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Individual differences in regularities of grapheme–color associations in synesthesia (共感覚色を規定する文字要因の個人差)

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Recent studies in grapheme–color synesthesia has revealed that grapheme–color correspondences have been shown to be systematically associated with grapheme properties, including visual shape difference, ordinality, and frequency. However, the contributions of grapheme factors differ across individuals. In this study, we applied multilevel analysis to test whether individual differences in regularities of grapheme–color associations could be explained by individual styles of processing grapheme properties. These processing styles are reflected by the type of synesthetic experience. Specifically, we hypothesized that processing focusing on ordinality or familiarity (closely related to frequency) would be associated with associator synesthetes. The analysis revealed that ordinality and familiarity factors were expressed more strongly among associators than among projectors. This finding suggests that grapheme–color associations are partly determined by the type of synesthetic experience.

Keywords: grapheme–color synesthesia, regularity of grapheme–color association, individual difference, synesthetic experience, multilevel analysis

Introduction

Grapheme–color synesthesia is a neurological phenomenon where visual perception of letters and numbers stimulates perception of a specific color. Grapheme-color pairs are consistent in individuals, and idiosyncratic between individuals. For example, when shown the letter “B”, one individual may report blue, another green, and others yellow. The several grapheme properties affect synesthetic grapheme-color correspondence: visual shape similarity and ordinality (positions in a grapheme sequence) for hue of synesthetic colors, and grapheme frequency for luminance of synesthetic colors [1].

However, there are individual differences in such regularities [1]. The previous study showed that shape similarity factors were expressed more strongly among projectors that perceive associated colors visually in external space than among associators that perceive colors in internal space (“in my mind’s eye” or “in my head”) [2]. This result was predicted based on a model for projectors in which cross-activation between graphemes and color processing areas is involved in the feature-component level of graphemes (lines, curves, etc.). However, this explanation does not consider associator synesthetes, who seem to rely less on low-level visual features, and more on conceptual processing of graphemes [3].

This study aimed at obtaining evidence for the following hypotheses: Because ordinality and familiarity reflect not lower-level perceptual property but higher-level conceptual properties of graphemes, associators tend to show strong effects of ordinality and familiarity on synesthetic colors.

Methods

Participants

Twenty-six Japanese synesthetes (19 women, 7 men; age range = 18-22 years) participated in the experiment. Synesthetes were classified as either projector or associator on the basis of the Illustrated Synesthetic Experience Questionnaire (ISEQ [4]) (16 associators, 6 undetermined, and 4 projectors).

Color matching experiment using a CRT monitor

Visual stimuli and Procedure

For the 26 Latin letters, the color coordinates (CIE L*a*b*) of each synesthetic colors were determined by a color-matching task using a CRT monitor. The participant was asked to adjust the color of the displayed reference patch so that it best matched their perceived synesthetic color of the test character.

Data preparation

To measure data at the within-person level, we used the same method as previous studies [1, 5]. First, we computed hue distances (Euclidean distance in the a*b* chromaticity plane), and luminance distances (difference of L* values in CIE L*a*b* coordinates) between grapheme pairs. Next, we compared each synesthetic color difference measure with three dependent measures of grapheme difference: visual shape difference [6], ordinality difference (the difference between the positions of two letters in the alphabet sequence, divided by their sum), and grapheme familiarity difference [7]. There were 325 English alphabet letter pairs, excluding doubles of the same letter. We computed separate values for the hue, and luminance distance of each pair. To measure between-person individual differences, we used the ISEQ [4] to measure the subjective synesthetic experience on the projector–associator continuum.

Analysis

Individual differences in regularities of grapheme–color associations was investigated using techniques of multilevel analyses. Two dependent variables (hue and luminance distance) were separately modeled. The multilevel modeling was defined as:

$$\text{Level 1} \quad Y_{ij} = \beta_{0j} + \beta_1(shape.diff.)_{ij} + \beta_2(ord.diff.)_{ij} + \beta_3(fam.diff.)_{ij} + r_{ij} \tag{1}$$

$$\text{Level 2} \quad \begin{aligned} \beta_{1j} &= \gamma_{10} + \gamma_{11}(syn.ex.)_j + \mu_{1j} \\ \beta_{2j} &= \gamma_{20} + \gamma_{21}(syn.ex.)_j + \mu_{2j} \\ \beta_{3j} &= \gamma_{30} + \gamma_{31}(syn.ex.)_j + \mu_{3j} \end{aligned} \tag{2}$$

In level 1 (the within-participant level), Y_{ij} was the distance for an alphabetical letter pair *i* in participant *j* as a dependent variable. β_{0j} was the mean distance in participant *j* as an intercept. $(shape.diff.)_{ij}$, $(ord.diff)_{ij}$, and $(fam.diff)_{ij}$ were values of the shape, ordinality, and familiarity difference, respectively, for alphabetical letter pair *i* in participant *j*. β_1, β_2, and β_3 were respectively slope 1, slope 2, and slope 3 of the impacts of the shape, ordinality, and familiarity difference on a distance. r_{ij} was the variance of distance for letter pair *i* around the mean of participant *j* as a residual error.

In level 2, β_{1j}, β_{2j}, and β_{3j} were the value of slope 1, slope 2, and slope 3 in participant *j*, respectively. γ_{10}, γ_{20}, and γ_{30} were the mean of slope 1, slope 2, and slope 3 across participants, as the intercept. $(syn.ex)_j$ was the value of synesthetic experience in participant *j*. γ_{11}, γ_{21}, and γ_{31} were the slope of the impact of synesthetic experience on β_{1j}, β_{2j}, and β_{3j}, respectively. μ_{1j}, μ_{2j}, and μ_{3j} were the variance in an individual's slope mean around the grand mean.

Results and Discussion

The ordinality difference for the hue distance and the familiarity for the luminance distance were significantly predicted by the synesthetic experience (γ_{21} for hue distance: $B = 2.30$, $p < .01$; γ_{31} for luminance distance: $B = 1.47$, $p < .05$). Results showed that the impact of the ordinality and familiarity was expressed more strongly with associator-like than projector-like experiences. This finding indicates that regularities of grapheme–color associations in associators are determined by processing conceptual characteristics of graphemes.

Table 6
Model Results for the hue and luminance distance.

parameter	HUE DISTANCE			LUMINANCE DISTANCE		
	B	(SE)	*p*	*B*	(SE)	*p*
Fixed effects						
Intercept						
γ_{00} (mean of distance)	56.60	(2.98)	0.00 **	27.26	(1.12)	0.00 **
γ_{10} (mean of slope1: shape-diff)	5.11	(1.00)	0.00 **	0.02	(0.62)	0.98
γ_{20} (mean of slope2: ord-diff)	12.16	(2.30)	0.00 **	-3.01	(0.87)	0.00 **
γ_{30} (mean of slope3: fam-diff)	5.31	(2.64)	0.05 *	-0.67	(1.46)	0.65
Slope						
γ_{11} (syn-ex → slope1: shape-diff)	0.42	(0.32)	0.18	-0.04	(0.25)	0.87
γ_{21} (syn-ex → slope2: ord-diff)	2.30	(0.79)	0.00 **	-0.51	(0.31)	0.10
γ_{31} (syn-ex → slope3: fam-diff)	0.70	(0.96)	0.47	1.47	(0.67)	0.03 *
Random effects						
r_{ij} (Level 1 variance)	857.01	(101.36)	0.00 **	396.58	(31.31)	0.00 **
μ_{0j} (Level 2 variance)	218.04	(80.07)	0.01 **	29.73	(7.37)	0.00 **
μ_{1j} (slope1 variance: shape-diff)	6.77	(6.81)	0.32	1.19	(1.83)	0.51
μ_{2j} (slope2 variance: ord-diff)	83.32	(47.00)	0.08	0.35	(10.02)	0.97
μ_{3j} (slope3 variance: fam-diff)	74.52	(57.27)	0.19	9.19	(18.27)	0.62

$^*p < .05$, $^{**}p < .01$.

Conclusion

Multilevel analysis revealed that the greater the tendency toward associator characteristics a synesthete showed, the greater the impact of ordinality and familiarity to synesthetic colors. The results partly support our predictions, and suggest that the kinds of grapheme properties individual synesthetes process in childhood are important in the formation of grapheme–color associations.

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