Birkbeck
UNIVERSITY OF LONDON

BIROn - Birkbeck Institutional Research Online

Enabling open access to Birkbeck's published research output

Gaze following in human infants depends on communicative signals

Journal Article

http://eprints.bbk.ac.uk/2335

Version: Accepted (Refereed)

Citation:

© *2008* Elsevier

Publisher version

_____

_____

Deposit Guide

Contact: lib-eprints@bbk.ac.uk

Gaze following in human infants depends on communicative signals

Atsushi Senju[1]* and Gergely Csibra[1]

[1] School of Psychology, Birkbeck College, Malet Street, London WC1E 7HX, UK.
* Correspondence: a.senju@bbk.ac.uk

Summary
Humans are extremely sensitive to ostensive signals, like eye contact or calling their name, that indicate someone's communicative intention towards them [1-3]. Infants also pay attention to these signals [4-6] but it is unknown whether they appreciate their significance in the initiation of communicative acts. In two experiments, we employed video presentation of an actor turning towards one of two objects, and recorded infants' gaze following behaviour [7-13] with eye-tracking techniques [11, 12]. We found that 6-month-old infants followed the adult's gaze (a potential communicative-referential signal) towards an object only when such an act is preceded by ostensive cues like direct gaze (Experiment 1) and infant-directed speech (Experiment 2). Such a link between the presence of ostensive signals and gaze following suggests that this behaviour serves a functional role in assisting infants to effectively respond to referential communication directed to them. While gaze following in many non-human species supports social information gathering [14-18], in humans it initially appears to reflect the expectation of a more active, communicative role from the information source.

Results
         In two experiments, 6-month-old infants watched simple actions on a computer screen while their gaze direction was continuously recorded by an eye-tracker. Each trial started with the model looking down to a table and ended with shifting her gaze towards one of two colourful toys placed to her either side (Fig. 1A and 1F). The crucial variable that separated the experimental conditions was what happened between these phases, and in particular, whether any ostensive communicative cues preceded the gaze shift. We measured whether infants (a) followed the model's gaze immediately after her head turn and (b) made more eye movements towards, or (c) fixated longer to, the gazed object. Difference scores were calculated for each measurement and tested against chance level as well as compared between conditions.

         In Experiment 1, infants in the eye contact (EC) condition watched the model looking up towards the viewer and raising her eyebrows slightly before turning to one of the objects (Fig. 1B). Eye contact and eyebrow raise are ostensive signals that indicate the actor's intention to initiate communicative interaction with the viewer. In this situation, infants were more likely to look to the same object than to the other one immediately after

the model's head turn ($t(9) = 4.11$, $p = .003$) and made more eye movements toward the gazed object than toward the opposite one ($t(9) = 4.52$, $p = .001$). This result replicates the earlier finding that infants at this age follow others' gaze on a computer screen when the objects are close to the model [12].

Another group of infants was assigned to the no eye contact (NEC) condition, where we removed the ostensive signal from the stimulus. Thus, instead of the model making eye contact with the viewer, a colourful moving cartoon image was overlaid on her head for the same duration as the eye contact in EC condition in order to attract infants' attention to the ensuing head turn (Fig. 1C). In this condition, the difference scores did not differ from zero in any measurements (all ts < .82, all ps > .31), indicating no tendency to follow the model's gaze in the absence of eye contact. Group comparisons revealed that infants in the EC condition were more likely to follow the model's gaze ($t(18) = 2.74$, $p = .013$) and made more frequent looks toward the gazed object ($t(18) = 2.17$, $p = .043$) than infants in NEC condition (Fig. 2A). In sum, a period of ostensive eye contact did, while a non-ostensive attention-directing stimulus did not, elicit gaze following in 6-month-olds. Note that the direct gaze and the moving cartoon image equally captured infants' attention to the model's face: Infants looked longer to the face during the eye contact or moving cartoon image (average duration per trial: 1.61 s for EC condition and 1.54 s for NEC condition) than during baseline (average duration per trial: 1.05 s for EC condition and 1.09 s for NEC condition; $F(1,18) = 51.08$, $p < .001$), while looking duration across experimental conditions did not differ from each other (all Fs < .51, all ps > .48).

Eye contact is not the only ostensive stimulus, and not the only one that infants are sensitive to. Adults tend to talk to infants with a specific intonation pattern, called infant-directed speech, which in most situations would inform a baby that he or she is being addressed. Infants, and even naive newborns, have been shown to preferentially orient toward the source of this stimulus [6] and respond to it similarly as they do to eye contact. If gaze following depends on the presence of ostensive cues in young infants, rather than being tuned to the specific stimulus of direct gaze that produces eye contact, infant-directed speech should also be sufficient to elicit gaze following.

In Experiment 2, new groups of infants observed exactly the same visual stimuli as we used in the NEC condition of Experiment 1, but we added a female voice saying "Hello" at the onset of moving cartoon image. Half of the infants heard the greeting in infant-directed speech (IDS), characterized by a wide range of pitch variation (Fig. 1D). Infants in this condition were more likely to look to the gazed direction immediately after the model's shift of gaze ($t(9) = 3.00$, $p = .015$), and made more eye movements toward ($t(9) = 3.37$, $p = .008$), and fixated longer at ($t(9) = 3.61$, $p = .006$), the gazed object than the opposite one. Thus, just like eye contact, a word uttered in infant-directed fashion before the head turn was sufficient to elicit gaze following in infants.

To check whether the infant-directed intonation or the speech stimulus itself made infant follow the gaze of the model, another group of infants were presented with the same stimuli with the exception that the word "Hello" was voiced in a flat adult-directed speech (ADS, Fig. 1E). Note that the speech was produced by the same voice, and had the same

duration and volume as in the IDS condition. Nevertheless, none of the difference scores differed from zero in the ADS condition (all ts < 1.40, all ps > .13). When we compared the two conditions in Experiment 2 (Fig. 2B), we found that infants were more likely to follow the model's gaze immediately after her head turn in the IDS than in the ADS condition ($t(18) = 2.38$, $p = .028$). Since the visual stimuli were exactly the same in the two conditions, these results again support our prediction that infant-directed speech, which the infant as the addressee, facilitate gaze following behaviour in 6-months-olds, while adult-directed speech does not (see also supplementary results).
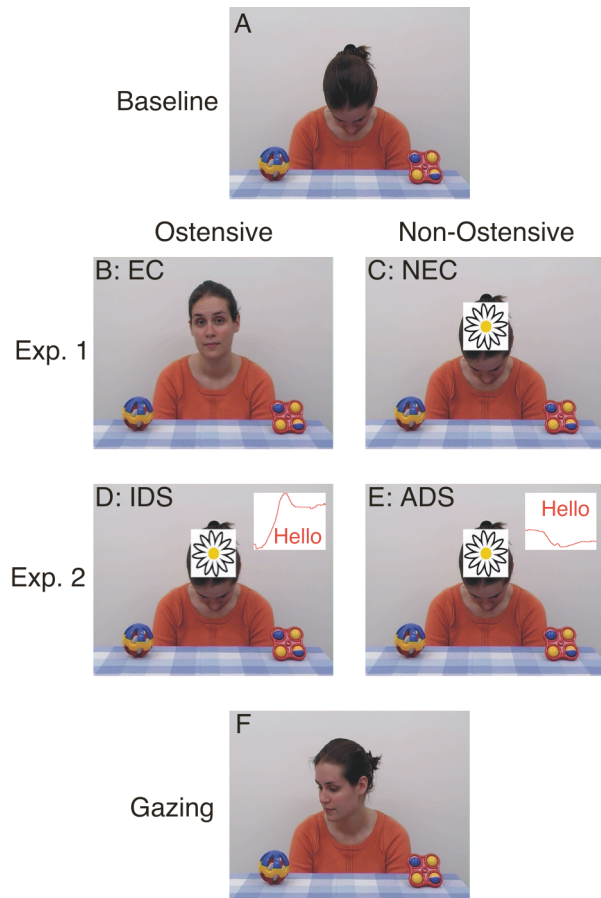
Figure 1. Selected frames from the stimuli. Each video started with the baseline phase (A), followed by the attention-getting phase (B-E) and gazing phase (F). The attention-getting phase included eye contact (EC) or no eye contact (NEC) in Experiment 1, and infant-directed speech (IDS) or adult-directed speech (ADS) in Experiment 2. The baseline and the gazing phases were identical across conditions. The curves on panels D and E represent the pitch countour of the speech.

We further analyzed whether the effect of the presence of ostensive signals on gaze following was consistent across the two experiments. The difference scores were analyzed

with two-way ANOVAs for experiment (1 or 2) and condition (ostensive or non-ostensive) as between-subject factors. The results revealed that infants were more likely to follow gaze after ostensive signals than after non-ostensive attention-getters ($F(1,36) = 13.1$, $p < .001$). Since the main effects of experiment and the interactions did not even approach the level of statistical significance (all Fs $< .70$, all ps $> .38$), we conclude that the effect of the presence of ostensive signals on gaze following was equivalent with eye contact and infant-directed speech, rather than being specific to the particular visual or auditory features of these stimuli.
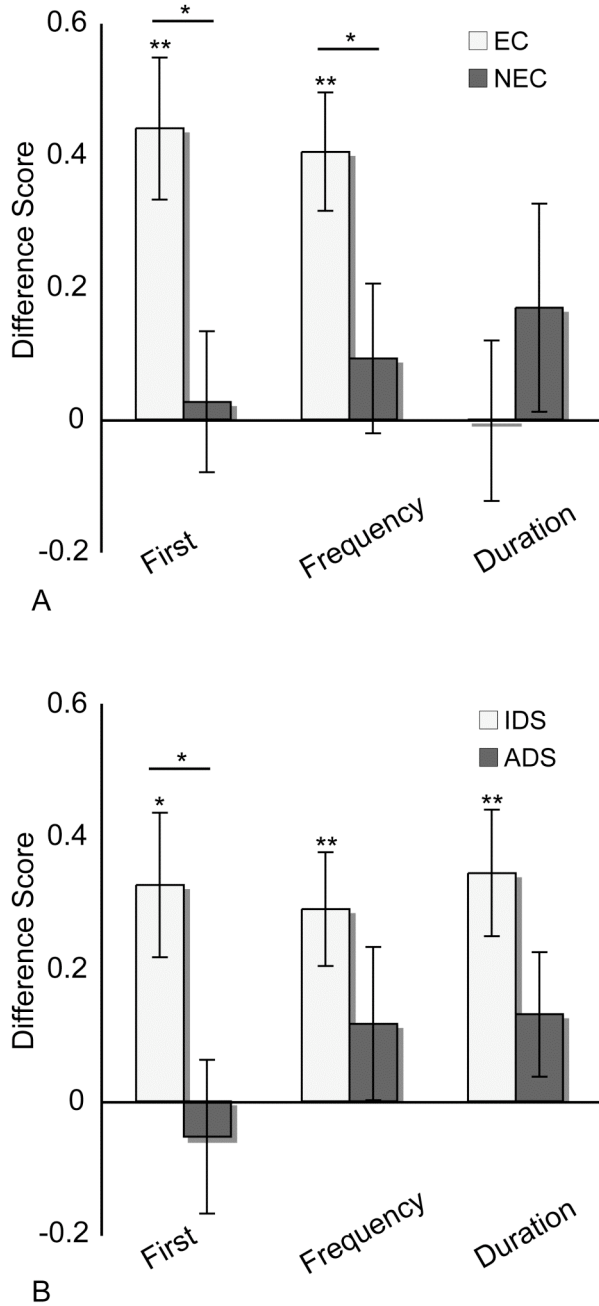
Figure 2. Difference scores for direction of the first face-to-object saccade following the model's head turn (First), frequency of face-to-object saccades (Frequency), and duration of object fixation (Duration) in each condition in Experiments 1 (A) and 2 (B). EC: eye contact condition, NEC: no eye contact condition, IDS: infant-directed speech condition, ADS: adult-directed speech condition, **: $p < .01$, *: $p < .05$, error bars: standard error.

Discussion

From immediately after birth, human infants are exceptionally sensitive to adults'

ostensive signals such as eye contact [4, 5] or infant-directed speech [6] that select them as the target of a simultaneous or subsequent communicative act. They preferentially orient toward the source of these signals, sometimes responding to them by smiling [19, 20]. The current results indicate that, at least by 6 months of age, they are also more likely to follow others' gaze when such signals are present. Such an effect cannot be solely explained by attentional factors, since non-social 'attention getters', which elicited the same amount of visual orientation to the model's head, did not facilitate gaze following behaviour. The current results also contradict the proposal that young infants reflexively shift their attention to the same direction as a perceived head motion, regardless of the communicative context [9, 10, 13]. Instead, our results are consistent with the observation that young infants require strong ostensive cues for gaze following [8] and attentional gaze cueing [21], and that additional communication signals, like pointing and verbalization, facilitate the response in older infants [7].

Neuroimaging studies have revealed that a network of brain regions that include parts of the prefrontal cortex is equally activated for stimuli, like eye contact and hearing one's name, that indicate self-directed communicative intentions [3], and a recent study has demonstrated a similar effect in 4-month-old infants [5]. Interestingly, the prefrontal cortex also specifically responds to object-referential gaze when it follows eye contact [22]. Infants have been shown to more likely detect referential gaze shifts when ostensive signals are present [23], and display prefrontal cortex activation in response to object-directed gaze shifts that follow eye contact [24]. These findings suggest that the neural processes that enable detecting ostensive signals and interpreting referential gaze shifts partly overlap, and that these processes mature early in life. It is not yet known whether gaze following behaviour relies on these neural processes in human infants, but this seems likely in the light of the present results.

Gaze following behaviour has been demonstrated in a wide range of animal species, such as non-human primates [16-18], goats [14] and ravens [15]. Such behaviour has a clear adaptive significance as it allows the observer to look at events in the environment that have already caught another individual's attention. This adaptive benefit does not depend on communication. Thus, the fact that gaze following is tied to ostensive contexts in human infants suggests that this behaviour may serve communicative purposes, such as interpreting deictic reference during interactions, in early human development. Comparative data from other species are not yet available to evaluate whether this effect is truly human specific. However, the fact that various non-human primates readily follow the head orientation of animals depicted on static pictures (e.g., [25, 26]) and that gaze-following is rare in the infant of non-human primates (e.g., [27, 28]) suggest that the link between communication signals and co-orientation was established in human evolution. Just like direct gaze, which is a threat signal in non-human primates [29-31] but gained a different function during human evolution by indicating the intention to initiate and maintain interactions between parties [1], gaze following may also have been 'exapted' for communicative purposes in humans, and not entirely homologous with similar behaviours displayed by other species.

In conclusion, our study demonstrated that beyond (1) the preference for signals that indicate for infants that they are being addressed by someone [4, 5], and (2) their tendency to follow behaviours (e.g., a head turn) that have potential referential significance [7-10], these two biases are linked together in human infants. Such combination of biases could function to allow human infants to benefit from referential communication directed to them, and could be one of the developmental roots of ostensive-referential communication in humans [32].

Experimental Procedure

Participants. In Experiment 1, twenty 6.5-months-old infants (10 female, 10 male) completed the study. Their mean age was 197.3 days (range: 180 to 209 days). Ten infants (5 female, 5 male, mean age: 199.1 days) were assigned for the eye contact (EC) condition, and the other 10 infants (5 male, 5 female, mean age: 195.5 days) were assigned for the no eye contact (NEC) condition. A further 12 infants were excluded from the analyses because of inattentiveness (8 infants who had less than 3 trials with gazing from the head to one of the objects after the head turn), parental interference (1) or technical error (3).

Another 20 6.5-months-old infants (10 female, 10 male) completed Experiment 2. Their mean age was 196.1 days (range: 180 – 211 days). Ten infants (5 female, 5 male, mean age: 192.9 days) were assigned for the experimental condition, and the other 10 infants (5 male, 5 female, mean age: 199.3 days) were assigned for the control condition. A further 9 infants were excluded from the analyses because of inattentiveness (8) and parental interference (1).   Informed consent was obtained from a parent of each infant before the study.

Apparatus. A Tobii (Stockholm, Sweden) 1750 Eye Tracker was used to record infants' looking behaviour. The eye tracker was integrated with a 17-inch LCD monitor, on which stimuli were displayed with Tobii's ClearView AVI presentation software. Infants were seated on a parent's lap 50 cm from the monitor on which the stimuli were presented. A video camera was mounted on top of the screen, through which the experimenter monitored the infants' face. A five-point calibration was administered before the recording (for technical details about the apparatus and the calibration procedure, see [11]).

Stimuli and Procedure. In Experiment 1, each stimulus started with a scene with a female model, seated behind a table, facing down. Two toy objects were placed on the table, one to each side of the model (Fig. 1). The videos consisted of three phases. The first one was the baseline phase (Fig. 1A), in which the model remained still for 2 s. This was followed by the attention-getting phase, which differed between conditions. In the EC condition, a beep sounded and the model looked up, looked into the camera, and raised her eye-brows. This phase lasted for 2 s (Fig. 1B). In the NEC condition, the model remained still and a colourful moving cartoon image was overlaid on the head of the model for 2 s (Fig. 1C). The third phase was the gazing phase. In this one, the model turned her head towards one of the two objects (1 s), and fixated the object for a further 5 s (Fig. 1E). Note that the model kept the neutral facial expression and remained silent throughout the whole

sequence. The videos were edited with Final Cut Express software (Apple Inc, CA) in order to control the duration of each phase and overlay the cartoon images on the face.

Six trials were presented to each infant. The stimulus in each trial contained a unique pair of objects. The direction of the model's gaze was counterbalanced in ABBABA order. Half of the infants saw a leftward gaze in the first trial, and the other half saw a rightward gaze first. Before the start of each trial, infants' attention was drawn to the centre of the screen, where the model's face would appear, by colourful cartoon animations and beeping sounds. When the infant was attending to the screen, the experimenter pressed the key and started the trial.

In Experiment 2, the stimuli and the procedure were the same as in the NEC condition of Experiment 1, except that, instead of a beep, a female voice saying "Hello" was presented at the beginning of attention-getting phase. The greeting was uttered either in infant-directed speech (IDS condition, Fig. 1D) or in adult-directed speech (ADS condition, Fig. 1E), differing primarily in pitch and pitch contour. The two versions were recorded from the same person and were edited with Final Cut Express software to match the overall amplitude and duration between conditions. The study was approved by the ethics committee of the School of Psychology, Birkbeck, University of London.

Data Analysis. Following the recording, a gaze replay movie file showing the exact location of each infant's gaze was exported at 25 frames per second temporal resolution. These data were then analyzed frame-by-frame for each phase (baseline phase, attention-getting phase and gazing phase). The principal measurement of gaze following was whether the first eye movement saccade from the head toward an object in the gazing phase (i.e., after the head turn started) went to the object looked at by the model (congruent saccade) or toward the object opposite one (incongruent saccade). Infants needed to elicit such face-to-object saccade in at least three trials to be included in the analyses. The standard difference score [9, 13] was calculated for each infant by subtracting the number of trials with incongruent saccade (i) from the number of trials with congruent saccade (c) and dividing it by the total number of trials with face-to-object saccades. In addition, the frequency of face-to-object saccades and the duration of the fixation to each object were calculated for both gaze-congruent and gaze-incongruent object in each trial. Then the difference scores were calculated for these measurements in a similar way to that of the first measure (i.e., $d = (c - i) / (c + i)$). To examine infants' attention to the head, the duration of looking to the model's head was also calculated separately for the baseline, attention-getting and gazing phases.

References

1.   Kleinke, C.L. (1986). Gaze and eye contact: a research review. Psychol. Bull. *100*, 78-100.

2.   Morey, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. Q. J. Exp. Psychol. *11*, 56-60.

3.   Kampe, K.K., Frith, C.D., and Frith, U. (2003). "Hey John": signals conveying communicative intention toward the self activate brain regions associated with "mentalizing," regardless of modality. J. Neurosci. *23*, 5258-5263.

4.   Farroni, T., Csibra, G., Simion, F., and Johnson, M.H. (2002). Eye contact detection in humans from birth. Proc. Natl. Acad. Sci. U. S. A. *99*, 9602-9605.

5.   Grossmann, T., Johnson, M.H., Farroni, T., and Csibra, G. (2007). Social perception in the infant brain: gamma oscillatory activity in response to eye gaze. Soc. Cogn. Affect. Neurosci. *2*, 284-291.

6.   Cooper, R.P., and Aslin, R.N. (1990). Preference for infant-directed speech in the first month after birth. Child Dev. *61*, 1584-1595.

7.   Flom, R., Deák, G.O., Phill, C.G., and Pick, A.D. (2004). Nine-month-olds' shared visual attention as a function of gesture and object location. Infant Behav. Dev. *27*, 181-194.

8.   D'Entremont, B., Hains, S.M.J., and Muir, D.W. (1997). A demonstration of gaze following in 3- to 6-month-olds. Infant Behav. Dev. *20*, 569-572.

9.   Corkum, V., and Moore, C. (1998). The origins of joint visual attention in infants. Dev. Psychol. *34*, 28-38.

10.   Brooks, R., and Meltzoff, A.N. (2005). The development of gaze following and its relation to language. Dev. Sci. *8*, 535-543.

11.   von Hofsten, C., Dahlström, E., and Fredricksson, Y. (2005). 12-month-old infants' perception of attention direction in static video images. Infancy *8*, 655-684.

12.   Gredebäck, G., Theuring, C., Hauf, P., and Kenward, B. (in press). The microstructure of infants' gaze as they view adult shifts in overt attention. Infancy.

13.   Moore, C., and Corkum, V. (1998). Infant gaze following based on eye direction. Br. J. Dev. Psychol. *16*, 495-503.

14.   Kaminski, J., Riedel, J., Call, J., and Tomasello, M. (2005). Domestic goats, Capra hircus, follow gaze direction and use social cues in an object choice task. Anim. Behav. *69*, 11-18.

15.   Schloegl, C., Kotrschal, K., and Bugnyar, T. (2007). Gaze following in common ravens, Corvus corax: Ontogeny and habituation. Anim. Behav. *74*, 769-778.

16.   Bräuer, J., Call, J., and Tomasello, M. (2005). All great ape species follow gaze to distant locations and around barriers. J. Comp. Psychol. *119*, 145-154.

17.   Itakura, S. (1996). An exploratory study of gaze-monitoring in nonhuman primates. Japn. Psychol. Res. *38*, 174-180.

18.   Tomasello, M., Call, J., and Hare, B. (1998). Five primate species follow the visual gaze of conspecifics. Anim. Behav. *55*, 1063-1069.

19.   Hains, S.M., and Muir, D.W. (1996). Infant sensitivity to adult eye direction. Child Dev. *67*, 1940-1951.

20.   Werker, J.F., and McLeod, P.J. (1989). Infant preference for both male and female infant-directed talk: a developmental study of attentional and affective responsiveness. Can. J. Psychol. *43*, 230-246.

21.   Farroni, T., Mansfield, E.M., Lai, C., and Johnson, M.H. (2003). Infants perceiving and acting on the eyes: tests of an evolutionary hypothesis. J. Exp. Child Psychol. *85*, 199-212.

22.   Bristow, D., Rees, G., and Frith, C.D. (2007). Social interaction modifies neural response to gaze shifts. Soc. Cogn. Affect. Neurosci. *2*, 52-61.

23.   Senju, A., Csibra, G., Johnson, M. H. (in press). Understanding the referential nature of looking: Infants' preference for object-directed gaze. Cognition.

24.   Senju, A., Johnson, M.H., and Csibra, G. (2006). The development and neural basis of referential gaze perception. Soc. Neurosci. *1*, 220 - 234.

25.   Deaner, R.O., and Platt, M.L. (2003). Reflexive social attention in monkeys and humans. Curr. Biol. *13*, 1609-1613.

26.   Scerif, G., Gómez, J.-C., and Bryne, R.W. (2004). What do Diana monkeys know about the focus of attention of a conspecific? Anim. Behav. *68*, 1239–1247.

27.   Ferrari, P.F., Kohler, E., Fogassi, L., and Gallese, V. (2000). The ability to follow eye gaze and its emergence during development in macaque monkeys. Proc. Natl. Acad. Sci. U. S. A. *97*, 13997-14002.

28.   Tomasello, M., Hare, B., and Fogleman, T. (2001). The ontogeny of gaze following in chimpanzees, Pan troglodytes, and rhesus macaques, Macaca mulatta. Anim. Behav. *61*, 335-343.

29.   Coss, R.G. (1978). Perceptual determinants of gaze aversion by the lesser mouse lemur (Microcebus murinus): The role of two facing eyes. Behaviour *64*, 248-270.

30.   Mendelson, M.J., Haith, M.M., and Goldman-Rakic, P.S. (1982). Face scanning and responsiveness to social cues in infant rhesus monkeys. Dev. Psychol. *18*, 222-228.

31.   Emery, N.J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. Neurosci. Biobehav. Rev. *24*, 581-604.

32.   Csibra, G., and Gergely, G. (2006). Social learning and social cognition: The case for pedagogy. In Processes of change in brain and cognitive development. Attention and Performance XXI, Y. Munakata and M.H. Johnson, eds. (Oxford: Oxford University Press), pp. 249-274.