Joint Visual Attention and Gaze Behavior in Infancy:

An eye tracking study

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14.10.15

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The neural basis of joint visual attention and emotional processing in infancy, and gender differences: an eye tracking study.

2015

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http://www.duo.uio.no/

Trykk: Reprosentralen, Universitetet i Oslo

Abstract

Joint visual attention is one of most important ways to communicate and socially relate to others, especially through facial expressions. Previous research using EEG have found an amplified sensitivity to happy faces for 7-month-olds, and a sensitivity similar to that seen in adults in 12-month-olds viewing angry faces (Grossmann, Striano, & Friederici, 2007). In this study, the primary hypothesis was that 6-month-old infants would show a greater gaze allocation to happy faces than angry or neutral, whereas 12-month-old infants would show a greater gaze allocation to angry faces. In addition, we hypothesized that female infants would look longer at faces than male infants in the 12-month-group, more so on angry than neutral or happy faces. Results did not support our hypotheses, but we found an interesting gender difference. Female infants looked longer at the model's face than male infants did, independent of their age and emotion viewed. Possible explanations linked to amygdalar development are discussed.

Acknowledgements

This study was a part of a bigger project under The Cognitive Developmental Research Unit (Enhet for Kognitiv Utviklingspsykologi: EKUP) at the University of Oslo.

First of all, I would like to thank PhD candidate Ida Tidemann for letting me be a part of her research project conducted under The Cognitive Developmental Research Unit (Enhet for Kognitiv Utviklingspsykologi: EKUP) at the University of Oslo. I would also like to thank my main supervisor Carolien Konijnenberg for guiding me with the analysis. A special thanks goes to my fellow master student Caroline Horgen, whose work in collecting data has been crucial in writing this thesis.

Thanks to the caretakers who gave us their valuable time. Thanks to my friends and loved ones for the support.

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1.0 Introduction

In this paper we will start by looking at the theme of joint visual attention in infants, followed by gender differences and previous research done on the topic. Next, the the behavioral research will be linked to the neurobiological basis of joint visual attention and the role of the amygdala. The method section will describe the experiment in detail, including statistical analyses used. The results will be presented and discussed in the light of previous research, and linked to further research.

1.1 Joint visual attention and gaze following in infants

Eye contact is thought to be the most important way of ascertaining communicative links between people (Grossmann & Johnson, 2007). Vision is one of the first senses infants participate in to orient themselves to the surrounding environment. Direct and mutual gaze are important abilities even from birth, as eye gaze is an essential social signal. One of the milestones in infant social development is the transition from engaging in dyadic interactions of face-to-face gaze behavior between two people, to engage in triadic interactions of mutual-gaze-to-object joint attention gaze behavior. *Joint visual attention* refers to the phenomena that occurs when one person observes the gaze direction of another person, and follows that gaze to a common interest (Moore, Angelopoulos, & Bennett, 1997). Triadic interactions require the infant to observe and monitor both the other person's attention in relationship to themselves, as well as the other person's attention to a third party, the object. Studies on newborns and infants have shown a clear preference for looking at faces with mutual gaze compared to averted gaze, and an enhanced neural processing for joint attention (Farroni, Csibra, Simion, & Johnson, 2002). Sensitivity to triadic attention has been demonstrated as early as in 3-month-olds, where infants gaze longer and smile more in a triadic joint attention interaction compared to a dyadic interaction (Striano & Stahl, 2005).

Although preferences for mutual gaze and triadic interactions emerge already from birth, a more conscious understanding of joint attention does not seem to be developed before months later (Grossmann & Johnson, 2007). Extensive research has concluded that gaze following and joint attention emerges between 2-4 months and that it gains stability around 6-8 months of age (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Gredebäck, Fikke, & Melinder, 2010; Gredebäck, Theuring, Hauf, & Kenward, 2008; Senju & Csibra, 2008; Striano & Bertin, 2005). During the first two years of life, human infants develop by relating socially to others, which is important for a healthy development. Some argue that the ability to relate to and learn from others, is the most important ability and adaptation of the human race (Klein, Shepherd, & Platt, 2009).

1.1.1 Gaze following in an evolutionary perspective

The socio-cognitive framework explains how all great ape species show an understanding of the gaze shifts of others to observe something stimulating or unusual. Two models are prominent in explaining cognitive mechanism underlying gaze-following behavior. The *orienting-response model* explains how gaze following is based on orientation. This model suggests that most animals have a tendency to look in the direction others are looking, and that this can be fruitful in detecting something interesting. The orienting-response model does, however, not say anything about the reason for looking. The *perspective-taking model* is based on an orienting-response, but with the deeper meaning that the observer understands that those they observe also have the consciousness to understand that there is something interesting to be viewed. Perspective-taking is besides seen in great apes, who have shown to be able to take on the visual perspective of humans knowing the placement of food while it is hidden to the apes, a trait seen to be acquired and learned after the age of 5-6 months (Bräuer, Call, & Tomasello, 2005). The perspective-taking model is the basis for the paradigm of joint visual attention.

In the process of natural selection, it seems that the ability to understand facial expressions has been strongly emphasized. Different emotionality observed in others can affect gaze and neural processing (De Groote, Roeyers, & Striano, 2007). Gaze is important in detecting other people’s emotional states and it provides cues on how to react appropriately (Grossmann et al., 2007). Evolutionary theory suggests a *negativity bias* in gaze behavior, which states that reacting to negative emotional and social cues from others is more vital for survival than reacting to positive cues, as negative cues more often can result in danger or injury (Cacioppo, Gardner, & Berntson, 1999). The negativity bias is a well-known psychological phenomenon, in the same way we more easily remember one bad thing than ten good things. Avoidance and escape are critical responses to threats, and they depend on an efficient analysis of the environment in localizing threatening cues. Studies have shown negativity bias in gaze behavior to manifest itself through a stronger response to negative facial expressions compared to neutral or positive facial expressions. In infants, a negativity bias is seen in as they show a longer gaze time at fearful rather than neutral faces (Grossmann et al., 2007; Peltola, Leppänen, Palokangas, & Hietanen, 2008). In adults, angry faces elicit a quicker and more accurate response than happy faces (Cacioppo et al., 1999; Schupp et al., 2004; Öhman, Lundqvist, & Esteves, 2001), and happy faces elicit enhanced amplitudes, as seen in EEG, compared to neutral faces (Sato et al., 2001). From an evolutionary perspective, the ability to react to fear seen in others has been important in defining social dominance and submission as well as danger (Schupp et al., 2004).

Human beings seem to rely more heavily on eye gaze than head direction compared to other primates, as well as perspective taking. Because humans have white sclera and more visible eyes than other species, gaze direction is easy to infer by looking at someone's eyes. The *cooperative eye hypothesis* suggests that the appearance of the human eye has evolved to make it easier to follow gaze directions, and has a social function to support social interactions and cooperation for survival (Tomasello, Hare, Lehmann, & Call, 2007). Moreover, observed gaze direction can help predict movement of both predators and prey (Klein et al., 2009). Understanding and processing eye gaze and its referential nature, is thought to be important in the development of theory of mind. Eye gaze can infer the intentions of other people. By following someone's gaze, it is thought that even young infants can comprehend that if someone is looking that way for a reason, they have an intention. Additionally, changes in gaze direction, body posture, facial expressions and vocal cues are good indications of people's intentions (Farroni, Johnson, & Csibra, 2004; Senju, Johnson, & Csibra, 2006).

The human brain is vitally modified to develop within a social environment and is therefore sensitive to social cues elicited from the face of others (Grossmann & Johnson, 2007). The ability to follow other people's gaze and partake in joint visual attention is important in development of both language skills and communication (Senju & Csibra, 2008). Eye gaze offers information about where and what other people bring attention to, their communicative intentions and what they might do next (Grossmann & Johnson, 2007). Although the preference for direct gaze seems to be innate and detected as early as in 2 days old infants, the ability to detect facial expressions is more complex. In regards to joint visual attention, processing and understanding facial expressions of others can help guide our own behavior and perception of a potential dangerous or rewarding situation. Happiness is detected from narrow eyes and a smile. Anger is detected by frowning brows, staring eyes and a closed tense mouth. Fear is detected by an open mouth and wide open eyes. Processing and reacting to these cues is vital for survival, as for example a fearful or angry expression can signal physical danger for the observer. In the same way, reacting to a happy facial expression can be rewarding (Grossmann et al., 2007). How infants at different ages process the different facial expressions is discussed below.

1.1.2 Functional gender differences in gaze behavior and emotional processing

A variety of gender differences have been identified in emotion and gaze-related behavior in humans. Studies on adults have found that adult male humans in general display weaker gaze-cuing effects than females, such as shorter gazing time, slower gaze shift and poorer accuracy in orientation to the direction of gaze (Bayliss, Pellegrino, & Tipper, 2005; Deaner, Shepherd, & Platt, 2007). Additionally, females tend to stronger and more vividly retain memories for emotional events compared to males (Canli, Desmond, Zhao, & Gabrieli, 2002; Seidlitz & Diener, 1998), while males have more difficulty distinguishing between different emotional expressions (Thayer & Johnsen, 2000). Gender differences have been found in investigating differences in behavioral data and ERPs. ERPs (Event-Related Potential) are measured using EEG, and are seen as small neural voltages generated in the brain in response to stimuli. ERPs measured in males and females during a recognition memory task for faces, showed how females perform significantly better than males, which could suggest females to be more neurobiologically oriented to faces than males (Sur & Sinha, 2009). A similar study found gender differences in ERP seen over fronto-central areas, specifically stronger ERPs seen in females when viewing faces (Guillem & Mograss, 2005), which is in line with previous research on the female ability to entail more detailed elaboration of information in general (Meyers-Levy & Maheswaran, 1991). In studying infants, research has shown that male infants at 12 months of age participate in less eye contact than females the same age (Lutchmaya, Baron-Cohen, & Raggatt, 2002), and that female infants are significantly better at joint attention than male infants at 12 months (Mundy et al., 2007; Olafsen et al., 2006). Male newborns also show a stronger preference for objects, while female newborns prefer to look at faces (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000).

Few studies are done on gender differences in viewing emotional content in infants, but studies on adults have shown that females are significantly better at rating emotions than males (Hall & Matsumoto, 2004). However, it has been suggested that any gender differences in evaluation of threat does not appear until adulthood. In a study from 2004, researchers used fMRI to investigate the orbitofrontal cortex, amygdala and the anterior cingulate cortex in adolescents vs. adults. While a gender differences in the evaluation of threat is seen in adults, no such effect has been found in adolescents, suggesting the gender differences not to be apparent until adulthood (McClure et al., 2004). Additionally, researchers have found that infant females around 3-4 months make significantly more mutual eye contact than males if the person interacting is female, which is thought to mirror the mother-infant interaction (Lavelli & Fogel, 2002; Leeb & Rejskind, 2004). Another reason why infant females make more mutual eye contact than males, is thought to be based on differences in habituation, hormones and arousal levels (Leeb & Rejskind, 2004). The same findings can be confirmed by a significant quadratic relationship found between prenatal testosterone and the amount of eye contact in 12-month-old infants (Lutchmaya et al., 2002), as well as the findings of earlier acquisition of language in females than males, as joint attention is related to language development (Olafsen et al., 2006).

1.2 Neurobiology of eye gaze and joint visual attention

1.2.1 Neural attentional networks and development

Although the basic development of the nervous system starts in utero, much of the development continues after birth. Despite their relatively new nervous system, infants can easily select and follow interesting aspects of the environment. Based on imaging studies on attention networks, researchers have been able to postulate how the development of the brain affects attention. In the field of attention, more specifically development of responding to joint attention (RJA), Michael Posner and colleagues (Petersen & Posner, 2012; Posner, 2001; Rothbart & Posner, 2001) have provided plausible a theory based on years of research. When examining objects, infants orient their head and eyes towards the stimuli. Even though eye gaze does not always mean the attention is in the same place, shifts in eye position are strongly associated with shifts in attention. As shown, the ability to orient toward peripheral objects develops rapidly between 2-4 months (Carpenter et al., 1998). Posner and colleagues suggest that RJA and gaze following develop along with executive abilities the first year of life, following the development of the posterior attention network. Moreover, by the end of the first month after birth, a brain pathway from the basal ganglia to the superior colliculus develops, which supports obligatory looking, the tendency for infants to fixate on stimuli. The posterior network develops rapidly the first 4 months of life. After the first 4 months, research has shown an increase in metabolic processes in the parietal lobe, suggesting a less automatic and more manual implementation of executive functions resulting in improvements in the infants' ability to shift attention. The posterior network includes the superior parietal lobe, which shows activity during disengagement from a focus, and the midbrain superior colliculus, which seems to be involved in shifting attention to a novel stimulus (Rothbart & Posner, 2001).

Viewing fearful or angry faces often causes a delay in disengagement of attention, compared to neutral faces (Georgiou et al., 2005). Similar findings of delayed disengagement of attention to fearful faces have been found in infants as young as 7-months-old. To exclude novelty as a factor, researchers examined whether novel facial expressions and fearful expressions had the same effects on viewing time and disengagement of attention. The results showed no differences between facial expressions, and the researchers concluded that novelty is not likely to be a factor in such a paradigm (Peltola et al., 2008). In an EEG study by Nelson and de Haan, 7-month-olds watched happy vs. fearful or fearful vs. angry faces on a screen. While they found no differences between angry and fearful faces, they did find an enhanced negative component when viewing fearful faces compared to happy faces (Nelson & De Haan, 1996). While stimuli that require more attention invoke a larger negative component, this negative component has shown to have its maximum at frontal and central brain areas, and is also often elicited as a response to familiarity (Snyder, Webb, & Nelson, 2002).

An ongoing debate is speculating whether gaze following is an innate response that matures with brain development or a social ability learned through experience and conditioning (Moore et al., 1997). There is however overwhelming evidence supporting the theory of an innate sensitivity to gaze and facial expressions. Research has shown how 2-5 days old newborns prefer to look at faces engaging them in direct mutual gaze rather than averted gaze (Farroni et al., 2002). EEG studies have also played an important part in investigating whether face processing is an innate process or developed through experience. The N170 is the component of ERPs shown in neural processing of faces, which has been proven to have slower peak latency in infants, and be specifically activated by human faces in adults. No gender differences have been found in cortical activations related to the N170 component (Batty & Taylor, 2003). Six-month-olds infants seem to elicit the same cortical activations in the N290 (the infant equivalent of N170) as adults in viewing pictures of humans, as well as a clear difference in activation between human and nonhuman species. In the same study, they found no difference between upside-down and upright pictures, which the researchers explained as although this system is innate, it requires a later development in gradual specialization of face processing systems in the cortex (Haan, Pascalis, & Johnson, 2002). These evidence support the notion that the system of processing facial expressions seems to gradually specialize and become more finely tuned by the end of the first year (Grossmann & Johnson, 2007).

1.2.2 The amygdala and neural processing of facial expressions

Because of its unique positioning in the brain, the amygdala has neural connections throughout the cortex to rapidly respond to sensory stimuli. The amygdala is closely linked to the hippocampus, and can therefore influence both physiological and behavioral responses (Adolphs, Tranel, Damasio, & Damasio, 1995; Calder, 1996). While subcortical processes cannot be inferred from EEG studies, differences in processing of angry and fearful faces can be seen in adults using fMRI. For example, a study from 2001 found different activation patterns in adults when viewing fearful vs. angry faces, localized in the amygdala (Whalen et al., 2001). Another fMRI study on healthy adults have found strong activation associated with the amygdala in viewing negative facial expressions in general (Sato, Kochiyama, Yoshikawa, Naito, & Matsumura, 2004). It has been an ongoing debate whether the amygdala is involved in threat processing or emotional processing in general. A vast number of studies have found stronger amygdala activation for all facial expressions of happy, sad, angry and fearful emotions, compared to neutral (Breiter et al., 1996; Habel et al., 2007; Williams, Morris, McGlone, Abbott, & Mattingley, 2004). Additionally, amygdala lesions can impair recognition of other emotions than fear (Fitzgerald, Angstadt, Jelsone, Nathan, & Phan, 2006). However, the strongest activations have been found viewing fearful and angry faces, suggesting the amygdala to particularly active in assessing and processing threatening cues and facial expressions (Gur et al., 2002; Mattavelli et al., 2013; Yang et al., 2002).

The role of the amygdala in social interaction and processing of facial expressions is undoubtedly important. Additionally, there are convincing evidence for age differences in the ability of emotional processing and latencies in joint attention. In a study from 2001, Thomas and colleagues showed that the amygdala activation in 12 children (mean age 11) was in fact lower for fearful faces than neutral faces. While the results found by Thomas and colleagues seem to show the opposite pattern of that in adults, researchers have concluded that fear conditioning and emotional learning has not been practiced as much for children as for adults, resulting in lower activation of the amygdala (Thomas et al., 2001). However, evidence does point to specific differences between infants, older children and adults in responses to gaze and facial expressions. Viewing the facial expression of disgust showed longer latencies in 3-6 month olds than 9-month-olds (De Groote et al., 2007). Moreover, 10- and 11-month-olds have shown to follow head turns significantly more when the person has open eyes versus closed eyes, whereas 9-month-olds show no differentiation (Brooks & Meltzoff, 2005). Thus, the age between 6 and 12 months seems to be a precarious phase in learning to react and adjust to facial expressions.

In an EEG study from 2007 (Grossmann et al., 2007), researchers investigated developmental changes in infants' processing of happy and angry facial expressions. Using two color portrait photos of the same woman with either a happy or angry facial expression, they measured ERPs while infants were presented randomly to the photos. Results showed that 7-month-olds elicited a larger negativity in ERP measurements from happy faces in their frontal, central, temporal and parietal sites. Additionally, 12-month-olds had a larger negativity in occipital sites from angry faces than happy faces, and no difference between angry and fearful faces. As the 7-month-olds showed amplified sensitivity to happy faces and 12-month-olds resembled adults in their sensitivity to angry faces, the researchers concluded that processing of both happy and angry facial expressions develops between 7 and 12 months. Additionally, in assessing the infants' visual preferences behaviorally by recording them with a video camera, researchers introduced both happy and angry facial expressions simultaneously. Two coders who were blind to the experiment were asked to code duration and frequency of the infants looking at each picture. The ERP measurements were the same as in the first experiment, showing that the ERP differences were not simply a reflection of differences in visual preferences. The researchers concluded that differences in topography show that different brain systems are involved in processing of facial expressions depending on the age of the infant (Grossmann & Johnson, 2007). Consequently, the detection of emotionally significant stimuli, especially threat-related stimuli, is observed to be developed at around 12 months. The ability to respond to angry or fearful facial expressions can be seen as threats in the environment and is of highly adaptive value for survival. Although no conclusions of specific cortical or subcortical structures involved can be drawn from the study of Grossman and colleagues (Grossmann et al., 2007), researchers have hypothesized that the amygdala is a part of the distributed network of determining the significance of external stimuli (Pessoa, Kastner, & Ungerleider, 2002). One environmental factor that might be involved in explaining the differences between 7- and 12-month-olds, is that 7-month-olds might not have been adequately exposed to angry faces, or learned the value of a threatening face (Grossmann et al., 2007).

1.2.3 Theory of amygdala maturation and volume

One theory explaining the reported differences between 7- and 12-month-olds' response to emotional expressions is put forth by Nim Tottenham and colleagues at the Sackler Insititute. As mentioned, Posner and colleagues' theory states that the ability to respond to joint visual attention develops the first year of life, as the posterior attention network develops (Rothbart & Posner, 2001). Seen in light of Posner and colleagues' theory of the development of attentional networks, Tottenham and colleagues' theory is based on amygdalar maturation and its role in attention (Hare, Tottenham, Davidson, Glover, & Casey, 2005; Tottenham, 2012). Previous research has shown that the human amygdala undergoes rapid development at very early stages of life (Ulfig, Setzer, & Bohl, 2003). Most of what we know about early postnatal amygdala development comes from animal models. In studies on rats, researchers have found that despite having an anatomically developed amygdala, rat pups do not show any signs of avoidance learning in fear conditioning using shocks (Moriceau, Roth, Okotoghaide, & Sullivan, 2004). Because conditioning depends on an initially neutral stimulus to be paired with an emotionally significant stimulus, resulting in the neutral stimulus itself to elicit the emotional response, we learn about the potential safety or dangers in our environment. Studies on rhesus macaques have found a rapid amygdala development within the first 2 postnatal weeks, and an amygdala maturation stabilizing around 8 months of age (Payne, Machado, Bliwise, & Bachevalier, 2010). As seen in rodents, evidence suggests that the amygdala lies dormant until the pup starts learning by experiencing the environment. Although the amygdala is matured, its development and learning continues through infancy and childhood. Therefore, there is a good reason to believe the differences between 7- and 12-month-olds to be caused by amygdala development, based on their level of experience. Tottenham suggests that early-life is an imperative period for the human amygdala, as its' rapid development early in life will increase the vulnerability to environmental influences during this time (Tottenham, 2012).

The implications of a larger amygdala volume have been shown to be varied. Tottenham's theory of amygdala development is supported by studies showing how insecure attachment during infancy predicts greater amygdala volume in adult brains (Moutsiana et al., 2015) and how larger amygdala volume measured at 6 months predicts lower scores on expressive and receptive language measures at 2, 3 and 4 years of age (Ortiz-Mantilla, Choe, Flax, Grant, & Benasich, 2010). Similarly, larger right amygdala volume in 3-4 year olds with autism has been associated with severe dysfunction in communication and social behavior at 6 years, while larger left amygdala volume has been shown to predict better language skills at 6 years (Munson, Dawson, Abbott, & et al., 2006). Interestingly, previous studies have reported the left amygdala to respond mainly to fearful events and faces (Hardee, Thompson, & Puce, 2008; Phelps et al., 2001).

1.2.4 Amygdalar gender differences in gaze behavior and emotional processing

Few studies have investigated gender dimorphisms in the structural development of the amygdala in healthy human infants, and the ones that have are few and inconclusive. One study reported the maximum volume of the human amygdala to be reached between 9-11 years (Uematsu et al., 2012). Another study reported the structural development of the amygdala to be complete by 4 years of age in females (Giedd et al., 1996). Differences in results might be attributed to different inclusion of data as well as difference in study design (longitudinal vs. cross-sectional). Animal research and models have been helpful in the area of early life brain development. In their study on rhesus macaques, Payne and colleagues investigated the development of the amygdala from 1 week to approximately 2 years of age using volumetric MRI. Ten monkeys were scanned in the infant group, while 12 were scanned in the juvenile group. Results showed significant age-related changes through the first 2 years of life, as well as a significantly larger left hemisphere in males. The male amygdala exhibited a larger right than left side and increased 86.49 % in males the first 2 years of life, while the female amygdala increased 72.94 % in volume but showed no enhancement of the right hemisphere throughout 2 years of development (Payne et al., 2010). In human adults, studies on gender differences in amygdala volume have been inconclusive. Some studies have reported a significantly larger amygdala in males than females (Caviness, Kennedy, Richelme, Rademacher, & Filipek, 1996; Filipek, Richelme, Kennedy, & Caviness, 1994; Goldstein et al., 2001), while other have found no significant differences except between the ages of 4 and 18 (Giedd, Castellanos, Rajapakse, Vaituzis, & Rapoport, 1997; Giedd et al., 1996).

In a study from 2012, researchers investigated typical volumetric trajectories of the amygdala from infancy to early adulthood, as well as gender dimorphism and laterality. In a cross-sectional morphometric MRI study done over 12 years, researchers examined 109 healthy individuals from 1 month to 24 years of age. Findings showed a significant non-linear age-related volume change most prominent the first years of life regardless of gender. Results also showed the female amygdala to reach its peak about 18 months earlier than the male amygdala, while the rate of growth decreased earlier in females. These results would suggest that a longer growth period of the amygdala can contribute to the structurally larger amygdala observed in males. Additionally, only males showed a right amygdalar laterality. Although the right amygdalar volume increased for a longer time, larger changes in growth rate for the left amygdala during early childhood was seen for both genders (Uematsu et al., 2012). Such a priority for earlier left amygdalar growth, can be explained by its association with detecting fearful stimuli for both events and faces (Hardee et al., 2008; Phelps et al., 2001). The researchers concluded that the findings highlight the importance of the first few years in both structural and functional development of the amygdala.

Moreover, gender differences and right side laterality of males indicates the involvement of sex hormones in development of the amygdala (Uematsu et al., 2012). Generally, the brain structures that differ in size between men and women, are the same regions that include high levels of sex hormone receptors, suggesting sex hormones (specifically estrogen and testosterone) to play an important role in determining the size of specific brain regions during development (Goldstein et al., 2001; Hamann, 2005). Taken together, studies suggest that the amygdala plays an important role in shaping emotion-related behavior, especially stimuli indicating fear or danger (Hamann, 2005). As noted earlier, a significant quadratic relationship has been found between prenatal testosterone and the amount of eye contact in infants at 12 months of age (Lutchmaya et al., 2002). However, examining changes in the structural volume of the amygdala cannot demonstrate the specific development of neural networks, and we need to be careful in making direct assumptions about the functional consequences.

1.3 Why measure eye behavior, and why eye tracking?

Studies on the neural processing of gaze behavior in infants have understandably been limited by both ethical and technological restrictions, as brain imaging techniques often are invasive and difficult to use on moving subjects. Another method of investigating gaze behavior in infants is to use eye tracking, which is completely non-invasive. Recording eye gaze behavior can provide a huge amount of information about the processing of facial expressions.

In the field of eye tracking, it is commonly accepted that people spend more time looking at internal features like eyes, nose and mouth, than external features like hair, ears and contour (Althoff & Cohen, 1999). Especially the eye region has been proven to be the main focus of people's attention in viewing faces (Henderson, Williams, & Falk, 2005; Itier, Villate, & Ryan, 2007). One reason for the eye region to be the most attended of all facial features is the amount of information the eyes carry that is necessary for recognizing emotions. In non-verbal communication, the eye region has shown to provide extensive amounts of emotional information about other people and their intentions (Itier & Batty, 2009). Fearful expressions are distinguished by a larger white sclera as the eyes tend to open wide, whereas happiness is distinguished by squinting of the eyes and hiding more of the white sclera. Differences in processing of fearful vs. happy expressions have been shown by presenting the eye whites alone as a noncanonical stimulus. For example, researchers have shown amygdala activation to be more responsive to viewing the eye whites from fearful eyes with larger eye whites than to happy eyes with smaller eye whites (Whalen et al., 2004).

Naturally, a difficulty lies in establishing a direct link between gaze and underlying neural processes. However, as eye tracking can be assessed over time, this allows for examination of changes in attention over stimuli sets, which can be linked to previously established findings of networks of particular patterns of eye movements. Eye tracking as a method offers the opportunity to measure infants' perception and attention with a high spatial and temporal accuracy. Eye tracking can provide almost an unlimited amount of data points. For example, data collected at 60 Hz for 5 minutes can provide approximately 18 000 data points (Gredebäck, Johnson, & von Hofsten, 2009).

1.4 The current study

Hypothesis 1: Posner and colleagues have proposed a rapid development of the posterior attention network to take place the first 4 months, including the ability to shift attention to novel stimuli (Rothbart & Posner, 2001), suggesting infants as young as 6 months to be able to participate in joint attention and follow gaze shifts. Our hypothesis was based on the EEG study by Grossman and colleagues (2007) describing how 7 month-olds show heightened sensitivity (greater negative component) to happy faces compared to neutral and angry faces, while 12 month-olds resemble adults in their heightened sensitivity to angry faces. Amygdala maturation is thought to start around 8 months of gestation (Ulfig et al., 2003). From studies on rhesus macaques, the amygdala is hypothesized to be fully matured around 8 months after birth (Payne et al., 2010), but the behavioral function of the amygdala has not been observed before around 10-12 months after birth (Grossmann & Johnson, 2007). Therefore, we hypothesized that younger infants (6 months) would demonstrate greater allocation to happy faces and may be better at following the gaze of happy faces compared to neutral and angry faces. Additionally, older infants (12 months) would demonstrate greater allocation to angry faces and would be better at following the gaze of angry faces compared to neutral and happy faces. The middle group (9 months) was expected to elicit gaze behavior closer to the older group than the younger group.

Hypothesis 2: Angry faces can indicate danger which is associated with the left amygdala, which is developed earlier in females than in males (Uematsu et al., 2012). As noted, male infants at 12 months of age participate in less eye contact than females (Lutchmaya et al., 2002), and 12 month old female infants are significantly better at joint attention than male infants the same age (Olafsen et al., 2006). Thus, we hypothesized that female participants would look longer at faces and be better at gaze following than males in the 12 month old group, more so on angry than neutral and happy faces.

Several research questions were of interest. Firstly, we were interested in whether age and condition had any effect on how quickly the infants' shifted their gaze from the model to the toy, as well as correctness of the first gaze shift and number of frames spent gazing at the face before gaze shift. Any main effects were followed by investigating any interaction effects by each trial. Secondly, we wanted to see if there were any differences in gender through the different variables, especially in frames gazing at the model before the first gaze shift through all conditions. In addition, we wanted to check if there was a preference for gaze side and toy side.

2.0 Method

2.1 Participants

Caretakers with infants of 6-, 9- and 12-month-olds were contacted via post through information gained from the Norwegian National Registry, and were invited to the lab to participate in the experiment. Sixty participants were recruited, and three infants were excluded due to lack of face fixation. The final participants were three groups of 57 infants in total. We included 32 males and 25 females. Age groups 6 included 10 females (M = 204 days, SD = 23 days) and 10 males (M = 206, SD = 13 days), age group 9 included 8 females (M = 274 days, SD = 22 days) and 15 males (M = 296, SD = 13 days), and age group 12 included 9 females (M = 371 days, SD = 20 days) and 5 males (M = 376, SD = 26 days).

2.2 Ethics

In doing research on infants, there are some ethical concerns to address. Any information linking the infants to the data was removed by using participant numbers, which is only accessible by the leading researcher on the project. No individual results were given to the caretakers, as it would require a licensed psychologist to analyze and interpret any test results. If the infants got fuzzy or uncomfortable, the experiment was immediately stopped to avoid any further agitation. After participation, the caretakers were given a small gift for the infant worth approximately 100 NOK.

The study was approved by the Regional Ethic Committee (REK sør-øst) and was conducted in accordance with the guidelines of the 1964 Declaration of Helsinki. Caretakers signed an informed consent upon arriving at the lab.

2.3 Stimuli and apparatus

For recording the videos, we used a Sony high definition digital camera, model HDRCX550V. The videos were made using a female volunteering student as a model. Her appearance was made as simple and normal as possible, no jewelry, little makeup, black clothes and hair pulled back. We used two light sources from each side pointing towards the model in a way that caused as few shadows as possible. We used a white background for easier post-processing when manipulating the videos. Two toys were placed on the table in front of the model. First, the model was instructed to look into the camera for 2 seconds to initiate eye contact. Next, the model was instructed to shift her gaze towards a blue toy placed to her right, with the head movement following 1 second after. The model fixated on the toy for 5 seconds, before returning her gaze and head towards the camera for 2 seconds. The same procedure was repeated with a green toy for all three conditions neutral, happy and angry. The videos were flipped to get the videos of the model looking to both sides as similar as possible. Each clip lasted for 12 seconds, and was shown twice in a randomized order. Three conditions were included for all groups, where the model was acting angry, happy or neutral. This gave us 12 different video clips; 3x2x2 (emotion x type of toy x side).

The angry condition was characterized by frowning eye brows, closed mouth and narrow eyes, whereas the happy condition was characterized by mouth closed, but with a smile and narrow eyes. In the neutral condition, the model was instructed to make sure she had a soft and mild neutral expression, in order to avoid a “still face” expression.

All video editing was done using the free open sourced video editing program Avidemux version 2.6.8. In editing the videos, they were set to 16:9 aspect ratio. The white background was made smoother by blurring any shadows, and the contrasts were enhanced. Additionally, audio was removed.

Gaze was measured by a Tobii TX300 eye tracker with a recording resolution of 1440 x 900. During eye tracking, the sampling rate was set to 60 Hz. Because of the low attention span of young infants, five calibration points were sufficient (Gredebäck et al., 2009). To calibrate the eye tracker to their gaze, five points were shown on the screen, one for each corner and the middle.

2.4 Procedure

As this thesis is a part of a bigger project under The Cognitive Developmental Research Unit (Enhet for Kognitiv Utviklingspsykologi: EKUP) at the University of Oslo, the infants were shown two different experiments, one of which is described here. The order of the experiments was counterbalanced, as well as the different conditions within each experiment.

After welcoming the caretakers and their infants, they were taken into a playroom for the infants to get comfortable and acquainted with the experimenters. The parents were asked to sign a written informed consent. Next they were taken into the experiment room where the infant was placed on the lap of the caretaker, approximately 50 cm away from the computer screen. The experiments were run in randomized order. The total time of the experiment added up to 5 minutes excluding calibration and attention grabbers.

2.5 Data analyses

2.5.1 Video coding

Three areas of interest (AOI) were defined incorporating the objects with some surrounding space to account for fixation on the edges and sampling errors, as well as the face of the model (see figure 1). Gaze fixations were defined by falling within one visual degree for minimum 200 ms fixation. The goal of the video coding was to investigate the length of gaze and gaze shifts performed between areas of interest, the model' eyes and the toys. Measures included gaze side, toy side, accuracy of infants' first gaze shift, correct and incorrect gaze shifts over all conditions. Time of gaze shift of the infants and the model was measured, including latency between them. Face presentation time before the model turns and number of frames where the infant gazes at the model was also included. The initial analysis was conducted using the standard video player VirtualDub (downloaded from http://www.virtualdub.org/) to conduct a frame-by-frame analysis of the infants' gaze shifts.

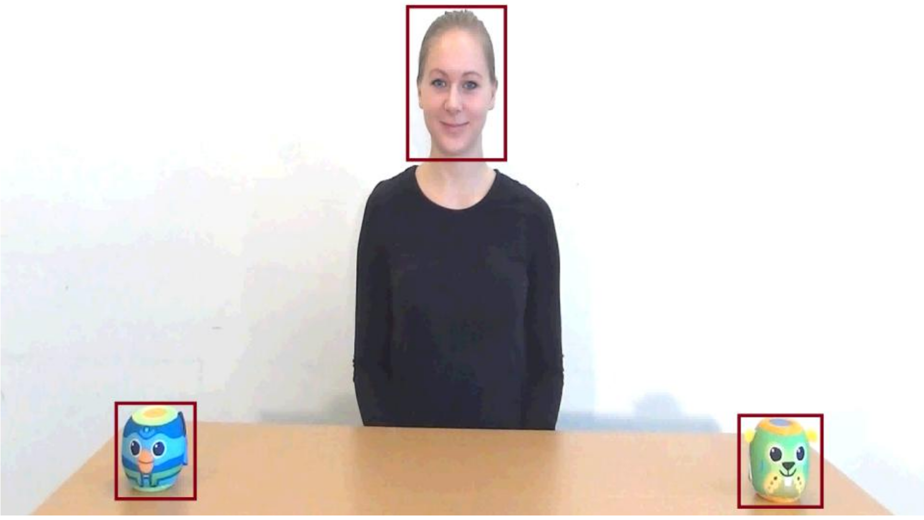

Figure 1. AOIs used to determine gaze fixations.

2.5.2 Statistical analyses

The following analysis was conducted using IBM's SPSS 22. Data was analyzed in two ways due to the fact that some infants had so few valid trials. A preliminary analysis was done where the different average scores of each infant were calculated and analyzed, which made it possible to treat the results of each infant equally. No differences were found between the two analyses. Consequently, the most extensive and explanatory analysis was chosen to be described here.

3.0 Results

To see whether there were any effect of side or type of toy on the infants' looking behavior, we performed a preliminary analysis showing that gaze side had no effect on correct gaze shift ($p = .182$) or time ($p = .899$). Similarly, toy side had no effect on correct gaze shift ($p = .897$) or time ($p = .752$). Consequently, the data was combined for further analysis. A .05 alpha level was used for all analyses.

The number of trials for each condition varied slightly (see table 1). Of the 624 trials, 134 (21.4 %) trials were included with gaze shifts, defined by fixating on the model's face for over 200 ms, followed by a fixation on either one of the toys for over 200 ms. Of the 134 trials with gaze shifts, 69 were accurate (the first gaze shift was to the same side as the model) and 65 were inaccurate (the first gaze shift was to the opposite side as the model) (see table 2).

Table 1

Number of total trials in each group and condition

		Condition	N
Age group	6		236
	9		248
	12		140
Total			624
Emotion	0	neutral	213
	1	happy	204
	2	angry	207
Total			624

Table 2

Number of correct and incorrect first gaze shifts per age group

Age group	Correct	Incorrect
6	15	16
9	34	35
12	20	14
Total	69	65

A two-way univariate analysis of variance (ANOVA) was conducted to examine the effect of age and emotion on correct gaze shift. No significant effects were found between correct gaze shift and emotion, F (2, 133) = 1.49, p = .227, or correct gaze shift and age, F (2, 133) = 1.49, p = .230. No significant interactions could be reported between age, emotion and correct gaze shifts (p = .805). Similarly, no significant interactions were found for the effects of age and emotion on incorrect gaze shifts (F (4, 133) = 2.37, p = .055).

A two-way univariate ANOVA was conducted to examine the effects of age and emotion on gaze shift time of the infants. The main effects of age, F (2, 133) = .165, p = .848, and emotion, F (2, 133) = 2.58, p = .079, were not significant. There was no significant interaction between the effects of age or emotion on the time of gaze shift, F (4, 133) = .78, p = .541.

A one-way ANOVA was used to test whether age affected correct gaze shifts independent of emotion through all age group 6 months (N = 32, M = .59, SD = .56), age group 9 months (N = 70, M = .63, SD = .57) and age group 12 months (N = 40, M = .80, SD = .69), F (2, 139) = 1.35, p = .262. No significant interaction was found between the number of frames the infants viewed the face before gaze shift, and emotion (F (2, 352) = .55, p = .580) or age (F (2, 352) = .39, p = .678. No gender differences were found for correct gaze shifts. No effects for emotion on gazing face time were found (F (2, 352) = .55, p = .580), nor age on gazing face (F (2, 352) = .39, p =.678).

Interestingly, independent samples t-test revealed there was a significant difference in the scores for females on gazing face time percentage (N = 151, M = 53.61, SD = 20.90) and male (N = 204, M = 48.96, SD = 20.05) groups; t (353) = 2.12, p = .035 (two-tailed) (see figure 2). The variances did not violate the assumption of homogeneity of variance, as shown using Levene's test: F (1, 353) = .388, p = .534. The effects were independent of emotion (F (4, 346) = .191, p = .943).

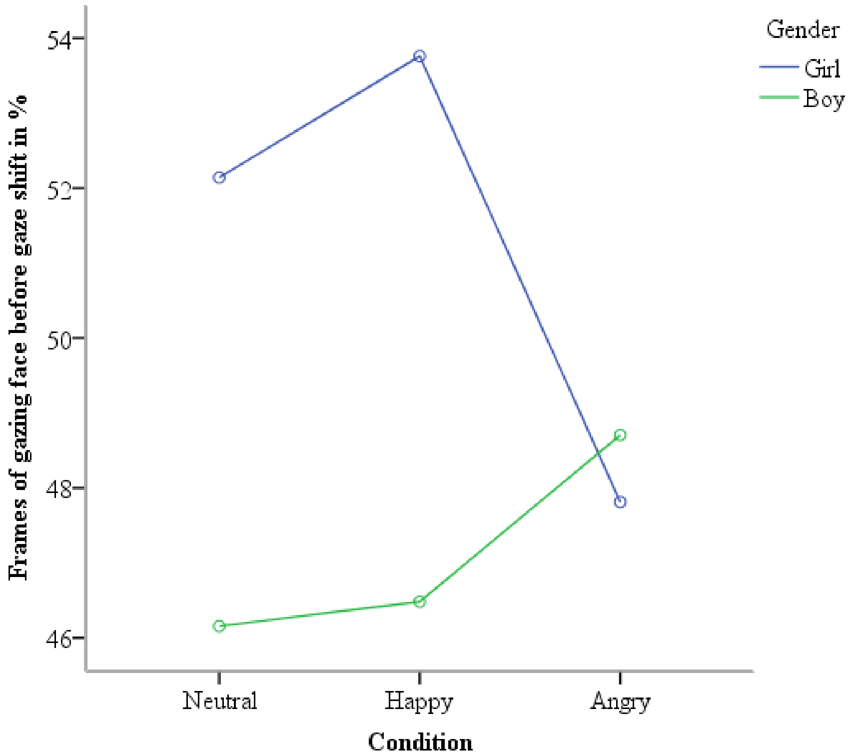

Figure 2. Percentage of frames during face presentation time where infants gaze at the face of the model, seen through all three emotions and divided by gender.

4.0 Discussion

In the current study, we wanted to investigate 1) the differences between age groups in gaze behavior over the three different conditions of neutral, angry and happy facial expressions in a female model, and 2) gender differences through age group and emotion. Results showed no significant effects of age and emotion on the speed of gaze shift, correctness of gaze shift or number of frames spent viewing the model before the first gaze shift. We did however find a significant effect of gender on face gazing time before the first gaze shift.

Evidently, the lack of significant findings can be attributed to the small sample sizes. Although the number of participants was assumed to be sufficient, the number of valid trials proved to be few through all age groups. Despite using both individual analyses making sure each participant's results counted the same amount, as well as analyses per trial, our specific hypotheses were not supported. The lack of support for our hypotheses is discussed.

Hypothesis 1 (Age and emotion): In the study done by Grossman and colleagues, they found larger negativity in ERPs in 7-month-olds viewing happy faces, through frontal, central, temporal and parietal sites. In contrast, they found larger negativity in ERP in 12-month-olds' occipital lobe when viewing angry faces (Grossmann et al., 2007). In our study, we did not find any significant effect on age or gender in viewing angry, happy or neutral emotional expressions. However, as this study is limited to eye tracking, we cannot infer any structural or neuronal activity in the brain. It is not unlikely that functional differences could have been prominent in our study, only not being able to be operationalized through the specific experimental paradigm. In Grossman and colleagues' study, they used pictures and not videos to present the facial expressions as it was not based on joint visual attention, which could also cause a more direct gaze to the infants.

Our hypothesis that the 6-month-olds would look longer at happy faces and the 12-month-olds would look longer at angry faces was not confirmed. However, due to the small sample size of valid trials, we cannot disconfirm our hypothesis. One possible explanation of the absence of any interaction effects between age and emotion, and gazing time might be the use of the same model throughout all emotional conditions. The facial expressions elicited in this study might have been too mild and not exaggerated enough to cause any structural or functional reactions. Additionally, fearful faces elicit greater activity in the amygdala than angry faces (Whalen et al., 2001), and using fearful faces instead f angry faces might have elicited an effect of emotion in this study. Meanwhile, Grossman and colleagues attributed the different ERPs between 7- and 12-month-olds to environmental and social factors (Grossmann et al., 2007). The system of processing facial expressions seems to gradually specialize and become more finely tuned by the end of the first year (Grossmann & Johnson, 2007). Depending on variables such as family relationships, siblings and environmental interactions, infants as young as 12 months might not have been sufficiently exposed to angry faces to learn the value of threatening stimuli. However, it is difficult to make any conclusion based on these results, as a larger sample size would be required.

Hypothesis 2 (Age, gender and emotion): As hypothesized, we found a significant gender effect, but not where we hypothesized. A significant effect was found between gender and gazing face, supporting previous research that male infants participate less in eye contact at 12 months of age than female infants (Lutchmaya et al., 2002). Additionally, previous research has suggested that gender differences in evaluation threat does not appear until adulthood (McClure et al., 2004), which could explain why we found no effects of emotion on age and gender. The effect we found was independent of emotion and age, showing no differences between 6-month-olds and 12-month-olds. These unexpected gender differences can be attributed to a few things. Firstly, we know there are clear functional gender differences reported in gaze behavior. Male infants participate less in eye contact at 12 months of age than female infants (Lutchmaya et al., 2002), while female infants show longer periods of joint attention than males (Mundy et al., 2007; Olafsen et al., 2006). Female infants also show a greater preference for faces than for objects, opposite of male preferences (Connellan et al., 2000). Females show greater ability to participate in joint attention if the person they share visual attention with is female (Lavelli & Fogel, 2002; Leeb & Rejskind, 2004). Taken together, these studies can explain the gender difference in gazing of face in this study, with a stronger gazing time for females compared to males.

Secondly, there are some structural differences between genders that can explain why there was no effect of age or emotion on gazing face time. Some studies have reported a significantly larger amygdala in males than in females (Caviness et al., 1996; Filipek et al., 1994; Goldstein et al., 2001), the findings are however conflicted. Uematsu and colleagues have found compelling evidence that the female amygdala reaches its peak approximately 18 months earlier than the male amygdala, suggesting an earlier maturation and development of the amygdala and its functions in females (Uematsu et al., 2012). A right amygdalar laterality and larger volume in males has also been reported in many studies (Goldstein et al., 2001; Uematsu et al., 2012). A larger right amygdala volume is seen in autism, where it is associated with dysfunction in communication and social behavior (Munson et al., 2006). In addition, a larger amygdala volume at 6 months is associated with poorer expressive and receptive language measures during childhood (Ortiz-Mantilla et al., 2010). However, a larger growth rate for the left compared to the right amygdala during infancy and early childhood has been reported in both genders, more so in females (Uematsu et al., 2012). The left amygdala has been associated with responding to fearful events or faces. Therefore, researchers have suggested the priority of left amygdalar development in early childhood to be attributed to the vital importance of detecting fearful stimuli in the environment (Hardee et al., 2008; Phelps et al., 2001). Because the female left amygdala develops faster than in males, we suggest that this can contribute to the observed gender differences in gazing at the model's face as well as the lacking of age effects at such an early age. The theory of amygdala maturation at around 8 months is based on macaques (Payne et al., 2010) and the lack of effect seen between age groups on gaze behavior can be based on the fact that the age intervals are too short to see any age differences at such an early stage in the development. This would support earlier findings that young males tend to respond faster with their when cues or objects are presented than females (Bayliss et al., 2005; Mezzacappa, 2004), resulting in females maintaining attention in the same place for longer than males. However, studying infants' attentional networks is a more difficult task, and no studies have been done on this specific topic as we are aware.

4.1 Limitations and future research

As noted earlier, this study is clearly limited by the small number of valid trials, as a result of limited time and resources. One theory could be that the videos were not interesting enough for the infants; it could also be that the videos were too repetitive and the infants lost interest quickly. Future research should include brain imaging techniques or EEG as a means of finding any correlations between the gender differences while using the same visual joint attention paradigm. Including sound to the different facial expressions have shown to make a difference in joint attention in 6 month old (Hoehl & Striano, 2008), and it would be interesting to see if the gender differences are more age and emotion specific with both visual and auditory stimuli.

4.2 Conclusion

In this study, we investigated infants and the effects of age, gender and emotional expression on correct gaze shifts in accordance with the model. We found no effects on the age groups 6, 9 and 12 months through the different facial expressions angry, happy or neutral. We did however find a significant gender difference independent of age and emotional condition. The findings support previous reports that female infants look longer at female faces than males, and have a stronger preference for looking at faces in general than male infants. The amygdala matures sooner in females than in males, and this is theorized to be the reason for the reported gender differences. The fact that the effect of gender differences was independent of age and emotional expression of the model, suggests amygdala development to have a weaker effect on infants of 12 months or younger, than older children and adults. Although some parts of the experimental design can explain the lack of effect from age and emotion, future research is ultimately needed to determine the exact effects of amygdala maturation on emotional processing in infants.

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