Development of social cognition: Pre-verbal infants' perception of everyday social interaction

An eye tracking study

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Abstract

Eye-tracking techniques were used to examine how 6, 9 and 12 month old typically developing infants perceive social interaction as a third party observer. The infants were presented with movies where two adult actors conversed about everyday events, in different conditions: With eye contact, with their eyes closed, or without eye contact. The two first conditions were also presented in a back-to-back manner. Gaze shifts between the two actors following the flow of the conversation were registered presumed to reflect the infants' understanding of the communicative meaning of a social situation in the observed event. The different conditions were included to tentatively disentangle the relative importance of the constituents' of the social interaction. There were no significant results between age groups, however, there were differences within age groups. Results demonstrated that 6 month old infants made more gaze shifts with the flow of the conversation when the actors were standing face-to-face with eye contact rather than back-to-back with their eyes open, which indicates the "face-to-face effect" demonstrated by Augusti, Melinder, and Gredebäck (2010). Furthermore, 9 month old infants made more gaze shifts between the actors in accordance with the conversation when they were standing face-to-face with eye contact rather than face-to-face with their eyes closed. This indicates sensitivity not only to body orientation, but also to the social information inherent in eye contact when observing others' social interaction.

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Introduction

Our distinctive social cognitive abilities are what fundamentally distinguish humans from other species and the development of social cognition is therefore one of the main themes in developmental psychology (Tetzchner, 2012; Tomasello, 1999). Previous research has shown that young children listen and pay attention to conversations (Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003; Tomasello, Hare, Lehmann, & Call, 2007), however, pre-verbal infant´s perception and understanding of others' social interactions are relatively unexplored (Handl, Mahlberg, Norling, & Gredebäck, 2013), although decades of research on how infants follow gaze in dyadic interaction have provided a vast amount of knowledge (Gredebäck, Fikke, & Melinder, 2010; Handl et al., 2013; Striano & Reid, 2006). There exists, however, a lack of understanding of the concrete cognitive mechanisms essential for detecting, following and understanding social interaction between other people (Handl et al., 2013). A recent eye tracking experiment by Augusti et al. (2010) investigated how infants observe a conversation between two adults. Their results demonstrated that infants' make more gaze shifts between the speakers of the conversation when they are facing each other rather than turning away from each other. These results demonstrated the "face-to-face effect", which suggests that body orientation has an impact on how infants observe a conversation. Until recently, very little is known about how infants perceive social interactions, as a third party observer (Augusti et al., 2010).

Children´s visual and auditory preferences orients them towards stimulation from other humans, and looking is one of the first behaviors to develop in infants (Gredebäck, Johnson, & von Hofsten, 2009; Tetzchner, 2012). Prior to language development, observation of infants' looking behavior can be a gateway to infants' mind and how they perceive the world (Gredebäck et al., 2009). The visual abilities of humans are special because they play an important role in social and non-verbal communication, as well as for other processes such as emotional processing and understanding the intentions of others' actions (Itier & Batty, 2009). Recent developments in corneal reflection (CR) eye tracking have provided researchers within human development with a new instrument. With this technique, it is possible to measure infants´ perception of their surroundings more accurately. Furthermore, while looking is a basic human behavior, it has until recently been very difficult to measure with high detail in both space and time (Gredebäck et al., 2009). The purpose of the current study is to investigate how pre-verbal infants (6, 9, 12 months of age) perceive everyday social interactions as an observer measured by eye tracking.

Infant social interaction

In order to understand how infants perceive social interaction, this chapter will outline a review of literature on the development of social cognition and how these abilities develop through infancy. Social cognition can be considered as the sum of the processes necessary to allow for those of the same species to interact with one another (Frith & Frith, 2007) The study of social cognition is fundamentally interdisciplinary as it embraces everything from perceptual skills that makes it possible for us to discriminate between people and objects and the complex interaction of social cues such as eye contact, tone of voice, body language, and facial expression (Striano & Reid, 2006). According to Striano and Reid (2006), social cognition can be referred to as the ability to understand other people as it involves our capacity to interpret, predict, and monitor the behaviors as well as mental states of other people (Striano & Reid, 2006). All the skills listed are inherently important for humans as our success and survival significantly depend on our capacity to succeed in a complex social world (Gallese, Keysers, & Rizzolatti, 2004; Striano & Reid, 2006).

Children's understanding of other individuals as beings with mental states such as desires, intentions, and emotions, separate from the child's own, is an important focus in developmental psychology (Legerstee, Barna, & DiAdamo, 2000). Infants are sensitive to social information from birth, and their way of communicating is preverbal at first (Elsner, Bakker, Rohlfing, & Gredebäck, 2014; Tomasello, 2008). Early experiences in interpersonal communication are recognized as a foundation for social communication later in life (Elsner et al., 2014; Tomasello, 1999). The ability to share information and knowledge through communication is one of the most essential interpersonal skills that humans have acquired (Melinder, Konijnenberg, Hermansen, Daum, & Gredebäck, 2015).

Infants are attracted to social stimuli from birth (Farroni, Csibra, Simion, & Johnson, 2002). Moreover, newborns are sensitive to faces, voices and eye contact, and have a visual preference for face like stimuli (Johnson, Dziurawiec, Bartrip, & Morton, 1992). During the first months of life, infants begin to engage in dyadic interactions. Such interactions are marked by reciprocations of affect and emotions between infant and caretaker. At 2-3 months, there are some changes in how infants interact. At 2-months, they begin to focus on the eyes and mouth of other people (Striano & Reid, 2006). During their first moths of life, infants have had just enough social experience to detect small perturbations in the flow of interpersonal interaction. With their increased sensitivity to social cues, such as eye contact, infants have developed the skills necessary to understand the significance of the social signals essential for learning and communication by 3 months (Striano & Reid, 2006). The ability to use another person to explore the environment is a very important human characteristic. One of the most basic ways to this is by gaze following. Following the gaze of another person allows the infant to attend to whatever the adult finds of interest (Moore, 1999).

Infants at 6- months of age display dyadic interaction with objects, by grasping and manipulating them. They also interact in dyads with other people by responding and expressing emotions back and forth in turn-taking sequences (Tomasello, 1999). An important transition in early development is when the infant moves from dyadic interactions, to participating in triadic (person-object-person) interactions. Triadic interactions, also referred to as joint visual attention, include two people in relation to a third, external object, event or situation (Striano & Reid, 2006). Joint attention is frequently referred to as milestone in social cognitive development as it allows infants to participate in social interactions and follow the gaze of others (Gredebäck et al., 2010). Joint attention is enriching infants' social cognitive abilities and has been linked to language acquisition, theory of mind and emotional regulation (Baron-Cohen, 1994; Gredebäck et al., 2010; Morales, Mundy, Crowson, Neal, & Delgado, 2005; Mundy & Gomes, 1998). In a recent study by Gredebäck et al. (2010) the researchers found that gaze following emerges between 2 and 4 months of age, and stabilized between 6 and 8 months of age. Moreover, their findings are not supporting acquired gaze through reinforcement learning, however, suggesting that infants are motivated by social cognitive motives when interacting with others (Gredebäck et al., 2010). Furthermore, research has demonstrated that infants at 3-months are able to shift their gaze back and forth between two social partners, and therefore are able to participate in complex social interaction far earlier than previously expected (McHale, Fivaz-Depeursinge, Dickstein, Robertson, & Daley, 2008).

By the end of the first year of life, between 9 and 12 months of age, infants move around more independently, become more active and interacts to a higher degree in a triadic manners (Striano & Reid, 2009). Also at this age, the infant begins to use communicative gestures to get the adult "tuned-in" to their attention (Tomasello, 1999). This period is sometimes referred to as the "nine month revolution" (Striano & Reid, 2006; Tomasello, 1999), and is additionally characterized by more speech-like vocalizations during interactions with caretaker as well as in other social settings (von Hofsten, Uhlig, Adell, & Kochukhova, 2009).

It is thought that social perception and its development is enabled through a set of innate attentional dispositions (von Hofsten & Gredebäck, 2009). Moreover, these attentional dispositions generate an optimal learning environment in terms of understanding social interaction. In other words, these dispositions guarantee that infants focus their attention to the appropriate information, causing infants and caretakers to enjoy interacting with one another. Furthermore, an important feature of the development of social competence is the capacity to distribute attention between others, when observing a social interaction (Wilkinson, Metta, & Gredeback, 2011).

Between 1 and 3 years of age, an additional increase in children's interest for the complete conversation emerges, which is expected with the development of language understanding (Bakker, Kochukhova, & von Hofsten, 2011; von Hofsten & Gredebäck, 2009). Moreover, von Hofsten et al. (2009) found that children's looking time at the speaker of a conversation almost doubled between the age of 1 and 3. This is also in line with Bakker et al. (2011) who investigated different components of a conversation in order to identify which are important to keep the children's (6-months, 1 year, and 3 years) attention. The study found that the older children (1 and 2 years of age) found spoken language more interesting than mechanical sounds; however, the 6-month-olds did not show any difference. According to Bakker et al. (2011) these results demonstrate that 6-month-olds have a poor speech comprehension and their understanding of the dynamics of the conversation has yet to be developed. However, at 1 to 2 years this ability has improved as the older children are more familiar with, and interested in conversations.

Recent advances in our understanding of early social cognition indicate that young infants entail many of the fundamental skills required for further maturation of their social cognitive functioning (Striano & Reid, 2006). Studying social cognition in typical infants can provide further knowledge to our understanding of the mechanisms involved in development as well as how these account for brain and behavioral functioning at different ages (Striano & Reid, 2006). The literature on infant development of social cognition and social interaction, demonstrate impressive set of abilities, which help them interpret the goals and intentions of others as well as these early experiences prepare them as social beings.

Cues in Social Interaction

It has been confirmed by several studies that, as early the first weeks of infants' life, they look at key features of a person's face, such as eyes, nose and mouth (Hunnius & Geuze, 2004). The human face provides us with a variety of socially relevant information, such as age, gender, familiarity, gaze-direction, emotions and so on (Grossmann & Vaish, 2009). The infant is dependent on several cues in order to actively engage in social interactions. Social cues such as eye contact, gaze direction, body orientation, speech and auditory cues are all important as they select infants as targets of communication (Senju & Csibra, 2008). According to Senju and Csibra (2008) infants are very sensitive to such cues, sometimes referred to as ostensive signals. Infants tend to preferentially orient towards the sources of these signals, often responding by smiling (Senju & Csibra, 2008). A recent study presented results indicating that by 6 months of age, infants are more likely to follow others' gaze when such signals are present (Senju & Csibra, 2008).

Infant's sensitivity to eye contact is evident already from birth (Hoehl et al., 2009). Among adults, it has been suggested that eye contact can be one of the most powerful and significant types of nonverbal communication. Moreover, establishing eye contact is considered to be a powerful way of forming a communicative link between humans (Kampe, Frith, & Frith, 2003). Eye contact is an integrated part of communication among adults, and is also an essential component of dyadic face-to-face interactions in infant-adult interaction (Symons, Hains, & Muir, 1998). It has been suggested that the sensitivity and responses to the infant's gaze, could be crucial for both social and cognitive development (Simon Baron-Cohen, 1994). These proposals are supported by numerous of studies demonstrating infants' sensitivity to the presence of eyes and the direction of other's gaze (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni et al., 2002; Lasky & Klein, 1979; Symons et al., 1998). A study demonstrated that neonates looked significantly longer at photographs of a human adult where the eyes are open rather than closed (Batki et al., 2000; Csibra, 2010). Furthermore, 12 month old infants display a sensitivity to the eye status of another person (Tomasello et al., 2007) and do not follow gaze when eyes are closed (Brooks & Meltzoff, 2005). Hence, closed eyes could change the communicative meaning of a social situation (Handl et al., 2013). Additionally, a study by Farroni et al. (2002) demonstrated that newborns could discriminate between direct and averted gaze. The newborns also looked longer at faces with direct or mutual gaze compared with faces with averted gaze (Farroni et al., 2002). The ability to discriminate between direct and averted gaze has been found across species and may have evolved because direct gaze can be a signal that a predator is approaching, making its detection an important tool for survival (Emery, 2000). Additionally, infants also use others' gaze to lead their own attention, and infants as young as 3 months old can detect the direction of gaze as indicated by eye status alone (Hood, Willen, & Driver, 1998). Consequently, both eye status and eye gaze direction provide important information for infants (Handl et al., 2013). Infant's specific scanning patterns provide them with the crucial information they need to engage with other people (Bakker et al., 2011).

Infant's gaze behavior provides important social cues. However, according to Crown, Feldstein, Jasnow, Beebe, and Jaffe (2002), the coordinated interpersonal timing in social interactions also requires infants to be able to hear and respond to adults vocalizations. Infants are born equipped for auditory perception as the brainstem and auditory cortex is functional at birth (Eisenberg, 1976). A study by Haith, Bergman, and Moore (1977) found that adult vocalizations made infants shift their visual focus to the eye-face region of the adult, and concluded that visual stimuli is not the only feature that control the visual scanning of infant's. Furthermore, there are other cues as well which infants might be dependent on to perceive where someone is directing their attention (Langton, Watt, & Bruce, 2000). Cues such as the orientation of the head, the posture of the body, and gestures, such as where someone is pointing their finger (Langton et al., 2000). It has been proposed that such cues are processed automatically by observers and contributes to other individuals' social attention (Langton et al., 2000).

Understanding Others' Social Interaction

The overall purpose of the current study is to investigate how infants look at social interactions as a third-party observer. More specifically, how do infants use their gaze as measured by eye tracking when observing a social interaction between two adults in different social interactions? There exists some research which has investigated such issues, and the next part of this chapter will outline these studies.

As mentioned previously, a large number of studies have attempted to understand how infants perceive other people´s actions, however, very little is known about how infants perceive social interactions where the infant is the observer (Augusti et al., 2010). Previous research have demonstrated that young infants are sensitive to cues in social interaction while they are actively engaged (Mayer & Tronick, 1985), yet less is known about the degree infants can apply such information to understand perceived social interaction that they are not actively engaged in (Augusti et al., 2010). In a study by (von Hofsten, Dahlström, & Fredriksson, 2005) 12 month old infants was presented with static video images of a female model. In the images, the model either looked toward visible objects, placed in front of her, and looked and pointed at them while looking straight ahead. The study applied eye tracking methods to measure gaze direction in infants. Their results showed that 12-month-old infants could correctly discriminate the gaze direction of the actor, hence, selectively attend to the speaker of social conversation. Thus, social directional cues provided by head direction and eye movement of another person can be applied by 12-month-olds in more precise way than only indicating that something interesting will be seen to the left or right of the infant. The study also showed that the infants did not need ADAs (attention-directing actions) to be part of live social interaction; in fact, they did not even need them to be dynamic. The infants were able to discriminate different directions of gaze from the static eye and head postures in still video images and demonstrated that 12-month-old infants selectively direct attention to the speaker in a social conversation (von Hofsten et al., 2005).

A recent study by Augusti et al. (2010) investigated infant's sensitivity to social interactions where the infant was an observer. Four, 6 and 11 month old infants were presented with movies, where two adult actors had a conversation, using eye-tracking techniques. The actors conversed either by facing each other (standing face-to-face) or looking in opposite directions (standing back-to-back). Their results demonstrated that infants from 6 months of age made more gaze shifts with flow of the conversation when the actors where facing each other. According to Augusti et al. (2010) their results are consistent with a social cognitive interpretation, suggesting that infants distinguish between face-to-face and back-to-back conversations. Moreover, infants from 6 months of age also preferred to attend to the typical form of a social interaction (i.e., when actors are standing face-to-face). The study by Augusti et al. (2010) is one of few attempts to investigate how infants perceive complex social interactions as a third party observer and suggests that gaze following directed towards social interactions is apparent between 4 and 6 months of age. Furthermore, Augusti et al. (2010) argue that infants' use the detection of others gaze direction to assist their understanding of social interactions, which argues for a social cognitive explanation of infants' sensitivity to social interaction from 6 months of age.

Handl et al (2013) explored gaze shifts in 9, 16, and 24-month-old infants presented with still images of a conversation between two individuals, applying eye-tracking methods. In the still images, the individuals were either standing face-to-face or back-to-back with open or closed eyes. They wanted to examine what cues the infant is dependent on which facilitated the face-to-face effect observed by Augusti et al. (2010). Their results demonstrated that body orientation is sufficient to affect the infants gaze shifts, hence providing them with essential information about social interactions. Their findings are in line with Augusti et al. (2010) arguing that body orientation for infants from 9 months functions as a cue for their observations and guides their attention, explaining the face-to-face effect. Although the study demonstrated the face-to-face effect, it did not find that infants use eye status as a cue, when relying on static visual information. However, the researchers point out that eye status might be relevant in a richer social context, and in combination with other cues (such as motion cues or language) (Handl et al., 2013).

von Hofsten et al. (2009) investigated how two groups of typically developed, young children (1 and 3-year-old) paid attention to a video-recorded conversation using eye tracking. The children were presented with two types of recordings. The first condition consisted of two women having a conversation with each other, and the second condition showed two colorful oval shapes moving up and down next to each other producing sounds. In the oval shapes condition, the timing and duration of each turn taking were approximately similar to the turn taking in the human condition. The results showed that the children switched gaze with the turns of the speakers and predicted the next turn of conversation by moving their gaze ahead of time. However, there were some differences between the two age groups. The 1-year-olds looked approximately equally at the two conditions, whereas the 3-year-olds looked much longer at the conversation condition. Furthermore the findings showed that the 3-year-olds moved their gaze more predictively between the speakers in the conversations than between the ovals in the artificial turn-taking condition; they were able to switch gaze to the next speaker before she started to speak. According to von Hofsten et al. (2009) it appears that the 3-year-olds found the social turn-taking more attractive than the non-social.

However, Bakker et al. (2011) questions what really constitutes the differences found in the von von Hofsten et al. (2009) study. The von Hofsten et al. (2009) study used social visual and auditory stimuli that were mechanical for the non-social turn taking. Bakker et al. (2011) wanted to investigate what effect it would have if the social stimuli presented were non-social. The researchers created four films in their study, with two types of visual events, social and mechanical, which were orthogonally combined with two types of auditory events, speech and motor sounds. The social film showed two women engaging in a conversation, while the mechanical film, the movements of the shovels of two toy trucks substituted the turns of the conversation. The timing of the turn taking events was precisely the same in both films. Furthermore, in the auditory condition, the voices of two women or two motor sounds were synchronized with the films. They presented the films to three groups of young children, respectively 6-month-olds, 1-year-olds and 3-year-olds, and expected that the children would prefer the social turn taking to the mechanical. Their results demonstrated that children are interested in different type of stimuli at different ages. In general they found that the older children were overall more interested in the videos than the younger children. However, all age groups showed more attraction to the stimuli with the human agents. Furthermore, all age groups appeared to be more interested in the social sounds, regardless of the video (trucks or humans). The overall conclusions from the study is that from around the age of 1 children rely to a large extent on the information from the social situations and the social sounds in order to understand the situation they are observing and to follow the dynamics of the conversation (Bakker et al., 2011).

The Current Study

Research on social-cognitive development in infancy has provided a greater insight on topics such as perception, action understanding and representations. However, the topic of social knowledge has not received the same amount of attention from researchers (Rochat & Striano, 1999). How infants understand and perceive a social interaction as a third party observer, is an area which is rather unexplored to this date.

The face-to-face effect demonstrated by Augusti et al. (2010) suggested that body orientation alone is sufficient enough information for infants to perceive the action as social engagement. The study by Handl et al. (2013) also confirmed the face-to-face effect using static visual information. These recent studies have begun to explore how infants perceive social interaction and how social events develop. The aim of this study is to provide further knowledge about how infants perceive social interaction and how social events unfold. The study will attempt to do so by mapping the importance of which cues infants are dependent on when observing others having a conversation.

The study aims to describe the developmental path of this property in typically developed infants, i.e., at what age infants learn to draw projections on social contexts. Furthermore, identify which elements of a social interaction that is important for the infant's to perceive it as a social interaction or a communicative action, as an observant. The current study will investigate infants´ ability to follow the flow of a conversation between two actors as measured by their ability to make gaze shifts between the speaker and non-speaker, with the flow of the conversation. The infants are presented with dynamic videos of two adult female actors having a conversation with eye contact, with their eyes closed, or without eye contact. The two first conditions are also presented in a back-to-back manner. Adding eye status as a cue and going beyond body orientation can provide further information to what facilitates the face-to-face effect.

This will be explored using a Tobii TX300 eye tracker in the Cognitive Developmental Research Unit (EKUP), the Department of Psychology at the University of Oslo. Applying eye tracking techniques make it possible to measure how pre-verbal infants observe the world with high special and temporal accuracy (Gredebäck et al., 2009). Furthermore, investigating how infants scan images or dynamic events can offer valuable information about their interest and (overt) attention, and can be a gateway into the infant's mind (Gredebäck et al., 2009).

Different age groups will be compared (6, 9 and 12 months of age) to map the developmental processes involved in this social cognitive ability. The current study has two research questions. The first is concerning the development of infants´ sensitivity to social interactions. At what age do infants develop the understanding of a social interaction as an observer and how does this develop through infancy, respectively through 6, 9, and 12 month of age. Secondly, further investigate which cues infants require to follow the flow of a conversation, respectively body orientation and eye status.

Materials and Methods

Participants

45 typically developed infants participated in the study. However, 10 participants were excluded due to lack of attention and fuzziness. The final sample consisted of 11 infants at 6 months of age (M = 196 days, SD = 18 days, 5, girls), 12 infants at 9 months of age (M = 285 days, SD = 21 days, 5 girls), and 12 infants at 12 months of age (M = 372 days, SD = 23 days, 7 girls).

The criteria for participation were that the infant was born within term date (three weeks before, to two weeks after) and that there was no known neurological complication.

Recruitment

The participants were recruited through mail with addresses in the Oslo area obtained from The National Register (Folkeregisteret). This is according to the standard procedures at the Cognitive Developmental Research Unit (EKUP), University of Oslo. The letters enclosed a description of the study and an invitation to participate. The response rate was approximately 15 %.

Ethical Considerations

The study was approved by the Regional Ethic Committee according to the 1964 Declaration of Helsinki. All the families were informed about the procedure of the study when they entered the lab and signed a consent form.

All information that can compromise the anonymity of the infant and the caretaker was removed and replaced by a participant number. Only the lead researchers directly linked to the study have access to the necessary file to reconnect the participant number and other registered information. Caretakers were also informed that no individual results will be reported from the study. Additionally, caretakers are asked to indicate whether they would like to receive the results on a group level upon the completion of the study.

The infants received a small gift for participating (approximate value of 100 NOK). No other economic resources were required in order to conduct the current study.

Stimuli and Apparatus

Video recordings of two actors having a conversation while facing each other created the stimulus for the experiment. Prior the recording, the conversations were written and rehearsed to make sure that each condition consisted of the exact same wording. There were two different conversations recorded, both mundane with neutral to positive content. One conversation concerned a shopping trip and the other was about buying ice cream. The conversations were not suited the infants understanding or interests as the study wanted to investigate how infants understand conversations that they are not a part of, but observing as a third party. To make sure that the infants would have to shift their gaze frequently, each utterance was kept relatively short. Furthermore, each conversation was recorded in three different conditions. In the first condition the actors have normal eye contact, in the second condition their eyes are open but without eye contact, and in the third condition their eyes are closed. The actors' posture was the same in each condition, but where digitally manipulated to create a condition where they are standing back-to-back. This manipulation was applied for the condition with normal eye contact and in the condition with eyes closed. The back-to-back manipulation was not necessary in the condition with no eye contact, as it would not be possible to differentiate it from the back-to-back condition with eye contact. In addition, the actors were also slightly tilted towards the camera to make sure both eyes were visible, and not just the nearest eye.

A high definition digital camera from Sony, model HDRCX550V, was used for the recordings. Additionally, two light sources and a green fabric sheet attached to the wall as a backdrop was used during the recording of the experiment. This type of background and lighting was used to diminish shadows and allow for easier post-processing when manipulating the adults´ body orientation.

The background color of the videos was changed so there were no differences in the lightning in addition to no shadows. The background color was set to be bright green (RGB code 74, 144, 94) in order to create a good contrast to the actors. This was done using the free video editing program VSDC version 2.3.0. Further, the videos were cropped to 16:9 aspect ratios before they were cut to last the exact same length of time. After this, each conversation was cut in half to avoid too many utterances before inserting an attention grabber in Tobii Studio. The program used was a free open sourced video-editing program, Avidemux version 2.6.8. Finally, the videos were split in half (i.e. the screen split in half) thus making it possible to vertically rotate each actor before merging the images again to create the back-to-back conditions. Here, Avisynth was applied to merge the two rotated halves of the video. Finally, 10 different clips of conversations were included in the experiment (see Table 1).

Table 1

Conditions included in the experiment

	Condition	Number of Clips
1	Face-to-face eyes closed	2
2	Back-to-back eyes closed	2
3	Face-to-face eyes open	2
4	Back-to-back eyes open	2
5	Face-to-face no eye contact	2

Each condition consists of 2 clips, each lasting for approximately 25 seconds. Thus the whole experiment lasted less than 5 minutes, excluding attention grabbers and the calibration procedure. Furthermore, each clip consisted of 4-6 utterances from each actor, allowing about 10 turn-taking events for each clip.

Gaze was recorded with a Tobii TX300 corneal-reflection eye tracker. Tobii Eye Trackers use infrared diodes to generate reflection patterns on the cornea of the participant's eyes. Image sensors are then collecting the reflection patterns and other visual data about the participant. Images processing algorithms identify relevant features such as the eyes and the corneal reflection patterns. The eye tracker uses mathematical algorithms to calculate the 3D position of each eyeball and the gaze point on the screen (Tobii Technology AB, 2010). Prior to the experiment, the infant was presented with a calibration. Calibration ensures high precision estimates of the infants' gaze behavior in relation to the vertical and horizontal space by tuning into the specific physiological features of the infant's eyes (Gredebäck et al., 2009).

The infants participating where presented with three sets of videos, representing three different experiments. The current study will only present data from one experiment. The order of the three experiments was randomized and the total length of these experiments was approximately 10 minutes.

Procedure

The study took place in the Cognitive Developmental Research Unit (EKUP) lab at the Department of Psychology, University of Oslo. Upon arrival, all families were informed about the study and then asked to sign a consent form on behalf of their children. They were also reminded that they could withdraw from the study at any time.

In the lab, the infants were placed in their caretaker´s lap, 50-70 cm in front of the Tobii TX300 eye-tracker display. Prior the experimental session, infants were presented with a short, individual 5-point calibration. The calibration lasted a few seconds and consisted of a red ball expanding and contracting to attract attention whilst moving over 5 points across the screen. During calibration, caretakers were asked to look away or close their eyes to ensure the eye-tracker only registered the infants' eyes. Infants were given breaks between videos if needed and were allowed to use pacifiers if the caretaker thought it would have a calming or soothing effect. If the infant at any point would show any sign of discomfort or reluctance, it was not pressured to carry out the experiment.

The stimuli for the current study consisted of 10 video clips presented in a randomized order. Tobii studio´s randomization feature was applied for this purpose to control for potential order effects. The infants were also presented with an attention grabber in between each video clip to maintain their attention. Each conversation lasted for approximately 20 seconds and the actors had about 5 utterances. In total, the whole experiment lasted for 5 minutes (not including calibration and attention grabbers). All infants were presented with all conditions. However, some experiments/trials had to be interrupted due to infant's fuzziness or inattentiveness. The eye tracking was conducted in approximately 15 minutes.

Following the eye-tracking, caretakers were asked to fill out questionnaires relevant to the research project. Data from these questionnaires were not included in the analysis of the accounted study nor described in greater detail.

After completion of questionnaires, the infant received a small gift as a reward for participating. The overall time for participation was about 1.5 hours.

Data reduction

The gaze recordings from the eye-tracking camera were available through gaze plots and data files. In order to estimate how infants follow the flow of the conversation in five different conditions, the analysis relied on gaze shift between two areas of interest (AOIs), covering each of the actors (see Figure 1). The size and position of the AOIs were identical in all conditions.

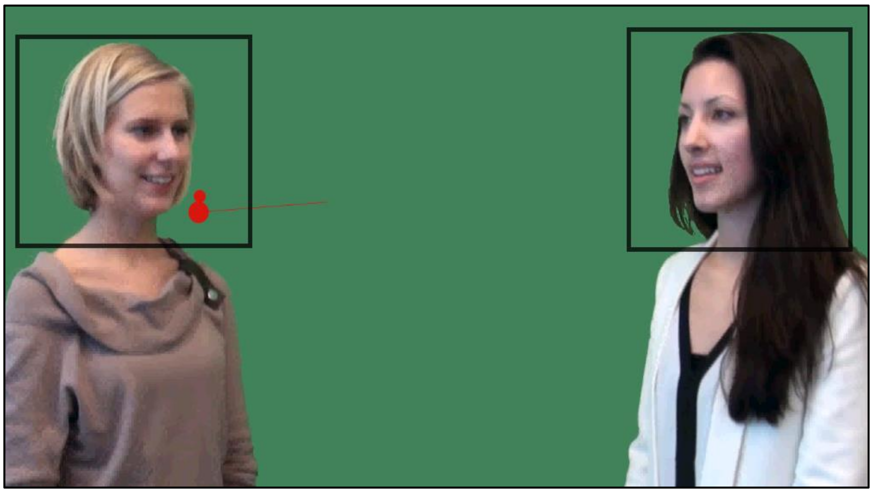

Figure 1. Sample picture of stimulus used in face-to-face no eye contact condition. AOI location is marked with black rectangles. The red circles indicate a participant's fixation, and the line indicates the saccade prior to the fixation. The blonde actor represents the left speaker and the brunette actor represents the right speaker.

The gaze shifts variable measures the amount to which the infants visually attend to the flow of the conversation between the actors. Specifically, the number of gaze shifts related to turn-taking events (i.e. when the left speaker stops talking and the right speaker starts talking, complemented by a gaze shift from left speaker to right speaker). If the infant made a gaze shift while the left speaker was still talking, then the gaze had to remain on the right speaker until she started talking to be certain the gaze shift was related to the turn-taking. If the gaze was completed while the right speaker talked, then the first gaze shift from the left speaker to right speaker was counted. Only gaze shifts that terminate in a fixation of 200 ms of continuous gaze data directed at the same actor was included in the analyses. Only gaze shifts per turn-taking event which accorded with the criteria's listed above, was counted and aggregated to the final gaze shifts scores. Therefore, gaze shifts provided a measure of how many turn taking events the infants attended to. The data reduction was performed by a frame-to-frame analysis of gaze replay movies including both gaze and the stimuli for each participant. The frame-to-frame analyses in gaze replays for each recoding was applied by a program called Virtualdub (www.virtualdub.org) and was time-locked at 67 Hz.

The inclusion criteria for the gaze shifts was similar to what is commonly applied in other eye-tracking studies such as Augusti et al. (2010) and Falck-Ytter, Gredeback, and von Hofsten (2006). Following these criteria's ensure that the gaze shifts counted are in the flow of the conversation and restricting overly fast gaze shifts or quick scanning patterns that are made without paying specific attention to the goal, is not included in the analysis.

Because some infants did not attend to all conditions due to inattentiveness or fuzziness, there was a slight difference in the total amount of utterances observed by each participant. Therefore, a new proportional variable was created making sure that the dependent variable was comparable between participants.

A statistical reduction for the dependent variable (gaze shifts) was conducted using general linear models, with age (6, 9, and 12 months of age) as a between-subject variable and experimental condition (face-to-face eyes closed, back-to-back eyes closed, face-to-face eyes open, back-to-back eyes open and face-to-face no eye contact) as within-subject repeated measures variable.

Results

Initially after preliminary analysis, inclusion criteria were set. The first inclusion criterion was that the infant had to attend to at least three of the five conditions at least once. Second, at least 35% of recorded data per participant was set as the second inclusion criterion. With these inclusion criteria, 10 participants were excluded from the analysis. The final data set consisted of 35 participants.

Analysis of gaze shifts

There was conducted a mixed between-within subject analysis of variance ANOVA with age as between-subject variable and condition as within-subject repeated measures variable. This demonstrated a main effect for condition, Wilks Lambda = .60, F (3, 22) = 4.87, p < .05, partial eta squared = .39 (See Table 2 and Figure 2) however, no interaction between age and condition was observed, Wilks' Lambda = .68, F (6, 44) = 1.5, p = .19, partial eta squared = .17.

Table 2

The effect of age across conditions

	6 months of age			9 months of age			12 month of age		
Condition	N	M	SD	N	M	SD	N	M	SD
Face-to-face eyes closed	8	.500	.151	8	.382	.151	8	.431	.226
Back-to-back eyes closed	8	.300	.226	8	.303	.098	8	.450	.246
Face-to-face eyes open	8	.443	.165	8	.500	.096	8	.462	.268
Back-to-back eyes open	8	.332	.145	8	.298	.197	8	.406	.165
Face-to-face no eye contact	8	.350	.217	8	.375	.225	8	.387	.283

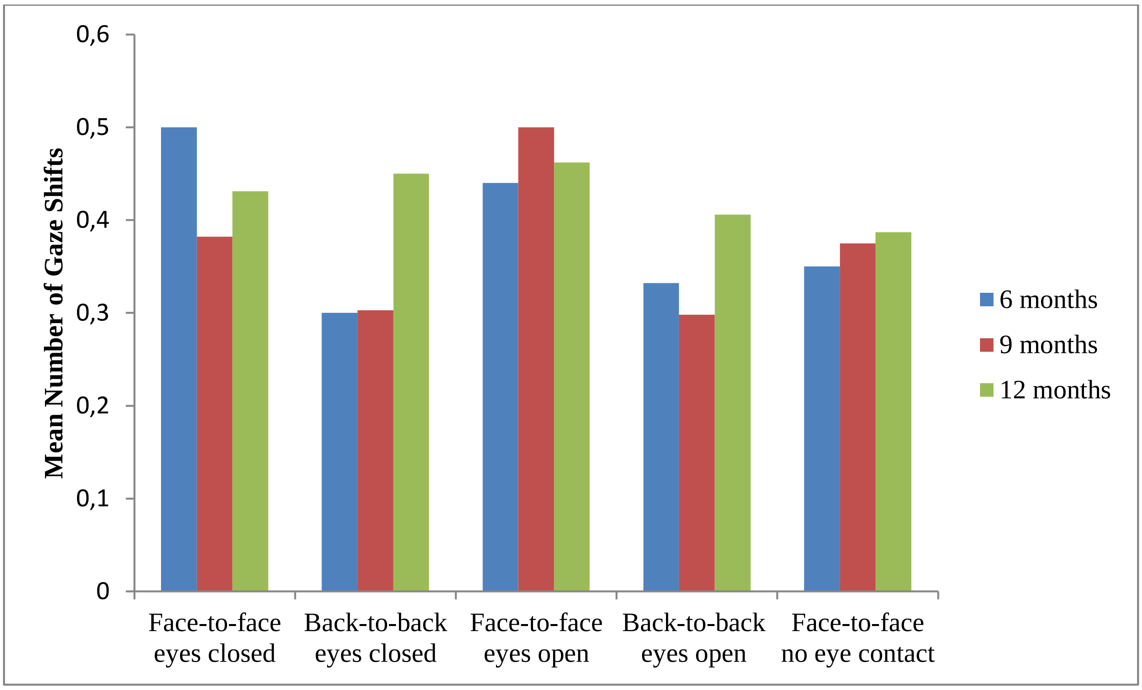

Figure 2. Illustrates the mean of gaze shifts performed in accordance with the flow of the conversation for each condition and age group. The y-axis display the mean number of gaze shift, and columns represents condition (x-axis).

There was no significant interaction between age and condition and therefore it was conducted LSD post hoc analysis in order to investigate the relative differences between conditions within each age group.

Based on pairwise comparisons in LSD post hoc analyses witch demonstrated significant differences within age groups between conditions it was conducted planned comparison t-tests within each age group to investigate the differences further.

There was a significantly increase in 6 month-olds for condition face-to-face eyes closed (*M* = .51, *SD* = .14) to back-to-back eyes closed (*M* = .30, *SD* = .21), *t* (9) = 3.09, *p* <. 05 (two-tailed) (See figure 3). The mean increase in gaze shifts was .210 with a 95% confidence interval ranging from .056 to .364. The eta squared statistic (.40) indicated a large effect.

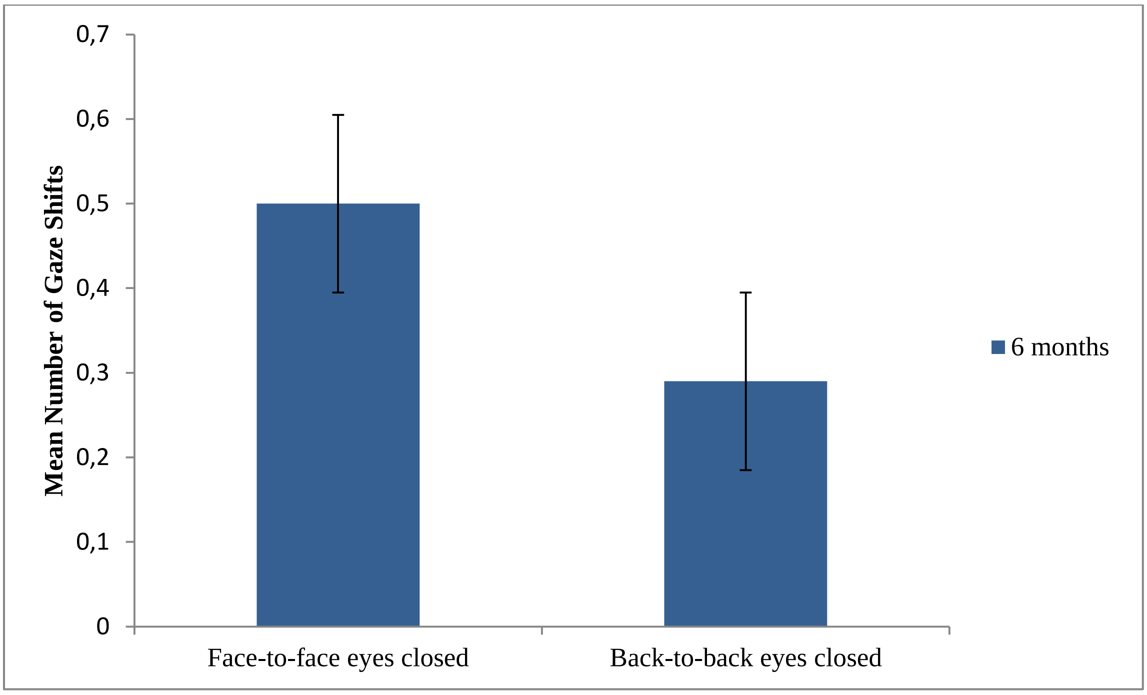

Figure 3. Histogram illustrates the significant difference found in the 6 month group on condition face-to-face eyes closed and back-to-back eyes closed, displaying more number of gaze shifts performed with the flow of the conversation in the face-to-face eyes closed condition. The y-axis display the mean number of gaze shift, and columns represents condition (x-axis).

There was a significant increase in number of correct gaze shifts in flow with the conversation for 9 month-olds in the condition face-to-face eyes open (*M* = .50, *SD* = .11) than the back-to-back eyes open (*M* = .33, *SD* = .19),), *t* (11) = 2.64, *p* <. 05 (two-tailed). The mean increase in gaze shifts was .163 with a 95% confidence interval ranging from .027 to .299. The eta squared statistic (.32) indicated a large effect.

The condition face-to-face eyes open and back-to-back eyes open in the 6 month group is approaching significance (p = .060). Infants in this group, however not significant, demonstrated more correct gaze shifts in the face-to-face eyes open condition (*M* = .43, *SD* = .17), than in the back-to-back eyes open condition (*M* = .29, *SD* = .15). The results of face-to-face eyes open and back-to-back eyes open in 6 and 9 month group is presented in Figure 4.

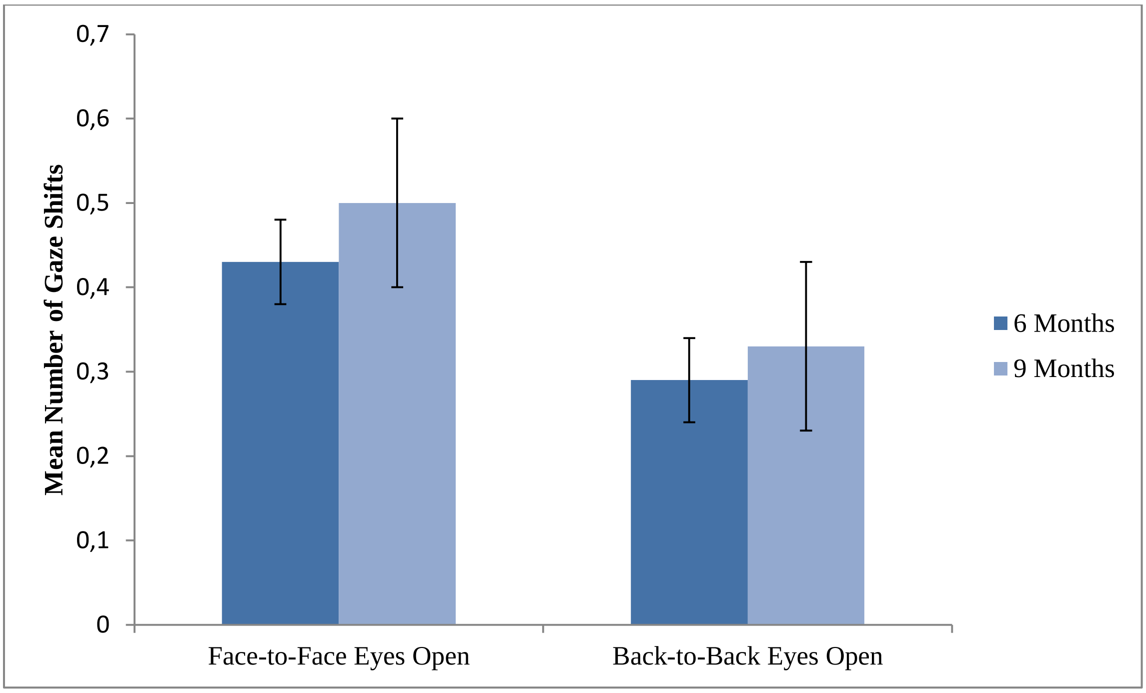

Figure 4. Number of gaze shifts performed in accordance with the flow of the conversation in face-to-face eyes open and back-to-back eyes open in 6 and 9 months. Although it only reached statistical significance in the 9 month group, it is interesting in the 6 month group as it appears to be a trend, almost reaching significance level (p= .060). The y-axis display the mean number of gaze shift, and columns represents condition (x-axis).

There was a significant increase in number of correct gaze shifts in flow with the conversation for 9 month-olds in the condition face-to-face eyes open (*M* = .50, *SD* = .11) than the face-to-face eyes closed (*M* = .33, *SD* = .15),), *t* (11) = 3.48, *p* <. 05 (two-tailed). The mean increase in gaze shifts was .16 with a 95% confidence interval ranging from .059 to .264 (see Figure 5). The eta squared statistic (.38) indicated a large effect.

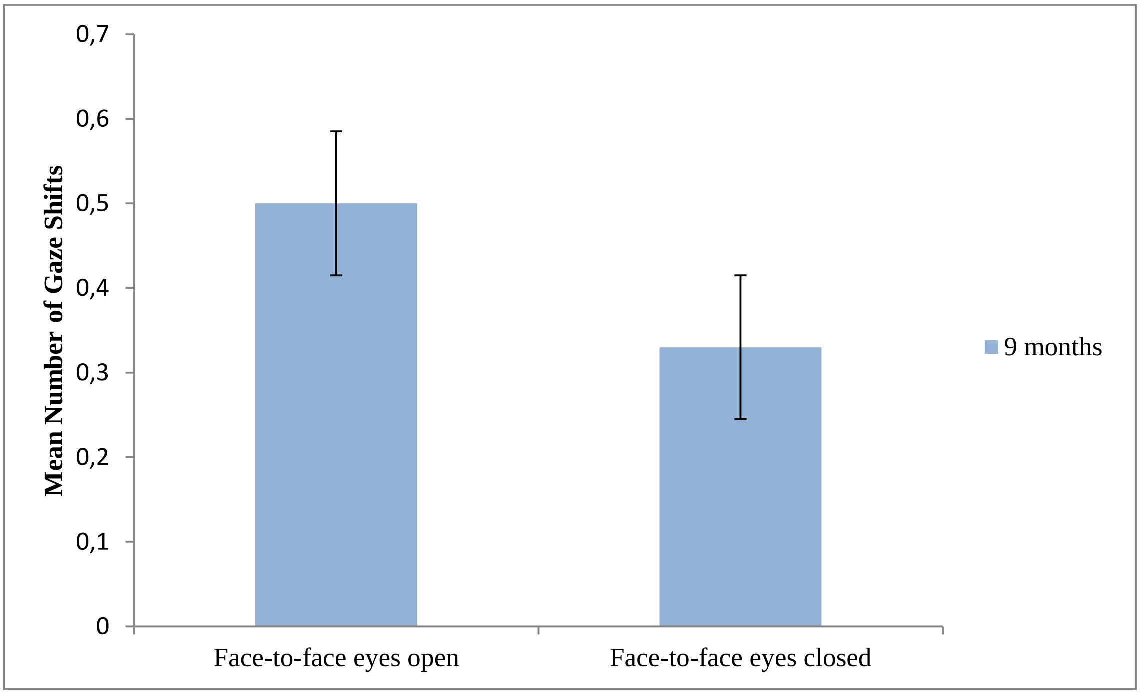

Figure 5. Number of gaze shifts made in accordance with the flow of the conversation in face-to-face eyes open and face-to-face eyes closed in the 9 month group, displaying a significant difference with more gaze shifts in the face-to-face eyes open condition. The y-axis display the mean number of gaze shift, and columns represents condition (x-axis).

Discussion

The overall aim of the current study was to disentangle what cues infants are dependent on when attending a social interaction as an observer. It attempted this by examining the effect of body orientation and eye contact in dynamic social settings. In line with Augusti et al. (2010) study we expected that infants would make more gaze shifts with the flow of the conversation when the actors are standing face-to-face rather than back-to-back. In everyday life, acts of communication are often taking place when people are looking at each other rather than looking away or in another direction (Augusti et al., 2010). Moreover the current study wanted to investigate this effect further by adding additional cues such as eye contact or no eye contact. The study hypothesized that closed eyes or no eye contact would result in a decrease in gaze shifts made by the infant. Furthermore, the study expected to find an interaction effect between age and conditions, i.e., that the infants would perform more gaze shifts with the flow of the conversation, as their age increases. Maturation and social experience are important factors during development of social cognitive abilities (Striano & Reid, 2006). Additionally, infants sensitivity to the social stimuli presented in the study are influenced by infants' experience with social interactions (Augusti et al., 2010). Statistical analysis of the current study did not find this effect. A possible explanation to why this result did not materialize could be due to small sample size (N=24). However, post hoc analyses found significant differences within age groups between conditions in the 6- and 9-month group.

The effect of body orientation

Results demonstrated significant differences within the age groups between the different conditions. In the face-to-face with eye contact and the back-to-back with eyes open, the current study found a significant effect in 9 months-olds. The results demonstrate that 9 month-olds made more gaze shifts with the flow of the conversation when the actors were having the conversation face-to-face with eye contact, rather than back-to-back with their eyes open. Analyses also demonstrated the same tendency among the 6 month-olds, however, the difference was not statistically significant ($p = .060$).

Furthermore, the difference on the dependent variable in the conditions face-to-face eyes closed and back-to-back with eyes closed was significant within the 6 month-old group as they demonstrated more gaze shifts with the flow of the conversation when the actors are conversing face-to-face with their eyes closed rather than back-to-back with their eyes closed.

These results show a similar pattern to Augusti et al. (2010) “face-to-face effect”, indicating that body orientation has an effect on how infants understand social interaction. Infants’ expectations about how social interactions are performed, are previously suggested to develop around 4 and 6 months of age, and in that way they attend to the transitions of the face-to-face interactions to a larger amount than the back-to-back conversations (Augusti et al., 2010). This is referred to as the social cognitive explanation (Augusti et al., 2010; Falck-Ytter et al., 2006; Gredebäck et al., 2010). Furthermore, according to Augusti et al. (2010) the selective attention to face-to-face conversations could represent the beginning of the development of conversation understanding, an ability that should be influenced by language development. Augusti et al. (2010) suggests that in accordance with their findings, infants may start developing a sensitivity and selective attention to face-to-face conversations, however, that the ability to predict the transition of the conversation develops later.

The effect of eye contact

The statistical significance in the face-to-face eyes closed and the face-to-face eyes open condition demonstrated that 9 month-olds performed more gaze shifts with the flow of the conversation when the actors, standing face-to-face, had their eyes open rather than closed. This suggests that eye contact can be an important cue for infants when observing a social transaction, and that they are not dependent on body orientation alone to follow the flow of the conversation.

Infants' sensitivity to eye status and eye contact have been well established (Batki et al., 2000; Brooks & Meltzoff, 2005; Csibra, 2010; Farroni et al., 2002; Hoehl et al., 2009; Tomasello et al., 2007). Because it is visible, the gaze conveyed between people is a potentially rich source of social stimuli for observers (Beier & Spelke, 2012). Eye contact provides the observer with vital information, not only where someone is directing their attention, but additionally offers the observer information about a social transaction. Hence, closed eyes could change the communicative meaning of a social situation (Handl et al., 2013). Handl et al. (2013) did not find that infants used eye status as a cue when presented with static images, however postulated that it would be relevant in combination with other cues in a richer social context. That suggestion fits with findings from the current study, as infants were presented with dynamic stimuli. Furthermore, this finding suggests that it is not only body orientation alone that facilitates the face-to-face effect. However, as this result only reached statistical significance for infants at 9 months of age, it needs to be further investigated before drawing any conclusions.

No significant results were found in the 12-month-group. One could make speculations regarding this issue. The mean age in the 12-month-group was 372 days, and at this age infants begin to develop some language understanding (Bakker et al., 2011). This emerging ability could make them less dependent on cues, such as body orientation and eye contact, to be able to attend and follow the flow of the conversation. Hence, 12 month-old infants may understand more of communicative content of the observed conversation and therefore demonstrated gaze shifts following the conversational flow regardless of body orientation and eye status. The study by Bakker et al. (2011) found that 1-2 year-olds were more interested in spoken language rather than mechanical sounds and at around that age the ability to understand the dynamics of a conversation gets improved due to interest and familiarization. More research is needed to make predictions to why 12 month olds did not significantly discriminate between the different conditions presented in the study.

Limitations in the current study and future directions

The duration of the overall eye tracking procedure could possibly have been a limitation. Observations of the raw-data indicated that infants followed a trend to actively attend to the first clips of the experimental stimuli, and then becoming more inattentive or passive towards the end. As the conditions were randomized, it did not result in more data in some conditions rather than others. However, shortening the overall eye tracking procedure could result in infants attending to the stimuli to a higher degree, consequently resulting in more gaze shifts from the infants.

In the fifth condition, face-to-face no eye contact, no significant results were found in any of the age groups. An explanation for this could be that the condition was too subtle for the infants to discriminate it from conversations face-to-face with eye contact. Nevertheless, the question to what caused the lack of finding remains unanswered.

The current study aimed to describe a developmental path in infants' ability to make more gaze shifts with the flow of the conversation as their age increased. This effect was not found. More research is needed with a larger sample size to answer this question. Furthermore, future studies should investigate further typically developing infants sensitivity to the different cues presented in the current study in order to gain deeper understanding. Infants may begin to develop a sensitivity for and selective attention to face-to-face conversations, but their ability to predict the transition of a conversation develops later (von Hofsten & Gredebäck, 2009), however, the onset of this ability is not yet known (Augusti et al., 2010). As there has only been a few attempts to explore infants' understanding of the interaction of others, future studies should apply the face-to-face paradigm by Augusti et al. (2010) to investigate this interesting and relatively unexplored issue in pre-verbal infant development.

Conclusion

The current study examined how pre-verbal, typically developing infants perceived complex everyday social interactions as an observer. Gaze shifts, as measured by eye tracking, between the two actors following the flow of the conversation were registered presumed to reflect the infants' understanding of the communicative meaning of a social situation in the observed event. Results demonstrated that infants' at 6 and 9 months-of-age displayed more gaze shifts between the actors in accordance with the conversation. 6-month-olds made more gaze shifts when the actors where standing face-to-face rather than back-to-back. 9-month-olds also made more gaze shifts in the face-to-face condition, rather than back-to-back. This was also the case in the condition when the actors where standing face-to-face with their eyes open, rather than face-to-face with their eyes closed.

The results from the current study indicates a sensitivity for, and selective attention to, the face-to-face conditions presented to infants' at 6- and 9-month-olds and are in line with previous findings from Augusti et al. (2010). Further the social information inherent in eye contact when observing others' social interaction seems evident based on the findings in 9-month-group. However, more research is needed to conclude on the different mechanisms involved in understanding others' social interaction. This is important both within the age groups investigated here, but also in order to outline the developmental path during the first year of life.

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