Possible Acquired Synesthesia Underlying the Consistency of Favorable Colors

– A Case Study of Grapheme-color Synesthesia and Sound-color Synesthesia among Competitive Karuta Players –

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Abstract: It has been conventionally assumed that synesthesia emerges during early childhood, indicating it is an innate trait, as supported by subjective reports. In contrast to this assumption, our investigation, focusing on grapheme-color/sound-color synesthesia, suggests possible acquired synesthesia among players of a Japanese card game. (In this game, players arrange the cards arbitrarily, and every time a reciter reads out a waka-style poem on the card, the players rush to find and touch the corresponding one. The players must memorize the card arrangement and, upon the start of recitation, discern which card is being chosen before they start reaching for the corresponding card.) Our investigation began with a questionnaire survey of experienced players, and the subsequent screening tests narrowed down the identity of synesthetes to 11, as they proclaimed themselves, all of whom were confirmed as synesthetes. The survey was followed by the scrutiny of their synesthesia, investigating whether the distribution of synesthetic colors among the players came in the same way as in a previous study, which indicated that synesthetic colors form clusters in a color space. The analysis of the distribution pattern of synesthetic colors of the 11 subjects revealed that the written/recited words elicit synesthetic colors that form clusters. The results are consistent with those in a prior study, and they also suggest that synesthesia can be acquired even after the onset of the training. Regarding some colors, at least, synesthetic associations are likely to occur, whether congenital or acquired.
Keywords: *Competitive Karuta, grapheme-color synesthesia, sound-color synesthesia, acquired synesthesia*

1. INTRODUCTION

Synesthesia is a neurological phenomenon in which ordinary stimuli elicit vivid individual perceptions of unrelated pathways without the corresponding physical stimuli [1]. Grapheme-color synesthetes experience subjective colors when viewing black alphanumeric characters. Likewise, sound-color synesthetes see colors when hearing particular sounds. Synesthetic experiences have two essential characteristics. First, the grapheme (or sound)-color association is consistent throughout childhood [2]. This feature of grapheme-color consistency is an important diagnostic criterion for synesthesia. Second, grapheme (or sound)-color association is idiosyncratic among individuals [3].

Previous research has generally assumed synesthesia is congenital based on subjective reports that it occurred in childhood. However, our preliminary survey revealed subjective reports from players of a Japanese traditional card game, called Competitive Karuta[1], suggesting that they acquired synesthetic color associations by practicing well beyond the age at which synesthesia is typically believed to emerge. The presence of individuals reporting the acquisition of synesthesia through game practice implies that there may be specific features of the game that foster synesthetic color associations.

To analyze the properties of the acquired synesthetic colors, we used spatial statistics as in [4]. [4] collected between 100 and 1,000 synesthetic colors associated with Japanese *kanji* characters for each synesthete and analyzed the distribution patterns of synesthetic colors in the color space using spatial statistics. The analyses showed that the synesthetic colors were concentrated in multiple regions of the color space. This tendency is referred to as "synesthetic color clusters," meaning that there are regularities in each synesthete in determining synesthetic color.

We aimed to investigate: (1) the frequency of subjective reports of acquired synesthesia through game practice using a questionnaire; (2) whether individuals who acquired synesthesia through the game also had synesthetic color clusters, which is consistent with [4]; and (3) whether synesthetic colors arising from each type of synesthesia were distributed in similar locations within the CIE L*a*b* color space, considering cases where individuals have both grapheme-color and sound-color synesthesia. Such similarities indicate that the selection of colors in each case depend on similar underlying regularities.

2. METHODS

This study involved three steps: an online questionnaire survey, two screening tests, and two color selection experiments. We used an online questionnaire survey to identify the details of the players' synesthetic experiences. Then, following the established criteria [5-6], we screened participants who self-reported synesthetic sensations during the game for grapheme-color and sound-color synesthesia. Finally, participants who successfully passed the screening tests were asked to engage in color selection experiments. We conducted the screening tests and the color selection experiments at the participants' homes at night only with a D65 standard lamp. We analyzed the color data based on spatial statistics.

2.1 Participants

A total of 109 players (79 women and 30 men) participated in the survey, of whom 11 (8 women, 3 men; mean age = 22 ± 4.5 years) participated in the screening tests and the color selection experiments. The participants were native Japanese speakers. All the participants provided written informed consent, and the Research Ethics Committee of Kwansei Gakuin University approved this study.

2.2 Online questionnaire survey

We aimed to determine whether the participants perceived synesthetic colors in response to card and poetry reading, whether they had had such experiences before starting Competitive Karuta, and when they began perceiving colors associated with card and poetry reading. We asked the following questions: "Do you perceive colors on the Karuta cards?" "Do you sense colors in the poetry reading?" "Did you sense such colors before you started playing Competitive Karuta?" "When did you start to see colors in relation to the cards and poetry reading?"

2.3 Screening tests

Screening test 1 for grapheme-color synesthesia involved software [5] installed on a laptop. The participants visually perceived Japanese *hiragana* characters on the screen and then selected a color from the color palette corresponding to the color they associated with each *hiragana* character. A total of 138 *hiragana* (46 characters, three times) were randomly displayed; we assessed the consistency of colors selected by the participants.

For Screening test 2 for sound-color synesthesia, *hiragana* sounds were presented using a newscaster's voice. The participants listened to a *hiragana* sound and selected the color using a 24-bit color palette within the iPad application (ibisPaint X). The audio for each of the 45 *hiragana* characters (excluding "ん") was randomly played three times on the tablet, totaling up to 135 characters. This screening test aimed to confirm the consistency of participants' color choices.

2.4 Color selection experiments

We collected synesthetic color data for participants we identified as grapheme-color and/or sound-color synesthetes. Initially, for the grapheme-color synesthetes, we presented scanned images of cards used in official Competitive Karuta tournaments produced by Ohishi-Tengudo Corporation. The participants used a 24-bit color palette on the painting app to paint colors on the 100 cards. In contrast, for sound-color synesthetes, we presented audio recordings of poetry readings by professional Karuta Recitors certified by the All Japan Karuta Association. Following the audio prompts, the participants, using the color palette, painted colors they heard on blank cards with no printed characters. For both tasks, the scanned images of the cards were positioned in the second layer, whereas the color painting was placed in the first layer. Only the first layer (containing no card text or edges) was adopted to analyze the painted colors.

3. RESULTS

3.1 Subjective reports of acquired synesthesia

The results of the questionnaire survey showed that 44 participants reported seeing colors in response to the cards. Of these, 24 perceived colors in relation to the cards after starting to practice the game (versus 20 had synesthesia originally, hence synesthesia possessors[2], SP). 20 participants perceived colors while reading poetry. Among these, 11 reported they had experienced synesthesia after practicing the game (hence acquired synesthetes, AS).

3.2 Within-subject consistency on the screening tests

On Screening test 1, all 11 individuals confirmed as grapheme-color synesthetes consistently chose colors according to the criteria [5]. For Screening test 2, we used regression analysis to verify the consistency of the sound-color associations. The dependent variables were the values of H (hue), S (saturation), and V (brightness). The independent variable was test-retest. We deemed participants with at least one significant hue value ($p <$

0.05) in the regression analysis (#2, #6, #8, #10, and #11) to be sound-color synesthetes (Table 1).

Table 1: Regression analysis in Screening test 2

participant	HSV	coefficient	*p*	participant	HSV	coefficient	*p*
2	H	0.640	0.000**	9	H	0.196	0.118
	S	-0.003	0.981		S	0.586	0.000*
	V	0.307	0.045**		V	0.163	0.147
6	H	0.876	0.000**	10	H	0.627	0.001*
	S	0.654	0.000**		S	0.284	0.003*
	V	0.669	0.000**		V	0.594	0.000*
7	H	0.237	0.112	11	H	0.998	0.000*
	S	-0.149	0.316		S	0.994	0.000*
	V	0.464	0.003**		V	0.856	0.000*
8	H	0.456	0.001**				
	S	0.150	0.276				
	V	0.295	0.019**				

3.3 Color selection experiments

We used the CIE L*a*b* color space to analyze the distribution of the synesthetic colors. The CIE L*a*b* coordinates specific colors using values along three axes: light and dark (L*), red and green (a*), and blue and yellow (b*). We obtained color coordinate values from the image of the tag using the "pictplot" of the R package [6].

We investigated the distribution of synesthetic colors using spatial statistics in the software spatstat [7], an R package for analyzing spatial point patterns. These point patterns can be classified into random, clustered, and uniform. First, we plotted the synesthetic colors obtained from the image data on a*b* chromaticity coordinates for each participant. Second, we forecasted the density of each distribution using kernel estimation. For instance, in the case of Participant 2 (a grapheme-color and sound-color synesthete), we identified the kernel density, as shown in Figure 1.

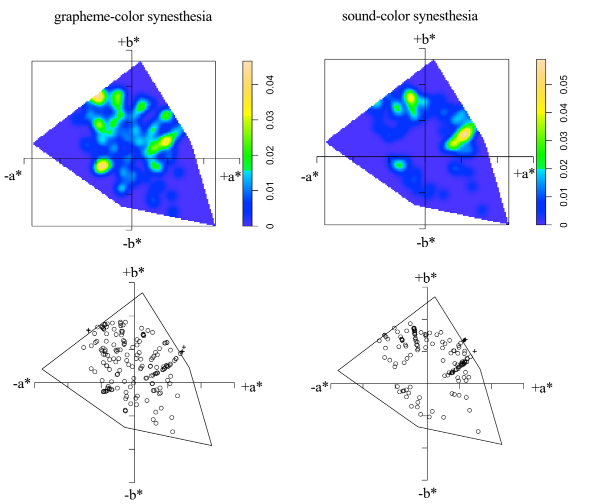

Figure 1: Point patterns of synesthetic colors

The areas displayed in yellow in Figure 1 represent high-density regions, whereas those in blue denote low-density regions. The results revealed clusters of synesthetic chromatic colors associated with the cards and the poetry reading. Third, to confirm the synesthetic color clusters, we explored the types of point patterns using the *L* function [4]. If the *L* function is a constant 0, it indicates a random pattern; if it is positive, it suggests a clustered pattern; and if it is negative, it implies a uniform pattern. As outlined in Figure 2, the *L*-functions returned positive values that were more significant than the confidence intervals (blue lines). This indicates that synesthetic colors form clusters.

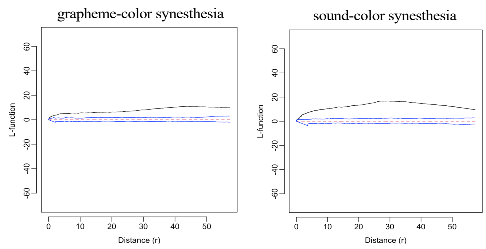

Figure 2: *L* functions of the point patterns

Finally, we referred to an extension of the *L* function called the cross-*L* function, which can evaluate the dependency of two types of point patterns. This function helps investigate the interrelation between synesthetic colors stimulated by different stimuli, such as synesthetic types (e.g., grapheme-color versus sound-color synesthesia). We divided the dependency of the distribution pairs into independent, attractive, or repulsive. If the cross-*L* function is a constant 0, it denotes an independent pattern; if it has a positive value, it implies an attractive pattern; and if it has a negative value, it suggests a repulsive pattern. As displayed in Figure 3, the cross-*L* functions returned positive values that were more significant than the confidence intervals (blue lines). This indicates that the distribution pairs between grapheme-color and sound-color synesthesia are attractive patterns.

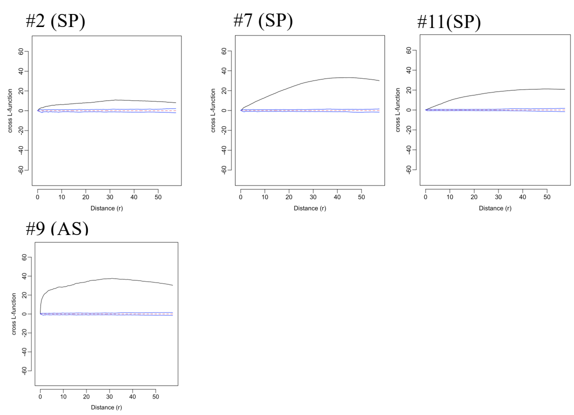

Figure 3: Cross-*L* functions between grapheme-color synesthesia and sound-color synesthesia

Table 2 outlines the results of the spatial statistics.

Table 2: Distribution pattern for each participant

participant	synesthesia	SP/AS	*L* function	cross-*L* function
1	grapheme	AS	clustered	
2	grapheme	SP	clustered	attractive
	sound	SP	clustered	
3	grapheme	SP	clustered	
4	grapheme	AS	clustered	
5	grapheme	AS	clustered	
6	grapheme	SP	clustered	attractive
	sound	SP	clustered	
7	grapheme	AS	clustered	
8	grapheme	AS	clustered	attractive
	sound	AS	clustered	
9	grapheme	AS	clustered	
10	sound	AS	clustered	
11	grapheme	SP	clustered	attractive
	sound	SP	clustered	

4. DISCUSSION

We investigated possible acquired synesthesia and the point patterns of synesthetic colors associated with the Karuta cards and poetry reading. Of the 109 participants, 44 subjectively reported grapheme-color synesthesia, and 20 subjectively reported sound-color synesthesia. Half of them mentioned experiencing synesthesia after playing the game. This suggests the possibility of acquiring synesthetic colors through Karuta game practice. Our results showed synesthetic color clusters of the cards and poetry reading, regardless of whether the synesthesia was innate or acquired, which is consistent with [4]. Furthermore, we found two types of distribution within an individual: grapheme-color and sound-color synesthesia. This implies that some colors are more likely to be synesthetic within an individual. At the same time, some are less likely to be synesthetic, regardless of whether the player acquired the synesthesias through the game.

Synesthetic color clusters [4] were centered around synesthetic colors associated with single characters (e.g., numbers, letters, Japanese *hiragana*, *katakana*, and *kanji*). As a result of this study, we considered the synesthetic colors linked to chunks of 14 *hiragana* characters on Karuta cards to indicate grapheme-color synesthesia and the chunking sounds of the initial key characters (*kimariji*[3]) to denote sound-color synesthesia. Our findings imply that a single character or sound is associated with not only synesthetic colors but also a chunk.

Competitive Karuta players must swiftly match the recited poem's *kimariji* with the corresponding card, typically in less than one second. This task requires higher-order cognitive processing involving cross-modal integration of sight, hearing, memory, and arm movement at an exceptionally rapid pace. This accelerated and multifaceted sensory processing is crucial for inducing grapheme-color and/or sound-color synesthesia. Our theory posits that the unique demands of Competitive Karuta—which requires lightning-fast imaging processing of cross-modal stimuli—play a pivotal role in triggering synesthetic associations between chunks of characters and sounds and their respective synesthetic colors.

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NOTES

1. Competitive Karuta (*Kyogi Karuta*) is a Japanese card game that requires memorization and quick reflexes, where players match the first part of a poem (read aloud) with the corresponding second part (depicted on cards) within one second.
2. Conventionally, the term 'innate' is employed to contrast with 'acquired.' However, given that this research does not engage in discussions about innate characteristics, we will describe them as 'synesthesia possessors' in this context for convenience.
3. *Kimariji* refers to the first to sixth sounds of the poem's first part that allows one to identify the poem's second part (14 *hiragana* characters).

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