The Social World Through Infants’ Eyes

How Infants Look at Different Social Figures

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Abstract

This thesis aims to study how infants actively look at different social figures: parents and strangers. To study infants’ looking behavior in “live” situations, new methods to record looking behavior were tested.

Study 1 developed a method to record looking behavior in “live” situations: a head-mounted camera. This method was calibrated for a number of angles and then used to measure how infants look at faces and objects in two “live” situations, a conversation and a joint action. High reliability was found for the head-mounted camera in horizontal positions and the possibility of using it in a number of “live” situations with infants from 6 to 14 months of age.

In Study 2, the head-mounted camera and a static camera and were used in a “live” ambiguous situation to study infants’ preferences to refer to and to use the information from parents and strangers. The results from Experiment 1 of Study 2 showed that if no information is provided in ambiguous situations in the lab, infants at 10 months of age look more at the experimenter than at the parent. Further, Experiment 2 of Study 2 showed that the infants also used more of the emotional information provided by the experimenter than by the parent to regulate their behavior.

In Study 3, looking behavior was analyzed in detail when infants looked at pictures of their parents’ and strangers’ emotional facial expressions. Corneal eye tracking was used to record looking. In this study, the influence of identity, gender, emotional expressions and parental leave on looking behavior was analyzed. The results indicated that identity and experience of looking at others influences how infants discriminate emotions in pictures of facial expressions. Fourteen-month-old infants who had been with both parents in parental leave discriminated more emotional expressions in strangers than infants who only had one parent on leave. Further, they reacted with larger pupil dilation toward the parent who was actually in parental leave than to the parent not on leave. Finally, fearful emotional expressions were more broadly scanned than neutral or happy facial expressions.

The results of these studies indicate that infants discriminate between mothers’, fathers’ and strangers’ emotional facial expressions and use the other people’s expressions to regulate their behavior. In addition, a new method, a head-mounted camera was shown to capture infants’ looking behavior in “live” situations.

Keywords: infant social looking, emotional facial expressions, experience, identity, behavior regulation, head-mounted cameras, eye-tracking

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To my family
List of Papers


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### Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AOI</td>
<td>Area Of Interest</td>
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<tr>
<td>EPFL</td>
<td>École Polytechnique Fédérale de Lausanne</td>
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<tr>
<td>ERP</td>
<td>Event Related Potential</td>
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<td>RMS</td>
<td>Root Mean Square</td>
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<td>Wearcam</td>
<td>Wearable camera designed by EPFL</td>
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Introduction

A few decades ago the picture of infants’ social development was quite different from today. Little was known about infants’ social capacities, and infants were seen as having little knowledge about other people’s minds (Reddy, 2008). This thesis studied how infants are active in looking at others and how they look at different people during their social development. In order to do this, another purpose was to test some of the methodology that is available today to study looking behavior in “live” situations.

A common vision of social development is that infants come to the world with some predispositions to learn about other people’s minds. However, as Carpendale and Lewis (2006) write, it is not that infants gradually come to understand the mind but “minds develop within the social process of interaction.” This accords with Vygotsky’s pioneering vision of the development of thought and language (from the 1920–1930s but not published until 1986). In Vygotsky’s theory (1986), it is through the interaction with others that the infant (and child) develops his/her capacities, learns new things and develops a language that will help him/her to further develop higher cognitive skills. Vygotsky considered the infant to be very social: “the child relations with reality are from the start social relations, so that the newborn baby could be said to be in the highest degree a social being” (1982-84, vol.4, p.281, cited by Ivic, 1994). A number of studies after Vygotsky seemed to confirm that infants are indeed social from a very early age (Bowlby, 1973; Carpendale & Lewis, 2006; Reddy, 2008; Schaffer, 1971; Tronick, 1982). However, it has been in the last twenty or thirty years that social cognition in infants has received the most interest (Carpendale & Lewis, 2006; Charman & Stone, 2006), and there are still many gaps in our knowledge about how infants learn about their own and the other people’s minds.

In this thesis I will focus on how infants learn from different social figures, but in order to discuss that, it is necessary to take a look at earlier research on infants’ understanding of other people’s minds. Some years ago, the Sally and Ann’s task (Wimmer & Perner, 1983; Leslie & Frith, 1988) and a number of tests on false belief and theory of mind (for a meta-analysis on false belief see Wellman, Cross & Watson, 2001) made a strong impression in the field of children development by showing how children younger than four years of age failed systematically to understand that others could have different beliefs than themselves. These results were in accordance with the idea that infants are ignorant about other people’s minds. Criticism has
been leveled against the validity of false belief tasks in measuring what they want to measure, as they may measure instead processes such as understanding of complex language, deception, and working memory (Carpendale & Lewis, 2006). Different results have been shown for infants’ predictions of other people’s beliefs depending on the difficulty of the task and on the type of test. For example, eye-tracking studies have shown earlier prediction of other people’s beliefs when looking behavior was recorded instead of verbal answers (Onishi & Baillargeon, 2005; Southgate, Senju & Csibra, 2007). This does not mean that more sensitive methodologies will reveal that infants at any age have the same capacities, but there may be earlier social skills (e.g., gaze prediction of behavior based on previously shown preferences) that gradually develop into more complex social skills (e.g., understanding of other people’s intentions).

Very young infants show some precursors to the understanding of other people’s beliefs and intentions. For example, infants share other people’s attention by following their eye and head direction (for a review on joint attention see Eilan, N., 2005). D’Entremont, Hans and Muir (1997) demonstrated that infants already at 3 months of age are able to follow other people’s gaze to some extent. In addition to connecting other people’s gaze with objects, infants have been shown, later in their first year, to make a connection between hands and goals (Biro, Csibra & Gergely, 2007; Falck-Ytter, Gredebäck, & von Hofsten, 2006; Gredebäck, Stasiewicz, Falck-Ytter, Rosander, & von Hofsten, 2009; Phillips & Wellman, 2005; Sommerville, Woodward & Needham, 2005; Woodward & Robert, 2005). Some studies have also investigated how infants follow social cues in everyday contexts, like conversations. von Hofsten, Uhlig, Adell, & Kochukhova (2009) found that 12-month-old infants had a preference for the speaker when they saw a conversation in a computer screen. Shortly after, Augusti, Melinder and Gredebäck (2010) showed that infants at only 6 months of age already looked more at the speaker, demonstrating an early preference for social cues while observing an interaction.

Another phenomenon in which the use of social information by infants has been observed is in social referencing processes. When infants are presented with an ambiguous object, they look at certain adults around them for information, and, depending on these persons’ reaction, infants regulate their behavior toward the object (Feinman et al., 1992; Stenberg, 2009; Walden & Ogan, 1988; Walden & Kim, 2005). Social referencing starts at the end of the first year, and it is an example of how infants can link stimuli to the emotional expression of adults. Of course, to be able to use other people’s facial expressions, infants need to have some previous understanding of the meaning of emotional facial expressions. In fact, discrimination of emotional expressions comes earlier than social referencing in development. A number of experiments on facial expressions have shown a stable discrimination of
positive and negative emotions from the age of 7 months (for a review see Lepännen, 2011).

All this research seems to indicate that infants are not passive learners; they are very active in exploring their environment and in seeking contact with others. Infants actively look at different people to learn about the world around them. However, only a few studies have addressed how infants look at different social figures like parents and strangers (Gredebäck, Fikke, & Melinder, 2010; Stenberg & Hagekull, 2007; Striano & Bertin, 2005; Walden & Kim, 2005). The parent or caregiver is an important figure in the social development of the child. According to the attachment theory, the child develops a social and emotional bond with the caregiver. Due to this bond, the infant will seek comfort from this person when he or she feels stressed or afraid (Bowlby, 1973; Ainsworth, 1992). However, infants also follow social cues from people other than parents. Below, I will discuss how infants take into account different social figures depending on the context.

Still face experiments are some of the experiments that have been done with both with parents and strangers (Mesman, Ijzendoorn & Bakermans-Kranenburg, 2009, for a review). One of these studies has shown that the identity of the model matters and that infants react more to the parents’ sudden lack of interaction than to that of strangers (Melinder, Forbes, Tronick, Fikke, & Gredeback, 2010). This could be because the infants are more used to seeing the parents interacting with them or because their attachment toward the parents makes the interruption more disturbing. On the other hand, infants have been shown to follow a gaze more from a stranger than from a parent (Gredebäck, Fikke, & Melinder, 2010), to share more attention with a stranger during free play (Striano & Bertin, 2005) and to reference the experimenter more than a parent in ambiguous situations (Stenberg, 2009; Walden & Kim, 2005). Infants start looking at parents for information, but later on they may learn that others can be important sources of information as well. Thus, infants may also start to use other adults’ social cues. And in some situations, for example in the lab, they may look at the experimenter more than at the parent. In this thesis, how and why infants look at parents or strangers was explored. In order to do this, different methods to study infant looking behavior were tested.

In the following section I will start with a detailed discussion of the methods that are available today to study infants’ looking behavior. Study 1 tests and develops one of these methods, a head-mounted camera. I will continue with a discussion of how infants look at parents’ and strangers’ facial expressions and how infants use the other people’s emotional reactions to regulate their behavior. Studies 2 and 3 address these questions.
Methods To Study Infant Looking Behavior

Many researchers have pointed out that infants are active in their learning processes (Piaget, 1952; Bruner, 1973). Infants have to be active, for example, in their motor development; as Karen Adolph commented, infants may take 9,000 steps every day, the length of 29 football fields (Adolph, Vereijken & Shrout, 2003). Infants are also active when they learn about physical properties of objects. The selection of objects and actions performed on these objects will determine how infants categorize and divide the continuous sensorial information into meaningful units (Thelen, Smith, Lewkowicz, & Lickliter, 1994). And infants are also active in their social interactions with others, which also contributes to their social and cognitive development. Before one year of age infants react negatively when others stop interacting with them (as in the still face experiment from 1979 by Tronick, Als, Adamson, Wise & Brazelton), respond differently to contingent or non-contingent mother’s speech (Murray & Trevarthen, 1985), follow other people’s gaze direction and predict other people’s goals (Eilan, 2005, Woodward & Robert, 2005). They also make contact with others by imitation (Meltzoff & Moore, 1977, Devouche, 2004), by pointing and by giving objects (Eilan, 2005; Hay & Murray, 1982; Liszkowski, Carpenter, & Tomasello, 2007), and they look at others for information about novel objects (e.g., Feinman 1992). Thus, infants present a predisposition to interact with others from birth; they seek this contact with others actively, and it is through this contact that they will develop more complex social skills, cognitive abilities, and language. In this section I will discuss how different methods can contribute to studying infants that are active.

Researchers in psychology have used different methods to study different behaviors in infants. Some of the behaviors that have been frequently measured are grasping, crawling, walking, sucking, pointing, and an even more frequently, looking, with paradigms such as habituation and preferential looking (for a discussion on methods see Rochat, 2004). Thus, of all the behaviors, looking has been particularly preferred and was the one used in the three studies of this thesis.

Why study looking? “Where one is looking is closely tied to what one is seeing” as Aslin and McMurray (2004) pointed out, and people can only
focus their attention on some parts of the environment. Attention is selective and, to a great part, voluntary; therefore it can tell us what others are interested in, what is new to them, or where they are looking for information. Also, looking is tightly coupled to the activities that we perform as well as with our goals (Hayhoe & Ballard, 2005). Infants’ looking behavior can provide information about how much infants understand or discriminate, for example, by looking at what actions they expect (prediction) or do not expect (habituation paradigms), or even to whom they look for information to learn about the world (e.g., social referencing).

Today some of the most common methods to study looking behavior in infants are static cameras and eye-trackers, and it is mainly the question of the study that will determine the method. Below we will discuss the pros and cons of these methods.

**Static Cameras**

Static cameras have been traditionally used to measure infants’ behavior in “live” situations. Some examples of “live” studies of social development include studies of imitation, helping behavior, social referencing, pointing, interactions with others, and infants’ play among others (e.g., Striano & Bertin, 2005; Devouche, 2004; Carpenter, Nagell, & Tomasello, 1998; Liszkowski, Carpenter, Striano, & Tomasello, 2006; Nishida & Lillard, 2007; Walden & Kim, 2005). An advantage of static cameras is that they can record the infant’s face so that the emotional expressions of the infant are visible. However, in contrast with eye-trackers, static cameras give a third-person view of the situation, which has to be interpreted and coded by an observer. Further, the field of view of static cameras does not have the same proportions as the child, as in the child’s view objects are closer to the child, and his/her view is tied to the infant’s body and movements (Thelen et al., 1994; Yoshida & Smith, 2008). Also, the camera’s field of view is not chosen by the child but by the experimenter, and the child may have other things in view that the camera does not capture. However, this latter problem could be solved if a number of cameras were located around the child.

**Eye Tracking**

Corneal reflection eye-trackers are also very common in the study of infant cognition. They record the first person view of the child and estimate where on a screen the subject is looking. They do this by using the reflection of infrared light in the cornea (Gredebäck, Johnson, & von Hofsten, 2010). The main advantages of eye trackers are that they calculate gaze position with a
precision of 0.25 degrees of visual angle and have high temporal accuracy (Falck-Ytter, 2008).

Corneal reflection has found several applications in infant research, from prediction of goals and scanning of faces to the study of temporarily occluded objects among others (for some examples see Falck-Ytter, Gredebäck, & von Hofsten, 2006; Gredebäck & von Hofsten, 2004; Hunnius & Geuze, 2004). Eye tracking is optimal for detailed studies on how infants look at stimuli as goal directed actions and faces. However, a main disadvantage of this method in comparison with static cameras is that the infant has to sit still and watch a video, not being able to participate in the situation. Thus, the method will work very precisely for experiments measuring how infants look at specific actions in a video, but the traditional eye tracker is not appropriate for research on “live” or more naturalistic situations. There have been some attempts, however, to create portable eye trackers that can measure eye movements when a person is acting, not only watching a movie, but these methods are not optimally adapted for “live” studies with infants at present (for example hats with mirrors and special glasses (EPFL, Switzerland; Positive Science; SMI, Germany; Tobii, Sweden).

Another option today is “live” eye-tracking methods. These methods are static eye trackers that aim to study looking behavior in “live” situations. However, current models of live eye tracking cover only a 70-degree horizontal and 35-degree vertical field of view and present some problems of missing data when the child looks outside this field (details taken from our model, Tobii TX300). This may place some limitations on how the interactions with others can be recorded with this method; for example, due to the narrower vertical plane, adults cannot be placed close to the infant as their heads would not be visible. Despite these limitations, live eye tracking seems a promising method to record very accurate gaze position in “live” situations.

Another interesting development of eye tracking is the possibility of studying pupil dilation. This measure has not been used extensively in infants, but it may offer new possibilities in the study of infant attention and emotional response. In adults it has been shown that pupils dilate in the presence of significant others (Laeng & Falkenberg, 2007), auditory emotional stimulation (Partala & Surakka, 2003), and cognitive load (Kahneman & Beatty, 1966) independently of luminance and scanning patterns. And infants have been shown to present pupil dilation when they observe faces in comparison with geometric shapes (Fitzgerald, 1968), unexpected outcomes (Jackson & Sirois, 2009), irrational social interactions (Gredebäck & Melinder, 2010), videos of peers expressing positive and negative emotions (Geangu, Hauf, Bhardwaj, & Bentz, 2011), and strangers’ faces in comparison to mothers’ (Fitzgerald, 1968). Changes in pupil diameter are involuntary (Lowenfeld, 1993) and occur below the threshold of consciousness, which makes them a good method to
study responses to stimuli in preverbal infants (Dehaene et al., 2006; Laeng, Sirois & Gredebäck, in press). Further, research in neuroscience has demonstrated a tight coupling between pupil activity and neuronal changes in the Locus Coeruleus (Rajkowski, Kubiak, & Aston-Jones, 1993; Rajkowski, Majczynski, Clayton, & Aston-Jones, 2004), a system that has been related to selective attention and memory retrieval processes (Laeng, Sirois & Gredebäck, in press). Thus, pupil dilation seems to be a direct and powerful measure of infant’s attention and arousal in experiments that use stimuli, such as pictures or videos with controlled luminance.

Nevertheless, eye trackers and static cameras have the disadvantage of not allowing the child to move around a great deal; thus, in these experiments looking data cannot be collected when the infant explores its environment by crawling or walking. Also, experiments outside the lab are difficult to perform.

Head-Mounted Cameras

Head-mounted cameras present a middle way solution between static cameras and eye trackers in the sense that they show the perspective of the child but at the same time the child is free to move and look around in a three-dimensional environment. The head-mounted cameras used most recently are very light and can be attached to the forehead of the infant as a hat. Some of these cameras are also wireless (Aslin, 2009; Corbetta, Guan & Williams, 2012; Franchak & Adolph, 2010; Piccardi et al., 2007). Toddlers have been reported to tolerate the head-mounted camera and to forget about it soon (Yoshida & Smith, 2008).

In comparison with the static cameras, head-mounted cameras show the perspective of the infant. Thus, the head-mounted camera sees the world from the infant’s eyes, skipping a level of interpretation that is necessary when video is recorded by an external camera. The first person perspective is important because the infant’s actions are tightly coupled to the infant body, and the infant has a very different perspective than the adult (Thelen et al., 1994). It is easier to follow the dynamic of the infant’s actions if we can study them from the infant’s perspective. A study by Pereira, Yu, Smith and Shen (2009) has shown how the perspective from the child is different from the perspective of the parent. The child has often one object in view while the adult has several, and objects are less stable in the child’s than in the adult’s view. Smith, Yu and Pereira (2010) also found that objects are bigger in the child’s view as the child is shorter and has shorter arms.

Another study by Yoshida, Smith and Weisinger (2008) has shown an interesting difference in learning new words depending on the perspective. In this study, adults were presented with videos of a mother teaching words to her child. The adults could see the videos (of the mother teaching new words
without sound) from the common third person view camera or from a head camera that recorded the child’s perspective. It was found that, in general, the adults could identify more nouns than verbs from all videos. However, the first-person perspective facilitated the recognition of verbs for the viewers. Thus, these studies have shown how the infant’s perspective can bring new information about what aspects of the world that are being processed. These studies investigated the interaction of the child with another person, often the mother, but none of them has shown to the infant how other people interact. To our knowledge no studies until today have tested how infants look at other people’s interactions in “live” situations, thus, there is a gap in our knowledge of how infants’ learn about others in more naturalistic situations.

However, there have been attempts to use head cameras to measure what attracts the infant’s attention outside the lab. Aslin (2009) presented a study in which an infant’s looking behavior was recorded at 15 and 38 weeks in different contexts (in a supermarket, playing, feeding, in a stroller) and then showed these videos to other 8-month-old infants in an eye tracker. It was found that infants at 4 and 8 months of age spent most of the time looking at salient objects and faces. These results contrast with Yoshida and Smith’s (2008) findings. In their study infants focused most of the time on hands acting on objects. However, these looking patterns were observed in a restricted play situation, a table with three toys. Naturally, infants, as adults, show different looking patterns in different contexts.

Head-mounted cameras, as their name indicates, measure head and not eye position. However, the coupling between eyes and head direction is strong in infants (Grönqvist, Gredebäck & von Hofsten, 2006), therefore, the head-mounted camera could be a good measure to estimate gaze (Yoshida & Smith, 2008). Surprisingly, only a few studies have tested the correspondence between the eye and head position, and they have done so in very restrictive fields. Such calibration is essential to prove the validity of the method, that is, to be able to say that gaze is being measured. Yoshida and Smith (2008) calibrated their head-mounted camera with three toys located on a table in front of the child (in the middle, right and left), and in Smith, Yu and Pereira’s (2010) study, the infants explored one toy at a time, thus having an even more restricted field of view. By testing the camera in only a few positions directly in front of the infant, it is not possible to know how the camera works for other positions in the field of view, including objects located further to the right or left in the field of view and higher and lower than the child.

In Experiment 1 of Study 1, a calibration of a wireless head-mounted camera was done in which head position and object position (assumed gaze) were measured for a number of vertical and horizontal angles. In Experiment 2 of Study 1, the head-mounted camera was used to analyze how infants look at two common situations, a conversation and a joint action between two persons.
How Infants Look at Others

From the beginning of life infants have a preference for social stimuli (e.g., small changes in facial expressions, gaze, and head direction) that will develop in interaction with other people. As infants grow older they start to grasp that what others see and how others react to different stimuli can give them important information about the objects around them (e.g., social referencing). Further, infants may eventually select to whom they look depending on the context.

This section starts with a discussion of how infants orient toward social stimuli like facial expressions and other people’s gaze and how infants use them to learn about the world. Thereafter the discussion turns to how the identity of the social figure matters when infants look at social cues. Head-mounted and static cameras can be appropriate methods to study these processes, as they are able to record the infant looking behavior in naturalistic, “live” situations. However, if higher precision is required, eye tracking can be the most appropriate method.

Face Processing and the Role of Experience

Before infants can use the other people’s expressions to learn about the world, they must be able to differentiate between different emotional facial expressions. Infants develop an understanding of facial expressions in part with the experience of interacting with others (Leppänen & Nelson, 2009, Haxby, Hoffman & Gobbini, 2000).

Recent research suggests that infants have a broad network of social cognition that becomes specialized with experience (Grossman & Johnson, 2007). For example, a widely cited study has shown that 6-month-old infants were able to discriminate human and individual monkeys based on pictures of their faces, while 9-month-olds and adults could only discriminate the identity of the human faces (de Haan, Pascalis, & Johnson, 2002). In an example of specialization in the area of language, infants at 4 and 6 months of age could discriminate lip movements matched to their own and other languages, while 8-month-old infants only matched the lip movements of their
native language (Weikum et al. 2007). Thus, infants specialize in human faces and human language with the experience of looking at others.

As infants develop and gain experience looking at faces, they are gradually able to discriminate between emotional facial expressions (Leppänen, 2011). Newborns have already some ability to discriminate and imitate facial expressions (Farroni, Menon, Rigato & Johnson, 2007; Field, Woodson, Greenberg, & Cohen, 1982; Meltzoff & Moore, 1977; Young-Browne, Rosenfeld & Horowitz, 1977). This early discrimination is not very consistent and is based on low configuration processes, meaning that newborns only discriminate the expressions if they present highly salient features, like for example, an open mouth (Field et al., 1982). But from 5 to 7 months of age infants start to recognize emotions in faces consistently across individuals. Studies presenting multimodal expressions of emotions to infants (synchronized face and voice) have demonstrated recognition of emotions earlier than studies with only auditory or visual information (Bahrick, Lickliter & Flom, 2004; Flom & Bahrick, 2007). And infants at only 5 months of age have been shown to look longer at happy facial expressions compared with angry or neutral ones (LaBarbera, Izard, Vietze, & Parisi, 1976; Wilcox & Clayton, 1968).

Later in development, infants start to recognize unimodal expressions (such as emotional facial expressions without voice) and to dedicate more attentional resources to fearful faces. A study by Peltola, Leppänen, Mäki and Hietanen (2009) showed that 7-month-old infants looked longer and presented a stronger ERP response to fearful faces than happy ones, a difference not present in the 5-month-olds. Furthermore, there are a number of studies that demonstrate that 7-month-old infants are able to discriminate between several emotional expressions (Hoehl, Palumbo, Heinisch, & Striano, 2008; Peltola, Leppanen, Palokangas & Hietanen 2008; Grossman, Striano & Frederici, 2007; Nelson & de Haan, 1996). Hunnius, de Wit, Vrins, & von Hofsten, (2010) found a different pattern of scanning angry and fearful faces compared to happy faces in 4- and 7-month-old infants. Thus, infants gradually discriminate between emotional facial expressions, fear being one of the most important ones, which gathers the most attentional resources of the infant.

Infants and children also present individual differences in their discrimination of facial expressions due to their experience of interacting with different social figures. Montague and Walker-Andrews (2002) found 3½-month-old infants to be more sensitive to their mothers’ facial expressions than to their fathers’ or strangers’. Infants in this study looked longer at the mothers when her voice and face showed the same emotion than when they showed differing emotions. However, infants did not make this differentiation when they looked at the fathers. The authors suggested that this could be due to their experience of being home with the mother. Along the same line, it was also observed that infants tended to be more sensitive to the emotional ex-
pressions of the fathers that were more engaged with their children. In cases of disrupted relations, neglected children have been found to have difficulties with the identification of emotional expressions, while abused children are very sensitive to small changes in emotional expressions (Pollak, Cicchetti, Hornung & Reed, 2000; Pollak & Kistler, 2002). All these studies indicate that experience with others influences how infants and children understand facial expressions of emotions.

Thus, it may be through interacting and looking at others that infants specialize and learn about other people’s emotions. However, infants pick up social cues other than changes in facial expressions as well. One of them, which we mentioned before, is eye and head direction, which enables a process called gaze following.

Infants Relate Seeing To Knowing

Infants gradually develop the ability to follow another person’s gaze (for a review on joint attention see Eilan, 2005). At the end of the first year of life, infants learn that gaze is referential (directed to an object) and they start to have a representation of what others can or cannot see. The following experiments have shown that infants make a link between seeing and knowing, an ability that becomes more sophisticated with age.

Lizskowski, Carpenter, and Tomasello (2008) found that infants at 12-months of age pointed more to an object that the experimenter did not see disappear than to an object that the experimenter saw disappearing. These results suggest that infants are willing to communicate to the experimenter something that she did not see happen. Therefore, infants seem to have some representation of what others know based on what others have seen. Also Moll and Tomasello (2004) found that 12 and 18-month-old infants would walk or crawl behind a barrier to see what the experimenter was looking at behind this barrier. Both experiments suggest that infants at these ages relate what others see with what they know.

In the same line, Surian, Caldi and Sperber’s (2007) study indicated that 13-month-old infants could attribute knowledge to an agent. In their experiment, an agent was able or not to see the location of an object. Infants expected the agent to search effectively for the object only in the condition when the agent had been exposed to information about the location. Certainly, there are different levels of understanding of how looking is related to knowing, and the one discussed here is probably very basic and implicit. This ability will develop further in the second year of life (Sodian & Thoermer, 2008).
Social Referencing And The Search Of Information

The ability to discriminate between emotional facial expressions together with the ability to know what others are seeing paves the way, at the end of the first year, for a new phenomenon: social referencing. It is critical for infants, as they meet new stimuli constantly, to be able to read from other people’s faces and behaviors how to react to new objects and persons. Social referencing is the ability to use another person’s emotional expression to interpret a situation and to regulate behavior according to the other person’s reaction (Feinman, 1992).

In Sorce, Emde, Campos, and Klinnert’s (1985) classic experiment, 12-month-old infants faced an ambiguous cliff (ambiguous because it did not produce strong reactions but made infants check the mother’s expression). Their results showed that infants looked at their mothers and used their emotional expression in order to cross the cliff or not. That is, infants crossed the ambiguous cliff more often when the mother’s expression was positive and encouraged them to cross than when the mothers showed fear or their emotional message was negative.

Even before infants are able to crawl, they look at others when something unexpected happens. In an experiment by Walden, Kim, McCoy and Karrass (2007) the authors found that infants as young as 6 and 9 months looked more toward the caregiver during unexpected than expected events. Striano and Rochat (2000) found that, later in development, 10- but not 7-month-olds refer to others in an ambiguous situation depending on their attention toward them. The authors studied the infants in a situation with a mechanical dog that barked. In one condition the experimenter looked toward the infants and in the other the experimenter looked away from the infants. The 10-month-old infants looked significantly more to the experimenter after the barking of the dog only in the condition when the experimenter was looking toward them. However this difference between conditions was not present in the 7-month-old group. Thus, infants, starting at least when they are 10-month-olds, seem to grasp that others must be looking toward them and the referred object to be able to provide information. These studies suggest that young infants may already be looking at others for information.

Social referencing studies have also shown that infants are not only consumers of information but they also are information seekers. This is a very important skill because human culture develops by a process of gathering information from others to build knowledge. Information-seeking processes seem to have an early origin in ontogeny. It has been demonstrated that infants use other people’s facial expressions and reactions at least from the age of 12 months (e.g., Sorce et al., 1985; Stenberg, 2003; Stenberg & Hagekull, 2007; Walden & Ogan, 1988).

Infants also have some preferences among the informants. As infants get older they may start selecting the referees that are more reliable. Chow,
Pulin-Dubois and Lewis (2008) presented to 14-month-old infants an experimenter that expressed joy when looking at a container that either had a toy inside (reliable condition) or was empty (unreliable). Then the experimenter would look at something located behind a barrier. Their results showed that infants in the reliable condition followed gaze more often behind the barrier than infants in the non-reliable condition. Also, Koenig and Woodward (2010) found that 24-month-olds’ learning of words was affected by the prior accuracy of the speaker. Later in development, Harris (2007) has demonstrated that 3-year-olds prefer to seek information from people that have been proven to know more in comparison with people who have made mistakes or acknowledged ignorance. All these studies suggest an early preference for reliable or knowledgeable persons.

Thus, infants orient toward social stimuli such as facial expressions and gaze direction early in development. And by and by, infants develop more complex social processes like social referencing. However, if infants distinguish between different social figures, does the identity of the social figures matter when infants look at social cues or stimuli?

Looking at Parents or Strangers

The identity of the social figure can be an important factor in how infants interact with their environment; infants may refer to different social figures such as parents, siblings, peers, and strangers in different contexts. Parents are special models as they are not only the first ones that the child interacts with but also the ones the child gets attached to. However, as it was noted above, infants are active searchers for information, and they also get information from people other than their parents. Thus, what do we know about how infants learn social cues from parents and strangers?

On one hand, infants discriminate the mother’s face from birth, based on the outer contour and internal configuration (Bushnell, Sai & Mullin, 1989). And at 6 weeks they are able to identify the mother’s face based only on the internal features (Schonen & Mathivet, 1990). Also, infants look differently at the mother’s and a stranger’s face depending on the situation; for example, when photographs of faces are shown, infants look longer at the mother, as long as the mother and the stranger do not look similar (Barrera & Maurer, 1981; Field, Cohen, Garcia & Greenberg, 1984; Bushnell et al., 1989). And as was stated above, infants also react more strongly to the mother’s than to a stranger’s still face (Melinder, Forbes, Tronick, Fikke, & Gredeback, 2010).

On the other hand, 4-month-old infants follow a stranger’s gaze shifts more than the mother’s in situations of joint attention (Gredebäck, Fikke, & Melinder, 2010). Infants have also been shown to share more attention with the experimenter than with the parent while playing with a toy (Striano &
Bertin, 2005) and to react with larger pupil dilation to pictures of strangers than mothers (Fitzgerald et al. 1968). If joint attention processes such as following gaze were simply learned by reinforcement, we could expect infants to follow gaze more often from their parents, as they see these behaviors most often in them. However, it has been suggested that joint attention is a social cognitive process related to other social abilities (e.g., social referencing, language learning); therefore, infants will respond to social actions performed by others, not only by the parents (Striano & Bertin, 2005; Gredebäck, Fikke, & Melinder, 2010).

Infants may learn first from the caregiver, the person who is at home with them, discriminate him or her from other people, and rely on him/her when they feel uncertain. However, infants may also learn that there are other people that can give them new information about the world, and sometimes they will look more at them than at the parents, for example, when the others have more information about something.

Comparing an infant’s looking at parent and experimenter can provide some answers about the infant’s preferences regarding informants. When something new or unexpected happens, infants may react with fear or with curiosity. If infants react with fear toward an ambiguous object, we could expect that they would look at the caregiver, the attachment figure, for reassurance. However, if infants react with curiosity toward the new object, they may look at the experimenter for information in the lab. Stenberg and Hagerekull (2007) tested the attachment and the information-seeking perspectives by analyzing infants’ looking preferences in a situation when either the mother or the experimenter gave a message about an ambiguous toy. The 12-month-old infants looked more at the experimenter than at the mother. Thus, the results did not lend support to the attachment theory. However, the experimenter was the person who presented the toy; thus, the infants could have associated this person with the toy. In Stenberg (2009), 12-month-old infants looked more at the experimenter than at the parent also in the condition when the parent presented the object and provided a positive message. Thus, neither could association-learning processes explain infant looking preferences. Instead, this preference for the experimenter has been suggested to reflect looking for information from an expert source (Stenberg, 2009; Walden & Kim, 2005). From 12 months of age infants may already be picking up cues about which person is more knowledgeable in a certain situation. Some cues that could indicate expertise are that the experimenter is showing the way, opening the door, or giving instructions. However, there could be still other motivations to look at the experimenter, for example, that the experimenter is novel.

It has been stressed that to study infants’ preferences for parents or experimenters, both figures should be presented simultaneously, and spontaneous looking behavior should be assessed (Baldwin & Moses, 1996). In social referencing studies, a message is provided for the purpose of studying
whether infants regulate their behavior according to this message. However, if no message was provided, spontaneous looking preferences could be recorded. A study by Kutsuki et al. (2007) found that in an ambiguous situation where neither the experimenter nor the mother gave information about a stranger, 7-month-old infants preferred to look at the mother, while 9-month-olds looked at both the experimenter and the mother. These results have been interpreted as a change in selectivity from looking at the source of comfort, the attachment figure, to information seeking, which can be provided by both adults. However, in Kutsuki et al.’s (2007) study, the adults reacted contingently to the infant looks, which may have made the infant look more at this person. In Experiment 1 of Study 2, infant’s spontaneous looking was studied in order to examine if infants younger than 12 months prefer to look at different persons in ambiguous situations. In Experiment 2 of Study 2 it was studied if 10-month-old infants would use the emotional information from the parent and the experimenter to regulate their behavior.

Infants differentiate not only between parents and strangers, they also have different relations with mothers and fathers. As was mentioned above, infants of only a few months of age have been found to be more sensitive to the mother’s than the father’s emotional expressions (Montague & Walker-Andrews, 2002). The authors discussed that the experience of being home with the father or mother could make the infants more sensitive to the emotional expressions of this parent. However, there could also be a biological preference for women over men, as the mother has been the primary caregiver in most cultures and in most eras. By performing a study in which parental leave or how much time infants spend with each parent is measured, it would be possible to distinguish between the influence of the gender of the parent and exposure to the parent. Study 3 was performed to explore this issue.

The main question in Studies 2 and 3 was if the other people’s identity affects infants’ looking at faces and emotional expressions. Experiment 1 of Study 2 investigated if infants as young as 10 months spontaneously look at the parent or at the experimenter in an ambiguous situation when no information is provided. In Experiment 2 of Study 2 information was provided, and it was studied if infants will use this information to regulate their behavior. As this study presented a “live” situation to the infant, a static camera and the head-mounted camera were used. However, Study 2 could not provide information on how infants look at other people’s faces more in detail. To study how infants look and react toward other people’s faces in detail, corneal eye tracking was used in Study 3. Some of the questions of Study 3 were if infants look in a different way at different emotional facial expressions (happy, neutral and fearful), at different identities (parent or stranger), and to different genders, taking also into account parental leave.
Aims of this Thesis

The main aim of this thesis was to study how the identity of the social figure influences how infants look at others. To do this, studies 2 and 3 analyzed infants looking at parents and strangers from the infants’ own perspective. Another purpose was to test methods to study looking behavior in infants that are participating in a social situation. One of the methods tested was a head-mounted camera. In Study 1 this method was developed and used in a naturalistic interaction.

Study 1’s objective was to calibrate a new method to study looking behavior in “live” situations, a head-mounted camera. This is the first study that calibrates a head-mounted camera extensively with infants from 6 to 12 months of age. The head-mounted camera was also used with 10- and 14-month-old infants during two “live” social situations. In these situations, what was studied was how the infants looked at faces, hands, and objects. Thus, our questions were: Is the head-mounted camera a reliable method to measure gaze? Can it be used in naturalistic situations where external cameras have been used until now? And how do infants distribute their gaze in such naturalistic situations?

In Study 2 the head-mounted camera was used together with a static camera to study looking preferences in an ambiguous situation. As explained above, infant’s preferences to look at different persons have been interpreted as a search of comfort or information. Thus, an ambiguous object was presented, and it was compared how much the infants would look at the parent and at the experimenter. The questions of this study were: To which person do 10-month-old infants look as a referent in an ambiguous situation? And do they later use the adults’ information to regulate their behavior?

In Study 3, looking at parents’ and strangers’ faces was analyzed in detail with corneal eye tracking. In this study, three different facial expressions (happy, neutral, and fearful) were presented to 14-month-old infants. The questions of this study were how the infants distribute their saccades and react in the form of pupil dilation toward the three emotional facial expressions in relation to the different genders and to parents versus strangers. It was also investigated if these looking patterns vary depending on how much time the infant had spent with the mother or father.
Empirical Studies

Participants

In these three studies families with infants living in the area of Uppsala, Sweden, were contacted by letter. In the letter, the aims of the studies were described and if the parents answered, they were contacted by telephone to make an appointment. In the lab, parents received verbal and written information about the experiment. They were also told that they could interrupt the experiment at any time and were asked to sign a consent form. After the experiment, the parents received a gift card with the value of approximately €10. All the studies were in accordance with the Declaration of Helsinki.

In Study 1, Experiment 1, forty full term infants participated in the study; 20 6-month-old infants ($M = 26$ weeks, $SD = 1.5$, 10 girls and 10 boys) and 20 12-month-old infants ($M = 51.5$ weeks, $SD = 1.7$, 10 girls and 10 boys). Ten additional infants were excluded because of fussing or technical problems. In Experiment 2, 19 10-month-old infants ($M = 43.1$ weeks, $SD = 0.8$, 9 girls and 10 boys) and 21 14-month-old infants ($M = 60.2$ weeks, $SD = 0.9$, 11 girls and 10 boys) participated. Eighteen additional infants (7 10- and 11 14-month-old infants) were excluded due to fussing or equipment problems.

In Study 2, forty full-term 10-month-old infants participated in Experiment 1 together with their parents ($M = 43.8$ weeks, $SD = 1.0$, 20 girls and 20 boys). Seven additional infants were excluded due to fussiness or equipment problems; these infants were replaced. In Experiment 2 forty-four infants participated ($M = 43.9$ weeks, $SD = 1.4$, 22 girls and 22 boys), in this experiment seven additional infants were excluded and replaced.

In Study 3, 49 14-month-old infants were included (24 girls, mean age 420.6 days, $SD = 9$ and 25 boys, mean age 419.5 days, $SD = 10$). An additional 15 infants participated in the study but were removed, as they did not attend sufficiently to the stimuli. All infants were born within 3 weeks of gestational age, living with both parents.

In this study infants were divided in two groups. Infants that were currently home with their mothers included 14 girls (mean age 419.6 days, $SD =$
9, max = 436, min = 401) and 10 boys (mean age 423.6 days, SD = 10, max = 445, min = 414). Infants in this group had predominantly spent time with their mothers; thus this group was referred as “maternal group.” Infants that were currently home with their fathers included 10 girls (mean age 421.6 days, SD = 11, max = 438, min = 407) and 15 boys (mean age 416.2 days, SD = 10, max = 441, min = 399). Infants in this group had been home with both their mother and father; thus this group was called “parental group”.

Methods and Stimulus

The Wearcam was used in Studies 1 and 2. This apparatus is a small, wireless camera (27 x 27 x 38 mm) developed by Piccardi et al., (2007). The camera provides a diagonal field of view of 92 degrees and records images of 640 x 480 pixels at 30 frames per second, essential to capture the child’s head movements. A rechargeable battery of 45 minutes of usable charge was placed on the back of the head to balance the weight of the optics on the forehead. The weight of the whole camera, including the battery, was 60 grams. The support of the camera was designed to be worn by children between 6 months and 2 years of age (head perimeter 35 to 48 cm). The camera sent data wireless to a computer, where the recordings from the experiments were stored for later analyses.

Experiment 1 of Study 1 was performed in a room equipped with a table (60 cm x 120 cm), the stationary video camera, and the portable computer connected to the head-mounted camera. A blinking buzzing object was used to attract the infants’ gaze at different positions. The object consisted of a battery-powered transparent ball (diameter 7 cm) mounted on a hand-held support. When it was activated, two sets of moving blinking lights moved rapidly inside the ball and a soft buzzing sound was heard. The toy was selected from a number of different toys that had been tested on 6- and 12-month-old infants. It attracted the gaze of the infants very effectively. This session was also videotaped by a stationary camera. The infant was sitting in a high chair at the table during the experiment with its eyes 90 cm from the floor and 80 cm from the opposite side of the table. Experiment 2 of Study 1 was performed in a laboratory playroom (5 m x 3 m) equipped with a table (1.25 m x 1.10 m), a highchair, three chairs, and a stationary video camera. The infant was seated in a highchair at the middle of the long side of the table with its eyes 90 cm from the floor, and two experimenters were seated to the right and left of the infant, facing each other, with their eyes 110 cm from the floor. Thus, the infant needed to turn her/his head in order to look at either of the adults. The parent was sitting in a chair slightly behind the infant’s chair during both situations. In Experiment 2 of Study 1 each experiment used four blocks of different colors (red, yellow, brown, and green).
The maximum size of the blocks was approximately 10 cm x 4 cm x 4 cm. These blocks were hidden under the table before the experiment started.

The ambiguous object used in Study 2 was a mechanical toy (a dinosaur, 20 cm high) that moved slowly at a steady speed. It had been used in several social referencing experiments and was found to elicit looking behavior toward an adult but not fear reactions or strong approach behaviors (e.g., Stenberg, 2009). A stationary video camera captured the infant’s gaze direction and affect (facial expressions). The laboratory playroom was equipped with a table (1.25 x 1.10 m). The infant was seated in a highchair, and the parent and the experimenter were seated to the right and left of the infant facing each other. Their placements were randomized.

In Study 3 a Tobii T60 corneal reflection eye tracker was used to measure saccades and pupil dilations. The stimuli presented to the infants were pictures of their mothers and fathers together with pictures of the parents of the other infants participating in the studies, “the strangers.” These pictures showed happy, neutral and fearful emotions. All pictures were taken in a photo studio with similar light conditions. The picture size was normalized (resolution = 1024 x 768 pixels; 34 x 25.5 visual degrees), white balanced, and edited to remove attention-grabbing accessories.
Study 1

Study 1 was performed to investigate the usability of a new method to record looking behavior in “live” situations, a head-mounted camera. The accuracy of the camera was tested in two experiments.

In Experiment 1, forty 6- and 12-month-old infants were presented with a toy in a number of vertical and horizontal positions. The aim of this experiment was to examine if the head-mounted camera could capture gaze reliably. Thus, gaze and head positions were compared. Another purpose was to examine how the contribution of the head movement changed over the visual field.

In Experiment 2 forty 10- and 14-month-olds were tested. This experiment was performed to study if the head-mounted camera captures the infants’ attention in a naturalistic situation, that is, a situation that is similar to the infants’ everyday context. Two “live” interactions were presented to the infant, a conversation and a joint action of giving and taking blocks. What the infants looked at was coded with a head-mounted camera and an external camera. The codings were compared.

Design

In both experiments the Wearcam was attached to the forehead of the infants and the external camera was located a few meters in front of the infant to capture the infant together with the experimental situation.

In Experiment 1 of Study 1 the infant sat in a high chair and a blinking buzzing toy was presented in different positions in a vertical or horizontal plane. For the vertical plane, the object was shown from behind a panel in positions from 0° (approx. in front of the child’s eyes) to 50° moving gradually higher or lower than the child’s eyes. In the horizontal plane, the object was shown from behind a table, first in front of the infant (0°) and then toward the right and left of the infant up to a maximum of 80°. The head and gaze positions were viewed and coded in a video-editing program (Vegas 7.0). In this program, the position of the object in the screen at 0° was used
as the calibration point (where the eyes and head were both directed toward 0°). The deviation from the calibration point was measured in millimeters for each object position in a computer screen and then transformed to degrees. As the Wearcam moved with the child’s head, the calibration point was always aligned with the head position but not necessarily with gaze. When the child looked at the object, the object position could be used to estimate gaze.

In Experiment 2, the infant sat at a table and two experimenters sat to the right and left of the child, also at the table. In the first situation the experimenters took turns carrying on a conversation about what they were going to do on that occasion. Each of them took turns saying a sentence four times. In the second situation, the experimenters took turns saying a sentence and putting a block in the middle of the table, the sentences were also about what they were doing. It was coded if the infant was looking at the person talking, or at the person who was not talking (Conversation Condition), at the person talking and building or at the non-acting person (Action Condition), at the parent or at other objects in the room (both conditions).

**Results**

In Experiment 1 the correlations between gaze and head positions ranged from .94 to .97 for the horizontal positions, and from .82 to .91 for the vertical positions. That is, the head accounted for 88% of gaze position in the horizontal plane and for 75% of gaze in the vertical plane. The deviations from the perfect correspondence between head and eye positions were calculated. Four ANOVAs were performed with the deviations in the horizontal plane for right and left and in the vertical plane for up and down. No differences between ages were found, $F(1, 38) = 1.38, p = .25$ (right), $F(1, 37) = 0.69, p = .41$ (left), $F(1, 37) = 0.06, p = .81$ (up), $F(1, 35) = 2.80, p = .11$ (down). It can be observed in the graphs that the eye position deviated in a higher degree from the head position in the most extreme angles (i.e. angles 50° and 80°). Also, the deviations showed linear trends for the horizontal positions to the right, $F(1, 38) = 160.98, p < .001, \eta^2 = .81$, and to the left, $F(1, 37) = 58.05, p < .001, \eta^2 = .61$. Linear trends were also found for the vertical positions up, $F(1, 37) = 156.89, p < .001, \eta^2 = .81$, and the vertical positions down, $F(1, 35) = 144.46, p < .001, \eta^2 = .81$. The deviations from linearity were small for all the angles. See Figures 1 and 2.
Figure 1 from Experiment 1, Study 1. The average position of the head for the 6- and 12-month-old infants when they fixated the object in the horizontal positions. Squares denote object position. Triangles show head position for 6-month-old infants and circles 12-month-olds. The error bars are Standard Errors.
In Experiment 2, a two-way mixed ANOVA was calculated using the percentage of looking time toward the speaker (from the total looking time to both speaker and non-speaker) as the dependent variable. The independent variables were condition (Conversation vs. Action conditions) and age (10 months vs. 14 month). An effect of condition, $F(1, 37) = 54.6, p < .001, \eta^2 = .60$ was found; no interaction effect was found between person and age, $F(1, 37) = .25, p = .62$. No age differences were found either, $F(1, 37) = .007, p = .93$. Infants looked in average 54% of the time to the speaker in the Conversation Condition and 79.5% of the time in the Action Condition. Two tests against chance (where .50 was the probability of looking at one person by chance) revealed that infants in the Conversation Condition looked equally at both persons $t(38) = 1.61, p = .116$, but in the Action Condition they looked more at the speaker than at the non-speaker, $t(39) = 11.47, p < .001$. The graphs below show the distribution of looking over time in both conditions. Thus, infants in the Conversation looked for a similar period of time at the person talking as at the person who was silent; however, in the Action Condition, infants looked more at the active person (the person talking and acting). The Action condition was further divided into these categories: look-
ing at the face of the person talking and acting, looking at the face of the non-active person, looking at the hands of the active or at the hands of the non-active person, looking at the blocks, and looking at the parent or at other things. See Figure 3.

*Figure 3 from Experiment 2, Study 1.* The upper pie shows distribution of gaze in the Conversation Condition. The middle pie shows the Action Condition. The lower pie shows the Action Condition divided into more categories. Note that the categories located to the right of the pie can be read in the pie in a clockwise manner.
Agreement for the categories (e.g., if the child looked at the parent in both the Wearcam and the stationary camera) between 25% of the codings from the stationary and the Wearcam ranged from 92% to 98%. Agreement for the gaze shifts (every time the infant looked to a different category) ranged from 91% to 95%.

Conclusions

The head-mounted camera was able to capture gaze quite accurately in a number of angles, although a larger deviation should be accounted for in the most extreme angles. Jonsson and von Hofsten (2003) also found that head movements underestimated gaze direction at the extreme peripheral positions while they were quite well geared at more central positions. In addition, gaze and head were more systematically related in the horizontal positions than in the vertical positions. These results are in line with the findings from Grönqvist, Gredebäck and von Hofsten (2006) of superior timing and gain in smooth pursuit during horizontal than vertical tracking. Infants at 6 and 12 months of age presented a close correspondence between head and gaze direction; thus, gaze could be measured with the head-mounted camera. These results can be taken into account in order to design experiments with head-mounted cameras. Objects located in positions to the right or left of the infant will be captured better with a head-mounted camera than objects located in positions higher or lower than the child.

Following these suggestions, Experiment 2, tested the head-mounted camera when two persons were located at the right and left of the child. In this experiment the aim was to test the camera when the child watched two “live” interactions between the experimenters. The results indicated different patterns in how infants look at two people talking versus talking and building. It is interesting that infants observing a “live” conversation did not show the same looking patterns that have been shown with infants looking at videotaped conversations. That is, eye-tracking studies have shown that infants looking at conversations in a screen prefer to look at the speaker rather than at the non-speaker (Augusti et al., 2010; von Hofsten et al., 2009). However, in this experiment, infants did not show this preference for the speaker during a “live” conversation. This difference could be due to a number of things, one of them being the greater effort required to turn their heads to look at the speaker in “live” settings. The reason for this is that people in “real life” are located farther apart than in videos. It is possible that as infants are preverbal, they do not have so much interest in looking at the speaker and thus do not make the effort to turn toward him/her. Or it could also be that infants are engaged in a different manner when they observe a conversation that is taking place in “real life” than when they watch it in a
video. In any case, infant’s looking behavior while watching a screen may not mirror an infant’s looking behavior in similar “live” situations.

On the other hand, in the second situation, talking and building, infants did look more at the actor. The movement could have attracted the infants’ gaze. Further, there is a growing interest in manual actions at this age, as infants interact with objects and start to learn about other people’s goals and intentions (Woodward & Robert, 2005).

Finally, the comparison of the external camera and the head-mounted camera revealed a close correspondence of the measures, which indicates that this kind of studies can be performed and analyzed with a head-mounted camera as well. Besides the demonstration of the reliability of the camera in two “live” naturalistic situations, Study 1 expands the calibration of the head-mounted camera toward several vertical and horizontal positions and demonstrates its possible use with infants from 6 to 14 month of age.

The results from Study 1 indicate that the Wearcam is a reliable method that can be used in some naturalistic situations. In Study 2 the Wearcam was used together with a static camera to observe a well-known process in infants, social referencing.
Study 2

In Study 2 an external camera and the Wearcam were used to examine social referencing in infants. The aim of this study was to analyze if 10 month-old infants show looking preferences in ambiguous situations. As mentioned above, infants around one year look at others when they see an ambiguous object, and they use the other person’s emotional reactions to regulate their behavior toward this object (Feinman, 1992). In order to study infant looking preferences toward different adults, the parent and the experimenter were present during the presentation of an ambiguous object. The hypothesis was that if infants were looking for comfort they would look more at the parent after looking at the ambiguous object, because the parent is the person the infants have an emotional bond with (Ainsworth, 1992). However, if they were looking for information, they may look more at the experimenter in the context of the lab (Walden & Kim, 2005; Stenberg, 2009). A preference for the experimenter in this kind of situations has been shown in 12-month-old infants (Stenberg, 2009); however, it is not know at which age such a preference starts.

Two experiments were performed. In the first one, looking preferences were studied when neither of the adults gave information about the ambiguous toy. This was done to be able to study spontaneous looking behavior. In the second experiment, the purpose was to study if the infants would use the information from the adults to handle the ambiguous toy. Thus, in the second situation, either the parent or the experimenter gave a positive message about the toy, and it was analyzed if the infants regulated more their behavior according to the message from the parent or from the experimenter. Based on previous results with 12-month-olds (Stenberg & Hagekull, 2007) infants were expected to look more at the experimenter than at the parent and to use her message more than the parent’s to regulate behavior.

Design

Eighty-four 10-month-old infants participated in two experiments with the caregiver. First, the experimenter explained the procedure to the parent, and
after a warm up period of 10 minutes, the experiment started. The infant sat at the table with two adults, the experimenter and the parent, who were sitting besides the child, facing each other. In one condition the experimenter placed the ambiguous toy on the table and in the other, the parent did. In Experiment 1, after the ambiguous toy, a dinosaur, was placed at the table, both the parent and the experimenter started reading a magazine. The toy walked slowly toward the child, taking about 45 seconds. In this time it was recorded where the child looked with both the external camera and the Wearcam. See Figure 4.

In Experiment 2, after the toy was placed in the table, depending on the condition, the parent or the experimenter gave positive information about the toy. Thus, the parent/experimenter said three sentences such as “This is a nice toy” while smiling. Meanwhile the other adult pretended to read a magazine. A behavior regulation phase followed the toy presentation; in this phase, the infants could play freely with the toy for three minutes. In the toy presentation phase, frequencies of looks toward parent and experimenter were coded. In the behavior regulation phase frequencies of behaviors such as looking, touching, or manipulating the toy were coded.

Figure 4 from Experiment 1, Study 2. Toy presentation phase. The head-mounted camera image is shown in the left-hand corner.
Results

Experiment 1: Neither of the adults provides information

A 2x2 ANOVA was performed with frequencies of looks as dependent variable and referee (within: looking at experimenter vs. at parent) and condition (between: experimenter presents the toy vs. parent presents the toy) as independent variables. A main effect of condition was found $F(1, 38) = 4.61, p = .04, d = 0.53$, infants looked more at both adults in the experimenter condition. There was also a main effect of referee, $F(1, 38) = 7.81, p = .008, d = 0.59$, the infants looked more at the experimenter in both conditions. The interaction was not significant $F(1, 38) = 0.68, n.s.$ In this experiment both the Wearcam and the stationary camera were used to test the applicability of this method. However, as social referencing experiments are traditionally performed with stationary cameras, in the article, only the data from the stationary camera was reported. Thus, the correspondence between the codings from both cameras is only reported in this summary. The correspondence between codings from the head-mounted camera and the static camera was established by comparing 20 recordings selected from both cameras. The correspondence for the two looking measures (looking at the experimenter and looking at the parent) was relatively high (> 91%).

Experiment 2: Parent or Experimenter provides information

A two-way ANOVA was performed to study frequencies of looks toward the adults. The two-way ANOVA with repeated measures on referee (looking at experimenter vs. at parent) and between-group comparisons for condition (experimenter vs. parent giving the message) showed no main effect of condition, $F(1, 42) = 3.26, n.s.$ A significant main effect of referee, $F(1, 42) = 41.49, p < .001, d = 1.27$, and an interaction effect were found, $F(1, 42) = 86.56, p < .001$, where the interaction effect was primary to the main effect. Planned t-tests showed that the infants looked more at the experimenter than at the parent when the experimenter provided the message $t(21) = 11.00, p < .001, d = 2.86$. No differences were found when the parent provided the message, $t(21) = 2.05, n.s.$

The analysis of the behavior regulation did not reveal differences in looking at or touching the toy. However, the infants played significantly more with the toy when they received the information from the experimenter. See Table 1.
Table 1. *Mean Frequencies, a* *Mean Number of 5-Sec Intervals, b* *Standard Deviations, and Group Differences by Condition for Infant Variables during the Behavior Regulation Situation* in Experiment 2, Study 2.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Experimenter presents toy</th>
<th>Parent presents toy</th>
<th>df</th>
<th>t</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look at toy a</td>
<td>3.77</td>
<td>5.95</td>
<td>42</td>
<td>1.72</td>
<td>NA</td>
</tr>
<tr>
<td>Touch toy a</td>
<td>3.27</td>
<td>1.59</td>
<td>42</td>
<td>1.18</td>
<td>NA</td>
</tr>
<tr>
<td>Play with toy b</td>
<td>13.09</td>
<td>6.05</td>
<td>42</td>
<td>2.36*</td>
<td>0.71</td>
</tr>
</tbody>
</table>

NA = not applicable

*p < .05

Conclusions

The results were partially in line with the hypotheses. When no one provided information, infants looked more at the experimenter than at the parent when the ambiguous object was presented. Infants might look at the experimenter because this person was novel. However, in these experiments there was a warm up situation in which infants were familiarized with the experimenter; thus infants should not look at her just because of this reason. Another interpretation of this preference for the experimenter comes from studies that show how infants may detect that some people are more knowledgeable or reliable than others (Chow, Poulin-Dubois, & Lewis, 2008; Harris, 2007; Koenig & Woodward, 2010). Infants may pick up cues that tell them that the experimenter is the person in charge in the lab. Some of these cues can be that the experimenter is showing the room and giving instructions to the parent.

A result that was not expected was that the infants looked more at both adults in the condition where the experimenter presented the toy. This could be because this condition was more unusual for the infant than the condition of the parent locating the toy. However, they looked more at both adults, not only at the experimenter, so this result does not explain the preference for the experimenter.

In addition, in this experiment the Wearcam was tested together with the external camera to see if this method was adequate to study looking behavior in a known social process, social referencing. The high degree of agreement in the codings between the methods indicated that the Wearcam could also be used in this situation.
In Experiment 2 infants looked more at the experimenter when she provided the message, but no differences were found when the parent provided the message. This is not in accordance with the previous results from 12-month-old infants, where infants looked more at the experimenter also when the parent gave the message. This could be interpreted as younger infants paying more attention to the parent’s message than older infants.

The results from the behavior regulation phase showed that infants regulated their behavior of playing with the toy in accordance with the positive message they received. Thus, infants seemed to be seeking and using information from others. Further, the infants used the information given by the experimenter more. From a social referencing perspective this preference to use the information from the experimenter has been interpreted as a growing understanding of others as relevant information providers, and this is in line with findings from previous studies (Stenberg, 2009; Walden & Kim, 2005).

Thus, Study 2 showed that infants are flexible when they use information from others and that at 10 months of age they show a preference for looking at the experimenter in the lab when no information is provided. To use the emotional information from others, infants must distinguish between emotional facial expressions. Study 3 analyzes in detail how infants look at emotional expressions of parents and strangers. For this type of analysis, corneal eye tracking was used.
Study 3

The purpose of Study 3 was to analyze infants’ discrimination of emotional facial expressions in parents and strangers. Forty-nine 14-month-old infants participated in this study. Number of saccades, spread of these saccades, and pupil dilation were measured with an eye tracker. The variables of interest were facial expression (fear, happy, and neutral), identity (parent or stranger), gender, and parental leave. From the previous literature it could be expected that infants would discriminate between these emotional expressions (Leppänen, 2011, for a review). Also, if experience helps infants to discriminate facial expressions, we could expect a better discrimination of parents’ facial expressions than strangers’ and especially of the parent they spend most time with (Montague & Walker-Andrews, 2002). However, Fitzgerald et al. (1968) found a larger pupil diameter for strangers than mothers in 4-month-olds; thus, pupil dilation might reflect other processes than discrimination. Due to the lack of studies measuring pupil dilation with these variables, these hypotheses were only tentative.

Design

Infants were divided in two groups depending on the distribution of parental leave. In the "maternal" group the infants had been at home most of the time with the mother. In the "parental" group, infants had been at home with both parents, that is, the father was on parental leave at least for the last month but the mother had been on parental leave before the father.

Ninety-six pictures of emotional facial expressions were presented to the infants. These images included neutral, happy, and fearful expressions (see Figure 5). The models showing these expressions were the mother and the father of the child or the parents of another child (strangers). Half of the infants were presented with the pictures of the parents first and half with the strangers first.

The number of fixations was calculated by counting fixations in the Tobii eye tracker during the 5 seconds that the stimulus was presented. The Root Mean Square of the fixations (RMS) was performed by calculating the root
mean square deviation between each fixation point and the average fixation point in this period. Thus, RMS measured how much gaze was spread over the faces. Finally, pupil dilation was calculated by normalizing the mean pupil diameter over the first 3 seconds. This time captured the initial dilation and later contraction of the pupil.

The data from individual stimulus presentation was included if more than 75% of the data existed for the 3 first seconds of the presentation. Outliers (more than 3 z-scores) and missing data were replaced by the means for each child; however, this constituted only < 5% of the data.

Figure 5 from Study 3. (a) an example of stimuli of the parents of a child presenting the three emotional expressions (neutral, happy, and fearful). (b) an example of the presentation of four emotional expressions with attention grabbers and white pictures.

Results

The analysis of the number of fixations indicated a different number of fixations for happy, neutral, and fearful expressions $F(2, 88) = 36.57, p < .0001, \eta^2_p = .45$. Fixations for the happy faces were $M = 7.4, SE = 0.15$, for the neutral faces $M = 7.8, SE = 0.17$, and for fearful faces $M = 8.3, SE = 0.17$. There was also an interaction between expression and distribution of parental leave $F(2, 88) = 3.4, p < .05, \eta^2_p = .07$. Post-hoc tests indicated that infants in the maternal care group differentiated all the expressions, while infants in the parental care group only differentiated happy from neutral and happy from fearful (LSD test, $p < .05$). Post-hoc tests also differentiated between maternal and parental groups when presented with happy and neutral expressions (with more fixations in the parental group). No other significant effects ($p < .05$) were found in this ANOVA. See Figure 6.
In the analysis of the RMS, infants in the parental group distributed gaze more than infants in the maternal group, $F(1, 46) = 6.46, p < .02, \eta^2_p = .12$. The average RMS for the parental group was 2.52, $SE = .07$, and for the maternal group was 2.28, $SE = .07$. Infants also distributed gaze more when looking at male than female faces $F(1, 46) = 6.1, p < .02, \eta^2_p = .12$ and when they looked at fearful faces $F(2, 92) = 13.6, p < .0001, \eta^2_p = .23$ as the post-hoc tests indicated (LSD test, $p < .05$). Further, an interaction between gender and expression was found $F(2, 92) = 3.4, p < .05, \eta^2_p = .07$. Post-hoc tests demonstrated that male fearful faces were scanned more broadly than all the other expressions, that neutral male faces were scanned more broadly than neutral female, and that fearful female expressions were scanned more broadly than male happy, female happy and female neutral expressions (LSD, $p < .05$). No other significant effects ($p < .05$) were found for the ANOVA testing RMS. See Figure 7.
Figure 7 from Study 3. This graph represents RMS for the different emotions, Happy, Neutral, and Fearful for pictures of males and females. Error bars represent Standard Errors.

In the analysis of the pupil diameter, a main effect of gender was found $F(1, 46) = 10.93$, $p < .002$, $\eta^2_p = .19$, in the direction of larger pupil diameter for females ($M = 3.21$, $SE = 0.06$) than males ($M = 3.18$, $SE = 0.06$). No other main effects were found in the level of $p < .05$. However, a three-way interaction between identity, expression, and distribution of parental leave was found: $F(2, 92) = 3.3$, $p < .05$, $\eta^2_p = .07$. In order to disentangle this three-way interaction, normalized pupil diameter scores from neutral facial expressions were subtracted from fearful facial expressions, creating a differential index. Another differential index was created for the neutral and happy emotional expressions. Separate analysis of these indexes resulted in an interaction between parental leave and identity (parent/stranger) for fearful and neutral expressions $F(1, 46) = 5.41$, $p < .05$, $\eta^2_p = .105$. Post-hoc tests (LSD, $p < .05$) indicated that infants in the parental group had a stronger differential reaction to the stranger’s fearful and neutral emotional expressions than infants in the maternal group (see figure 8C). No differences were found for happy versus neutral emotional expressions.

Correlations were performed on infants’ pupil response to neutral emotional expressions for mothers and fathers and parental leave. Parental leave correlated with the infants’ pupil response toward the parent who was not currently on parental leave. That is, when the mother was on parental leave, infants’ pupil diameter was larger for the father’s neutral expression and smaller for the mother, while the opposite was true for infants who were more at home with the father. Figure 8A illustrates the positive correlation
between increased distributed parental leave and pupil dilation toward mothers’ neutral expressions ($r = .34, p < .05$). Figure 8B shows the negative correlation between increased shared parental leave and pupil dilation toward fathers’ neutral expressions ($r = -.33, p < .05$).

![Figure 8 from Study 3](image)

**Figure 8 from Study 3.** In A and B normalized pupil diameter and its variation depending on father’s parental leave is represented for mothers and fathers with neutral expressions. The horizontal line represents an equal distribution of parental leave (50%). The diagonals are the regression lines. C shows a differential pupil diameter for fear and neutral emotions in parents and strangers for the parental and maternal care groups. The horizontal line with two circles indicates a significant difference.

**Conclusions**

Regarding the emotional expressions, the results from number of fixations, RMS, and pupil dilation all indicated some discrimination between the emotional facial expressions. Infants scanned more broadly and presented a larger pupil diameter toward the fearful emotions, while they reacted to a lesser degree toward the happy faces.
Some differences were found in the way that the infants looked at female and male faces. Infants spread more their gaze when they were looking at males but presented a larger pupil diameter when looking at females. These differences may reflect different types of processes, as fathers and mothers may have a different relationship with the child. However, the results could be due to perceptual differences between males and females as well.

The difference in pupil dilation between strangers and mothers that Fitzgerald (1968) reported was not found in this study. This may be due to the age difference between the experiments; Fitzgerald tested 4-month-old infants while our subjects were 14 months of age, and substantial development of the child occurs between these ages.

In Study 3 the parents of one child were matched to the parents of the other child (who were the strangers of the first child), thus, differences between parents and strangers could only be due to the relationship between the child and the model and not because of perceptual differences between the stimuli (which could be the case for the male/female comparison).

The distribution of parental leave could be more important than has previously been thought. Infants in the parental group scanned faces in a broader way than infants in the maternal group. A more global scanning of faces has been interpreted as more mature face processing (Carey, 1992). Differences in pupil dilation also indicated that infants who had spent more time at home with both parents had an enhanced processing of stranger’s fearful facial expressions. That is, infants in the parental group presented a stronger differential reaction between fear and neutral faces than infants in the maternal group.

It was also found that infants reacted with a larger pupil diameter toward the neutral expression of the parent who spent less time at home. This could be due to the ambiguity of the neutral expression, thus, infants might find it harder to interpret an uncertain emotional expression of the parent that is not so often at home (Bar, Neta & Linz, 2006). Thus, the experience of being home with the parent may make a difference in how infants understand his/her emotional expressions. Montague and Walker-Andrews (2002) demonstrated an enhanced sensitivity toward the mother’s expressions in comparison with the father’s in a group of children that had been cared for by the mother most of the time. The current study suggests that the experience of being cared more equally for by both parents may influence how infants process other people’s emotional expressions.

Coming back to the methods, the infant’s distribution of saccades provides a measure of global scanning of faces, which contributes to the understanding of face processing. Further, pupil diameter is a measure that can provide information of arousal or information processing. The combination of these measures can bring new insights to the field of infant emotional face processing.
In this study we have shown that spending more time with mothers and fathers seems to make a difference in how infants look at emotional expressions. Further, this difference is related to parental leave, that is, to how much time infants spend with each parent. It is a question for parents and society if parental leave could be distributed more equally, especially if this could be beneficial for the infants.
General Discussion

The studies in this thesis analyze infants’ looking behavior toward different social figures. It was also studied which methods can be used to measure looking behavior in situations where the infant can participate. Thus, first, in Study 1, a method to study looking behavior in “live” situations was tested. The method, a head-mounted camera, was reliable in these situations and functioned better in the horizontal than in the vertical plane. Secondly, in studies 2 and 3 looking toward different social figures was analyzed. The results indicated that infants look to different social figures depending on the context. Infants in Experiment 1 of Study 2 looked more at the experimenter than at the parent in an ambiguous situation when no message was provided. And when a positive message was provided in Experiment 2 of Study 2, infants regulated more their behavior according to the experimenter than the parent. In Study 3 both the identity of the social figure and the experience of being home with the parent influenced infants’ looking at other people’s emotional facial expressions. These results suggest that infants are flexible when they look at others. Below I will discuss the contributions of the different methods that we have used. Then I will continue describing in detail the findings on how infants look at others.

Different Methodologies For Different Purposes

As was argued above, infants are active in their relation with the world, including their interaction with others. Thus, we need methods to study infants when they are active.

Different methodologies have been used to measure infants’ looking behavior depending on the question of interest. In studies 1 and 2, infant behavior was analyzed when the infant was present in a “live” situation. Nowadays these kinds of situations are recorded with stationary cameras. The results of these studies demonstrated a high reliability between the stationary and the head-mounted camera. Thus, the same experiments that have been traditionally done with stationary cameras could also be done with head-mounted cameras. But why would we need the head-mounted cameras?
First of all, besides the Wearcam being an instrument able to capture the child when he/she is active, the head-mounted camera gives a direct picture of what the child sees; thus, this is a method that sees the world "from the infant's eyes." Traditional cameras include one step more in the interpretation of the infant's gaze: first the infant’s head or gaze direction has to be coded (e.g., to the right), and then, what is in the place where the child is looking has to be coded as well (e.g., the mother is at the right of the infant). The head-mounted camera captures the infant's perspective directly, that is, the researcher sees what the infant is seeing (e.g., the mother).

Besides this, the infant's perspective is qualitatively different than the adult’s. As mentioned in the introduction, some experiments have demonstrated how the perspective can change how a behavior is analyzed. In their study, Yoshida, Smith & Weisinger (2008) showed that it was easier for adults to link an action to a verb if the action is presented from a first-person perspective than if it is presented from a third-person perspective. Thus, to see an action from a first-person perspective can facilitate the identification of verbs. It is possible that the third-person perspective misses some relationship components of a sequence that the actor sees.

In addition, as the head-mounted camera records the child’s perspective directly, programs can be made to automatically detect faces or other objects of interest avoiding the time-consuming frame by frame analysis of the videos (some attempts at automatic coding of head-mounted cameras’ videos have been made by EPFL). Another advantage for many labs is that head-mounted cameras are much more affordable than eye-tracking systems.

The precision of the head-mounted camera is not as fine as eye trackers; however, the precision needed to measure gaze in the real world does not have to be as high as in computer screens. In the real world objects and people are much bigger than in a computer screen so a difference of a few degrees does not matter much. Studies with head-mounted cameras have also found that infants often bring the object of interest closer to their field of view, occupying, thus, a large proportion of the view (Smith, Yu & Pereira, 2010). Thus, if the head-mounted camera is used with the right design, it can measure the infant’s looking behavior in situations where the infant can move freely. A wireless head-mounted camera doesn't have limits on how much the infant can move, and researchers are now more often interested in active subjects.

On the other hand, to analyze looking at faces more in detail, when a few degrees make a difference, more precise methods are needed. This is why Study 3 was performed with eye tracking. Eye tracking allows the recording of very precise looking patterns and pupil dilation.

Infant studies generally make assumptions about what looking means. For example, when infants get habituated to one stimulus and a new stimulus is presented, if the infants detect differences between the two objects they may look more at the new one. In this case, looking would reflect an ability to
detect differences. On the other hand, infants may look more at an object that is familiar; in this case, looking can be related to memory processes (Kavsek & Bornstein, 2010). The main assumption about looking behavior is that it reflects attention processes; however, it is difficult to interpret looking behavior outside of the observation context. Adding the measures of pupil dilation to other behavioral measures of gaze can give new insights into what the stimuli means for the person, that is, pupil dilation has been shown to be a direct physiological measure of attention and arousal processes (Laeng, Sirrois & Gredebäck, in press).

“Live” situations also have limitations in comparison with videos, as they introduce more variability and are less controllable than presenting the same video to all infants. Researchers have to find a balance between making situations more naturalistic and with higher ecological validity and how much control they can have over these situations. A possible solution is to use different methods that complement and validate each other.

By testing the head-mounted camera in situations where the infants looked at several horizontal and vertical angles, we have shown for the first time how the camera works for a large number of vertical and horizontal angles around the infant. Further, by presenting people talking and acting we have validated the method for its use in situations where the child is observing “live” interactions of others.

How Infants Look at Others in “live” Situations

In Experiment 2 of Study 1 two “live” situations were presented to the infants and their looking behavior was studied from the infants’ perspective. The results indicated that infants look differently at conversations and joint actions. In fact, infants looking at “live” conversations did not present the same looking patterns that have been shown in studies of infants looking at videos of conversations (Augusti, Melinder, & Gredebäck, 2010; von Hofsten, Uhlig, Adell, and Kochukhova, 2009). It was expected from the previously mentioned studies that infants would look more at the speaker than at the non-speaker. However, it could also be the case that preverbal infants do not follow the turns of a conversation, as they do not use language yet. Actually, in Experiment 2 of Study 1, infants did not show this preference for the speaker when they were presented with an adult conversation not directed toward them. In this experiment, infants looked at both adults independently of who was talking. Conversely, when von Hofsten, Uhlig, Adell, and Kochukhova (2009) and Augusti, Melinder and Gredeback (2010) presented a conversation in a video, infants looked more at the person talking. It could be speculated that it requires less effort to look at people talking on a screen, as they are very close together in terms of visual degrees, while in “real life” situations the infant has to turn toward the person talking.
However, infants usually make the effort to look at what it is interesting to them, and in the second part Experiment 2, the action grabbed the infants’ attention. When the manual actions started, infants looked and paid more attention to the hands and face of the person acting. The preference for looking at hands has also been reported in studies in which a person has interacted with objects and with the child (Yoshida & Smith, 2008; Yu, Smith, Christensen & Pereira, 2007; Pereira, Yu, Smith & Shen, 2009). This interest in hands may be due to infants’ learning about intentions and goals (e.g., Woodward, 1998), although it could also be that the movement attracts their attention. This cannot be disentangled from this study; however, it is likely that both the movement and the hands are interesting to the infants at the end of their first year. Studies of goal understanding have shown that infants at the end of the first year start using goal-directed gestures like pointing and associating hands to goals (Woodward 1998; Falck-Ytter, Gredebäck & von Hofsten, 2006). Thus, at this age, infants not only manipulate objects but also observe other people’s actions with objects to learn about other people’s intentions.

Thus, when looking behavior was studied in Experiment 2 of Study 1, infants at 10 and 14 months of age did not have preferences for the speaker in this “live” conversation. However, infants looked more at the actor when this person collaborated in giving and taking objects. Thus, this experiment gives some information about how infants look at others in two naturalistic situations. However, in this study only experimenters were presented to the infants; Study 2 and 3 addressed the question of whether the identity of the different social figures matters when infants look at others.

When Strangers Are More Interesting than Parents

Infants differentiate parents from strangers from very early on and prefer to look at one or the other depending on the situation. As was discussed above, infants may look more toward parents than strangers when they are younger or when they feel stressed or afraid (Ainsworth, 1992; Melinder et al. 2010; Kutuski et al. 2007). And they may look for social cues from strangers when the strangers are more informative than the parents (Walden & Kim, 2005; Stenberg, 2009).

In Study 3 infants saw pictures of their parents and strangers with different facial expressions. In this study no differences were found between how much infants looked at parents and strangers. This could be because both adults were interesting in this situation. That is, infants are used to seeing the parents’ facial expressions, so the strangers’ can be more interesting to them. At the same time, as the parents are the attachment figures it is important for the infants to look at their emotional expressions as well.
On the other hand, in Experiment 1 of Study 2, when the infants were presented with an ambiguous toy, 10 month-old infants looked more at the experimenter than at the parent when neither of them provided information. In addition, in Experiment 2 of Study 2, when a positive message was provided, infants used the experimenter’s information more by playing more with the ambiguous toy. But why would the infants prefer to look at the experimenter who is a stranger? A first explanation that comes to mind is that the experimenter is novel. The experimenter is always going to be novel compared with the parent, but, as in these experiments, the infant had time to become familiar with the experimenter, so novelty is probably not the main reason why infants looked at her. An experiment from Stenberg (2011) suggested that novelty was not a reason to look at one experimenter over another in an ambiguous situation. That experiment compared infants’ looking behavior toward two experimenters who knew how to use toys. No differences in looking were found between the conditions in which the experimenter was novel or familiar.

Another explanation for this preference could be that as infants get older they grow more independent from the parent and start relying more on other people. This explanation is not incompatible with the following research, which indicates that infants may seek information from the most knowledgeable individuals. Previous studies have shown that around one year of age infants can grasp that a person has information about something (Liszkowski, Carpenter, & Tomasello, 2008; Surian, Caldi, & Sperber, 2007) and that later on infants prefer to look at the person who is more reliable or who has correct information (Chow, Poulin-Dubois, & Lewis, 2008; Harris, 2007; Koenig & Woodward, 2010). This may be one reason why infants prefer to look at the experimenter, because this is the person who has more information about the lab (Stenberg, 2009).

Thus, the results of these studies showed that when no information was provided in an ambiguous situation, 10-month-old infants looked more at the stranger than at the parent. And when either the experimenter or the parent provided information, the infants regulated their behavior more according to the experimenter’s message. These results suggest that infants can use information from people other than their parents. But of course, infants also use information from their parents; the next section discusses how infants differentiate emotional expressions of parents.

The Importance of Parental Leave

Previous research has found differences in infants’ discrimination of emotional facial expressions in fathers and mothers (Montague & Walker-Andrews, 2002). The authors argued that these differences were probably
best explained by exposure to the parent, that is, infants may have reacted differently to the parent they had spent more or less time with.

A result from Study 3 indicated a larger differentiation in pupil diameter between neutral and fearful expressions for pictures of strangers in the parental group, that is, the group that had been cared by both parents (the father was in parental leave at least for the last month but the mother had been on parental leave before the father). These results suggest that when the child has two models of facial expressions (the mother and the father), their recognition of fear in others is heightened. Also, the results indicate that infants in the parental group processed the emotional faces in a more distributed, global manner. Configural processing of faces, or the ability to process a face as a whole and not only as a number of independent features, has been found to develop with age (Carey, 1992; Rose, Jankowski, & Feldman, 2002). Therefore, our results may indicate that infants’ processing of faces was more mature in the parental group.

In addition, infants reacted with a larger pupil diameter to the neutral expression of the parent who was less frequently at home. This was shown in the correlations between parental leave and infants’ pupil diameter toward mothers and fathers. As neutral emotional expressions can be ambiguous, an explanation for the larger pupil dilation for the parent who was not at home so often could be that the infants find it harder to understand this expression in this parent. However, there could be other explanations of this preference, and more research is needed to explain this difference. From these results we can conclude that infants as young as 14 months react differently to the parent that is not in parental leave.

Some research has also found that infants learn about emotions from the persons they have contact with (Montague & Walker-Andrews, 2002; Pollak, Cicchetti, Hornung & Reed, 2000; Pollak & Kistler, 2002) and that sensitivity toward facial expressions develops and specializes in interaction with others (Leppanen & Nelson, 2009; Haxby, Hoffman & Gobbini, 2000). Our results go in the same direction, suggesting that infants’ experience of being home with both parents can facilitate their discrimination of emotional expressions in others. Infants learn language, expressions, and many other behaviors from the persons around them; thus, they could be expected to learn more from the person who is more often at home with them. However, to what degree parental leave may influence infants’ social development is a question for future research.

The results from 14-month-old infants showed that parental leave makes a difference in how infants process other people’s facial expressions. And together, studies 2 and 3 suggest that infants around one year look differently at strangers, mothers, and fathers depending on the context. Thus, identity seems to matter when processing facial expressions, but does identity influence all emotions in the same way or are there differences between the emotions?
The Attraction of Fearful Faces

As mentioned above, experience with others seems to be important in order to discriminate facial expressions. A great amount of research has found that some facial expressions will get more attention than others, at least from a certain point in development (see Lepannen, 2011, for a review).

In Study 3 some discrimination between fearful, neutral and happy facial expressions was found for number of saccades, RMS, and pupil dilation. The discrimination between emotional facial expressions was expected in 14-month-old infants, as studies with 7-month-olds have shown some discrimination of positive and negative facial expressions (Hoehl et al., 2008; Peltola et al., 2008; Grossman, Striano & Friederici, 2007; Nelson & deHaan, 1996). A recent study by Geangu, Hauf, Bhardwaj and Bentz (2011) also found differences in pupil dilations in 6- and 12-month-old infants when they observed videos of peers showing positive, negative, and neutral emotions. In their study, infants’ increase in pupil dilation after seeing the negative emotions lasted longer than when they observed positive emotions. The Geangu et al. (2011) study complements the present study by presenting more naturalistic, dynamic, expressions of emotions. However, the visual characteristics of videos are difficult to control as they vary constantly; thus, still pictures of emotional faces have a higher control of these factors.

Infants in Study 3 spread their gaze more when they looked at fearful expressions than when they looked at neutral or happy faces, which was also in line with previous research. Hunnius et al. (2010) found that 4- and 7-month-old infants looked at the threat-related face expressions with a less focused, broader, “vigilant” scanning pattern. The authors reasoned that fear is an indicator of danger and therefore the observer must be vigilant regarding possible danger in the environment.

In addition, in this study, infants made a larger number of saccades when looking at fearful faces compared to happy or neutral ones, although, as this was the mean number of saccades for 5 seconds, this means that infants were more active while scanning the fearful faces, not that they made a larger total number of fixations. A study by Bronson (1991) showed that younger infants scanned faces more slowly than older infants, or what is the same, made fewer, but longer fixations. This suggests that more fixations in the same period of time may indicate a more mature scanning pattern. Thus, it is likely that this looking pattern also indicates deeper processing of fearful expressions. On the other hand, looking time directed toward the faces was not analyzed in this study. This analysis could have been interesting, as previous research indicates that 7-month-old infants look longer at fearful faces in comparison to other positive emotions (Kotsoni, de Haan & Johnson, 2001; Nelson & Dolgin, 1985).

There is a discussion in the literature about the evolutionary importance of discriminating angry and fearful faces, as they may be indicators of dan-
ger or threat (Hunnius et al., 2010). This interpretation suggests a more innate, or evoluti-
onal account of the discrimination of facial expressions. It could also be the case that infants at this age already had some experience with negative expressions and have learned something about their valence. In any case, the children’s understanding of facial expressions will develop further in interaction with others and will be essential in developing other social processes such as social referencing or understanding other people’s emotions and thoughts.

What Is Normal in Social Development?

Infants’ social development has attracted the interest of researchers mainly in the last few decades, so there are still many gaps in our knowledge about the social development of the infant. For example, it is well known that infants at one year of age are expected to smile back, to look when their name is called, to point and show things, and to make eye contact (e.g., Leekam, 2005; Baron-Cohen, 1992). However, there aren’t many studies that tell us how frequent these behaviors are and there is no clear baseline about normal social behavior in naturalistic situations. For example, it was hard for us to find “live” studies on how infants look at other people when they observe a conversation. There are plenty of studies on how infants interact with toys or with an adult, but only a few studies have looked at how infants look at other people interacting, and these studies have not been done in “live” situations (Augusti et al., 2010; Kochukhova & Gredebäck, 2010; von Hofsten et al., 2009; Frank, Vul & Saxe, 2011). A baseline on what infants pay attention to in their environment and how they learn about other people’s intentions, expressions, and actions is needed to be able to detect abnormalities in social development. In other words, we still lack knowledge of how social infants are. Thus, what can be added to the social development literature from our studies?

• First, for the first time a head-mounted camera has been tested thoroughly; this is a method that can be used to capture the infant's interaction with the world when they are active. Further, this method allows us to analyze infant looking behavior from the infant's perspective.

• Second, infants’ looking behavior was observed in two naturalistic, “live” situations. The results indicated that infants around one year of age visually follow manual actions but not so readily conversations.

• Further, it was shown, using different methods, that infants can distinguish and use emotional facial expressions from others. And in situations in the lab they may use more the emotional message from the experimenter than from the parent.

• The results also suggest that providing different models to the infant may heighten their sensitivity to detect fear in others. In addition, it was
shown that 14-month-old infants react with a larger pupil diameter to the neutral face of the parent who is not on parental leave.

- Finally, measures of pupil dilation proved to be useful in detecting differences in infants’ processing of facial expressions.

Why Do We Care?

It was just mentioned that a baseline is needed to know what is normal in social development, but why is this baseline important?

From a theoretical point of view, studying infant social development can give answers about how humans develop, even from an evolutionary perspective. Many theories claim that social development is not a consequence of development of thought but the cause of it (Bruner, 1973; Hobson, 2002; Vygotsky, 1986). For example, Hobson (2002) has argued that it was through the social nature of humans that they came to develop communication, gestures, and thought. Also, Vygotsky (1986) and Tomasello (1999) concurred in that it is through the interaction with others that we are able to develop cognition, language, and other social constructions that funnel into a culture of knowledge. By studying infants we can investigate other basic questions about human nature, like, for example, how much in humans is innate and how much is learned, or whether we develop in a gradual or stepwise manner.

These answers are also important for education, as authors such as Vygotsky (1986), Bruner (1973), and Reddy (2008) have stressed. If parents know that infants are already learning about the social world, they will treat them differently and encourage them more to learn about others; in fact, there is evidence for how parents can enhance children’s learning about other people’s minds (in theory of mind, Ruffman, Perner & Parkin, 1999, Pears & Moses, 2003). In addition, practices of parental leave could change if it can be demonstrated that a shared parental leave is beneficial for the infants.

The growth of studies on early social development has run in parallel with research on autism. This is so because individuals in the autistic spectrum have been hypothesized to have a fundamental difficulty with the social and communicative aspects of development (DSM-IV). Thus, a baseline in everyday behaviors is needed to detect deviations from it. In fact, a number of researchers have attempted to teach early social skills, such as joint attention in treatments for toddlers in the autistic spectrum (Yoder & McDuffie, 2006, for a review). However, there is a discussion in the literature about whether autism has a main emotional or cognitive component and which behaviors are affected (Leekam, 2005). Some researchers have argued that it may be a problem that arises from the primary intersubjectivity, that is, the ability to share emotions or feelings with another person (Hobson, 2005; Trevarthen, 2001) while others have claimed that other basic cognitive processes, such as
gaze following, may be impaired (Baron-Cohen, 1995). The studies from this thesis suggest some areas in which differences between normal developing children could differ from children in the autistic spectrum. If children with autism are tested in everyday situations, it is likely that differences are found in their looking behavior toward social stimuli such as faces and hands. Further, if children in the autistic spectrum do not look so often at faces, it could be expected that they will not use other people’s emotional facial expressions to regulate their behavior. In fact, it is possible that differences are found even at the level of scanning facial expressions. For example, Falck-Ytter (2008) found that children with autism had a stronger tendency than normal developing children to scan the same features in upright and inverted faces. Further, children with autism reacted with larger pupil dilation to inverted than to upright faces, a difference not present in the normally developing group. Although there is still a long way to go to reach any agreement about the origins of the disorder, everything seems to indicate that early social development is crucial to later cognitive development (Charman & Stone, 2006). However, it is necessary to have a deeper knowledge of the normal development in infants to identify the deviations from this development.

In sum, a broader knowledge of infants’ social development can help in the development of theories about human nature, in education, in policies on parental leave, and in the treatment and detection of autism or other conditions in which social development is affected.

Limitations and Future Steps

This thesis aimed to explore how the identity of different social figures matters in infants’ social development. The results point toward a flexibility in the infant in looking at parents and strangers. However, other figures such as older siblings or peers can also influence infants’ social development, but these influences have not been studied so often. For example, older siblings can be “experts” for the infants in some areas and teach them different things than the parents do. Some research has found a more rapid development of infants’ understanding of theory of mind when they have older siblings (Perner, Ruffman & Leekam, 1994; Peterson, 2000; Ruffman, Perner, Naito, Parkin & Clements, 1998). However, it is not only a question of the identity of this social figure; simply having more than one person available seemed to make a difference in how infants discriminated facial expressions in Study 3. Thus, future studies could address how families with only one parent could benefit from having other persons close to the infant. Also, more research is needed to determine the importance of the exposure of the infant to both parents. Results in this area can make parents and society consider shared parental leave something beneficial for their children.
The studies presented here have some limitations. Study 1 tested the head-mounted camera method in two “live” situations, but in these situations the child did not walk or crawl. Thus, these studies cannot answer how the head-mounted camera would capture gaze in situations where the infant is totally free to move and many objects are in view. Future studies could test the head-mounted cameras when the child can move freely in different contexts like in their own home, at school, or anywhere outside the lab. Further, many other social processes besides social referencing could be tested, such as following gaze, pointing, and even studies of how infants learn words. Another limitation of these studies (and infant studies in general) is that more participants are excluded than in studies with adults or children. There are a number of reasons why infants can be dropouts; they can be “fussy” because they are tired, hungry, or not in the best mood. These reasons together with technical problems can raise attrition for reasons not related to the experiment and which may or may not be related to the infants’ personality.

Study 2 tested 10-month-old infants’ looking preferences toward the parent and the experimenter. However, a limitation of this study is that as the experimenter is always more novel than the parent, expertise cannot be solely addressed. To complement these results, the same experiment could be performed in the house of the infant, where the parent is the expert. Further, it would be interesting to study if even younger infants also have this preference for the stranger.

Study 3 compared a group of children being cared for by the mother (maternal care group) and another group in which the father was on parental leave for the last months (parental care group) but in which the mother had been on parental leave before the father. Thus, a comparison between a group only cared for by the mother and another only cared for by the father was not possible. It is difficult to have such a group, as the mother is normally the first caregiver of the child. Sweden is one of the few countries where parental leave is shared at all, which makes the comparison of parental groups possible. Another limitation of this study is that it is one of the first studies to analyze pupil dilation when infants look at different emotional expressions, so it is difficult to interpret these differences. More studies need to replicate these findings and link them to other cognitive or emotional processes. However, a number of research questions could follow the results from Study 3. For example, it could be studied to what extent the parent that is at home influences the infant and if this influence is only in the context of facial processing or if it is extended to the development of other processes such as language or empathy.
Conclusions

The use of different methods can deepen our knowledge of infant’s interaction with the world. A head-mounted camera (Wearcam) has been validated in this thesis for its use in different “live” situations. This method allows researchers to measure infant looking behavior in more naturalistic situations than, for example, eye trackers. However, eye trackers are also needed to analyze infant’s looking behavior more in detail, for example, to be able to measure scanning patterns and pupil dilation. In this thesis, measures of pupil dilation revealed differences in infants’ reactions toward emotional facial expressions. The replication of studies with different methods strengthens every result in science, and its generalizability.

Further, the results from these studies indicated that infants around one year of age are active seekers of information and can discriminate and use emotional expressions from experimenters and parents in their interaction with the world. It was shown that 10-months-old infants look spontaneously more at the experimenter than at the parent in ambiguous situations and use more the emotional information from the experimenter than from the parent. In addition, the experience of looking at the caregivers’ facial expressions seems to make a difference in how 14-month-old infants look at other people’s expressions. Thus, whether one parent or both take parental leave could make a difference in infant’s processing of emotional facial expressions. What the consequences of these differences might be remains a question for future research.
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