Personality and Individual Differences 135 (2018) 45–50

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

2nd to 4th digit ratio (2D:4D) but not salivary testosterone concentration is associated with the overall pattern of color preference in females

Hirokazu Doi, Kazuyuki Shinohara*

Graduate School of Biomedical Sciences, Nagasaki University, Japan

ARTICLE INFO

Keywords:
Color
Preference
Individual differences
Androgen
2D:4D
Sex difference
Testosterone

ABSTRACT

Color is integral dimension of human visual experience. Many studies have shown individual difference in the pattern of color preference but its cause remains equivocal. Androgen exerts influences on various domains of perceptual and cognitive functions. On the basis of this, we hypothesized that organizational and activational effects of androgen influence color preference pattern.

The present study examined this hypothesis by investigating the association between the pattern of color preference and the indices of androgenic effects. We measured second-to-forth digit length ratio and salivary testosterone concentration as indices of organizational and activational effect of androgen respectively. The preference evaluations to colors were modeled by trigonometric functions to obtain parsimonious representation of the overall pattern of color preference.

The analysis revealed that the preferred color was shifted to more reddish color within blue-purple spectrum in females with high (female-typical) than low (male-typical) digit ratio. There was no association between salivary testosterone concentration and color preference either in females or males. This pattern of results indicates the possibility that organizational effect of androgen influences individual differences in color preference, giving support to the contention that biological predispositions underlie aesthetic tastes.

1. Introduction

Colors constitute an integral dimension of people's visual experience (Palmer & Schloss, 2010; Palmer, Schloss, & Sammartino, 2013; Young, 2015) and have supposedly conferred a variety of benefits for the survival of mankind throughout evolutionary history (Dominy & Lucas, 2001; Han et al., 2018; Jacobs, 2009). One interesting aspect of color is its potency to give aesthetic pleasure to viewers (Palmer et al., 2013), a function that has been aptly exploited by painters and designers (Nascimento et al., 2017; Ou, Luo, Woodcock, & Wright, 2004).

Since the early days of experimental research on color perception (Eysenck, 1941), many researchers have demonstrated the existence of prominent individual differences in preferred colors. Later studies found many factors affecting the pattern of color preferences, such as personality (Pazdaa & Thorstenson, 2018; Rosenbloom, 2006), ecological association (Palmer & Schloss, 2010; Yokosawa, Schloss, Asano, & Palmer, 2016), psychiatric condition (Grandgeorge & Masataka, 2016) and location of residence (Saito, 1996). One of the most influential determinants of color preference pattern is participants' sex. Although several studies have failed to find robust sex difference (Bonnardel, Beniwal, Dubey, Pande, & Bimler, 2018; Yokosawa et al., 2016), many have replicated the general pattern that female participants show a preference for warmer and reddish colors, while male participants prefer bluish colors more strongly than their opposite sex counterparts (Ellis & Ficek, 2001; Hurlbert & Ling, 2007).

There is a controversy over the roots of sex difference in color preference. Some researchers point out the possibility that sex difference is formed through the process of cultural assimilation (Turgeon, 2008). According to this theory, boys and girls are prompted to play with toys or wear clothes of gender-stereotypical colors, *e.g.* pink for girls and blue for boys in industrialized countries, and thereby postnatally acquire preference for each color. At the same time, others argue in favor of the contributions of biological predispositions (Alexander & Hines, 2002; Wallen & Hassett, 2009) as the determinants of color preference pattern (Hurlbert & Ling, 2007).

Androgen plays pivotal roles in shaping sexual dimorphism in behavioral patterns (Cohen-Bendahan, Van De Beek, & Berenbaum, 2005; Hönekopp, Bartholdt, Beier, & Liebert, 2007). Visual perception is no exception to this, and support for the androgenic influence on color preference comes from the analysis of drawings by girls with congenital adrenal hyperplasia (CAH), a condition in which excessive level of androgen is secreted due to the lack of the enzyme necessary for

* Corresponding author at: Graduate School of Biomedical Sciences, Nagasaki University, 1-12-4 Sakamoto-Cho, Nagasaki City, Nagasaki 852-8523, Japan.
E-mail address: shinokazu0403@yahoo.co.jp (K. Shinohara).

https://doi.org/10.1016/j.paid.2018.06.047
Received 12 April 2018; Received in revised form 21 June 2018; Accepted 22 June 2018

corticoid synthesis. Iijima, Arisaka, Minamoto, and Arai (2001) reported that girls with CAH use warm colors less frequently in their drawings than those without CAH. Considering this, it is plausible to conjecture that androgen influences individual differences in color preference.

Androgen is supposed to shape each individual's behavioral pattern through organizational and activational effects on the neural system although some researchers dispute the clear dissociation of these effects (Arnold & Breedlove, 1985). Exposure to different levels of androgen from the first trimester of gestation leads to sexual differentiation of the brain ("organizational effect"; Malas, Dogan, Evcil, & Desdicioglu, 2006). The neural system is exposed to differential levels of androgen in male and female individuals after puberty, which also shapes sexually dimorphic patterns of neural function and behavior ("activational effect"). Given the scarcity of studies that directly examined the association between color preference and androgenic function, it remains to be seen whether these two facets of androgenic effect influence color preference pattern in a differential manner.

The present study aimed to investigate the influences of androgen on the pattern of color preference in healthy male and female samples. As an index of organizational effect of androgen, we measured second-to-fourth digit length ratio (2D:4D; Hönekopp et al., 2007). The length of the index finger divided by the ring finger, 2D:4D, is generally accepted as the marker of the level of prenatal androgen exposure (Hönekopp et al., 2007; Manning, Scutt, Wilson, & Lewis-Jones, 1998): higher level of prenatal androgen exposure leads to smaller 2D:4D (Hönekopp et al., 2007; Malas et al., 2006). In support of this, many studies have replicated smaller 2D:4D in male than female subjects. Moreover, 2D:4D can be controlled by manipulating bioavailability of androgen in rodents (Talarovicová, Krsková, & Blazeková, 2009; Zheng & Cohn, 2011). In addition to being present before two years of age (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004; Malas et al., 2006; Manning et al., 1998), 2D:4D is reported to be predictive of the degree of sexually dimorphic traits even within same-sex population (Aycinena & Rentschler, 2018; Collaer, Reimers, & Manning, 2007; Hönekopp, Voracek, & Manning, 2006; Pokrywka, Rachoń, Suchecka-Rachoń, & Bitel, 2005). Activational effect of androgen was quantified by measuring salivary concentration of testosterone. Because the testosterone level in a saliva sample is reflective of free testosterone and testosterone only weakly binds to sex hormone binding globulin (Papacosta & Nassis, 2011), it is considered to be a reliable indicator of bioavailability of testosterone. Previous studies have repeatedly found associations between the trait-level of testosterone and a variety of behavioral traits including rebelliousness and impulsivity (Dabbs, Jurkovic, & Frady, 1991; Dabbs, Carr, Frady, & Riad, 1995; Mazur & Booth, 1998, 2014).

The majority of previous studies on color preference measured people's preference for discretely-sampled color set. Conversely, we adapted a model-based approach to characterize each individual's pattern of color preference. Recently, Schloss, Lessard, Racey, and Hurlbert (in press) have shown that individual's color preference pattern can be modeled in cylindrical coordinate system within CIE L*a*b* color space using trigonometric functions with phase shift. Using this approach, we quantified fundamental pattern of color preference in a parsimonious way and investigated their association with organizational and activational effects of androgen.

2. Method

2.1. Participants

The present study included 39 male (age range: 18–29) and 45 female (age range: 18–38) participants with normal or corrected to normal visual acuity after they gave written informed consent. They were recruited from universities and vocational schools in Nagasaki City by flyers and posters. None reported a history of psychiatric condition or problems in trichromatic vision. The demographic information is summarized in Table 1. As expected, the testosterone level was significantly higher (t (82) = −9.73, p < .001) and 2D:4D was significantly smaller (t (82) = −3.31, p = .0013) in male than female participants.

Table 1
Mean and standard deviation of age, salivary testosterone concentration and 2D:4D in each sex. In the parenthesis are the standard deviations.

	Female		Male	
Age (years)	22.6	(5.7)	21.1	(2.6)
Testosterone (pg/ml)	62.1**	(26.3)	163.8	(64.2)
2D:4D (%)	97.7**	(2.8)	95.7	(2.7)

** p < .01 in group comparison.

2.2. Procedure

2.2.1. Color preference measurement

Color preference was measured with an in-house-made software using 21 inch LCD monitor whose color was calibrated using Spyder 4Pro (datacolor, New Jersey, USA). The luminance at the white point was 121.7 cd/m^2. In each trial, a square picture window subtending about 4.2 × 4.2 cm was presented on the left side of the display against gray background with a vertical trackbar on the right side. At the start of each trial, the picture window was painted in the same gray color as the background. After 2 s of the start of the trial, the color of the picture window changed from gray to the color that the participant had to evaluate. After 2 s of color change, the trackbar was enabled. The uppermost edge of the trackbar was labeled "Like Very Much" while the lowermost was "Don't Like At All." The participant's task was to move the trackbar to the location where their feeling towards the color was most appropriately reflected in 19 levels. The colors from eight color categories (Red, Orange, Yellow, Yellow Green, Green, Green Blue, Blue, and Purple) were each presented four times. In order to avoid repetition of the identical color, the lightness and chroma of colors were slightly changed within each color category. Thus, a participant made evaluations of a total of 32 colors (see Appendix A for the attributes of the 32 colors presented).

2.2.2. 2D:4D measurement

The lengths of index and ring fingers in right and left hand were measured directly (Ribeiro, Neave, Morais, & Manning, 2016) using a digital caliper (Shinwa Measuring tools Corp. Niigata, Japan) and recorded by the experimenter (HD). Each finger was measured twice and averaged in each hand. This procedure for 2D:4D measurement was modeled after the previous studies (Collaer et al., 2007; Rothkopf & Turgeon, 2014; Turgeon, 2008). We used finger length in the right hand in the further analyses, because previous studies suggested that 2D:4D in the right hand is more closely linked to the level of prenatal androgen exposure than the left hand (Hönekopp & Watson, 2010; Manning et al., 1998; Williams et al., 2000). The intra-class correlation (ICC; McGraw & Wong, 1996) for the repeated measurement of 2D:4D in the right hand was high (ICC = 0.968).

2.2.3. Salivary testosterone concentration measurement

The saliva sample was collected between noon and 14:00 h in order to mitigate the influences of circadian fluctuation (Dabbs, 1990). Each saliva sample was collected into a polystyrene tube by passive drool and stored at −80 °C until the assay. The participants refrained from eating, drinking, smoking, brushing teeth, and exercising for 1 h prior to the experiment. They also rinsed their mouths with water about 15 min before the sample collection.

After all participants had completed the experimental tasks, the concentration of salivary testosterone in each sample was assayed