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Both "나" and "な" are yellow: Cross-linguistic investigation in search of the determinants of synesthetic color

Eun-hye Shin, Chai-Youn Kim*

Department of Psychology, Korea University, Seongbuk-Gu, Anam-ro 145, Seoul 136701, Republic of Korea

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ABSTRACT

Individuals with grapheme-color synesthesia experience "colors" when viewing achromatic letters and digits. Despite the large individual difference in synesthetic association between inducing graphemes and induced colors, the search for the determinants of synesthetic experience has begun. So far, however, research has drawn an inconsistent picture; some studies have shown that graphemes of similar visual shape tend to induce similar synesthetic colors, while others suggested sound as an important factor. Moreover, meaning seems to affect synesthetic color. In the present work, we sought to investigate the determinants of synesthetic color by testing four multilingual grapheme-color synesthetes who experience "colors" upon viewing Korean (hangul), Japanese (katakana and hiragana), and English (Latin alphabet) characters on a standardized color-matching procedure. Results showed that pairs of characters of matched sound tended to induce similar synesthetic colors. This was the case not only between two scripts within the same language (Japanese hiragana and katakana) but also between two different languages (Japanese and Korean). In addition, pairs of characters with similar initial phonemes tended to induce similar colors; this was general across multiple languages. Results also showed that pairs of sequential words in Korean, Japanese, English, and Chinese that have the same meaning tended to elicit similar synesthetic colors. When those pairs of words shared not only meaning but also sound, the similarity of the induced synesthetic colors was even greater. Our work is one of the few initial attempts to examine the influence of visual shape, sound, meaning, and their interaction on synesthetic color induced by characters across multiple languages.

1. Introduction

Synesthesia is a condition under which a stimulus in one sensory modality induces perceptual experience not only in the relevant modality but also in another, ordinarily irrelevant modality (Cytowic and Eagleman, 2009). For example, an individual with auditory–olfactory type synesthesia smells a specific scent when hearing a particular word, while another individual with gustatory–tactile type synesthesia feels a specific shape when having a taste sensation (Cytowic, 1993). Previous research on this beguiling condition has shown that synesthesia can take on various forms, and that the association between the inducing stimulus and induced sensation is idiosyncratic in nature (Jordan, 1917). Both of these make individual differences a key issue in the investigation of synesthesia.

Recent studies on synesthesia, however, have begun to focus on commonalities of associations between the inducing stimulus and induced sensation. Such approaches have been mainly based on grapheme-color synesthesia, one of the most prevalent (Rich et al., 2005; Simner et al., 2006), and most studied types of the condition. In this form of synesthesia, association is not between different modalities but within the same visual modality. People with grapheme-color synesthesia experience vivid and consistent colors when viewing achromatic letters and digits. Despite the wide variety of individual grapheme-color associations, early reports revealed some consistencies. For example, vowel characters tend to induce white or weaker synesthetic colors: "e" and "i" have been found to be associated with yellow or white (Marks, 1975) and "o" is often experienced as white or transparent (Baron-Cohen et al., 1993; Day, 2005; Lay, 1896; but also see Beeli et al., 2007; Smilek et al., 2007). Intrigued by these observations, researchers set out to explore the factors determining synesthetic color in grapheme-color synesthesia.

The search for the determinants of synesthetic color was first attempted by examining large-scale color-matching data sets. For example, Rich and colleagues examined 150 adult lexical-color synesthetes' color-matching results coded in 11 basic categories of color in combination with lightness.[1] They found that the first

* Corresponding author. Tel.: +82 2 3290 2866.
E-mail address: chaikim@korea.ac.kr (C.-Y. Kim).

[1] The eleven color terms include black, white, red, yellow, green, blue, brown, orange, purple, pink, and gray, based on Berlin and Kay (1969).

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letter of the color name tended to induce that color. For a large proportion of the synesthetes tested, "Y" was experienced as yellow and "B" was blue (Rich et al., 2005). Simner and colleagues also tested 70 grapheme-color synesthetes with a questionnaire including a color-matching task, and categorized the reported colors into 11 basic color categories. Their results showed that "A" tended to be experienced as red at a significantly higher level of probability than chance. Upon careful examination, Simner and colleagues found that the frequency of the inducing character seemed to be correlated with the frequency of the names of the induced colors (Simner et al., 2005).

Since the inducing stimuli in grapheme-color synesthesia are linguistic units, other basic linguistic features than frequency including shape (orthography), sound (phonology), and meaning (semantics) were also considered to influence synesthetic color (see Simner (2007) for a review). Results so far, however, do not provide a consistent picture. Some researchers found that graphemes of a similar shape tended to induce similar synesthetic colors (Brang et al., 2011; Rich et al., 2005; Watson et al., 2012). Other researchers emphasized the importance of meaning over shape by showing that a similarly shaped character could take on different synesthetic color based on the semantic context in which it appeared (Dixon et al., 2006; Ramachandran and Hubbard, 2001). For example, "ß" induced the color of the digit "13" when it appeared between "12" and "14," whereas the same character induced the color of the letter "B" when it appeared between "A" and "C" (Blake et al., 2005). Furthermore, it was also suggested that graphemes of a similar sound tended to induce similar synesthetic color (Asano and Yokosawa, 2011, 2012).

These seemingly inconsistent results might stem from differences in stimuli and synesthetes tested as well as differences in test procedures and data analysis. Among those various potential sources of inconsistency, we focused on the stimulus aspect here. Brang et al. (2011) suggested that the shape of inducing stimuli was an important factor influencing synesthetic color; they used Latin alphabet characters and single digits as inducing stimuli in the color-matching test. In the studies of Asano and Yokosawa (2011, 2012) where sound was suggested to be important, Japanese characters in three different scripts were used. The choice of Japanese scripts in the latter studies was, as the authors themselves emphasized, based on the shallow orthography (i.e., simple and consistent correspondence between character and sound) of the Japanese language, in contrast to the deep orthography (i.e., complex and inconsistent correspondence between character and sound) found in English. In a more recent work, they also suggested that a Latin alphabet grapheme is different from a Japanese character by having two kinds of phonological information – i.e., its name and its pronunciation, which might weaken the influence of sound on synesthetic colors induced by Latin alphabet grapheme (Asano and Yokosawa, 2013). Asano and Yokosawa suggested that those studies showing the important role of shape over sound in determining synesthetic color might be due to the choice of the particular stimuli (Latin alphabet) and its intrinsic characteristics.

In the current work, we went further from Asano and Yokosawa's suggestion, and explored whether the keen relationship between the sound of the inducing stimulus and the induced synesthetic color found within Japanese scripts can be extended and generalized. We were able to do this because we were fortunate to have access to four multilingual grapheme-color synesthetes who experience colors with Korean, English, Japanese, and some Chinese characters and words as well as digits. Our approach had the following advantages over previous ones. First, it enabled us to explain the factors driving particular grapheme-color pairings within a single individual, with more exemplars. Moreover, this approach enabled us to take into account the linguistic characteristics of multiple languages. The choice of Korean script hangul was critical in particular, since it shares features of Japanese scripts by having shallow orthography whereas it is similar to Latin alphabet in that a hangul grapheme is associated with two kinds of phonological information: the name of the character and how it sounds in a syllable. The latter feature of hangul is retained by hangul consonants. A consonant having its own name (e.g., 'ㄱ (/kiyeok/)' cannot stand alone without being accompanied by a vowel (c-v; e.g., '가(/ka/)') or a vowel plus another consonant (c-v-c; '강(/kang/)'). A syllabary comprising c-v or c-v-c in specific spatial arrangement is a unit character for reading in hangul (Taylor, 1980). Thus, a hangul consonant 'ㄱ' can be associated with different phonemes, though the initial phoneme remains the same. These two characteristics shared by hangul were suggested as what might be behind the discrepancy of previous studies on the determinants of synesthetic color using Latin alphabet and Japanese scripts (Asano and Yokosawa, 2013). Therefore, hangul was expected to provide a clue to estimate the importance of sound as a determinant of synesthetic color.

We are not the first to adapt the cross-linguistic strategy in search of the determinants of synesthetic color. Graphemes of similar shapes, then those of similar sounds were shown to induce similar synesthetic colors across English and modern Greek (Rich et al., 2005) or Cyrillic (Witthoft and Winawer, 2006), both of which suggested visual similarity as a stronger cue than sound similarity. Our study, however, differs from those previous attempts since we examined synesthetic colors associated with characters over four different languages, some of which share more linguistic features (e.g., Korean and Japanese) than others (e.g., Korean and English).

By exploiting the different characteristics of multiple languages, we hoped to elucidate whether any single linguistic feature (e.g., shape, sound, or meaning) outweighs the others or interacts with each other. Specifically, we tested the four multilingual synesthetes with color-matching procedures using (1) Japanese katakana and hiragana, the Korean hangul syllabaries sounds of which match Japanese syllabaries, (2) Korean hangul and English Latin alphabet graphemes, and (3) sequential words, including numbers and weekdays, in Korean, Japanese, English, and Chinese. By utilizing those three classes of stimuli, we predicted (1) that similar synesthetic colors associated with pairs of Japanese and sound-matched Korean syllabaries would extend previous findings from the two Japanese scripts and emphasize the importance of sound in determining synesthetic color. If this would be the case, we also predicted (2) that syllabaries and graphemes, with only initial phonemes shared, would induce similar synesthetic colors, but the degree of induced color similarity might follow the degree of sound similarity. We also predicted (3) that sequential words with the same meaning over multiple languages would induce similar synesthetic colors, and the impact of meaning and sound would be additive. Last but not least, we re-examined the three predictions above with a data-driven approach comparing the degrees of influence of shape, sound, and meaning on synesthetic color. Results from these tests and analyses are described below.

2. Methods

2.1. Participants

Four Korean grapheme-color synesthetes (3 females, 21–27 years of age) participated in the study. All four synesthetes reported "seeing" colors in their mind's eye when viewing individual graphemes, syllabaries, and words, and were, therefore, classified as *associators* (Dixon et al., 2004). Moreover, our participants were multilingual synesthetes who experienced synesthetic colors when viewing not only Korean but also English, Japanese, and Chinese characters and words. Three of the four participants reported differences in the strength of synesthetic colors elicited by the different languages. For example, SKK reported experiencing stronger synesthetic colors upon viewing graphemes and words in Korean and English than upon viewing them in Japanese. However, we found no obvious