "cite" may both elicit the same color sensation, whereas the initial letters of "site" and "cite" appear to elicit different colors (Simner, 2007). Synesthetic colors are often font and case invariant (i.e., upper and lower case letter counterparts are similarly colored; Ramachandran & Hubbard, 2001). Phonological influences (i.e., of phonemes) appear weaker than graphemic ones in eliciting synesthetic colors. Witthoft and Winawer (2006) reported that colors induced by letters in a second language (Cyrillic letters) are determined by their visual or phonetic similarity to letters in a first language (English). However, phonemic effects were limited to instances in which no visually similar counterpart was found in English letters. Several semantic (or conceptual) factors also

* Corresponding author at: Department of Psychology, Graduate School of Humanities and Sociology, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan. Fax: +81 3 5841 8969.
E-mail address: asano@L.u-tokyo.ac.jp (M. Asano).

1053-8100/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.concog.2011.05.012

appear to affect synesthetic colors. For example, the use of an ambiguous figure which may be seen as conveying either a "5" or an "S" might elicit a different synesthetic color depending on its interpretation as a number (5) or a letter (S) (Dixon et al., 2006; Ramachandran & Hubbard, 2001). In addition, grapheme-color associations often reflect initial-letter priming; thus, "b" tends to be blue whereas "y" tends to elicit a yellow sensation (Rich et al., 2005; Simner et al., 2005). Previous studies also suggest a role for letter frequency. Beeli et al. (2007) reported that letter frequency correlates with the saturation of synesthetic colors. Simner et al. (2005) also showed that higher-frequency letters tend to pair with higher-frequency color terms. In sum, investigations of various factors associated with inducers of synesthetic color sensations are important because they inform us of the underlying mechanism of grapheme-color synesthesia, including the neural substrate (Cytowic & Eagleman, 2009).

Existing neural models of mechanisms underlying synesthesia fall into two groups (Bargary & Mitchell, 2008; Cytowic & Eagleman, 2009): direct models (Bargary & Mitchell, 2008; Ramachandran & Hubbard, 2001), and indirect models (Dixon, Smilek, & Merikle, 2004; Grossenbacher & Lovelace; 2001; Smilek, Dixon, Cudahy, & Merikle, 2001). Direct models assume that synesthetic experience is caused by direct cross-activation between an inducer brain area and a concurrent brain region. For instance, in the case of grapheme-color synesthesia, a letter processing area, such as the visual word-form area (VWFA) in the fusiform gyrus, serves as the inducer area which directly cross-talks to the color processing visual area, V4 (Ramachandran & Hubbard, 2001). Alternatively, indirect models also assume cross-activation between the inducer and concurrent areas, but this cross-talk is assumed to be mediated by a higher order cortical area(s). According to indirect models, the synesthetic color experiences which are associated with letters are elicited by cross-activation of V4 with a higher order processing area in a language processing circuit activated by visual letter input. Areas encoding conceptual representations of letters, words and numbers, such as the posterior inferior temporal (PIT) or the anterior inferior temporal (AIT), have been proposed as candidates for a higher order (mediating) area, largely because synesthetic colors are often modulated by meanings (Cytowic & Eagleman, 2009; Dixon et al., 2004; Smilek et al., 2001). Finally, it is possible that both direct and indirect models are valid. For instance, synesthetes have been distinguished as either projectors or associators. This distinction has led some to assume different types of neural processing underlie these categories (Cytowic & Eagleman, 2009; Dixon et al., 2004; van Leeuwen, Petersson, & Hagoort, 2010).

The key difference between direct and indirect models concerns whether or not a linguistic processing area(s) higher than the VWFA is involved. The influence of graphemes on synesthetic color experience can be explained by either kind of model (Ramachandran & Hubbard, 2001; Simner, 2007; Ward et al., 2005). This is because both kinds of models involve the VWFA and this area is a letter-form processing area that is neither font nor case sensitive (Cohen & Dehaene, 2004). Moreover, the VWFA is sensitive to linguistic frequency (Kronbichler et al., 2004), meaning that frequency effects that have been reported can be explained by both direct and indirect models (Beeli et al., 2007; Simner et al., 2005). Finally, the most important evidence favoring an indirect account comes from findings that semantics or concepts affect the synesthetic experience (Dixon et al., 2006; Ramachandran & Hubbard, 2001; Rich et al., 2005; Simner et al., 2005). This strongly implicates higher-order processing areas, as assumed by indirect models.

Others point to problems for indirect models, however. Ramachandran and Hubbard argue that the top-down effects on synesthetic experiences, which are associated with semantics or concepts, should not be interpreted as support for indirect models. They claim that semantic effects do not necessarily imply that grapheme–color synesthesia itself is a conceptual phenomenon because cognitive influences can affect early sensory processing (Ramachandran & Hubbard, 2001). Furthermore, skepticism regarding another form of semantic influence, namely initial-letter priming, is related to the fact that this priming cannot explain all of the observed grapheme-color associations (Rich et al., 2005; Simner et al., 2005). For instance, some letters are the initial letters of many different names of colors and objects with high color diagnosticity (e.g., "b" is for "blue", "brown", "black", "beige", "bear", and "bamboo").

In this discussion, one line of inquiry has not been fully explored. This involves the role of phonemes associated with graphemic stimuli in grapheme-color association. This is relevant because orthographic information (from graphemes) is converted into phonological information in the inferior frontal gyrus (IFG), which is a higher order area when compared to the VWFA (Burton, 2001; Fiebach, Friederici, Müller, & von Cramon, 2002). Therefore, if phonemic/phonological properties elicited by graphemes have a systematic influence on synesthesia, this would provide support for indirect models. But, thus far, phonology has not been demonstrated to have a strong influence on synesthetic color choices (Simner, 2007; Witthoft & Winawer, 2006). Its impact is evident only in special cases such as generalization from first language to second language (Witthoft & Winawer, 2006).

We suspect, however, that the weak effects of phonemes reported in previous research are due to certain characteristics of the English alphabet employed in these studies (e.g., in Simner, 2007; Witthoft & Winawer, 2006). The English alphabet is characterized by a one-to-many relationship between graphemes and phonemes (e.g., "c" is either /k/ or /s/). This complex grapheme-phoneme correspondence can reduce phonemic influences on grapheme-color associations. Consequently, it remains possible that phonemes do impact synesthetic color choices in those languages with a one-to-one relationship between graphemes and phonemes. Japanese is such a language. Two different Japanese phonetic scripts (Hiragana and Katakana) each retain a one-to-one relationship between graphemes and phonemes. The present study exploits this fact to investigate the role of phonology on synesthetic color choice for Japanese characters using Japanese synesthetes.

The Japanese language has three kinds of scripts: Hiragana, Katakana, and Kanji. Hiragana and Katakana both consist of phonetic characters, while the Kanji characters are logographic (i.e., each character has its own meaning) and are mainly