Non-Verbal Mapping between Sound and Color - Mapping Derived from Colored Hearing Synesthetes and its Applications -

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Abstract. This paper presents an attempt at 'non-verbal mapping' between music and images. We use physical parameters of key, height and timbre as sound, and hue, brightness and chroma as color, to clarify their direct correspondence. First we derive a mapping rule between sound and color from those with such special abilities as 'colored hearing'. Next we apply the mapping to everyday people using a paired comparison test and key identification training, and we find similar phenomena to colored hearing among everyday people. The experimental result shows a possibility that they also have potential of ability of sound and color mapping.

1 Introduction

Musical pieces and pictures, upon their production, are often used to supplement each other to enhance the impression they give. For instance music is attached to pictures that matches its image or vice versa [1]. If it were possible to find which elements of the parameters contained in music and pictures produce such effects, it would serve as a clue in making 'hearing pictures and seeing music' possible. This in turn would enable the possibility of use in the creation of support systems for multimedia applications such as web pages.

So far in the field of affective computing, the affective correlation between the same or different sorts of media such as image and music has been mostly intervened by adjective words. This study approaches 'non-verbal mapping' as shown Fig. 1, that is to say, to clarify what kind of direct and affective correlation or mapping can be found between the mutual physical parameters of pictures and music.

As seen in such musical pieces titled 'Pastoral' or 'Planet', in many cases composers compose their work based on visual images. Also some performers use colors to express the image of the music in their performances. Particularly, when performing in an ensemble with many kinds of musical instrument, such as orchestras, many people attending the performance feel color sensations within the harmony of the instruments.

Further, in the field of musical psychology and cognitive science, there is a phenomenon referred to as synesthesia, which is the remarkable experience of cross-sensory perception where the stimulation of one sensory modality consistently causes sensations in one or more other senses. One type of synesthesia is 'colored hearing'. People with colored hearing can call to their minds a specific color when hearing an instrument's timbre or musical scale [2]. It has been reported that performers with a sense of absolute pitch have the common feature of this colored hearing [3]. The color sensation seen in colored hearing is not a phenomenon common to all those with absolute pitch. Some people see it as attributable to the recollection of experience or individual sensitivity [4].

Based on these studies, first of all, we will define 'color' in images and 'key, timbre and height' in music as physical parameters, in an attempt to clarify the correspondence when these are changed. This study will not focus particularly on the correspondences that apply to only those with such special abilities as colored hearing (the colored hearing group) but on clarifying the correspondence that apply to everyday people (the general group) with no special abilities such as absolute pitch or colored hearing. When conducting this study, we performed an experiment based on the following idea. The colored hearing group were not regarded as a group with completely different abilities as compared with the general group but as a group with sharply developed abilities of part of the senses that the general group have. In other words the colored hearing group can present a correspondence between sound and color actively while the general group, despite possessing the same kind of sense, may not be able to present it actively but can judge the superiority or inferiority in the correspondence of sound and color, given that they receive some kind of assistance.

First of all, we conducted a parameter mapping derivation experiment between a given color and given sound on the general group. In this experiment, no correspondence could be derived. Then the same experiment was conducted on the colored hearing group in an effort to derive a mapping. Next, we verified whether this mapping was acceptable or not to the general group using a method based on a paired comparison test and key identification training.

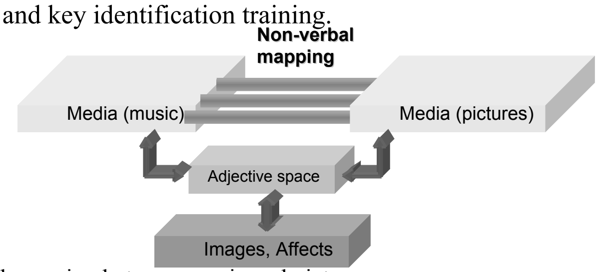

Fig. 1. Non-verbal mapping between music and pictures

2 Mapping Derivation Experiment

The object was to derive what kind of non-verbal mapping exists in the sound and color parameters from the colored hearing group and the general group.

2.1 Selection of color and sound parameters

Color parameters. For color parameters, lightness, saturation, hue and tone in addition to the complex concept of lightness and saturation in the PCCS (Practical Color Co-ordinate System) system designed by the Japan Color Research Institute were used.

Sound parameters. Key, timbre and height were used as sound parameters in the experiment.

Key: The rising scales that start from each white piano key were used. The scales consist of fourteen types of C major to B major and C minor to B minor.

Timbre: There are various possible factors that affect the impression of timbre such as the power envelope. In this study, to make things simple, we focused our attention on the difference in the higher harmonic wave structure.

The timbres provided are as follows:

- Sine wave (SW): Pure sound that does not contain a higher harmonic wave.
- Harmonic series 1, harmonic series 2 (H1, H2): H1 means a higher harmonic wave component which is an integral multiple of a fundamental frequency added to a five-fold sound, and IM2, to a ten-fold sound.
- Odd harmonic series 1, odd harmonic series 2 (OH1, OH2): OH1 means a higher harmonic wave component which is an uneven number of multiples of a fundamental frequency added to a five-fold sound, and OH2, to an eleven-fold sound.
- Even harmonic series 1, even harmonic series 2 (EH1, EH2): EH1 means a higher harmonic wave component which is an even number of multiples of a fundamental frequency added to a five-fold sound, and EH2, to an eleven-fold sound.

Height: A rising scale of D major starting from height D0, D2 and D4 in the same timbre was used.

2.2 Experiment Procedure

From the parameters selected as in 2.1, the sound parameters the subjects listen to were changed in various ways to see how which sound corresponds to what color.

The following 3 types of experiment were conducted on subjects.

Mapping of key and color: Piano timbre sound samples of major and minor scales were given to the subjects randomly. Then they selected a color closest to the sample image. The color selection method is described afterwards.

Mapping of timbre and color: Eight types of timbre samples outlined in 2.1 were given randomly. The subjects selected a color close to the sample images. Sounds were given in non-scale sound order to prevent subjects from feeling key images.

Mapping of height and color: A D major scale starting with D0, D2 and D4 were given in both pure sound and piano sounds randomly to the subjects to select a color.

The experiments were conducted using the following procedure;

1. A pccs color chart was provided so that it could be glanced through.
2. This chart was shown to the subjects and they memorized where the colors were located.
3. A sound sample was given with the color chart invisible.
4. The subject imagined the color in their mind that was close to the sound sample just heard. A time limit of 10 seconds was set to allow intuitive imaging.
5. The color chart was then shown to the subject to select the color close to the image in mind. From the same reason the time limit was 10 seconds.

2.3 Experimental result (Colored hearing group)

Four females aged 23 to 25 with colored hearing were selected as subjects. The experiment using the procedure as in 2.2 was conducted on the colored hearing group.

Mapping of key and color. Table 1 shows the mapping result of key and color. The codes in the diagram indicate the number of the color and the tone symbol defined in the pccs colorimetric system.

Let's take subject A as an example. We can see that she selected white as C major, light blue as D major, green as E major, yellowish green as F major, blue as G major, orange as A major and dark blue as B major. In this way the colored hearing group shows a correspondence between each key and hue. However, there is no similarity in the correlation since all four people selected different hues for the same key. Also, in order to confirm individual repeatability, we performed the same test 3 months later, and 3 out of 4 people gave the same answers. Thus it was confirmed that although there is no common feature in this mapping, there is individual repeatability.

Mapping of timbre and color. The mapping result of timbre and sound showed no similarity of hue, with subject A giving off-neutral, B and D grey and C navy blue for the sine wave. Fig. 2 shows the change in the lightness and saturation of selected colors according to each timbre for scale sounds.

Table 1. Mapping Results of Key/Timbre and Color

	subject A	subject B	subject C	subject D
C major	w [W]	lt18 [B]	p18 [B]	b8 [Y]
D major	lt18 [B]	sf22 [P]	lt8 [Y]	dp12 [G]
E major	v12 [G]	g8 [Y]	sf4 [O]	p20 [V]
F major	v10 [YG]	g10 [YG]	sf10 [YG]	lt18 [B]
G major	b18 [B]	dp8 [Y]	d2 [R]	b6 [O]
A major	v4 [O]	ltg6 [O]	offN-2 [W]	b16 [B]
B major	dp18 [B]	ltg6 [O]	offN-6 [W]	ltg14 [BG]
C minor	dp24 [RP]	p18 [B]	d22 [P]	sf24 [RP]
D minor	Gy7 [gray]	g4 [O]	dk8 [Y]	d8 [Y]
E minor	dp14 [BG]	sf6 [O]	b4 [O]	sf12 [G]
F minor	d6 [O]	d16 [B]	dk12 [G]	ltg22 [P]
G minor	lt20 [V]	p22 [P]	offN-14 [O]	ltg18 [B]
A minor	v2 [R]	dk8 [Y]	sf22 [P]	d8 [Y]
B minor	v22 [P]	ltg10 [YG]	offN-6 [W]	ltg14 [BG]

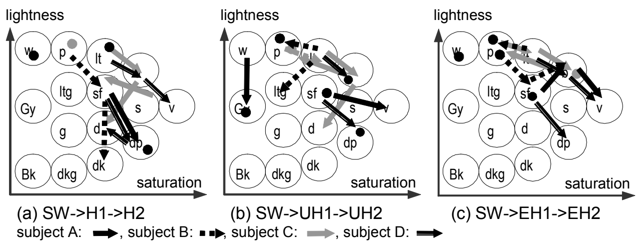

Fig. 2. The change in tone of colors according to each timbre for scale sounds

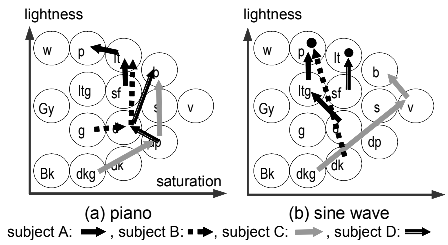

Fig. 3. The change in tone of colors when the height was changed

With Fig. 2a as an example, we will describe how to observe the graph. Fig. 2a shows the timbre of the integral multiple and the change in the lightness and saturation of the selected color. Two arrows for each subject show the change in the selected lightness and saturation when the timbre was changed SW -> H1 -> H2. In the diagram, the lightness increases in the upward direction and the saturation increases in the rightward direction. On the whole, it is seen that about 83% of arrows are directed downward and about 71% to the right. From this it can be said that, irrespective of the timbre type, the more higher harmonic wave components are contained, the higher the tendency of selecting colors of lower lightness and higher saturation.

Moreover, in spite of there being no similarity in the hues chosen by the 4 subjects, a tendency to select colors of similar hue for sound samples of the same key whatever the timbre was seen in each subject. Taking C major for example, subject C selected p18 (as piano, H1, H2, OH1, OH2 and EH1), b18 (SW) and lt18 (EH2). All these belong to blue, and correspond to the color which they selected in the mapping experiment of key and color. Therefore it is considered that the key image comes before the timbre image in colored hearing.

Mapping of height and color. As for the relation between hue and height, subject A gave blue green, B purple and C and D yellow, showing no similarity. The change in the lightness and saturation of the selected colors when the height was changed from D0 -> D2 -> D4 is shown in Fig. 3. Taking subject A as an example, in the case of the piano, when it is changed from D0 -> D2 -> D4, colors that increase in lightness are selected such as sf -> lt -> p. In the case of a sine wave, colors that increase in lightness are also selected such as d -> ltg -> p when changed as D0 -> D2 -> D4. It was found that in this way with an increase in height, the color lightness also increases. Also, all the selected colors corresponded to the colors which they selected for D major in the mapping experiment of key and color, because the samples used were D major scales. Thus, it is confirmed that the key image has a great influence on colored hearing. Added to this, a tendency to select colors of similar hue for sound samples of the same height, whatever the timbre was seen in each subject. Thus it is considered that the height image has a higher priority than the timbre image in colored hearing.

As mentioned above, it was found that there was a mapping rule for the colored hearing group as follows:

1. Key: no common features, but individual repeatability on hue
2. Timbre: more higher harmonic wave components, lower lightness and higher saturation
3. Height: higher height, higher lightness
4. Priority: key > height > timbre

2.4 Experimental result (general group)

The same experiment was conducted on the general group to attempt at derivation of a mapping. The five subjects could not select colors clearly in all experiments. In the interview conducted after the experiment, the following comments were heard. “Is there anyone who can actually do this kind of thing?” “Even if I did select one color, I would choose a different color if the same experiment were conducted again.”

3 Effectiveness of Mapping 1 (paired comparison test)

This experiment tried to verify whether the mapping rule seen in the colored hearing group was acceptable to the general group or not when support was given. The purpose was to confirm whether the same mapping rule as the colored hearing group exists in the general group also.

3.1 Experimental method

Forty-six subjects of men and women in their early 20s (with no such special abilities as absolute pitch) are selected to perform the following experiment.

Mapping of key and color. In the colored hearing group, a tendency of correspondence between key and hue was seen. Then, we gave a sound sample containing key information and at the same time presented two of colors that were complementary.

How the hue of the color sample should be set was a problem. In the mapping experiment of key and color conducted on the colored hearing group, no similarity was seen in the selected colors, but 3 out of 4 selected colors of the same hue for 5 types of sound sample, F and A majors and C, G and A minors. In this experiment, using these 5 types of samples, we decided to present those hues and hues that are psychologically complementary. A projector was used to project color samples. Using this task as one set, a total of 3 sets of tasks were preformed. By comparing the colors selected for each set, we verified the repeatability of mapping among the subjects.

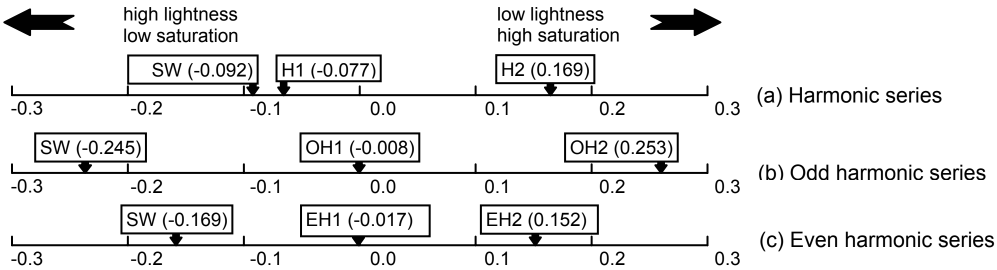

Fig. 4. The interval scales of timbres

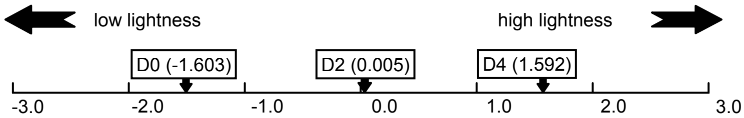

Fig. 5. The interval scales of height

Mapping of timbre and color. In the colored hearing group, a tendency to select lower lightness and higher saturation colors was seen for sounds with higher harmonic wave component for timbre. Thus, two types of sound sample of different timbres were given continuously and at the same time color samples of high lightness and low saturation and low lightness and high saturation were presented. Then we asked for a response on which image was close to which image of the sounds heard.
Mapping of timbre and color. In the colored hearing group, a tendency was seen to select colors of higher lightness for a higher height. Two types of sound samples of different height were given continuously with high lightness color and low lightness color samples, and a response was requested on which image was close to which image of the sounds heard. We made it an obligation to create two groups for color and sound as in the experiment in the previous section. For the sound sample, a major scale starting with D0, D2 and D4 in the sine wave was used.

3.2 Result and discussion

Mapping of key and color. Of the 5 types of scales given to the subjects, the value obtained by dividing the number of samples, in which the subjects selected the same color three times, by a full scale number of 5 was set as the repeatability rate. For instance, if the same color was selected three times for 4 types of 5, the repeatability rate was (4/5) × 100 = 80(%). Theoretically, the repeatability rate must be more than 80% for it is estimated at the significant level of 95%, whereas, in the experiment result, no one showed results higher than 80%. From this fact, we confirmed that there is no repeatability in the answers of subjects.
Mapping of timbre and color: For each group of (SW, H1, H2), (SW, OH1, OH2) and (SW, EH1, EH2), we calculated the values on the three timbre impression interval scale, by scaling based on the comparison judgment rule. The scale values of those are shown in Fig. 4.

In any group, it can be seen that the scale value is larger for timbres with a higher harmonic wave component. From this, it can be seen that sounds with higher harmonic wave components contained correspond to colors of lower lightness and higher saturation. That is to say that for the mapping between timbre and color, it was confirmed that this mapping rule can be applied to the general group.

Mapping of height and color. By scaling based on the comparison judgment rule, values on three height impression interval scales were calculated. The scale values are shown in Fig. 5. It can be seen that the higher the height, the higher the scale value. This shows that high pitched sounds correspond to high lightness colors. In other words, it has been confirmed that also for mapping of height and color, the mapping rule of the colored hearing group can be applied to the general group.

Consideration. In the experiment, we could not confirm the repeatability of the mapping between key and color in the general group. However, a rule or similarity in the relationship between tonality and color was observed rarely even in the colored hearing group. It must be still more difficult in experiments with the general group. We next tried to apply this mapping to the general group from a different viewpoint.

4 Effectiveness of Mapping 2 (key identification training)

The next experiments concerned training in key identification utilizing the mapping between key and color. The purpose of this experiment was to verify positively whether mapping as in the colored hearing group is also inherent in the general group, being brought out by effective training. The subjects who didn't have absolute pitch were trained to memorize the name of the key by hearing a sound sample of the key. At that time they were also shown a color based on the mapping and they memorized the key of the sound with the color as a cue. It was an experiment based on the hypothesis that if the general group had immanent mapping like the colored hearing group, the utilization of the color as a cue would be effective in memorizing the key.

4.1 Subjects of experiment

Eight men and seven women around the 20 years old were selected to perform the following experiment. They didn't have absolute pitch, but were highly motivated to gain that ability. (Here, absolute pitch means the ability for long-term memory to identify or label a musical tone without reference to an external standard. For reference, perfect pitch means the ability to have some sort of super resolution in their pitch perception and to tell whether a sound is perfectly in tune or not.5, 6) The men were members of a university glee club, and the women had experience in playing musical instruments.

4.2 Training method

The subjects were trained to listen to the sound samples while being shown the name of the key on repeated occasions for 8 minutes per day, for a period of 5 days. Then the subjects were divided into 2 groups. Group A (the 'seeing color' group) were given sound samples with a color sample based on the mapping, and Group B (the 'no seeing color' group) were given only the sound samples.

The sound samples were a piano timbre sequence of 'tonic chord (for 3 seconds), rising scale (for 6 seconds), tonic chord (for 4 seconds)' of the 7 major keys. The color samples were shown by projecting images of each color onto a screen. Here as prototypical mapping, the colors were determined based on the results of Ogushi's experiment, which included the most subjects.

The subject were training in a dark room, wearing a pair of headphones, close to a screen in order to be absorbed in the training. The name of the key of the sound was also displayed before and after giving the sound sample (for example, "next is C major"), and the subject was prompted to imagine the sound corresponding to the key in advance. For Group A, the characters of the key name were displayed with the color, and the subject was strongly requested to imagine the sound from the color as a cue. After that, in Group A, the color sample was given at the same time as the sound sample was given. In Group B, there was no color on the screen.

The training included three sets per a day (a set consisted of the sound samples of the seven keys given randomly).

4.3 Test method

The subject was examined by being given the seven sound samples from the training randomly and requested to give the name of the key. The time limit was 10 seconds. The results of the test were evaluated by the number of correct answers. The tests were carried out three times in total. The first one was done just before the first training, the second was before the last training on the 5th day, and the third test was after the last training on the same day. Also, at the same time of the third test, the subject filled out a questionnaire about what kind of cue was used to identify the key.

4.4 Results

The results of the tests are shown in Tables 2. From the results of the first test, it was confirmed that none of the subjects had the ability of key identification because the number of the correct answers was four or under. According to the increase in correct answers in the second test, most subjects seemed to be gaining ability in key identification. In the last test, the number of correct answers was down in some subjects. This was considered to be because they were confused by the strong effect of the training.

For the above reasons, the subjects were evaluated based on the results of the second test. The subjects who had seven correct answers in the second test were called the 'short-term absolute pitch (sAP)' gainers, and those who had five or more correct answers in both the second and third tests were called the 'short-term partial absolute pitch (sPAP)' gainers. Two sAP gainers and one sPAP gainer appeared in Group A, and no sAP gainers and two sPAP gainers appeared from Group B. Therefore, it was suggested that training was more effective in Group A than in Group B.

Table 2. Results of Tests

Subject	Correct answers			Effectiveness of training
	1st day	5th day		Gaining sAP or sPAP
	1st test	2nd test	3rd test	
A1	4	7	7	sAP gainer
A2	0	7	5	sAP gainer
A3	3	5	5	sPAP gainer
A4	0	5	4	
A5	1	2	4	
A6	1	2	2	
A7	4	2	1	
Av. A	1.86	4.29	4.00	
B1	4	5	7	sPAP gainer
B2	2	5	6	sPAP gainer
B3	0	5	3	
B4	2	4	5	
B5	0	3	2	
B6	2	3	2	
B7	1	3	0	
B8	0	2	4	
Av. B	1.38	3.75	3.50	

4.5 Consideration

Next as shown in Table 3, the images and cues used in the recognition of the key obtained by the questionnaires are listed. They are divided into four categories, ‘color’, ‘lightness’, ‘height’ and ‘other images’ with their frequency as shown in Table 4.

Independence on pitch height. It can be seen from the table that the subjects in Group B greatly depended on the pitch height. To the contrary in Group A, they seemed to identify the keys by using cues other than height, such as color and images. As for the pitch height, we must consider the fact that the key and the height of the sound samples used in these experiments were not proper because they were in a one-to-one ratio. After the experiments, such comments from subjects as “I remembered that the lowest sound was A major and the highest sound was G major” was heard. We intend to devise better sound samples in the future. However the dependence on pitch height was rarely seen in Group A in spite of the samples being the same. Therefore, it is supposed that while Group B judged the keys by the relative pitch height, Group A identified the keys by using the other images as absolute cues, which helped them gain sAP easily.

Reference to color. All the sAP and sPAP gainers referred to color as a cue in the identification of the key of the scale. Subject A3 said “Color appears when a chord sounds”, in other words, the given colors themselves could be cues. Also subject A1 mentioned the given colors and images related to those. More noteworthy was that the two sPAP gainers in Group B associated color with sound by themselves in spite of seeing no colors. Subject B1 mentioned colors for every key though they gave descriptions concerning the pitch height as a cue. Subject B2 talked about color association such as “They were the same colors which I imagined” after the experiment. It follows from this that color is an important cue for key identification to the two from Group B.

Same colors in the mapping. Associations of color or images related to color were observed in most subjects in Group B, and not a few of the colors, 10/16, were the same as the mapping. Examples of these are G major as blue (subjects B3, B6 and B7), A major as red (B1 and B2) and F major as green (B1). Though subject B1 stated "I was shocked that the colors were different from those I had imagined", actually their association of C major as blue was same as 3 out of 4 of the colored hearing group selected as shown in 4.2.

Table 3. Results of Questionnaire on Cues or Images used for Key Identification

Subject	C Major	D Major	E Major	F Major	G Major	A Major	B Major	Overall impressions	To A only: Is color useful for identification?
A1 [sAP]	basic color; brand-new white	a little higher than C; uneasy	light sound; yellow	clear sound; bright green	highest sound; sky color; busy tone of cell phone	lowest sound; heavy red	dignified image; dark blue		somewhat
A2 [sAP]	obedient feel				clear feel; image of sky				somewhat
A3 [sPAP]		Takemoto piano						color appears when a chord sounds	somewhat
A4	No particular image	light, but not as light as F	a little dark image	extremely light sound	no particular image	lowness of depth	begins with higher sound than A but has a darker impression than A	impressions depending on keys are related to light/ darkness of colors	somewhat
A5				light	high-pitched	Clear; heavy feel	Dim		somewhat
A6								Light or dark feeling appears more clearly than before	somewhat
A7								confused in my own mind as just after training	little
Subject	C Major	D Major	E Major	F Major	G Major	A Major	B Major	Overall impressions	To B only: To see colors of samples after experiment
B1 [sPAP]	standard sound (blue)	like F	high sound and like G (white)	begins with Fa (green)	begins with So (pink)	low sound and like B (brownish - yellow)	low sound and like A		shocked that the colors were different from those I had imagined
B2 [sPAP]						wine		the lowest sound was A and the highest sound was G	the same colors which I imagined
B3	spatial sound		gypsophila (kasumi-sou)	unexpected high sound	little blue flower	rose	tulip	images of flowers came, but didn't stay with me for long	surprised that the colors of G and A were exactly the same as I imagined
B4		time to feel sound neither C nor E	lower image than accompaniment	like accompaniment of concert	higher image than F	roughest feel	darker image than C	let F a standard	
B5	Standard-like, rather light sound	Takemoto piano	suspicious D	Maki Goto	higher than F ?	rather dark feel	time to feel sound neither A nor C	the lowest sound was A and the highest sound was G	
B6	white image		orange image		resounding highly; blue image	vibration comes up low			
B7	fittest sound; slope (uphill)	beginning of radio exercises	river; lake	like raindrops fall in petal of hydrangea	pure blue sky	muffled dark sound	nothing distinctive		
B8	solemn feel	a little solemn feel	undecided	undecided	something like white curtains	dark feel	dark feel	the lowest sound was A and the highest sound was G	

Table 4. Categories and their Frequency of Cues

Subject	Height	Lightness	Color	Other images	Main factor
A1 [sAP]	2	1	6	6	color; image
A2 [sAP]	0	0	1	2	image
A3 [sPAP]	0	0	7	1	color
A4	2	4	2	0	lightness
A5	1	1	0	2	image
A6	0	3	0	0	lightness
A7	0	0	0	0	-
AV. A	0.71	1.29	2.29	1.57	
B1 [sPAP]	4	0	5	0	color
B2 [sPAP]	2	0	2	2	color; height
B3	1	0	4	5	image
B4	3	1	0	1	height
B5	3	2	0	2	height
B6	2	0	3	0	color
B7	0	1	1	4	image
B8	2	2	1	2	height
AV. B	2.13	0.75	2.00	2.00	
AV. s(P)APs	1.60	0.20	4.20	2.20	
AV. Non s(P)AP	1.40	1.40	1.10	1.60	

Concrete images. There were more concrete images such as 'rose', 'Maki Goto' and 'white curtain' in Group B than in Group A. This can be considered to be because Group B enlarged their scope for imagination more than Group A because they had no information other than sounds, so that their concrete images increased. However it does not necessarily make mapping between key and color.

It follows from these considerations that the subjects who attempted to identify the keys with color as a cue could gain sAP more efficiently than those who applied the pitch height or other images as cues. Especially in Group B, the 'no seeing color' group, a lot of color associations came to their minds by themselves and not a few of those corresponded to the mapping the colored hearing group had. We may therefore conclude that mapping between sound and color like colored hearing synesthetes have is inherent in the general group also.

5 Conclusion

We have presented non-verbal mapping between sound and color. Even everyday people with no special abilities such as absolute pitch or colored hearing, get a vague non-verbal sense that a picture they see and music they hear do not match or match well when they are exposed to a stimulation that contains visual and audio information. Based on this fact, we attempted deriving a mapping between selected parameters on the general group but could not find a desirable result. It is considered that the general group could passively obtain a sense from the visual and audio stimulation, but could not correspond the two parameters actively.

On the other hand, colored hearing synesthetes could correspond the two parameters actively, as they originally had the ability to clearly visualize images from auditory stimulation. Also, when the mapping rule obtained from the colored hearing group was presented to the general group, we found that this mapping was acceptable by the general group. Thus it is thought that the colored hearing group does not have a completely different ability from the general group but has more sharply developed senses than the general group.

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