

ピッチクラス-カラー共感覚における音名認知の役割の解明： デュアルタスクを用いたアプローチ

Exploring the Role of Pitch Name Recognition in Pitch Class-Color Synesthesia: A Dual-Task Approach

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Abstract

This study retests the "2-step" hypothesis and the "rainbow-like" theory concerning pitch class-color synesthesia, as proposed by Itoh et al. (2017). The experiment involved 16 adults with pitch class-color synesthesia and used a dual-task paradigm to explore the cognitive mechanisms underlying their synesthetic experiences. Interviews were also implied to gain insight into the development and nature of synesthetic experiences. The findings of this study suggest that Itoh et al.'s 2-step hypothesis may have limited applicability, as it can only account for a subset of individuals with pitch class-color synesthesia. Additionally, there may exist 1-step synesthetes, whose synesthetic experiences may be governed by a different mechanism. The variation in mechanisms is likely influenced by the different ways in which synesthetes form their associations. Furthermore, the "rainbow-like" theory may only represent the experiences of 2-step synesthetes. The color perception of 1-step synesthetes deviates from the description of a rainbow-like pattern.

Keywords — Pitch class-color synesthesia, synesthesia

1. Research Background

Synesthesia is an uncommon cognitive trait in which stimuli in one sensory realm, such as hearing a sound, stimulates a perceptual experience in another sensory realm, such as color (Ward, 2013). Pitch class-color synesthesia is a type of synesthesia in music, in which the cognitive-level concept of pitch class (i.e., do re mi fa so la si) is associated with colors (Itoh, et al., 2017).

2. Research Purpose

Itoh et al. (2017) proposed a 2-step hypothesis for pitch class-color synesthesia mechanism. That is, pitches are first identified with pitch class names, and then pitch class names are associated with the colors (Figure 1).

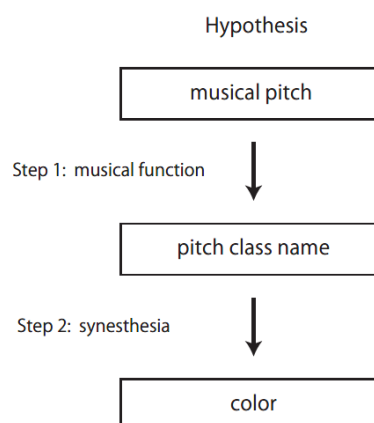


Figure 1 2-step hypothesis (Itoh et al., 2017)

In their research, they also proposed a "rainbow-like" theory. They let the participants with pitch class-color synesthesia select the colors they felt from each pitch in a color-selection test, and it turned out that the average color gradient was like a rainbow (Figure 2).

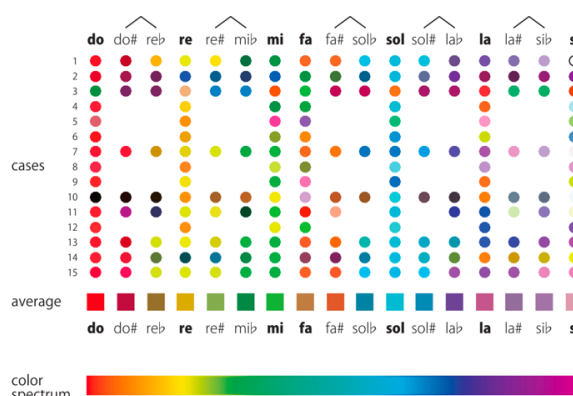


Figure 2 "Rainbow-like" theory (Itoh et al., 2017)

The primary objective of this study is to retest the "rainbow-like" theory and the "2-step" hypothesis proposed by Itoh et al. (2017) regarding pitch class-

color synesthesia, ascertain its scope of applicability.

By confirming or refuting Itoh et al.'s hypothesis, the present study will contribute to our understanding of the cognitive processes underlying pitch class-color synesthesia and may have broader implications for the study of multisensory perception and integration.

3. Methods

Previous research has demonstrated that pitch name recognition is an ability related to verbal capacity (Hou et al., 2017). Furthermore, it has been reported that when tasks with similar cognitive processes are performed simultaneously (dual task), the two tasks interfere with each other, resulting in reduced task performance. Building on this principle, the present study will employ a dual-task paradigm to experimentally demonstrate that a verbal task interferes with the pitch name recognition process in pitch class-color synesthesia. If Itoh et al.'s (2017) 2-step hypothesis holds, the performance both on the pitch naming task and on the color correspondence task will decrease.

(1) Participants: The study recruited 16 adults with pitch class-color synesthesia.

(2) Procedure: Prior to the experiment, participants answered an online questionnaire about the code numbers of the colors they could perceive from the seven pitches: Do, Re, Mi, Fa, So, La, Si. Then, each participant underwent eight experimental sessions, which involved a series of tasks designed to assess their pitch naming and color correspondence abilities under various interference conditions (Table A-1). The tasks were required to be completed individually, or concurrently with other tasks. The order of the eight sessions will be counter-balanced among participants using a Latin square design. Following the completion of the eight sessions, participants were interviewed to gain insight into the development and nature of their synesthetic experiences.

(3) Description of each task: [Pitch naming] Listen to a piano tone, and answer the pitch name of the tone.

[Color corresponding] Listen to a piano tone, and

answer the color feeling from the tone. **[Visual]** Look at a word and judge the shape of the word (Figure A-2).

[Verbal] Look at a word and judge the pronunciation of the word (Figure A-2).

(4) Expected Results (hypotheses): If Itoh et al.'s 2-step hypothesis holds, participants' performance both on pitch naming task and on color correspondence task will be significantly worse in sessions requiring verbal task, i.e., silent reading (Session 6 and Session 8; refer to Table 1); and color corresponding tasks will take more reaction time (RT) than pitch naming tasks because the former requires two steps instead of one. In addition, if the “rainbow-like” theory holds, a “rainbow-like” pattern will be found in the result of color selection questionnaire.

4. Results

(1) Color selection: The specific colors associated with the pitches do re mi fa so la si as chosen by the 16 participants, are presented in the Figure A-2. By averaging colors, it is possible to see that the color changes from ‘do’ to ‘si’ are approximately red to purple, which is similar to the “rainbow-like” pattern claimed by Itoh et al. (2017).

(2) Reaction time (RT): We analyzed the RTs (as the benchmark of the performance mentioned in the hypotheses) of the participants in different sessions in turn. The RT was analyzed using two-way repeated measures ANOVA; specifically, one factor was response (two levels: pitch naming/color corresponding) and the other was interference (three levels: none/visual/verbal).

Contrary to our hypotheses, the results of the analysis yielded a non-significant main effect for response ($F=4.00$, $p=.527$, $\eta^2 <.001$); and though participants showed better performance in no-interference conditions than in dual-task conditions ($F=242.056$, $p<.001$, $\eta^2 =.213$), no significant difference between visual interference condition and verbal interference condition ($p=1.000$) was found (Figure 3).

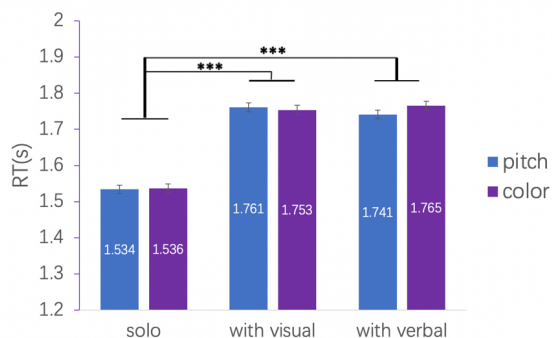


Figure 3 RT in different interference conditions

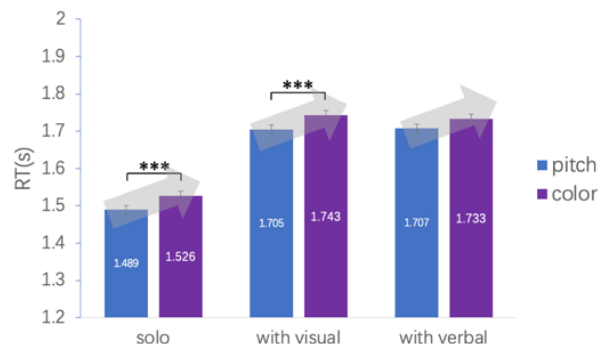


Figure 4 RT for 2-step group

(3) Interviews: To investigate why the results diverge from our hypotheses, we endeavored to seek clues from the interviews. We found that while the majority of participants claimed their synesthesia conformed to the 2-step hypothesis proposed by Itoh et al., a subset (4 participants) of participants argued that their synesthesia followed a 1-step process, in which auditory stimuli could directly evoke color sensations.

Interestingly, through comparison, we found that participants who claim to possess a 2-step synesthesia generally indicated that they obtained synesthesia through a one-to-one method, such as using a specific color to mark a specific pitch during their early childhood. On the other hand, participants who possess a 1-step synesthesia more often stated that they acquired synesthesia through a generalized method, for example, generalizing the impression from a particular song to the impression of an individual pitch.

(4) Supplementary Analysis Based on Interviews: Because the aforementioned interview suggests the possibility of the existence of both 2-step and 1-step processes, participants' data were divided into Self-reported 1-step and Self-reported 2-step groups, and a two-way repeated measures ANOVA was conducted again.

The results of the analysis yielded a significant main effect for response ($F=11.136$, $p=.001$, $\eta^2=.016$) only in 2-step group (Figure 4). Which means, only for participants in 2-step group, color corresponding tasks required longer RT than pitch naming tasks.

In addition, we averaged the reported colors for both the 1-step group and the 2-step group (Figure 5). It can be seen that only the average color of the 2-step group presents a 'rainbow-like' pattern.

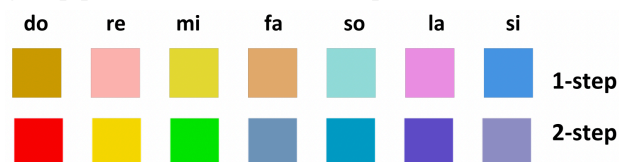


Figure 5 Average color "1-step" vs. "2-step"

5. Discussion & Conclusion

Results suggest that Itoh et al.'s 2-step hypothesis may have limited applicability, as it can only account for a subset of individuals with pitch class-color synesthesia. Additionally, there may exist 1-step synesthetes, whose synesthetic experiences are governed by a different mechanism. The variation in mechanisms is likely influenced by the different ways in which synesthetes form their associations.

Furthermore, the "rainbow-like" theory may only represent the experiences of 2-step synesthetes. The color perception of 1-step synesthetes deviates from the description of a rainbow-like pattern.

References

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Appendix

Table A-1 Combination of tasks in different sessions

Interference Response	(Visual) Closed area judging	(Verbal) Silent reading	None
Pitch naming	Session 7	Session 8	Session 2
Color corresponding	Session 5	Session 6	Session 1
None	Session 3	Session 4	

単語を見て、単語に「閉じた枠」が存在する場合だけスペースキーを押す

先輩

「閉じた枠」が存在する場合

参考

「閉じた枠」が存在しない場合

Closed area judging

単語を黙読し、単語の発音に「ん」が存在する場合だけスペースキーを押す

せんぱい
先輩

Silent reading

Figure A-1 Instructions for Visual (Closed area judging) task and Verbal (Silent reading) task

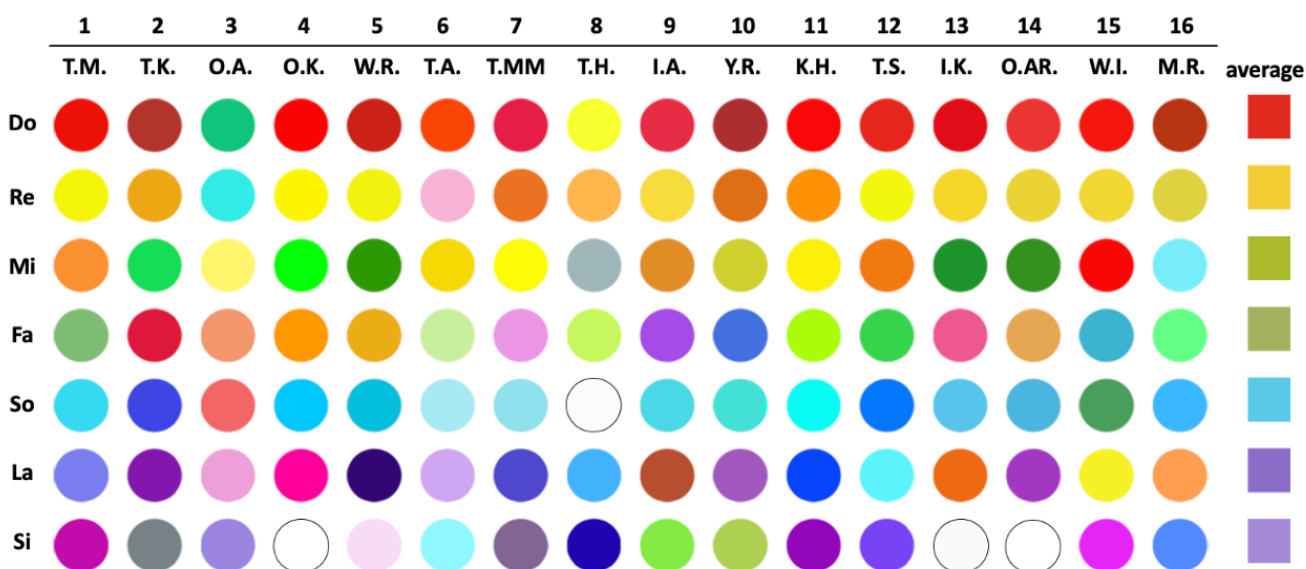


Figure A-2 Colors selected by each participant