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Is there an innate gaze module? Evidence from human neonates

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Abstract

Evidence from various fields that suggests humans have a specialized neural system dedicated to perceiving another's eyes and detecting the direction in which they are gazing. The evidence is, however, inconclusive about whether this system is already operating in neonates. 105 neonates were presented with two photographs separately. One was a female adult face with the eyes open and the other was the same face with the eyes closed. Results indicated that the neonates spent significantly more time looking at the photograph with the eyes open than at the photograph with the eyes closed. This result may reflect that neonates have a special neural mechanism that detects eye-like stimuli in the environment and orients attention towards them. This new visual preference in infants warrants further research. © 2000 Elsevier Science Inc. All rights reserved.

1. Introduction

Neonates show a preference for face-like patterns very early in development (Fantz, 1963; Fantz, 1961; Goren, Sarty & Wu, 1975; Johnson et al., 1991; Valenza et al., 1996). This has been explained by the structural hypothesis, which argues that the content and configuration of the stimulus matter, not just its sensory and energy properties (Johnson & Morton, 1991; Morton & Johnson, 1991). There is considerable evidence in favor of the structural hypothesis (Simion, Valenza & Umilta, 1998; Valenza et al., 1996).

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The structural hypothesis claims that at birth, the visual system is oriented towards faces by a subcortical neural mechanism (Conspec) that contains structural information about the relative spatial location of elements within a face. Conspec's function is to direct the newborn's gaze to any face-like pattern in the visual field. A number of experiments lead to the conclusion that "Conspec is specified in (no) more detail than three high-contrast blobs." (Johnson & Morton, 1991). On this account, the face is only special to neonates in the sense that three blobs in the natural configuration are sufficient to trigger a simple face-detector. It appears to not matter whether the blobs are square or oval.

One implication of this is that the eyes are not special stimuli. This seems odd, given that from an evolutionary point of view, it would appear highly adaptive to be sensitive to another organism's eyes and to be able to analyze where that organism's gaze is directed (Baron-Cohen, 1995; Langton, Watt & Bruce, 2000). Recognizing that you are the focus of attention of another organism serves as an early warning system that the other animal may aim to attack you, or be interested in you for some other reason. Detecting eyes turns out to be widespread among various species. This may be particularly important in the relationship between prey and predator, or threat, since most animals react with avoidance or fear to eyes directed at them (Baron-Cohen, 1995). In primates, eye contact can mediate both playful, affiliative, and aggressive interactions (Argyle & Cook, 1976; Van Hooff, 1962). In humans, eye contact is used to regulate turn-taking in conversation, to express intimacy, and to exercise social control (Kleinke, 1986).

One idea is that there is an evolved neural mechanism devoted to gaze processing (Baron-Cohen, 1994, 1995)—an eye-direction detector (EDD) or gaze module. It is proposed that this is dedicated to the task of detecting the presence of eyes (or eye-like stimuli). There are 5 lines of evidence supporting these claims.

(1) Infancy research: By the age of 2 months old, human infants show a preference for looking at the eyes over other regions of the face (Hainline, 1978; Haith, Bergman & Moore, 1977; Maurer, 1985). By 4 months of age infants discriminate between direct and averted gaze (Johnson & Vecera, 1993; Vecera & Johnson, 1995) and by 5 months of age infants look longer at a face showing direct eye-contact (Lasky & Klein, 1979). Three-month old infants also turn their eyes to a given target more rapidly if the location of that target had been previously cued by an adult's gaze direction (Hood, Willen & Driver, 1998).

(2) Adult attention studies: Using a cueing paradigm (Posner, 1980), eye direction triggers automatic shifts in adult viewers' visual attention. This is even the case when participants are asked to try to ignore these cues, or if the gazed-at direction does not predict the location of the target (Driver et al., 1999; Friesen & Kingsone, 1998; Langton & Bruce, 1999). These findings are in line with the idea of a gaze module, which processes gaze rapidly and obligatorily.

(3) Neurophysiology research: Using single-cell recording, certain cells have been identified in the superior temporal sulcus (STS) in the macaque brain temporal lobe that respond maximally to the particular direction in which another monkey's eyes are looking or head is pointing (Perrett, 1992, 1985). Mutual eye contact also produces

galvanic skin responses (Nichols & Champness, 1971) and brainstem arousal in monkeys (Wada, 1961).

(4) Neuroimaging studies: PET and fMRI studies in humans confirm the role of the STS in gaze perception (Puce et al., 1998; Wicker et al., 1998).

(5) Lesion studies: Lesions in the STS area of the macaque brain lead the monkey to fail on eye-direction judgments while their performance on other face-processing tasks is unaffected. Humans whose brains are damaged in corresponding areas also show impairment in gaze recognition tasks (Campbell et al., 1990; Heywood & Cowey, 1992).

All of the above evidence suggests the existence of a specialized neural system dedicated to perceiving another's eyes and the direction in which they are gazing. Perrett and colleagues raise the possibility that this could simply be part of a broader 'direction of attention detector'. However, we still do not know if there is an inborn tendency to orient towards the eyes. Therefore the study reported below tested whether detection of and orientation to the eyes is evident in neonates only a few hours old.

One hundred and sixty randomly selected normal, healthy neonates were tested at the Rosie Maternity Unit, Addenbrookes Hospital, Cambridge. 105 (47 males and 58 females) of the 160 neonates completed testing according to our previously set inclusion criteria. The mean age of the final sample was x = 36.6 hr (sd = 25.9). The mean gestation age was x = 39.6 weeks (sd = 1.3). The mean birth weight was x = 3480.8 grams (sd = 450.3). 61 had been born by normal delivery and 44 by Cesarean section. All subjects had an Apgar score of 9 or 10 at 5 min. Written consent to the testing was always obtained from one of the parents.

Two life-size photos of the same female face were used in the experiments. The expression of the face on the two photos was the same: neutral. The only difference between the photos was that on one of them the eyes were closed and on the other one they were open (see Fig. 1). The photos were attached to a stick, back-to-back. Each stimulus was presented separately, for a maximum of 70 s, to allow a large enough range to detect individual differences in looking time at the stimulus.

The neonates were presented with the photos in one of two counterbalanced orders (eyes-open first, then eyes-closed; or vice versa). Testing was carried out at the mother's bedside or in the neonatal nursery on the maternity ward, the choice of location depending on which was quietest. Overhead lighting was held constant. The subject lay on his or her back in the crib or on the parent's lap, care being taken that the parent's face could not be seen by the infant. If needed, the subject's head was supported on either side with two pillows so as to keep it in middle position. Each stimulus was positioned 20 cms above the subject's face.

A trial began when the newborn was spontaneously in a state of alert inactivity (Ashton, 1973). Each stimulus was presented for a maximum of 70 s. If the infant became fussy or cried, the trial was suspended and later restarted so that the total presentation time of the stimulus still amounted to 70 s. If the infant completed $>$ 53 s (75% of the target time) before becoming distressed, the trial was not restarted. Thus, the stimulus was presented for a minimum of 53 s and a maximum of 70 s. During this time a second experimenter filmed the

Fig. 1. The two photos used in the experiment.

infant's face and thus eye-direction and -movement. To be included in the sample, an infant had to be judged to be looking at the stimulus for at least 3 s. Looking time was calculated as a proportion of total duration of trial.

The videotapes were coded by two judges to calculate the number of seconds each infant looked at each stimulus. While coding, the judges were blind to which stimulus the infant was actually looking at. A second pair of observers, independent of the first pair, were trained to use the same coding technique for 20 randomly selected infants, to estimate the inter-rater reliability. The agreement, measured as the correlation between the observers' recorded looking time for both conditions was 0.69, $p < 0.001$.

The data were analyzed to determine whether newborns looked longer at the photo of a face with eyes open than the photo of the same face with the eyes closed. A repeated measures analysis of variance (ANOVA) comparing percentage of time looking at the eyes open vs. eyes closed. The between-subject factors were gender (male vs. female), birth type (spontaneous delivery vs. Cesarean section), and order of stimulus presentation (eyes open first vs. eyes open second). As predicted, the only significant result was a main effect of stimulus type ($F(1, 89) = 9.4$, $p = 0.003$). The babies spent more time looking at the photograph with the eyes open (mean percentage looking time = 46.5, sd = 24.4) than at the photograph with the eyes closed (mean percentage looking time = 40.0, sd = 23.9). The results from the ANOVA were replicated when age, birth-weight, length of gestation, and duration of each subject's trial, were entered as covariates. These results show that newborns prefer to look at a photo of a face with eyes open than the same face with the eyes closed.

From this study the following conclusions can be drawn. Using a preferential looking paradigm, human neonates look significantly longer at a photo of a face with eyes open than at a photo of the same face with eyes closed. This new infant visual preference finding warrants further investigation. One possibility is that this may reflect the existence of an innate mechanism in neonates that detects eye-like stimuli in the environment and orients attention toward them. This will need to be tested against other possible interpretations.

In other experiments, no significant difference in the attractiveness of a schematic face over a stimulus composed of three dark squares in the appropriate locations for eyes and mouth was found (Johnson & Morton, 1991; Johnson et al., 1991). These results can may be reconciled with our findings by noting the differences in the stimuli used. In the earlier work, the stimuli were schematic. In the present experiment the stimuli were realistic. This suggests that to the extent that there is an innate preference for looking at open eyes over closed eyes, only highly realistic eye-like patterns are recognized.

The two photos were carefully matched to be as similar as possible in every way except the eye-region, to eliminate other differences between the stimuli (e.g. in emotional expression, orientation of eyebrows, mouth position, skin color, luminance, etc.). However, one alternative interpretation of our results is that these reflect differences in the amount of effective energy in the patterns, or simply, their visibility to the infant, as claimed by advocates of the sensory hypothesis. The sensory hypothesis claims that the neonatal face preference effect is simply a function of the amplitude spectrum, comprising the amplitude and orientation of the component spatial frequencies, and the phase spectrum, comprising the phase and orientation of the components (Banks & Salapatek, 1981; Kleiner, 1987, 1990, 1993). This could be relevant to the present results because the eye, as a visual stimulus, has a number of simple and potentially powerful features (Watt, 1999), outlined next.

Detecting gaze direction involves among other things detecting the contrast between the white of the sclera and the dark of the iris and the pupil, with contrast sensitivity being a general property of the visual system (Baron-Cohen, 1994, 1995). There may be external features that also need to be coded, such as head direction or body orientation, but the information within the eye-region is clearly important. Eye direction is particularly simple to detect because of the form of the eye and its interaction with the functional properties of cortical simple cells (Langton et al., 2000). These simple cells of the striate cortex respond vigorously over the whole of the eye.

The response of these cells is divided into three spatially separate parts: one to each of the two visible parts of the sclera and one to the pupil. As the eye turns, the cells' response to the scleral parts change in their relative strength, resulting in the monotonic function of eye direction detection. This implies that the eye may be a special stimulus only in the sense that a vast amount of sensory information can be recovered from it with simple processing mechanisms. To test if the sensory hypothesis can explain the present results a further experiment would be needed, comparing eyes facing forward vs. eyes averted, these being equated for sensory information. Note that the sensory hypothesis and the EDD theories are not mutually exclusive: it may be that the eyes are indeed special stimuli, *and* we have evolved sensory mechanisms to perceive them.

The present results have implications for the structural theory of neonatal face perception. The view that the cognitive mechanism underlying neonatal face perception is indifferent to what the high-contrast elements are like so long as they are in the right spatial location (Johnson & Morton, 1991) is clearly not sufficient to explain our results. This is because even in the eyes closed stimulus, there are still three high contrast blobs. Rather, the newborns' visual system appears to specifically search for eyes in another human face. This preference that we have found warrants further investigation.

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