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研究課題名（和文）Color-shape associations in developemental disorders

研究課題名（英文）Color-shape associations in developemental disorders

研究代表者
陳　娜（Chen, Na）

国立障害者リハビリテーションセンター（研究所）・研究所　脳機能系障害研究部・流動研究員

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研究成果の概要（和文）：アンケート調査の結果、色-形の連合は自閉傾向と関連する可能性が示唆されており、自閉傾向が高い人では、色と形の連合の数が少ない、共通性が高くないことが明らかになった。行動実験の結果では、自閉傾向が高い人では、色と形の連合（円―赤；三角形―黄色）が強い傾向が見られ、事前の予想とは反対の結果となった。この結果は、色と形の連合のメカニズムやASD者における視知覚特性の解明に資するものである。

研究成果の学術的意義や社会的意義
People with higher autistic traits showed a stronger binding of color-shape associations. Autistic traits play a role in the construction of color-shape associations. Those results shed light on the nature of color-shape associations and autistic perception, which could be used in visual design.

研究成果の概要（英文）：The present study used both explicit and implicit experimental methods to examine color-shape associations in developmental disorders. By the online questionnaire survey, participants with higher autistic traits showed fewer consensual color-shape associations. However, using computer-based indirect experimental method, participants with higher autistic traits showed stronger congruency effect of CSAs on both feature discrimination and feature binding (e.g., circle-red, triangle-yellow) tested by IATs and illusory conjunction task. Thus, autistic traits play a role in the construction of color-shape associations. Those results may be explained by the Bayesian model underlying autistic perception. People may construct color-shape associations at an early age, and the strength of those associations have been weakened by learning with co-occurrence of colors and shapes in the environment, while people with higher autistic traits may influenced less by prior learning experience.

研究分野：Experimental psychology

キーワード：color-shape association

１．研究開始当初の背景

Previous studies showed that non-synesthetic people systematically associate shapes with colors (e.g., circle-red, triangle-yellow, and square-blue; Chen et al., 2015a). Those color-shape associations (CSAs) can be explained by language based semantic sensory correspondence (Chen et al., 2015a; Chen et al., 2016). In other words, CSAs are not intrinsically determined but learned during developments. However, little has been known about the formation processes and the individual differences of those CSAs.

Autism spectrum disorder (ASD) is a pervasive neurobiological developmental disorder, characterized by difficulties in social interactions and communications, restricted and repetitive behaviors/interests/activities, and atypical sensory behaviors (American Psychiatric Association, 2013). Studies showed that individuals with developmental disorders (e.g., autism) exhibit atypical sensory processing and impairment in multisensory integration, deficiencies in language and emotion processing (Stevenson et al., 2014; Robertson & Baron-Cohen, 2017). For example, individuals with ASD were reported to show less pronounced crossmodal correspondences ("Bouba-Kiki" effect was weaker in individuals with ASDs compared with controls; Oberman & Ramachandran, 2008; Occelli et al., 2013; Gold & Segal, 2017; Król & Ferenc, 2020). It might be possible that autistic traits could affect the learned CSAs, that people with high autistic traits may show weaker CSAs. However, little has been known about the effect of autistic traits and developmental experience on CSAs. Learning CSAs in developmental disorders (e.g., ASDs) will help to test the structural/statistical correspondence hypothesis.

２．研究の目的

The purpose of the proposed study is to examine individual difference and the origins of CSAs, to reveal individual experience, including cognition styles, developmental trajectories, language skills, autistic symptoms, and personality traits effect on CSAs. The proposed study was the first to address the construction factors of CSAs, and to investigate intra-visual CSAs with developmental disorder. It would be helpful to understand individual cognition and developmental experience effect on CSAs, to further develop an explanatory framework of CSAs, and shed light on the nature of crossmodal correspondence.

３．研究の方法

Here, I used both direct and indirect experimental methods to explore the effect of autistic traits on CSAs. For direct experiments, I used an online questionnaire survey recruiting 85 Japanese participants to examine the effect of autistic traits on explicit color-shape associations. For indirect experiment, I adopted two experimental methods, including the implicit association tests (IATs) and illusory conjunction tasks, to examine the effect of autistic traits on the strength and feature binding of CSAs. In each experiment, around 45 participants were recruited (including 10 ASDs), and they were instructed to participants in the two indirect experiments using computer-based behavioral performance tasks. The results from those experiment will reveal the effect of autistic traits on explicit CSAs and CSAs tested by IATs and illusory conjunctions. It will help to show the contributions of autistic traits on shaping CSAs, and to understand the effect of structural/statistical experience on CSAs and to shed light on autistic perception.

４．研究成果

In the explicit experiment, eighty-five Japanese (52 females; age from 15-60) volunteered to participate in an online questionnaire survey (Chen et al., 2021). Participants filled three sessions investigating color-taste, color-shape, and shape-taste associations, and finally answered the AQ-10 questionnaire. The results showed that the participants established strong color–taste/shape–taste/shape–color associations (e.g., yellow–sour, triangle–sour, and triangle–yellow), which are consistent with previous findings (Wan et al., 2014; Chen et al., 2015a; Spence et al., 2015; Velasco et al., 2015, 2016a; Spence, 2019). Moreover, significant associations were observed between the proportion of choosing consensual color–taste/shape–color associations and autistic traits. That is, the participants with higher AQ scores chose fewer of the consensual color–taste/shape–color associations, while there was no difference in shape–taste associations. Thus, the autistic traits play a role in the construction of color–taste/shape–color associations. This might be explained by a Bayesian prior hypothesis that autistic perception may have different levels of statistical learning with regularities in the world, leading to a lower prior knowledge effect on constructing those learned associations. These results provide further evidence for the "hypo-priors" account for autistic perception and shed light on the nature of visual–taste associations.

Effect of autistic traits on CSAs by IC task

In the indirect experiments with the illusory conjunction (IC) task, forty-three Japanese people (including ten diagnosed ASDs; twenty-three males, *M* age = 22.84 years, *SD* = 4.39) undertook an experiment designed to reveal illusory conjunctions induced by incongruent and congruent colored-shape pairs (as in Chen & Watanabe, 2021), and filled the AQ–50 Japanese version.

Results showed that participants made more illusory conjunctions in incongruent colored-shape pairs than congruent ones, replicated previous finding (Chen & Watanabe, 2021). Thus, CSAs could be strong enough to bias feature binding processes, and lead to more binding errors in incongruent color-shape pairs.

More importantly, significant correlations between AQ scores and illusory conjunctions induced by color-shape associations were observed (circle-red/triangle-yellow associations; Fig. 1). Individuals with higher autistic traits made more illusory conjunctions in incongruent colored-shape pairs than congruent ones in circle and triangle pairs. Thus, individuals with higher autistic traits tended to have stronger bindings of circle-red and triangle-yellow associations. Moreover, the stronger binding of color-shape associations is related to ASD sub-traits in attention switching (Fig. 1).

Those results suggested that autistic traits play a role in the construction of color-shape associations. The congruency effect of CSAs on bias feature binding may suggest that CSAs could be strong enough to exert a top-down effect on feature binding, or CSAs may occur earlier than the binding processes. The effect of autistic traits on biasing feature binding of CSAs, that people with higher autistic traits showed stronger binding of CSAs, may suggest that some CSAs might have statistical/structural basis. Pellicano and Burr (2012) suggested a Bayesian explanation for autistic perception, that people with autism weight their prior experience to a less extent than neurotypical individuals, which leads to fewer perceptual interference. In our previous study, we found that CSAs could be established as an early age, that children at the age of 8 could show similar pattern of CSAs as adults (Chen & Watanabe, 2021). It might be possible that people construct CSAs earlier in life, and updated with later statistical learning with co-occurrences in the environment, while individuals with autism could not able to be updated their CSAs by later statistical learning with color and shape interactions, and stayed strong binding. The binding of CSAs in neurotypical individuals without autism might be weaken by later learning with colors and shapes in the living environment.

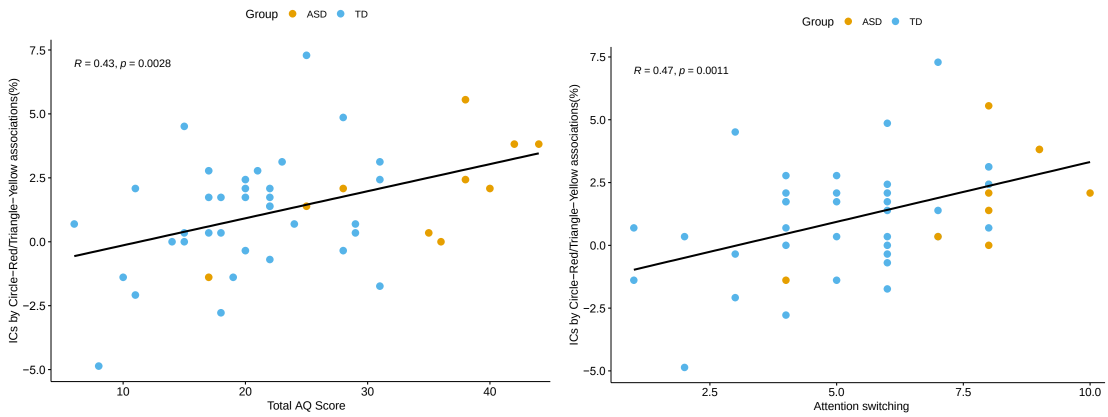

Figure 1. Correlation between total AQ scores and the ICs induced by circle-red and triangle-yellow associations; Correlation between subscale AQ score of attention switching and ICs induced by circle-red and triangle-yellow associations.

The effect of CSAs on biasing feature binding might also suggest that CSAs are occurring earlier than binding processes. Evidence from neuropsychology and brain imaging showed that learned color-shape conjunctions could be efficiently conjunction-coded in early visual areas of the brain (Lu et al., 2010; Price & Humphreys, 1989; Rappaport, 2013; Seymour et al., 2010; Walsh, Ashbridge, & Cowey, 1998; Zeki & Marini, 1998). It might be possible that some neurons may carry a unified coding of color–shape combinations earlier, leading to a bias in feature binding (Ramachandran & Hubbard, 2001; Seymour et al., 2009, 2010; Sumner et al., 2008). It was suggested that individuals with ASD have different brain activities for sensory processing of visual high-level processing, that the CSAs might be stronger bindings in individuals with CSAs. The structural basis of CSAs got decreased with learning processes with statistical learning in neurotypical individuals, and resulting in weak binding of CSAs.

Effect of autistic traits on CSAs by IATs

In the IATs, forty-six Japanese people (including ten diagnosed ASDs; twenty-five males, *M* age = 23.98 years, *SD* = 6.53) joined the experiment, and filled the AQ–50 Japanese version. The experiment paradigm and procedure were identical to our previous study (Chen et al., 2015b; Chen et al., 2016).

Results showed that the D scores from the three IATs all shifted towards a positive direction, and the response times were larger in incongruent color-shape combinations than congruent ones. Thus, participants responded more rapidly when circle-red, square-blue, and triangle-yellow were mapped onto the same response key than when they were paired with different response keys. Those results replicated our previous findings (Chen et al., 2015b).

Moreover, the D score of IAT2 (circle-triangle pair) were significantly correlated with the AQ scores (Fig. 2). Participants with higher autistic traits tended to show stronger congruency effect of CSAs on facilitating recognition of color and shape features. No significant correlation was observed from AQ scores and D scores from IAT1 and IAT3. These results were consistent with finding from IC task, that circle-red and triangle-yellow associations tended to be stronger in people with higher autistic traits tested by both feature discrimination and feature binding.

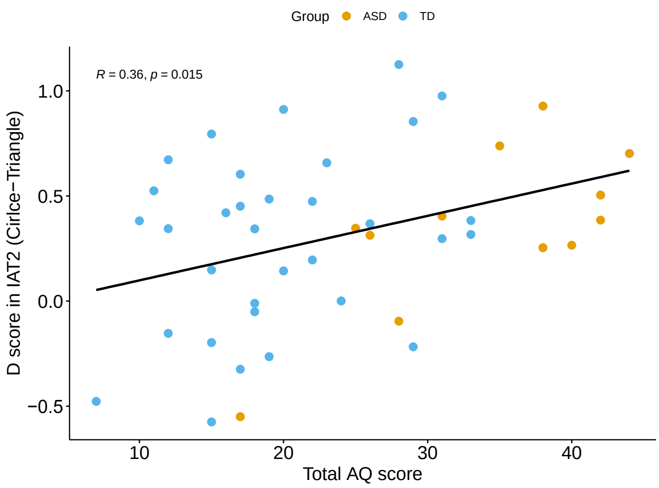

Figure 2. Correlation between total AQ scores and the D scores in IAT2 tested by circle-red and triangle-yellow associations.

It can be noticed that circle-red and triangle-yellow associations are stronger than square-blue as reported in previous studies using explicit matching task (circle-red:34%; triangle-yellow: 33%; square-blue:19%; with a chance level of 12.5%; Chen et al., 2015a). It might be possible that people with higher autistic traits have intact and stronger circle-red and triangle-yellow associations.

In summary, the current study showed that autistic traits play a role in the construction of color-shape associations. When asked explicitly, people with higher autistic traits showed fewer amount of consensual color-shape associations, suggesting a weaker prior knowledge effect. However, when tested by indirectly experimental method, using both IATs and IC task, participants with higher autistic traits showed stronger congruency effect of CSAs on both feature discrimination (revealed by IATs) and binding (revealed by IC task) for circle-red and triangle-yellow associations. Those results suggested that color-shape associations might also have statistical/structural basis, and provided further evidence for the “hypo-priors” account for autistic perception. It might also be helpful in the application level with providing support for visual design using colors and shapes for both developmental disorders and diverse people.

５．主な発表論文等

〔雑誌論文〕　計2件（うち査読付論文　2件／うち国際共著　2件／うちオープンアクセス　1件）

１．著者名 Chen Na, Watanabe Katsumi, Wada Makoto	４．巻 12
２．論文標題 People With High Autistic Traits Show Fewer Consensual Crossmodal Correspondences Between Visual Features and Tastes	５．発行年 2021年
３．雑誌名 Frontiers in Psychology	６．最初と最後の頁 1-13
掲載論文のDOI（デジタルオブジェクト識別子） 10.3389/fpsyg.2021.714277	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Chen Na, Watanabe Katsumi	４．巻 1
２．論文標題 Color-shape associations affect feature binding	５．発行年 2021年
３．雑誌名 Psychonomic Bulletin & Review	６．最初と最後の頁 169-177
掲載論文のDOI（デジタルオブジェクト識別子） なし	査読の有無 有
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〔学会発表〕　計3件（うち招待講演　1件／うち国際学会　0件）

１．発表者名 Chen Na，渡邊克巳，和田真
２．発表標題 自閉傾向が高い人は視覚と味覚のクロスモーダル対応が少ない
３．学会等名 日本心理学会
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１．発表者名 Chen Na，渡辺克巳
２．発表標題 親子ペアの色と形の連合が似ているか？
３．学会等名 日本認知心理学会
４．発表年 2021年

1．発表者名 Chen Na
2．発表標題 Color-Shape Associations in Japanese People
3．学会等名 第20回感性学研究会（招待講演）
4．発表年 2020年～2021年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関