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Brief Report

Preference for human eyes in human infants



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ABSTRACT

Despite evidence supporting an early attraction to human faces, the nature of the face representation in neonates and its development during the first year after birth remain poorly understood. One suggestion is that an early preference for human faces reflects an attraction toward human eyes because human eyes are distinctive compared with other animals. In accord with this proposal, prior empirical studies have demonstrated the importance of the eye region in face processing in adults and infants. However, an attraction for the human eye has never been shown directly in infants. The current study aimed to investigate whether an attraction for human eyes would be present in newborns and older infants. With the use of a preferential looking time paradigm, newborns and 3-, 6-, 9-, and 12-month-olds were simultaneously presented with a pair of nonhuman primate faces (chimpanzees and Barbary macaques) that differed only by the eyes, thereby pairing a face with original nonhuman primate eyes with the same face in which the eyes were replaced by human eyes. Our results revealed that no preference was observed in newborns, but a preference for nonhuman primate faces with human eyes emerged from 3 months of age and remained stable thereafter. The findings are discussed in terms of how a preference for human eyes may emerge during the first few months after birth.

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Introduction

One hypothesis about how infants process face stimuli is that early mechanisms, which have evolved from our ancestral history, predispose us to initially attend to faces at birth and subsequently to learn about faces via visual experience (Pascalis & Kelly, 2009; Slater & Quinn, 2001). Newborns' attraction toward typical faces compared with scrambled faces might be an illustration of those early mechanisms. Johnson (2005) proposed that this early orientation may be driven at birth by a face detector system, CONSPEC, which is a low spatial frequency (LSF) subcortical system responding to very basic information regarding the visual structural characteristics of a human face such as positive stimulus contrast, a bounded oval, two eyes, a nose, and a mouth. A cortical system that retains fine details regarding the visual characteristics of individual conspecifics via experience, CONLERN, will emerge at around 2 months of age.

If a crude representation of the human face (two eyes, a nose, and a mouth) attracts infants' attention, any faces that share the same general arrangement should have the same power. However, Heron-Delaney, Wirth, and Pascalis (2011) found a neonatal preference toward human faces compared with macaque faces using colored pictures, concluding that a few days of exposure to human faces was sufficient to allow them to differentiate human from nonhuman primate faces. Di Giorgio, Leo, Pascalis, and Simion (2012), using similar stimuli equated for low-level perceptual properties, failed to replicate such a preference for human faces in newborns. However, Di Giorgio, Meary, Pascalis, and Simion (2013) reported it as early as 3 months of age. In the latter study, most of the infants' fixations were toward the eye region of the faces, but infants were even more focused on the eye area of the human faces.

The scanning path observed in Di Giorgio and colleagues' (2013) study suggests that human eyes engaged the visual attention of 3-month-olds more so than monkey eyes. An attraction toward human eyes early in development would be consistent with the fact that the human eye is distinctive relative to that in nonhuman primates and other animals; it has a widely exposed white sclera that is paler than the facial skin or iris (Kobayashi & Kohshima, 1997). The unique anatomical evolution of the human eye may be linked to the emergence of an elaborate system of social cognition (Emery, 2000). This hypothesis is in line with Baron-Cohen's (1995) theory that human eyes play a predominant role in the early face processing system via the existence of an "eye direction detector." The system first detects the presence of eyes and then codes their direction. The first of these functions was argued by Baron-Cohen to be innate, whereas the second should emerge later.

An issue raised by the prior work on face preference and attention to the eyes is whether the early preference for human faces is driven mainly by a preference for human eyes. The importance of eyes for categorization and social cognition has been well documented in adults. Eyes attract attention, convey an extensive amount of information, and are well known to play a central role in face processing and social communication in general (Emery, 2000). Adults electrophysiological studies suggest that the early perceptual stage of face processing, elicited approximately 170 ms after face presentation, is driven by the eye region, which would be processed first, between 100 and 150 ms (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996; Itier, Alain, Sedore, & McIntosh, 2007; Schyns, Petro, & Smith, 2007). Interestingly, it has been shown that the early perceptual stage of face processing is human specific, and it has been suggested that human eyes contribute to a large extent to this species specificity (Itier, Van Roon, & Alain, 2011; Shibata et al., 2002).

The importance of the eye region in face processing is also supported by empirical studies in infants. Newborns prefer to look at faces with open eyes or gaze directed straight at them when paired with the same faces with closed eyes or averted gaze, respectively (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). Farroni and colleagues (2005) showed that the preference for upright schematic faces in newborns (Simion, Turati, Valenza, & Leo, 2006) requires the contrast polarity characteristic of the eyes. Finally, electrophysiological data indicate that the brain response to isolated eyes is mature well before the brain response to a full face, suggesting that the importance of the eyes may be even more apparent early in development than in adults (Taylor, Edmonds, McCarthy, & Allison, 2001). Taken together, these studies reveal the crucial role of the eye region from an early age.

However, an attraction for *human* eyes per se, which could drive the preference observed for human faces compared with animal faces, has not been directly shown in newborns or older infants. Regardless of the reason for such attraction (e.g., low-level visual cues, a more sophisticated human eye detector), our main objective was to determine whether *human* eyes can trigger a heightened level of attention early in development. The current study aimed to investigate this question and determine whether and when the importance and attraction for human eyes might appear during the first year after birth. We created stimuli that differed only by the presence or absence of human eyes. To avoid interference from the overall structure of the human face, we inserted human eyes into a monkey or ape face, which has the advantage of having a structure similar to human faces but with eyes that do not present the human species' specificity (e.g., sclera). If human eyes per se trigger a heightened level of attention, infants should orient more toward a nonhuman primate face with human eyes (HumanEyes–Face) when paired with the original nonhuman primate face with nonhuman eyes (NonHumanEyes–Face). Furthermore, given the high contrast of the human eye, such behavior would be expected from the first week after birth. Thus, we tested newborns and 3-, 6-, 9-, and 12-month-olds.

Method

Participants

A total of 145 healthy full-term newborns and 3-, 6-, 9-, and 12-month-olds were included in the final analysis. There were 29 newborns (mean age = 3 days, $SD = 1$, 16 girls and 13 boys), 30 3-month-olds (mean age = 113 days, $SD = 5$, 16 girls and 14 boys), 30 6-month-olds (mean age = 194 days, $SD = 5$, 15 girls and 15 boys), 30 9-month-olds (mean age = 283 days, $SD = 6$, 13 girls and 17 boys), and 26 12-month-olds (mean age = 376 days, $SD = 7$, 11 girls and 15 boys). A further 85 infants were eliminated from the analysis due to technical problems or mother's interference during recording (6 newborns, 6 3-month-olds, 5 6-month-olds, 1 9-month-old, and 2 12-month-olds), changing state during the test (8 newborns, 2 3-month-olds, 7 6-month-olds, 6 9-month-olds, and 1 12-month-old), strong position bias where the child looked in one direction more than 95% of the time (11 newborns, 5 3-month-olds, 9 6-month-olds, 2 9-month-olds, and 2 12-month-olds), or insufficient looking time toward the stimuli (3 newborns, 4 3-month-olds, 2 6-month-olds, and 3 9-month-olds). An additional 18 infants were randomly eliminated from the analysis in order to equalize sample sizes.

Stimuli

Stimuli were fully colored face stimuli of three Barbary macaques and three chimpanzees (21×17 cm, i.e., 41×33 degrees for newborns and 20×16 degrees for older infants). Nonhuman primate faces were duplicated by replacing the original eyes with human eyes. Two different exemplars of human eyes were used to create two pairs of stimuli for each individual, pairing the face with original eyes with the face with human eyes. This yielded a total of 12 different pairs of stimuli (2 species \times 3 individuals \times 2 pairs of human eyes). Analysis of the low-level visual properties of the pictures showed that inserting human eyes resulted in a significant increase of luminance and contrast in the eye region (Fig. 1).

Procedure

Overall, the same procedure was used for all age groups. The infants were tested in a quiet room, where they were seated on a parent's lap approximately 60 cm (30 cm for newborns) away from a screen onto which the pairs of face stimuli were projected using E-Prime 2 software. All parents were instructed to fixate centrally above the screen and to remain quiet during testing. A video camera (specialized for low light conditions) was used to film the infants' eye movements during stimulus presentation. The film was then digitized to be analyzed offline, frame by frame, by two blind independent observers. Inter-observer agreement was calculated on 33% of the participants from the final sample and showed high reliability (Pearson's $r = .96$).

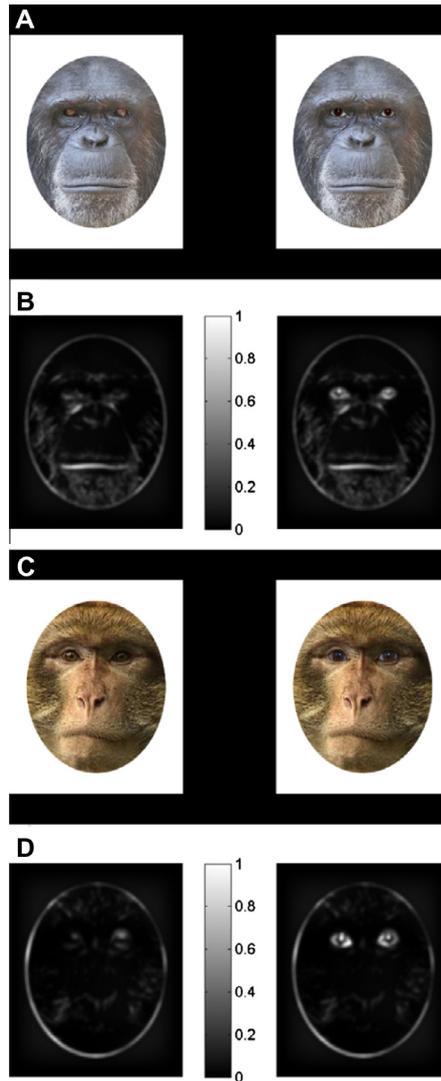


Fig. 1. Experimental stimuli (A,C) and their averaged saliency maps (B,D). Chimpanzee (A) and Barbary macaque (C) faces with their original eyes and human eyes were prepared using Adobe Photoshop 12.0. Inserting human eyes resulted in a slight but significant increase of luminance in the eye region compared with nonhuman primate faces with original eyes (23.36 candela/m² for NonHumanEyes–Face vs. 25.17 candela/m² for HumanEyes–Face), $t(5) = 3.02, p < .05$. Luminance values were estimated for each face on the basis of spectrophotometric measurements of screen emittance (SpectraScan PR650, PhotoResearch). With respect to contrast, the effect of inserting human eyes into a nonhuman primate face is illustrated here by the chimpanzee (B) and Barbary macaque (D) saliency maps, expressed in arbitrary units normalized for the maximum saliency found over the set of stimuli (Ho Phuoc, Guyader, & Guérin-Dugué, 2010). As shown, inserting human eyes into nonhuman primate faces resulted in a significant increase of contrast in the eye region, where saliency for each pair was, on average, multiplied by 2.8 compared with stimuli with original eyes, $t(5) = 6.81, p < .005$. Because saliency models are derived from an adult model of low-level visual processing, the saliency maps used here can only approximate local energy according to an infant model. The overall lower contrast sensitivity of infants up to 8 months of age and their lack of sensitivity for spatial frequencies over 3 cycles per degree (CPD; Banks, 1982) would result in lower saliency values for the high spatial frequency components of the image. Still, the maps capture the gist of the infant saliency maps because the human eyes inserted into the monkey faces subtended approximately 3 degrees of visual angle for the newborns and approximately 1.5 degrees for the infants. We can estimate the main spatial frequencies of the high contrast region formed by the sclera and iris at 0.5 and 1 CPD for the newborns and infants, respectively. In sum, the images are large enough for the detection of the high contrast region formed by the human eyes, even for our younger participants.

Half of the participants saw chimpanzees' faces, and the other half saw macaques' faces. There were two test trials during which two pairs of different individuals were presented. Images were displayed side by side, separated by a 13-cm gap. The different pairs of stimuli were counterbalanced across participants. The left–right position of the original and human eyes was counterbalanced across infants on the first trial and reversed on the following trial.

Before each trial, an attention-getter attracted the infants' gaze toward the screen middle. The trial started when the infants looked at one of the two stimuli and ended after 10 s had elapsed for the 3-, 6-, 9-, and 12-month-olds. For newborns, it ended after a cumulative 10 s of looking time duration. This procedural difference in presentation time is not unusual (e.g., Quinn et al., 2008) and allowed us to obtain maximum as well as similar looking durations for newborns and older infants.

Results

Preference for HumanEyes–Face compared with NonHumanEyes–Face was assessed for each participant by calculating the relative percentage of time spent looking at HumanEyes–Face. This score corresponded to the summed looking time to HumanEyes–Face divided by the summed looking time to both HumanEyes–Face and NonHumanEyes–Face, then converted to a percentage score. On average, newborns spent 49% of the time looking at HumanEyes–Face, whereas older infants looked longer at HumanEyes–Face with mean scores above 50% (see Fig. 2). An analysis of variance (ANOVA) with age (newborns or 3-, 6-, 9-, or 12-month-olds) and species (chimpanzee or macaque) as between-participant factors was conducted using Statistica (version 10) in order to test whether and when a preference for human eyes appeared during the first year. The analysis revealed a main effect of age, $F(4, 135) = 2.52$, $p < .05$, $\eta_p^2 = .07$. The main effect of species, $F(1, 135) = 1.37$, $p > .05$, and the Age \times Species interaction, $F(4, 135) < 1$, were not significant.

The age effect was further explored using a contrast analysis (decomposition of the omnibus effect in its 1 degree of freedom components). Bonferroni post hoc corrections for all possible pairwise comparisons ($c = 10$) were applied on the alpha threshold because we did not have a clear-cut a priori hypothesis about when the preference for human eyes might appear. The analysis showed that newborns differed from older infants (i.e., 3-, 6-, 9-, and 12-month-olds), $F(1, 135) = 8.92$, $p = .003$, $\eta_p^2 = .06$, $\alpha_{\text{Bonferroni-adjusted}} = .005$. It explained 88.5% of the total variance of the age effect, and the test of the residual treatment (the unexplained variance) was not significant, $F(3, 135) < 1$, showing that older infants did not differ from each other. Thus, the contrast analysis showed that the time spent looking at HumanEyes–Face increased significantly at 3 months after birth and remained stable until the end of the first year.

To confirm that the age effect was associated with the emergence of a reliable preference for HumanEyes–Face in older infants, we tested the mean percentage scores of looking time against chance (i.e., 50%) by performing one-sample Student t tests. Given that our design comprised an unusually high number of age groups, performing multiple t tests (one in each group) would have substantially increased Type I or II errors. Because the ANOVA revealed a theoretically coherent two-step function that contrasted newborns and older infants without any species effect, we overcame this problem by performing two independent t tests on newborns and on the combination of older infants' data collapsed across species. We applied Bonferroni post hoc corrections because the combinations of age groups were a posteriori defined. Consistent with the contrast analysis, the newborns' scores did not differ from 50% ($t < 1$), showing no preference for any faces, whereas the older infants' scores were significantly greater than chance, $t(115) = 5.80$, $p = 1\text{E-}07$, $\alpha_{\text{Bonferroni-adjusted}} = .01$, demonstrating that older infants as a whole systematically preferred looking at HumanEyes–Face. Note that separate analyses in each of these older infant groups confirmed a significant preference for human eyes in all groups ($ps < .05$). In addition, the proportion of infants displaying individual preference for the human eyes was significantly greater than 50% in each older infant group except for the 3-month-olds, where the proportion was marginally significant (Fig. 2).

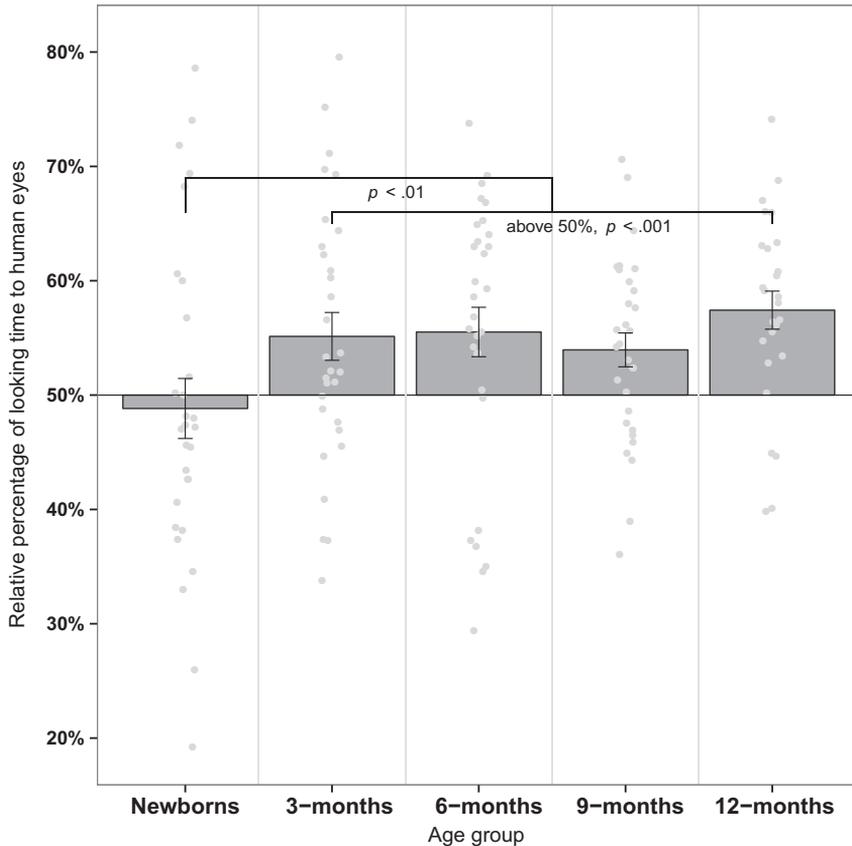


Fig. 2. Percentage of time spent looking at HumanEyes–Face for each age group. Dark gray bars indicate mean scores (\pm SE), whereas light gray dots illustrate individual scores. Percentage scores greater than 50% mean that infants looked longer toward nonhuman primate faces with human eyes than at nonhuman primate faces with their original eyes. Those percentages were relative to the total time spent looking at the stimuli (i.e., both faces), which was high and similar in each age group. Newborns spent 10 s looking at the stimuli (as required in the procedure), whereas the mean total looking times in older infants reached 8.8 s ($SD = 1.0$) for 3-month-olds, 8.6 s ($SD = 0.7$) for 6-month-olds, 8.6 s ($SD = 0.8$) for 9-month-olds, and 8.8 s ($SD = 1.0$) for 12-month-olds. As shown, older infants looked significantly longer at HumanEyes–Face, with mean percentages of 55.1% for 3-month-olds, 55.5% for 6-month-olds, 54% for 9-month-olds, and 57.4% for 12-month-olds. Regarding the individual scores, 20 of the 30 3-month-olds ($P[A] = 0.67$, $p = .07$), 23 of the 30 6-month-olds ($P[A] = 0.77$, $p = .004$), 21 of the 30 9-month-olds ($P[A] = 0.70$, $p = .029$), and 22 of the 26 12-month-olds ($P[A] = 0.85$, $p = .0004$) displayed individual preferences for HumanEyes–Face.

Discussion

When presented with two nonhuman primate faces that differed only by the nature of the eyes, human infants from 3 months of age looked longer toward the stimuli containing human eyes. However, no looking preference was observed in newborns. Because human infants would not have seen many live monkeys or apes, they would not likely have formed a representation of “normal” nonhuman primate faces (i.e., with nonhuman eyes). Thus, the “strangeness” of HumanEyes–Face stimuli is an improbable explanation of the attraction observed. Therefore, our results demonstrate the importance and attraction of the human eyes for infants, even when embedded in a nonhuman face.

As hypothesized in adult studies, low-level visual cues such as the high contrast of the human eyes may largely contribute to making human eyes salient (e.g., [Ttier et al., 2011](#)). This observation is not

contradictory with the emergence of an early elaborate system for detecting eyes (Baron-Cohen, 1995; Emery, 2000); low-level cues could favor the emergence of such a system and its specialization in humans, but they could also help to quickly detect human eyes. To test this hypothesis, one could have equalized the contrast between the human eyes and the nonhuman primate eyes, but that would have reduced the contrast between the sclera and iris in human eyes, thereby removing the factor that gives human eyes their distinctiveness (Kobayashi & Kohshima, 1997).

Our data have implications for face perception research in general. The fact that human eyes alone, embedded in a nonhuman primate face, are sufficient to attract infants' attention suggests that infants' attraction toward human eyes is not entirely driven by human face processing. It also suggests that human eyes may explain, or at least contribute to, the early preference for human faces observed from 3 months of age (Di Giorgio et al., 2013). In addition, given that the preference for human eyes remains stable after 3 months of age, eyes may remain critical for face processing at least until the end of the first year. This hypothesis is in agreement with the experimental evidence and theory supporting the critical role and precedence of the eyes in face processing (Bentin et al., 1996; Itier et al., 2007; Schyns et al., 2007; Shibata et al., 2002).

From a developmental perspective, how can we explain the absence of preference in newborns? To discount any explanation based on procedural difference between newborns and older infants (cumulated vs. fixed 10-s trials), we performed an additional analysis on the first 10 s after first look for the newborns, which led to the exclusion of a further 15 of the original 29 newborns due to insufficient looking time or strong position bias. This analysis still showed no preference for either of the nonhuman primate faces (t test against chance: $t[13] = -1.49$, $p > .05$), thereby rendering such an explanation as unlikely. In agreement with previous findings (Di Giorgio et al., 2013), our study instead supports the idea that attraction for human eyes is not inborn and that it develops during the first months after birth.

A possible explanation for this developmental change could be a lack of sensitivity for the human eyes at birth related to newborns' immature visual system. In effect, newborns might be unable to detect a difference between human eyes and other species' eyes. A low-level-based capacity to detect human eyes would emerge later with the improvements in acuity, contrast sensitivity, and color vision (Slater, 2001). However, this proposal appears to be inconsistent with our luminance and contrast analysis showing that infants and newborns should be able to discriminate NonHumanEyes–Face with HumanEyes–Face (see Fig. 1). Alternatively, the lack of sensitivity to human eyes at birth could be related to face context. Human eyes might be important, but having them embedded as internal features in a face limits their processing, with neonates paying more attention to the external parts of faces (Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995), perhaps especially when embedded in a nonhuman primate face. In other words, newborns would be able to detect eyes and their direction in faces (Farroni et al., 2005), but their processing might not be sufficient for the visual system to notice more subtle information such as the specificity of human eyes.

A second explanation, also based on face context, is that neonates might not even have attended to the eye region, thereby rendering the side-by-side images identical looking. A general lack of attention to the eye region is unlikely because previous work has shown that eyes are important at birth when embedded in a human-like face context (Farroni et al., 2002, 2005). Nevertheless, it is possible that attention to the eye region is dependent on the face context, with newborns being inattentive to the eye region when embedded in a nonhuman primate face with salient external contours emphasized by fur. A possible avenue of further investigation would be to determine with an eye-tracking system whether newborns even notice the human eye in the nonhuman primate faces or whether they are just not scanning the nonhuman primate faces with human eyes in the same way as they do human faces.

A third explanation would be that sensitivity for human eyes emerges several months after birth based on accrual of experience with conspecifics. Given the lack of age effect after 3 months, it appears that 3 months of exposure to human faces and eyes is sufficient to drive infants' attraction toward the familiar human eyes even when they are embedded in unfamiliar nonhuman primate faces. Sensitivity to eyes in general at birth, which may become specialized to humans from 3 months of age, is supported by the well-known idea that the system underlying face perception at birth is broad and devel-

ops according to the type of input received, thereby tuning face-space dimensions toward the category to which infants are predominantly exposed (Nelson, 2001). In particular, it is consistent with the data demonstrating the emergence, at 3 months of age, of a preference for faces that match the gender of infants' primary caregiver (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002) and for faces of their own racial group (e.g., Kelly et al., 2005). Our results are the first to suggest a preference toward own-species internal features from 3 months of age.

Regardless of which of these or other accounts comes to be confirmed on the basis of additional research, the current investigation indicates that there is a preference for human eyes per se during infancy that is not likely innate and may instead develop over the course of the first several months after birth.

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