Evolution and Human Behavior 37 (2016) 35–39

Contents lists available at ScienceDirect

Evolution and Human Behavior

journal homepage: www.ehbonline.org

Original Article

Preferences for visible white sclera in adults, children and autism spectrum disorder children: implications of the cooperative eye hypothesis☆

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ARTICLE INFO

Article history:
Initial receipt 4 April 2015
Final revision received 26 June 2015

Keywords:
Gaze-signaling
Social cognition
Eye morphology
Autism spectrum

ABSTRACT

Visible white sclera (i.e., the opaque white outer coat enclosing the eyeball) is a uniquely human trait. An explanation for why such coloration evolved has been put forward by the Cooperative Eye Hypothesis (Kobayashi and Hashiya, 2011; Kobayashi and Kohshima, 1997, 2001; Tomasello et al., 2007), which states that visible white sclera evolved to facilitate communication via joint attention and signaling of gaze direction. Therefore, we hypothesized that viewers comprised of both typically developing children and adults would show reliable preferences for stimuli with visible white sclera. However, because autism spectrum disorder (ASD) individuals have impaired social cognition and show gaze aversion, we also hypothesized that ASD children would show no consistent preference for eyes with visible white sclera. We tested these hypotheses by obtaining participants' preferences across six sets of stuffed animals, identical but for the manipulation of eye size, eye color, and presence of visible sclera. Both hypotheses were supported. In addition to providing evidence consistent with the Cooperative Eye Hypothesis, our results also suggest that eyes and gaze serve a central role in social cognition. Furthermore, our results from ASD children have practical applications for therapeutic practices and evidence-based interventions.

1. Introduction

Visible white sclera (i.e., the opaque white outer coat enclosing the eyeball) is a uniquely human morphological trait. Other primates have sclera, but it is either pigmented or, if white, not visible (e.g., Fig. 1 compares the sclera of the orangutan and human). The Cooperative Eye Hypothesis asserts that visible white sclera evolved to facilitate communication via joint attention and signaling of gaze direction (Kobayashi & Hashiya, 2011; Kobayashi & Kohshima, 1997, 2001; Tomasello, Hare, Lehmann, & Call, 2007). Tracking another's gaze facilitates variant forms of social exchange, giving benefits to both signaler and receiver. As with other biological signals, visible white sclera evolved because it was beneficial to the signaler through its influence on the behavior of receivers (Bradbury & Vehrenkamp, 1998). That is, possessing visible white sclera allowed one to enjoy the benefits of social life.

The African great apes, as well as humans, track the gaze direction of others. A series of controlled experiments showed that chimpanzees follow the direction of others geometrically to given locations (Tomasello, Hare, & Agnetta, 1999). Specifically, chimpanzees looked around barriers more when humans did so than when humans directed their gaze elsewhere. In addition, when presented with a distractor, the chimpanzees looked at it, but continued to follow the human experimenter's gaze.

In another series of experiments, two chimpanzees, one orangutan and ten human infants (age 18 to 27 months) were observed to determine if they relied on experimenter cues while engaging in object-choice tasks. The five types of cues were experimenter tapping on the correct object, gazing with pointing, gazing closely, gazing alone and glancing in the absence of head orientation. All five cues were used by the three subject groups (Itakura & Tanaka, 1998). Another object-choice study showed that gorillas performed well when experimenter cues included tapping or pointing to an object that held a reward. Performance stayed high when the experimenter gazed with head held in the direction of the correct choice while withholding manual gestures. However, performance fell when gaze direction was the only cue, suggesting differences in inferring intentionality, via gaze tracking, among the great apes (Peignot & Anderson, 1999). It has been argued that humans are unique in following the eyes of another in the absence of head movement. As such, it has been proposed that gaze tracking of the great apes may rely more exclusively on head direction than on other cues (Tomasello, 2007).

Preference for large eyes, by both human infants and adults, has been shown experimentally, and appears to emerge by age five months (Geldart, Maurer, & Carney, 1999). However, attraction to facial stimuli

☆ We wish to acknowledge Jennifer Jo-Brout of SENetwork for her support of this project.

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http://dx.doi.org/10.1016/j.evolhumbehav.2015.06.006
1090-5138/

with gaze directed toward the viewer has been observed in newborns between 13 and 168 h after birth (Farroni et al., 2005). A subsequent study showed that infants between 3 and 12 months of age looked longer at pictures of nonhuman primate faces in which the eyes were replaced with human eyes, as compared with non-manipulated pictures; however, this difference was not observed in newborns (Dupierrixa et al., 2013).

The color of the sclera may also be a marker for health, physical attractiveness and age. Provine, Cabrera, and Nave-Blodgett (2013) and Russell, Sweda, Porcheron, and Mauger (2014) found that individuals shown in photographs with eyes digitized to appear red or yellow were rated as less healthy, less attractive and older than individuals whose scleras were white. They proposed that a white sclera may have evolved as a contributor to human sociality. Bouissac (2001) concluded that white ocular (as well as dental) patterns enable an efficient means for conveying facial signals, a clear advantage under threatening circumstances.

1.1. Gaze Aversion in Autism Spectrum Disorder (ASD) Individuals

Gaze aversion has long been known as a marker for ASD in infants and young children (Richer, 2001; Richer & Richards, 1975). ASD children actively avoid social contact with others, even appearing to be threatened by the social approaches of others (Richer, 1976). Interestingly, ASD children in an experimental setting displayed less avoidance behavior when adults were instructed to do nothing but look back, as compared with smiling or gaze averting (Richer & Richards, 1975). In a subsequent study, ASD children looked more at adults with covered eyes and expressed less flight behavior, and looked less when adults covered only one eye. In contrast, typically developing children displayed more eye contact with adults, and showed less stereotypical behavior and less flight response (Richer & Coss, 1976).

1.2. Present study

If visible white sclera evolved in humans because those with such a trait were more likely to be selected as social partners (whether for social exchange, alliances, mating, etc.) than those without visible white sclera, then we would expect that receivers (i.e., viewers) should prefer interacting with targets with visible white sclera.

However, manipulating the visibility of a human's sclera creates disturbing images that are perceived as non-human (Seyama & Nagayama, 2007). Thus, in a unique test of the cooperative eye hypothesis, we hypothesized that typically developing children and adults would prefer toy animals with visible white sclera. And given that eyes and gaze tracking ability serve a central role in social cognition (Baron-Cohen, 1995; Itier & Batty, 1999), we also hypothesized that ASD children, whose social cognitive abilities are impaired, would not show a consistent preference.

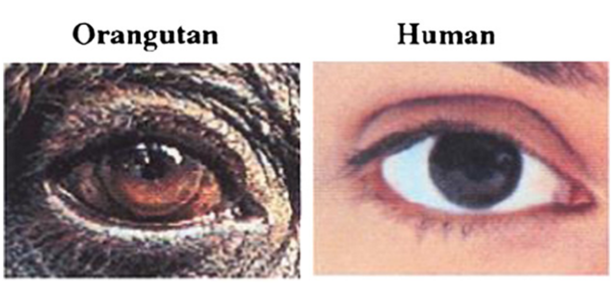

Fig. 1. Different colored sclera of the orangutan and human. Adapted from Kobayashi and Kohshima (2001).

Table 1
Age in years and sex composition of the three participant groups.

Group	N	Age (SD) Range	Males	Females
I. ASD[a] Children	25	6.80 (1.87) 4–11	20	5
II. Typical Children	49	6.76 (0.92) 4–8	32	17
III. Typical Adults	40	22.90 (2.20) 19–29	17	23

[a] Autism Spectrum Disorder

2. Method

2.1. Participants

The sample was composed of three participant groups: Group I included 49 typically developing children who attended local public elementary schools. Group II included 40 adult student volunteers who attended a large public university. Group III included 25 children with a diagnosis of ASD, including one child with Asperger's syndrome. These children were variously recruited via graduate student assistants working with ASD individuals, contacts to the university's Twin Studies Center, KIDA (Kids Institute for Development and Advancement), and personal referrals. Diagnoses of ASD were made by the children's physicians and school personnel. All participants were living in Southern California at the time of the study.

Among the ASD children were a set of monozygotic (MZ) female twins concordant for autism, one dizygotic (DZ) male co-twin (whose co-twin had a brain tumor so was excluded from the study) and the male member of an opposite-sex DZ triplet set. Their zygosity (twin type) was assessed by DNA analysis, a standard physical resemblance questionnaire and the sex difference, respectively. The male triplet had two typically developing female co-triplets included with the typically developing children; the zygosity of the two females was uncertain, based on parental responses to a physical resemblance questionnaire and inspection of photographs. There were also three male sibling pairs in which a child in one pair had physical and behavioral problems as well as ASD. The data for one child in Group III were omitted from the analyses due to her failure to comprehend the task.

The age and sex compositions of the sample are displayed in Table 1.

Table 2
Group I (ASD children): background characteristics.

	Parental Age in Years[a]		
	M	(*SD*)	Range
Mother	36.73	(5.85)	28–47
Father	38.93	(7.28)	29–54

	Diagnosis		Age in Years at Diagnosis		
	N	%	*M*	(*SD*)	Range
Asperger's Syndrome	1	4.8	5.75		
Autism	18	85.7	3.41	(1.60)	1.00–6.08
PPD-NOS[b]	1	4.8	4.17		
ASD	1	4.8	2.00		

	Classroom Type	
	N	%
Inclusion/Mainstreaming With Support	4	19.0
Special Education	3	14.3
Autistic Support	6	28.6
Special Education + Mainstreaming	1	4.5
Mainstreaming + Support	6	28.6
Not Apply	1	4.8

[a] Parents of twins and siblings entered once; data missing for 2 families ($N = 15$).
[b] Pervasive Developmental Disorder-Not Otherwise Specified; used interchangeably with ASD.