Social information processing in infancy and adolescence

Examining the role of different interaction partners

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Examining the role of different interaction partners

Hoe baby's en pubers sociale informatie verwerken:

Wat is de rol van de interactiepartner?
(met een samenvatting in het Nederlands)

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Chapter 1

General Introduction

Social development

From birth onwards infants seek contact with other people in various ways, for instance by making eye-contact, smiling and conveying distress by crying. Over the course of development, children develop multiple other skills to communicate with other people (Rose-Krasnor, 1997). It is vital to develop proper social skills, as these skills can possibly impact many other processes. They can for example influence language learning in toddlerhood, making friends in adolescence and dealing successfully with the challenges of adulthood.

There are several proposed theoretical models on the processes underlying social development (for a review, see Rosenblum, Dayton, & Muzik, 2009). The *maturational model* states that social development is an innate unfolding of preset maturational time points (Gesell & Armatruda, 1974). Social skills appear at the moment the brain has reached a sufficient growth level to support these skills. Other models also take the environment of the children into account. For example, the *ecosystem model* proposes that both the immediate environment of the child (e.g., interaction and relation to parents) as well as more distal contexts (e.g., child care, cultural values) shape social development (Bronfenbrenner, 1979). There are several other models which highlight the importance of the interaction between a child and the people in their environment. The main focus of these models is that both interaction partners (i.e., child and parent) shape each other’s social development in a dynamic, ongoing fashion (Rosenblum et al., 2009). These models therefore emphasize the important role interaction partners play in social processes and the development thereof.

Although social development continues over the entire life span, there are two periods in development which seem especially important in acquiring proper social skills: infancy and adolescence. During infancy, the building blocks for all later social development are formed. For example, learning to differentiate emotions early on in development is needed to later develop the capacity to rely on the emotional expressions of others to determine how to respond in a certain situation. There are several of such prominent developmental milestones which can be observed in infancy (c.f., Rosenblum et al., 2009). For example, due to certain neurological changes at 2-3 months of age, infants will be more awake and more focused (Bowlby, 1969/1982), which results in more interaction and engagement between infants and their parents. Infants, for instance, start to make vocalizations in response to social encounters. Around 7-9 months of age, infants start to display a focused attachment with their primary caregivers (Emde & Buschbaum, 1989). From 18-21 months onwards infants noticeably change their social interactions. The infant uses affective expressions of others to guide responses to novel situations (Feinman, Roberts, Hsich, Sawyer, & Swanson, 1992) and their interactions are increasingly facilitated by the use of language.

During childhood, children further develop and extend on the social skills acquired in infancy. They mainly learn to flexibly use social tactics in different social situations (Burnett & Blakemore, 2009). However, over adolescence, extensive changes in social behavior and environments take place. Both neuroimaging as well as behavioral studies indicate that the social brain network and social cognition undergo significant development (for a review, see Kilford, Garrett, & Blakemore, 2016). Moreover, adolescence is characterized by a notable change in the type of social interactions. The closeness with parents diminishes, as parental support declines with increasing age (Helsen, Vollebergh, & Meeus, 2000; Steinberg & Silverberg, 1986). At the same time, peer relations also change. Adolescents spent more time with peers and also turn to their friends more often as sources of advice and comfort (Bokhorst, Sumter, & Westenberg, 2010; Gould & Mazzeo, 1982; Helsen et al., 2000). Especially in early adolescence peers seem to play an important role in social interactions (Fuligni, Eccles, Barber, & Clements, 2001; Helsen et al., 2000). This behavioral re-orientation towards peers appears to influence neural processes as well. For example, adolescents exhibit a ‘dip’ in their performances on adult face recognition, whereas they excel in recognition of peer faces (Picci & Scherf, 2016).

In the current dissertation I will dive into the development of several social processes in both infants and adolescents, and consider the role that different interaction partners might play in this social processing. Knowledge about these processes is fundamental in supporting people who have difficulties with social interactions, such as people with autism (Baron-Cohen, Leslie, & Frith, 1985). Eventually, this research might inform the design of new early interventions which help infants and children with communicative disorders in the development of their social skills. In the first part of this dissertation, I will investigate word learning in both typical and atypical two-year-olds. In the typical infants I further examine whether maternal speech is advantageous in the novel word learning process. In the second part, I will focus on the development of three social processes over the course of adolescence: gaze cueing of attention, emotion recognition and empathy. Furthermore, I will try to disentangle whether the behavioral re-orientation towards peers observed in adolescence has an effect on these social processes.

Part I: Language development in two-year-olds

In the first part of this dissertation the focus will be on language processing in infants. Infancy is defined as the period from birth until two years of age. I specifically target language processes in this developmental group, as around two years of age infants display an enormous increase in word production, also known as the 'vocabulary spurt' (e.g., Goldfield, & Reznick, 1990). Infants learn novel words by detecting co-occurrences between a certain word and a certain object, such that associative links between words and their referents are formed (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). This early vocabulary formation appears to be supporting for later intellectual functioning, as vocabulary size and the speed of word recognition at 25 months of age is related to linguistic and cognitive skills at eight years (Marchman & Fernald, 2008). It is therefore important to unravel both typical and atypical language learning processes at this age and indicate the factors which may be beneficial for novel word learning, which will be the aim of this part of the dissertation.

Typical population

One of the factors that potentially could facilitate novel word learning is the familiarity with the voice that is uttering the novel word. From two months onwards infants are able to discriminate different voices (Boyd, 1974). The voice of the own mother is recognized even earlier in development. Already in-utero fetuses react with a higher heart rate to hearing their mother's voice (Kisilevsky et al., 2003; 2009; Lee & Kisilevsky, 2014), a reaction which starts around 32-34 weeks gestational age (Kisilevsky & Hains, 2011). Newborns also show a specific behavioral preference for their mother's voice (DeCasper & Fifer, 1980; DeCasper & Prescott, 1984; Hepper, Scott, & Shahidullah, 1993; Lee & Kisilevsky, 2014). These studies suggest that the mother's voice might play a vital role in infants' language processing. Indeed, brain imaging studies show that the mother's voice elicits increased activation in brain regions associated not only with language processing but also with attention and reward processing (Abrams et al., 2016; Beauchemin et al., 2011; Dehaene-Lambertz et al., 2010; Naoi et al., 2012). These results imply that the mother's voice is processed effectively and in a highly attentive state.

Despite the extensive amount of studies examining maternal voice processing, specific research on the effect of the mother's voice on novel word learning is lacking. To our knowledge, there is only one study which examines maternal effects on word learning. This study revealed a marginal beneficial effect for the mother's voice on word learning processes in 6- to 24-month-old infants (Krcmar, 2010). However, a comparison between learning from the own mother and from a stranger was only made in a condition where teaching of the novel words took place through a video connection, without any live interaction. It is therefore still unclear whether the mother's voice has a facilitating effect on the formation of novel word-object mappings, especially when there is direct interaction between mother and child, which is the most natural learning setting.

Chapter 2 will therefore specifically address the question whether the mother's voice can boost the formation of novel word-object mappings. The mother's voice could facilitate novel word learning in at least two ways. First, an acoustic account would state that it is the acoustic familiarity with the mother's voice itself that results in more efficient voice processing (Purhonen, Kilpeläinen-Lees, Valkonen-Korhonen, Karhu, & Lehtonen, 2004; 2005). Because of the ample prior experience with the mother’s voice, infants should find it easier to recognize and understand her speech (Barker & Newman, 2004; Bortfeld, Shaw, & Depowski, 2013). Second, a social account would state that familiarity with her as the person who provides most of the learning possibilities makes children quickly understand the intention of the word learning situation (Csibra & Gergely, 2009). This awareness is likely to boost their motivation, which in turn aids novel word learning (Bruner, 1981; Smith, 2000; Spelke, Bernier, & Skerry, 2013; Tomasello, 2003).

Although it is nearly impossible to separate these two (not mutually-exclusive) accounts (Bortfeld et al., 2013), I reasoned that the way in which maternal speech is presented might modulate outcomes. I therefore adopt two different social word learning settings in *Chapter 2*. Half of the children will be taught in a live interaction setting, in which the teacher is speaking directly to the child. The remaining half of the children will be taught in a prerecorded setting, in which speech is played over the loudspeakers. Although significant beneficial effects of the mother’s voice are observed with live interaction (e.g., Parise & Csibra, 2012) as well as with prerecorded stimuli (e.g., Barker & Newman, 2004; Purhonen et al., 2004), none of these studies directly compared both learning situations. The study described in *Chapter 2* will be the first to asses word learning from familiar and unfamiliar speech in both a live interaction and prerecorded learning setting, such that possible additional beneficial effects of social interaction with the mother can be detected.

Children at risk for autism spectrum disorder

One developmental disorder that is characterized by impairments in social interaction and communication is autism spectrum disorder (ASD) (DSM-V; American Psychiatric Association, 2013). Although atypical language development is no longer considered a key characteristic in identifying children with autism (DSM-V; Constantino & Charman, 2016), clinicians still consider lagging behind in vocabulary size as one of the first signs of atypical behavior in infants who later develop ASD (Wetherby, Watt, Morgan, & Shumway, 2007). Impairments in language abilities are first found to emerge at 12 months of age and are still present in childhood (Charman, Drew, Baird, & Baird, 2003; Hudry et al., 2010; Landa & Garrett-Mayer, 2006; Mitchell et al., 2006; Yirmiya, Gamliel, Shaked, & Sigman, 2007; Zwaigenbaum et al., 2005). Moreover, there is a strong correlation between word learning performance in three-year-olds and autistic-related traits such as the ADOS score (Autism Diagnostic Observation Schedule, Lord et al., 2000; Gliga et al., 2012).

There are several explanations for the delay in language abilities in children with ASD. First, children with ASD show atypical gaze-following behaviors (Baron-Cohen, Baldwin, & Crowson, 1997). A study with three-year-old children shows that it is not the gaze-following behavior per se that is impaired in ASD, but it is rather the divergent distribution in looking time to the gazed-at object and a distracter object which determines poor word learning outcomes (Gliga et al., 2012). Similar results are found in a study with 6- to 11-year-olds with ASD (Akechi et al., 2011). Apparently, difficulties in word learning arise because of a diminished preference for gazed-at objects. Indeed, five-year-old children with ASD are able to direct their attention to specific objects in response to social cues, yet they show difficulties in word learning when the referred object is not interesting enough to hold their attention (Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007).

Another explanation for the language delay in children with ASD is that they might have troubles with the motivation to attend to human speech. Children between 14 and 36 months old at risk for ASD show a reduced preference for infant-directed speech (IDS) compared to typically-developing (TD) children (Paul, Chawarska, Fowler, Cicchetti, & Volkmar, 2007). Moreover, these infants show no preference for language patterns tuned to their native language, something which is seen from six months onwards in TD infants (Paul et al., 2007). At a later stage, preschool-aged children with ASD show an opposite preference pattern compared to their peers: they prefer non-speech sounds over IDS (Kuhl, Coffey-Corina, Padden, & Dawson, 2005). Furthermore, 6- to 12-year-olds with ASD exhibit difficulties in orienting attention towards changes in speech sounds, although their sensitivity to detect these changes is intact (Čeponienė et al., 2003). These studies imply that it is not the speech processing itself that is impaired, but rather the orientation towards speech which is altered in children with ASD.

It is specifically this orientation towards speech which seems to be fundamental to language development. A recent study examining speech preference in nine-month-olds shows that at the group level, infants at risk for ASD do not prefer human speech over monkey calls. However, at the individual level, the infants who preferred human speech over monkey calls had larger vocabularies and fewer autistic traits at 12 months than the infants who showed the opposite preference pattern (Sorcinelli, Ference, Curtin, & Vouloumanos, 2019). Similar results are found in 12-month-old infants (Curtin & Vouloumanos, 2013) and three-year-old toddlers (Kuhl et al., 2005). Thus, attention towards speech appears to be relevant for subsequent linguistic development in infants with ASD. A possible explanation is that a decreased orientation towards speech might discourage people in the environment of the infant to provide the adequate amount and quality of speech to the child, which further decreases language learning.

Despite the ample evidence that children with ASD are lagging behind in vocabulary size, it is interesting to note that most of this evidence comes from parental questionnaires. These questionnaires can be prone to biases as some parents require their child to overtly react to object naming as proof of word understanding (Houston-Price, Mather, & Sakkalou, 2007). Nonetheless, children may not always respond to words according to their parents' expectations. This might specifically be true for infants with ASD, who have difficulties with social interactions. If parents indeed have troubles with interpreting their child's behavior and consequently find it hard to determine which words their child does and does not understand, this results in underestimation of a child's true vocabulary size.

Remarkably, experimental evidence that children with ASD are limited in their vocabulary formation is still missing (but see Gliga et al., 2012, with three-year-olds). In *Chapter 3* word learning in two-year-olds at risk for ASD (i.e., with an older sibling diagnosed with ASD) will therefore be assessed in an eye-tracking study. In this way, the infants do not need to explicitly react and interact in order to determine on word learning abilities. Instead, their gaze patterns (i.e., preferential looking) are used to deduct whether they correctly pair novel objects with novel words. This will be the first study to experimentally test word learning abilities in a sample of two-year-olds at risk for ASD.

Part II: Social development in adolescence

In the second part of this dissertation I shift from infancy to the period of adolescence. Adolescence is typically defined as the period between 13 and 19 years of age, although the physical and psychological changes that belong to this period can start earlier, during the pre-adolescence phase (ages 9 through 12). As language processes are typically developed at this stage, I now turn towards non-verbal social processes. Adolescence is an interesting period to investigate social processes, because this is the moment in development when children display a motivation to master new developmental tasks which prepare them for adult social roles, such as developing confiding friendships and romantic relationships (Scherf, Behrmann, & Dahl, 2012). The aim of the second part of this dissertation is to examine whether this new focus on peer relationships, rather than mostly focusing on caregivers, alters adolescents' social information processing.

Pubertal 'dip'

Social information processing appears to change at the onset of puberty, as experimental studies report on a 'dip' in face and emotion processing performance around the start of adolescence (e.g., Carey, Diamond, & Woods, 1980; Diamond, Carey, & Back, 1983; McGivern, Andersen, Byrd, Mutter, & Reilly, 2002; Peters & Kemner, 2017). For example, in a face memory task adolescents show worse performance for the recognition of adult faces compared to the performance of prepubertal children and adults. However, they perform better than the other age groups for the recognition of adolescent faces (Picci & Scherf, 2016). This peer bias is further shaped by pubertal status, as adolescents in early puberty are better at recognizing other early puberty adolescents, whereas adolescents in late puberty are better at recognizing other late puberty adolescents. Thus, pubertal status, irrespective of age, seems to influence the development of face processing abilities (see also Diamond et al., 1983; Lawrence, Campbell, & Skuse, 2015).

A possible explanation for these effects lies in the tremendous surge of gonadal hormones at the onset of puberty, which impacts both physical and cognitive development. It is hypothesized that this influx of gonadal hormones initiates the transition from a caregiver-bias towards a peer-bias, which results in increased computational demands that will require re-organization of the involved processing systems (Scherf et al., 2012). For example, adolescents will be motivated to encode social information from faces that is related to the new peer interactions, such as attractiveness, trustworthiness and social status. Moreover, the sensitivity to detect complex facial expressions improves as a function of pubertal development (Motta-Mena & Scherf, 2017). As a consequence of these changes, a period of relative instability in the existing face processing system will occur, as there will be a shift in balance among existing neural regions supporting these processes. This period of relative instability will manifest itself as a transient disruption in existing face processing abilities. Thus, although one might expect a linear improvement with age from infancy to adulthood on face and emotion processing, the influx of gonadal hormones temporarily disrupts this improvement.

If there indeed is an influence of gonadal hormones on the re-organization of the cortical circuitry underlying face processing, than this hormonal influx should also influence other social processes dependent on similar brain structures. In *Chapter 4* I will examine three of these other social processes: gaze following, emotion recognition from the eyes, and empathy. Evidence from studies using functional Magnetic Resonance Imaging (fMRI) suggests that the brain areas involved in face processing are also part of the brain circuitry underlying these other social processes. Especially the superior temporal sulcus (STS) seems to be of high importance in face processing (Gobbini & Haxby, 2007). Likewise, this brain area is the main focus in studies examining eye-gaze processing (e.g., Hoffman & Haxby, 2000; Mosconi, Mack, McCarthy, & Pelphrey, 2005; Vaidya et al., 2011). Furthermore, STS activity is also found in studies on emotion recognition from the eyes (e.g., Adams Jr et al., 2010; Castelli et al., 2010; Gunther Moor, et al., 2012) and empathy (e.g., Dziobek et al., 2012; Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006; Zaki, Weber, Bolger, & Ochsner, 2009). These studies suggest that if gonadal hormones re-organize cortical activity, including STS activity and connectivity, this would not only influence face processing, but also other social processes. More specifically, I would expect to find a 'pubertal dip' in the performances on a gaze cueing task, an emotion recognition task and empathy measures. The study described in *Chapter 4* is the first to test whether these three social processes are affected by the influx of pubertal hormones. This will be the first step in mapping the developmental time course of these processes over adolescence.

Gaze cueing of attention

In *Chapter 5*, I will focus on only one of the social processes examined in *Chapter 4*¸ which is the reorientation of attention in response to eye-movements. I specifically focus on this process as it is one of the key processes in social development. Already early in development, infants are able to follow gaze, but seem incapable to use this gaze information to deduct information from the environment. At around 12 months of age, infants start to follow gaze towards objects in their surroundings (Morissette, Ricard, & Décarie, 1995). Over development, infants gradually refine the cues they use to follow gaze. First, they only follow whole head movements, whereas later in development infants are able to follow subtle gaze shifts (Moore, 2008). Early gaze following supports important developmental tasks such as language learning and understanding other people's actions and intentions. For instance, shifting attention in response to gaze cues during infancy correlates with subsequent language development (Brooks & Meltzoff, 2005; Morales, Mundy, & Rojas, 1998; Morales et al., 2000). Also later in development, much of children's learning occurs in the context of social interactions in which joint attention processes are key. Joint attention refers to moments when children and adults attend to the same object or event, and are both aware that the focus of attention is shared (Baldwin, 1995). The coordination of one's own perspective and another person's perspective (e.g., based on that person's eye-gaze) relative to a third object provides experiences that are fundamental to social-cognitive neurodevelopment (Mundy, 2016; Mundy & Jarrold, 2010; Mundy & Newell, 2007).

Someone's tendency to follow gaze cues is measured with the gaze cueing paradigm. In this paradigm, a central stimulus face shifts it's gaze to either the right or the left, after which a target is presented at one side of the screen (Friesen & Kingstone, 1998). People show faster target detection when the gaze direction correctly predicts target location (congruent condition) compared to a situation where the gaze shifts to the location opposite to where the target will appear (incongruent condition). This is called the gaze cueing effect.

The magnitude of the gaze cueing effect appears to be dependent on the faces which are used as stimuli. Face characteristics such as species, race, age, gender and identity determine to what extend attention is redirected in response to a gaze cue (cf., Macchi Cassia, 2011). For example, using familiar faces as stimulus models enhances the gaze cueing effect, yet this effect is only observed in women (Deaner, Shepherd, & Platt, 2007). Moreover, young adults show larger gaze cueing effects for young adult stimulus models compared to older adult stimulus models (Slessor, Laird, Phillips, Bull, & Filippou, 2010). However, these studies are all performed with adult samples. It is still unclear how face characteristics modulate gaze cueing effects in children.

Although there is no information on the effect of the age of the stimulus model on the process of gaze following in children, there is ample evidence for a stimulus-age effect in the field of face recognition (for reviews, see Macchi Cassia, 2011; Rhodes & Anastasi, 2012; Wiese, Komes, & Schweinberger, 2013). Children show superior recognition of child faces compared to adult faces (e.g., Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Hills, 2012; Hills & Lewis, 2011; Lindholm, 2005), and also adolescents show an own-age effect in face recognition (Picci & Scherf, 2016). It therefore appears that children might be more tuned towards processing faces of their own age-group. This enhanced processing of own-age faces might boost their performance on a gaze cueing task as well. I therefore examine in *Chapter 5* whether the age of the stimulus face modulates gaze-following behavior in adolescents. This will be the first step in determining the effect of stimulus characteristics on gaze-following processes in puberty.

Eye-tracking with developmental samples

All of the research described in this dissertation made use of eye-tracking technology in a developmental sample. Eye-tracking was used as it is a suitable measure for all age ranges. Furthermore, it is a non-invasive technique which is relatively easy and quick in set-up procedure, and very portable for on-site measurements, in contrast to for example electroencephalography (EEG) or functional near-infrared spectroscopy (fNIRS). With eye-tracking, an infrared light source is directed towards the eye. A camera tracks the reflection of this light source, along with several features of the eye itself. This data is used to extrapolate the direction of the eye-gaze (Duchowski, 2003). In this way, it becomes possible to follow a person’s eye-movements and determine where on the screen a person fixates. Eye-tracking is a very useful tool in measuring infant and child behavior. Young children are mostly unable to verbally tell what they think, yet by measuring their looking behavior it becomes possible to infer their preferences and cognitive processes. A general assumption is that infants and children fixate on a point on the screen which they are most interested in at that specific moment.

One can imagine that using eye-tracking with infants and young children to study gaze behavior is not as straightforward as with adult participants. For example, it is impossible to instruct infants to sit still in front of the eye-tracker and not move for the total duration of the experiment. Furthermore, it is sometimes hard to perform a good calibration procedure, as one cannot instruct infants to look at a certain point on the screen at a specific moment in time. These difficulties might significantly influence data quality (Hessels, Andersson, Hooge, Nyström, & Kemner, 2015; Hessels, Cornelissen, Kemner, & Hooge, 2015; Wass, Smith, & Johnson, 2013).

To minimize the influence of participant movement on our data quality several actions were taken. First, our lab investigated which eye-tracker was most capable of dealing with tilting head orientations and looking away from the screen, which are both actions often observed in infant participants (Hessels et al., 2015b). Moreover, infants were always positioned in a baby seat in front of the computer screen, instead of positioning them on the parent's lap. This results in more accurate measurements (Hessels et al., 2015a). For the older children, a chin rest was used to minimize head movement. Last, for the analyses of the eye-tracking data I used a fixation-detection algorithm built specifically for data across a wide range of noise levels and when periods of data loss may occur (I2MC; Hessels, Niehorster, Kemner, & Hooge, 2017). By applying these different action points, I attempted to minimize the influence of participant movement on the data.

Outline of the present dissertation

The general aim of the current dissertation is to examine social information processing in infants as well as adolescents, and to investigate the possible role of different interaction partners in these social processes. Because of the broad age range in our participants, I divided this dissertation up into two different parts. In the first part, I will examine word learning in two-year-olds. In *Chapter 2* I test the novel word learning abilities in typical two-year-olds. More specifically, I will investigate whether maternal speech boosts the formation of new word-object mappings. In addition, I test whether this hypothesized advantage of maternal speech holds across two different settings: a live interaction setting in which an infant is actively taught, and a prerecorded setting in which the voice is played over loudspeakers. In *Chapter 3* I adopt a similar word learning paradigm with two-year-olds at risk for ASD. This will be one of the first studies to experimentally test whether children at risk for ASD have difficulties with novel word learning, something one would expect based on results from parental questionnaires assessing vocabulary size.

In the second part of this dissertation, I switch focus towards non-verbal social processing in adolescence. In *Chapter 4* I will examine the developmental time course of three social processes: gaze following, emotion recognition from the eyes and empathy. I will specifically test whether these three processes show a ‘pubertal dip’ in performance, as is observed in basic face processing. Then, in *Chapter 5*, I will tune-in on the process of gaze cueing of attention and investigate whether young adolescents show different gaze-following behaviors when confronted with either an adult or a child who provides the gaze cues. Finally, in *Chapter 6*, all results will be combined and discussed to give a broad overview of the development of several social information processes and the role interaction partners might play in this social processing. An overview of the chapters and concepts is provided in Figure 1.1.

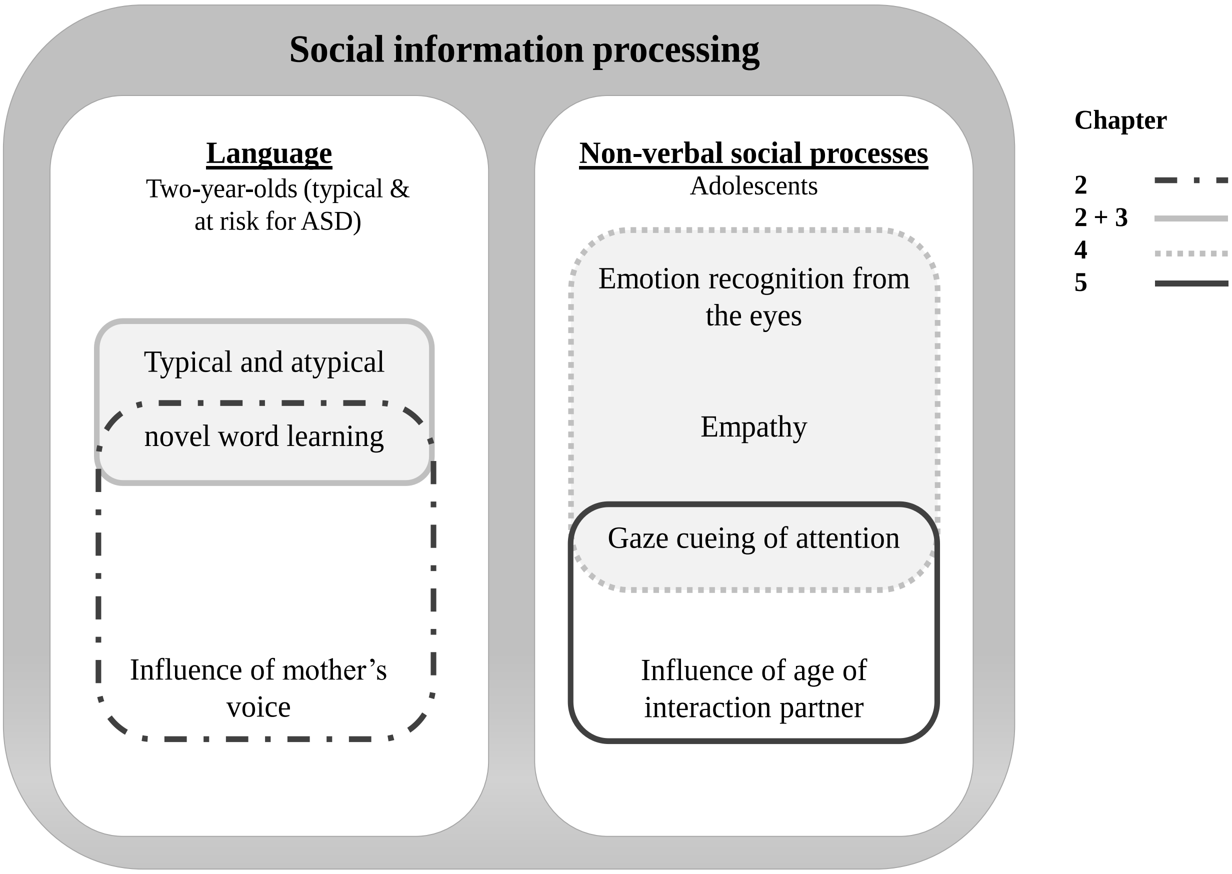

Figure 1.1. Schematic overview of the chapters and concepts discussed in the present dissertation.

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Chapter 2

Beneficial effects of the mother's voice on infants' novel word learning

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Submitted

Author contributions:
EB and CJ contributed conception and design of the study; RR and EB were responsible for programming the experiment and data collection; RR was responsible for data processing and data analyses; RR wrote the first draft of the manuscript; All authors contributed to manuscript revision, read and approved the submitted version.

Abstract

For language acquisition, the maternal voice is special as it is the voice infants are most familiar with. The current eye-tracking study investigated whether 24-month-olds (*n* = 149) learn novel words easier while listening to their mothers compared to unfamiliar speakers. Results show that maternal speech facilitates the formation of new word-object mappings across two different settings: a live setting in which an infant is actively taught by the infant’s mother or the experimenter, and a prerecorded setting in which the voice of either the infant’s own or another infant’s mother is played over loudspeakers. Furthermore, this study explored whether infants' pointing gestures and novel word repetitions during task serve as meaningful indexes of word learning behavior. Infants who repeated more target words during task also show a larger learning effect in their looking behavior. Thus, maternal speech as well as infants’ willingness to repeat novel words are positively linked with novel word learning.

Introduction

Building a vocabulary is one of the main tasks in infants' language development. Key in language learning is generating associative links between words and their referents by noticing the co-occurrence between a certain word and a certain object (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Forming such word-object associations is not a trivial task, due to the highly variable context in which these words and objects occur. Nonetheless, children are able to learn novel word-object associations quite rapidly (Woodward, Markman, & Fitzsimmons, 1994). For instance, experimental evidence indicates that from six months onwards infants understand some words (Bergelson & Swingley, 2012). In the second year of life, most infants greatly expand their vocabulary: at 24 months, the average (American-English) infant understands around 300 words (http://wordbank.stanford.edu/; Frank, Braginsky, Yurovsky, & Marchman, 2017). Even though this suggests that with increasing experience infants easily learn words, their word learning is far from robust in a laboratory setting: infants find it difficult to learn words uttered in adult-directed speech (Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011) or to recognize words across different speakers (Houston & Jusczyk, 2000), across different registers (Singh, 2008) or across different accents (Best, Tyler, Gooding, Orlando, & Quann, 2009; Schmale, Cristia, Seidl, & Johnson, 2010). Several factors might contribute to the facilitation of novel word learning (Shafto, Goodman, & Frank, 2012). Knowledge about these facilitating factors may lead to more insight into language development and could help in designing optimal intervention strategies aimed to boost word learning. In the current study we test whether speaker familiarity, in this case the voice of an infant's mother, facilitates the formation of novel word-object associations.

Speaker familiarity is a main factor in language development (Pierrehumbert, 2003). Especially the mother's voice appears to have a vital role in infants' language processing as it is the one voice infants are most familiar with from as early as their hearing develops. Already in-utero, fetuses react with a higher heart rate to hearing their mother's voice (Kisilevsky et al., 2003; 2009; Lee & Kisilevsky, 2014), a reaction which starts around 32-34 weeks gestational age (Kisilevsky & Hains, 2011).

Moreover, newborns show a specific preference for their mother's voice right after birth (DeCasper & Fifer, 1980; DeCasper & Prescott, 1984; Hepper, Scott, & Shahidullah, 1993; Lee & Kisilevsky, 2014). In addition, six- to nine-month-olds show enhanced speech segmentation skills (Barker & Newman, 2004) and word comprehension (Parise & Csibra, 2012) in challenging listening situations only when they listen to their own mothers.

There is a noticeable difference in language processing at the brain level as well. Electrophysiological studies reveal that four-month-olds detect phonetic changes faster with maternal speech (Purhonen, Kilpeläinen-Lees, Valkonen-Korhonen, Karhu, & Lehtonen, 2004; 2005). Studies measuring hemodynamic responses show that the mother’s voice elicits increased activation in brain regions associated not only with language processing but also with attention and reward processing (Beauchemin et al., 2011; Dehaene-Lambertz et al., 2010; Naoi et al., 2012). Note that most evidence highlighting the special status of the mother’s voice demonstrates this for infants below their first birthday. It is unclear whether maternal speech continues to play a special role. One study suggests that the mother's voice remains salient over the course of development: even at the age of 10 years it elicits greater brain activity in children’s voice processing, affective and reward systems (Abrams et al., 2016). These results suggest that the child’s brain remains tuned towards processing the maternal voice from a very young age onwards.

So far, most studies regarding the mother's voice have only investigated the processing of familiar words (e.g., Barker & Newman, 2004; Parise & Csibra, 2012). There is one study investigating the effect of the mother’s voice on novel word learning. In this within-subject study 6- to 24-month-olds were first familiarized with the task of how word learning was assessed: their mother labeled five familiar items several times before the infant was asked to pick the requested item from a tray with these items. This procedure was then repeated with five novel items in three versions: live with the mother, from a video with the mother or from a video with a stranger. Although especially the 13- to 20-month-olds benefited from live interaction, there was only a marginal beneficial effect for the mother’s voice on word learning processes (yet only contrasted in the video condition; Krcmar, 2010). However, it is possible that the familiarization of the task procedure (i.e., with the infant’s mother labeling known objects prior to test) might have mitigated the difficulty of the learning situation (Swingley, 2007; van Heugten & Johnson, 2017), thus masking beneficial effects. Alternatively, the task might have been too difficult for the youngest age group since the 6- to 12-month-olds score at chance level in all conditions, thus also potentially masking clear advantages of maternal speech. It is therefore still unclear whether the mother's voice has a facilitating effect on the formation of novel word-object mappings, especially when there is live interaction between mother and infant, which is the most natural learning setting.

We examine with the current study whether 24-month-olds benefit from being taught by their mothers compared to a stranger in a novel word-object learning situation, using a preferential looking paradigm highly similar to the paradigm used by Ma and colleagues (2011). In this paradigm, the infants observe short animations in which two novel objects are introduced and named, after which we test their word learning performance with a preferential looking paradigm (using eye-tracking). We chose this design because it represented a challenging learning situation. Ma and colleagues (2011) showed that at a group level, 21-month-olds only display evidence of learning when listening to infant-directed speech, but not when listening to adult-directed speech. Given that advantages of maternal speech might manifest itself predominantly in challenging learning situations, we expect that this design is suitable for finding possible beneficial effects of the mother's voice on novel word learning abilities.

The mother's voice could facilitate novel word learning in at least two ways. First, an acoustic account would state that it is the acoustic familiarity with the mother's voice that results in more efficient voice processing (Purhonen et al., 2004; 2005). In other words, infants find it easier to recognize and understand their mother’s speech due to ample prior experience with her voice (Barker & Newman, 2004; Bortfeld, Shaw, & Depowski, 2013). Second, a social account would state that the mother is (one of) the key socially meaningful person in a child’s life who provides most of the learning possibilities to that child (Csibra & Gergely, 2009). Linking the mother's speech to the person of one's mother - which infants can do from an early age (e.g., Cohen, 1974) - would lead children to understand the intention of the word learning situation, as they experienced so many occasions of word learning from her in their daily life. This awareness is likely to boost their motivation, which in turn aids novel word learning (Bruner, 1981; Smith, 2000; Spelke, Bernier, & Skerry, 2013; Tomasello, 2003). This account fits with findings from hemodynamic studies which observe that maternal speech not only elicits activation in language areas but also in areas related to attention and reward (Abrams et al., 2016; Beauchemin et al., 2011; Dehaene-Lambertz et al., 2010; Naoi et al., 2012).

Although it is nearly impossible to separate these two (not mutually-exclusive) accounts (Bortfeld et al., 2013), we reasoned that the way in which maternal speech is presented (live vs. prerecorded) might further modulate outcomes. Beneficial effects of maternal speech have been observed with live interaction (e.g., Parise & Csibra, 2012) as well as with prerecorded stimuli (e.g., Barker & Newman, 2004; Purhonen et al., 2004). A social account might predict that infants learn better in a live setting, as recognizing the mother as speaker might be more transparent in this situation. We therefore incorporated two different social word learning situations in our study. Half of the infants were taught in a live setting, with either the infant's mother or the experimenter (i.e., stranger) labeling the novel objects via subtitles underneath the animations. The remaining half of the infants were taught in a prerecorded setting, in which the speech was previously recorded and played over the loudspeakers during the experiment. Here, infants heard either speech of their own mother or of the mother of another infant (i.e., stranger). In this prerecorded condition the mother was in the room as well, but was seated slightly behind the infant such that social interaction was discouraged. By using these two settings we can better understand the scope of the (hypothesized) advantage of maternal speech.

The current design further allows us to explore whether the way in which auditory stimuli are presented during word-object mapping additionally influences novel word learning in two-year-olds. Although studies with prerecorded speech stimuli have proven to be effective in the laboratory and are usually the dominant way of presenting speech stimuli in word learning experiments (e.g., Barker & Newman, 2004; Ma et al., 2011), there is reason to believe that in some cases infants experience more difficulty learning from prerecorded input such as video’s. When children can view an actor teaching them novel words either via video or in real life, they often succeed in learning tasks only when direct social interaction is possible, that is, when the actor can respond to the child’s behavior (DeLoache et al., 2010; Hakuno, Omori, Yamamoto, & Minagawa, 2017; Krcmar, 2010; Krcmar, Grela, & Lin, 2007; Kuhl, Tsao, & Liu, 2003; Linebarger & Walker, 2005; Myers, LeWitt, Gallo, & Maselli, 2017; Robb, Richert, & Wartella, 2009; Roseberry, Hirsh-Pasek, & Golinkoff, 2014). In our study we can compare word learning abilities when speech is either presented live or presented via loudspeakers, although note that in both cases social interaction was rather constrained as the speakers were instructed to read scripted texts, and the speaker was never present as an actor in the animations. As a result, the difference between our two settings is less pronounced in allowing for social interaction possibilities than the contrast that studies demonstrating ‘the video deficit’ usually employ. We therefore did not make any predictions whether or not there would be an additional effect of live speech over prerecorded speech.

In short, the current study examines several questions related to infant novel word-object learning. We first ask whether infants learn better from their own mother compared to a stranger. We further test whether the hypothesized advantage of maternal speech for word-object learning holds across two different settings: a live setting in which an infant is actively taught by the infant’s mother or the experimenter, and a prerecorded setting in which the voice of either the infant’s own or another infant’s mother is played over loudspeakers. If two-year-olds do not show any advantage of maternal speech for word-object mapping, this could indicate that by the age of two, infants have been exposed sufficiently to a variety of speakers to overcome a possible speaker-familiarity effect for word learning, as additional exposure to different speakers facilitates word learning (Rost & McMurray, 2009).

Besides speaker characteristics, such as voice familiarity or speaking in infant-directed speech, as possible factors boosting children's early word learning, it appears that certain behaviors by the children themselves, too, can be predictive of better word learning. In a set of explorative analyses, we report on two indexes of infant behavior, that is novel word repetition and pointing to the screen. To our knowledge, this is the first study that attempts to link infants' eye-tracking behavior to other indexes of spontaneous infant behavior. Both behaviors have been shown as instances of how infant behavior itself might further propel word learning, and can arguably be taken to reflect an infant's engagement during task (word repetition: Baddeley, Gathercole, & Papagno, 1998; Gathercole & Adams, 1993; Masur 1995; Vihman & Keren-Portnoy, 2011; pointing: Brooks & Meltzoff, 2008; Fenson et al., 1994; Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Iverson & Goldin-Meadow, 2005; Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007; Rowe, Özçalışkan, & Goldin-Meadow, 2008; Wu & Gros-Louis, 2014; for a review, see Colonnesi, Stams, Koster, & Noom, 2010). For each measure, we first ask whether it varies per learning situation (i.e., at the group level). If infants are more attentive to situations with maternal speech, it is possible that this is reflected in more word repetitions and more pointing gestures. We further speculate that live interaction would also contribute to a more active learning situation. Finally, we used both indexes to explore whether they contribute to variation in word learning ability at the individual level.

To summarize, in our first set of analyses we use a preferential looking paradigm to examine whether infants learn words easier from maternal speech, and whether this hinges on the way speech is presented (i.e., live vs. prerecorded speech). In our second set of analyses we take a more explorative approach and evaluate whether infant word repetition and pointing can serve as meaningful indexes of behavior that relate to their word learning ability.

Materials and methods

Participants

A total of 149 monolingual Dutch full-term two-year-olds (69 boys; *M* age = 24.37 months, *SD* = 0.67, range 23.01-25.62 months) participated in this study. These infants had no history of visual or auditory impairments, and were not at increased risk for language impairments. Another two infants were excluded as no eye-tracking data were acquired for these infants. The infants were randomly assigned to either the live or the prerecorded setting. Within these groups, the infants were allocated to one of two conditions, either the mother's voice condition or the unfamiliar voice condition. These groups did not significantly differ in gender or age. The infants were recruited by sending out letters via the municipalities of Utrecht, Houten and Zeist. Parents who were interested in participation could contact us. The project was approved by the local ethics committee and all followed procedures were in accordance with the Helsinki Declaration of 1975, revised in 2008. Parents signed an informed consent form and the infants received a gift in appreciation for their participation.

Stimuli

Visual stimuli. The visual stimuli consisted of images of two familiar and two novel objects. These stimuli were the same as used by Ma and colleagues (2011). The two familiar objects were an apple and a book, only used during familiarization. With the novel objects, we made similar animations as used by Ma and colleagues (2011) in Adobe Photoshop CC 2014. The object first dropped into the window, moved forwards and backwards, turned 360 degrees, jumped to the right, turned around, jumped to the left and out of sight, and then reappeared from the left corner of the screen. The animations had a white background and a size of 720 x 480 pixels. These animations were only used during the training phase, during all other phases static images of the objects were used (familiarization and test phase: size 500 x 480 pixels; reminder phase: size 800 x 480 pixels). All stimuli were shown against a light gray background. Static images of the visual stimuli are depicted in Figure 2.1.

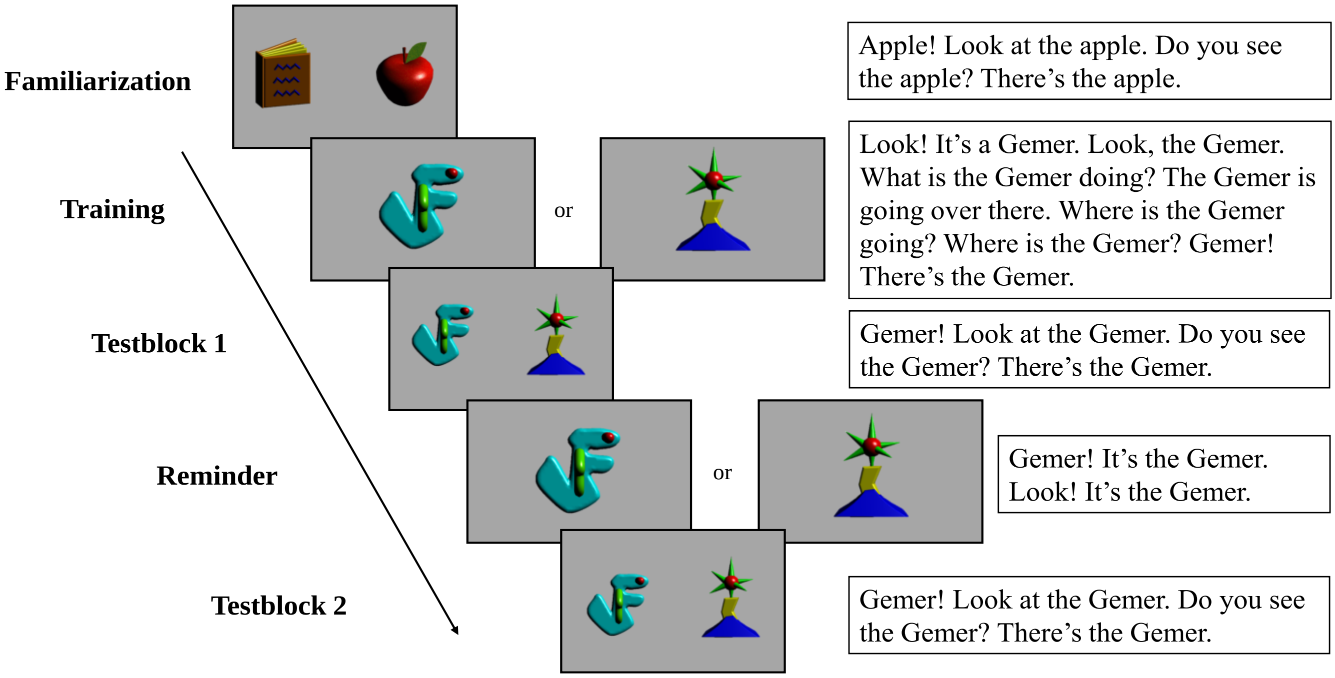
Auditory stimuli. We translated the sentences used in the study by Ma and colleagues (2011) into Dutch. The novel objects were named ‘gemer’ /ˈxemər/ and ‘miekel’ /ˈmikəl/, two Dutch pseudowords. In the live setting, the auditory stimuli were read aloud during the experiment by either the infant's own mother or the experimenter, with the sentences presented as subtitles below the visual stimuli. For the prerecorded setting, we had previously recorded the sentences during home visits. The stimuli were recorded with an Olympus digital voice recorder WS-450S and edited in Praat (version 5.4.08; Boersma & Weenink, 2015). We cut the audio recordings in sections corresponding to the different types of trials (see Figure 2.1). The sentences belonging to the training trials were again divided into four sections, such that they could be played in congruence with the stimulus animation. The recordings had a mean intensity of 75 dB. The audio recordings of a mother served as the familiar voice for her own infant as well as the unfamiliar voice for another infant. In both the live and prerecorded setting the speaker was instructed to speak clearly, slowly and in infant-directed speech (‘How you would read a book to your child’).

Procedure

The infants were seated in a car seat mounted on top of a table in front of a computer screen (size 24 inch; 1920 x 1080 pixels, refresh rate 60 Hz) at a distance of approximately 65 cm. The mother of the infant and the experiment leader were seated on either side of the infant in the live setting. In the prerecorded setting, both the mother and the experimenter sat slightly behind the infant to discourage social interaction. The infant's looking behavior was recorded with a Tobii TX-300 eye-tracker (sampling rate 300 Hz, 5-point calibration; for details on calibration see Hessels, Andersson, Hooge, Nyström, & Kemner, 2015), mounted below the screen. The Tobii TX-300 was used, as it has been shown to be robust to infant movement (Hessels, Cornelissen, Kemner, & Hooge, 2015; Niehorster, Cornelissen, Holmqvist, Hooge, & Hessels, 2017). A webcam was positioned on top of the screen to record the infant's behavior. Stimuli were presented with Matlab R2013a and PsychToolbox (version 3.0.11; Brainard & Vision, 1997).

The novel word learning task consisted of five phases (similar to Ma et al., 2011). Figure 2.1 gives a schematic representation of the task procedure. In the familiarization phase, infants saw an image of two familiar objects side-by-side (apple and book). They were directed to look at one of both objects. The order of which object was asked for first was counterbalanced across participants. These trials were also meant for the speaker to get acquainted with the procedure. If needed, speaking rate or intonation was corrected during these trials. Familiarization was followed by a training phase in which the novel objects were introduced in a short animation. The object was named nine times within one trial. Each novel object was presented twice, in alternating order. The training phase therefore consisted of a total of four trials. The test phase consisted of two blocks of two trials, separated by the reminder phase. In the test trials, two static images of the novel objects were presented side-by-side, and the infant was directed to look at one of the objects. Each object served as target object once in each training block. The position of the objects on the screen and the order of target words was counterbalanced across participants. Between the two test blocks a reminder phase took place. This phase consisted of two trials, one for each object. A static image was presented on the screen, accompanied by a reminder sentence introducing the object name again three times.

Each trial started with a fixation star in the middle of the screen (55 x 55 pixels). The experimenter manually started a trial the moment the infant was fixating the middle of the screen. As trial length was dependent on the speaking rate, trial duration was variable. Yet, all trial types had a minimum duration time. The familiarization, test and reminder trials all had a minimum duration of 10 s, training trials lasted at least 20 s. The task had a total duration of around five minutes.



Apple! Look at the apple. Do you see the apple? There’s the apple.

Look! It’s a Gemer. Look, the Gemer. What is the Gemer doing? The Gemer is going over there. Where is the Gemer going? Where is the Gemer? Gemer! There’s the Gemer.

Gemer! Look at the Gemer. Do you see the Gemer? There’s the Gemer.

Gemer! It’s the Gemer. Look! It’s the Gemer.

Gemer! Look at the Gemer. Do you see the Gemer? There’s the Gemer.

Figure 2.1. This figure shows the screen display per experimental phase. On the right, the text accompanying each trial is displayed. The displayed sentences contain the target word ‘gemer’, which is replaced by the target word ‘miekel’ in half of the trials. Which object received which of the two labels was counterbalanced between participants.

Data reduction

Eye-tracking data. We classified fixations using the Identification by 2-Means Clustering algorithm (I-2MC; Hessels, Niehorster, Kemner, & Hooge, 2017), an algorithm specifically designed for noisy infant eye-tracking data. Using Steffen interpolation we interpolated periods of data loss up to 100 ms in the raw data when at least 2 samples of valid data were available at each end. A moving window of 200 ms width was used for fixation classification. Fixations that were not more than 30 pixels apart and that were separated by no more than 30 ms were merged. If a fixation had a total duration shorter than 40 ms it was removed.

For the training phase, we determined total proportion looking time to the screen. Infants who had attended to the screen less than 25% of training time were excluded from analysis (*n* = 4). As trial duration differed between subjects, we chose as our critical time window for test trials a time window from 200-2200 ms after first target word onset. Over this time period we determined fixation time on both the target and the non-target by adding the fixation durations of all fixations on each image (x-coordinates AOIs: right image 0-940 pixels, left image 980-1920 pixels). Then, we calculated the proportion looking time for each object by dividing the total fixation time on each object by the time window duration (i.e., 2 s). Test trials were excluded when the infant had not looked at both objects on the screen over this two-second time period. Infants with less than two valid test trials over both test blocks were excluded from analyses (n = 9). Therefore, the final sample composed 136 infants (live/mother: n = 37, 17 boys; live/unfamiliar: n = 39, 18 boys; prerecorded/mother: n = 32, 14 boys; prerecorded/unfamiliar: n = 28, 15 boys).

Acoustical analysis. We performed an acoustical analysis to determine whether there were any differences between the voices rather than just speaker familiarity that could account for differences in word learning. We determined speaking rate during training (in syllables/second) as this might specifically affect word learning (e.g., Weismer & Hesketh, 1996). To evaluate differences in type of speaker, we compared speaking rate of the maternal voices vs. the unfamiliar voices. This analysis was only performed for the live setting as in the prerecorded setting audio recordings were counterbalanced with each recording presented once to a mother's own infant and once to an unfamiliar infant (although not all infants made it to the final analyses). We observed a difference in speaking rate between maternal and unfamiliar voices in the live setting ($F(1,74) = 4.07$; $p = .047$; $\eta^2 = .05$). The mothers had a slightly faster speech rate ($M = 3.04$, $SD = 0.27$) compared to the experimenters ($M = 2.93$, $SD = 0.17$). To evaluate differences in speaking rate between learning settings, we compared speaking rate in the live setting vs. the prerecorded setting. We observed an effect of learning setting on speech rate ($F(1,134) = 53.08$; $p < .001$; $\eta^2 = .28$). Speaking rate was faster in the prerecorded setting ($M = 3.49$, $SD = 0.55$) compared to the live setting ($M = 2.98$, $SD = 0.23$).

Next to speaking rate, we also checked for deviations from the initial script. We specifically counted the amount of target words pronounced per trial. We scored whether the speaker had pronounced either more or less target words than indicated in the script. This score was used as a control variable in the analyses, as differences in the exposure to the target words might influence learning effects. In 35 of the task performances (25.7% of all task performances) the speaker deviated from the script in the amount of target words: five of the mothers in the live speech setting omitted target words (average of 1.6 target words omitted) whereas 16 mothers pronounced extra target words during the task (average of 3.25 extra target words). The experimenters pronounced extra target words in 10 of the task performances (average of 1.7 extra target words). In the prerecorded setting, three infants heard extra target words while the own mother's voice was played (average of 1.6 extra target words), whereas one infant heard extra target words while an unfamiliar voice was played (1.0 extra target word).

Explorative analyses. We quantified infant behavior based on the video recordings of the experimental session. We coded infant speech and pointing gestures, deviations from the script and interference of the (non-)speaker (coded in ELAN version 5.2). A pointing gesture was defined as raising the arm and pointing with one finger to the screen. For the analyses, we counted the number of target word repetitions and the number of pointing gestures made by the infant over the entire course of the experiment. In addition, we controlled whether the speaker had said either more or less target words than stated in the script.

Results of the preferential looking paradigm

First, we tested whether the infants in the four different conditions looked equally long at the screen during the training and test periods. We observed no differences between conditions in the time spent attending to the screen in both the training and test phases (all *p*s > .20).

We performed a repeated measures ANCOVA with object (target vs. non-target) and test block as within-subjects factors and learning setting and voice condition as between-subject factors. In the analyses, we controlled for hearing fewer or more target words over the course of the experiment due to deviations from the script by the speaker. There were no interaction effects with test block (*p*s > .3), so for the remaining analyses we collapsed over all test trials. We observed a main effect of object which showed that over all test trials infants looked significantly longer at the target than the non-target (target: *M* = 0.42, *SD* = 0.12; non-target: *M* = 0.37, *SD* = 0.12; *F*(1,131) = 9.94; *p* = .002; η^2 = .07)[1]. There were no main effects for learning setting and voice condition (*p*s > .46). There was also a significant interaction effect between object and voice condition (*F*(1,131) = 6.86; *p* = .010; η^2 = .05). Post-hoc t-tests showed that irrespective of setting, infants looked significantly longer at the target than the non-target in the mother's voice condition (target: *M* = 0.44, *SD* = 0.12; non-target: *M* = 0.34, *SD* = 0.11; *t*(68) = 4.17, p < .001, Cohen's *d* = 0.86), yet no such looking difference was observed in the unfamiliar voice condition (target: *M* = 0.39, *SD* = 0.12; non-target: *M* = 0.39, *SD* = 0.13; *t*(66) = 0.21, p = .84, Cohen's *d* = 0.04). Figure 2.2 displays the proportion looking time at target and non-target for each condition separately.

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[1] Another common reported measure is proportion target looking as a proportion of total looking time to both target and non-target (instead of proportion of total time window). Using this measure led to similar results and the same conclusions. This analysis further showed that infants taught by their own mother looked at the target object significantly above chance level (*t*(68) = 4.16, *p* < .001), whereas infants taught by an unfamiliar voice did not (*t*(66) = 0.27, *p* = .79).

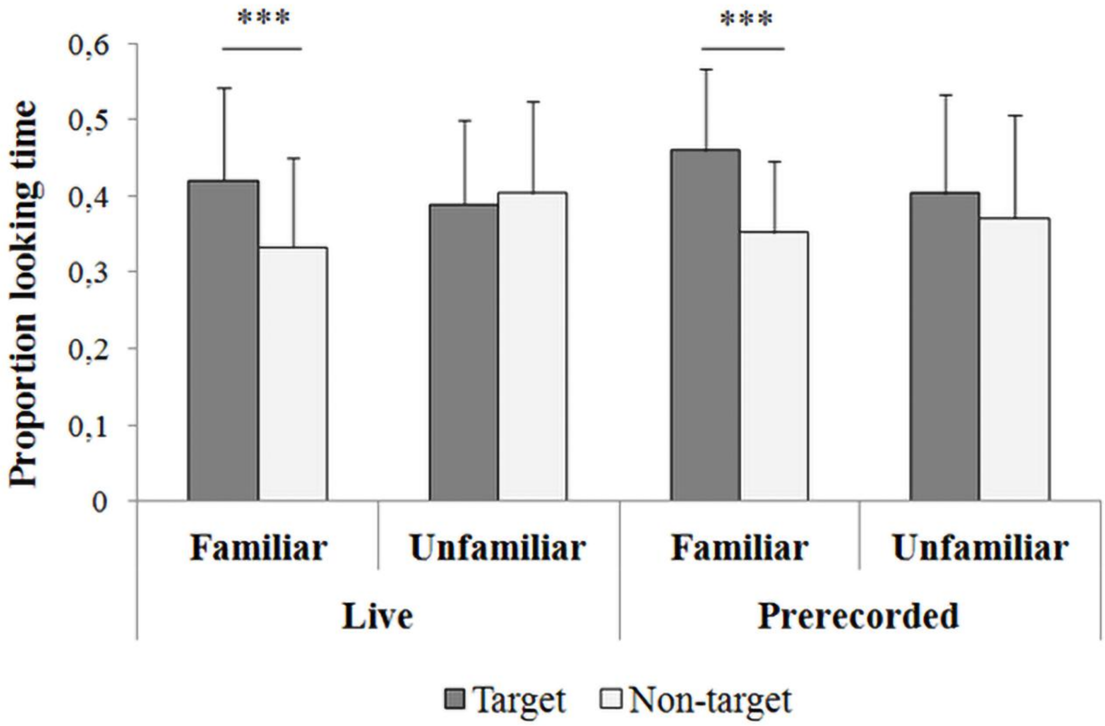

Figure 2.2. Proportion looking time per condition. Dark gray bars represent target looking, light gray bars represent non-target looking. Error bars represent one standard deviation from the mean. ****p* < .01.

Interim summary and discussion

The eye-tracking analysis of the current study examined whether the mother's voice provides beneficial effects on 24-month-olds' novel word learning abilities. Here, we distinguished between a live setting in which the infant was actively taught by either the own mother or the experimenter, and a prerecorded setting in which the voice of either the own or another infant's mother was played over the loudspeakers. We indeed observed a beneficial effect for the mother's voice on novel word learning, yet learning setting did not affect learning outcome.

Our hypothesis that the mother's voice would facilitate novel word learning was confirmed in the current study. Infants who were taught by their own mother were able to form new word-object mappings, whereas infants who were taught by a stranger were not. This is in accordance with several other studies which observed beneficial effects for the mother’s voice (Barker & Newman, 2004; Parise & Csibra, 2012). This study adds that these beneficial effects extend to the process of the formation of novel word-object mappings in 24-month-olds.

It is however notable that we observed no significant word learning in the group of infants who were taught by an unfamiliar voice. In the study of Ma and colleagues (2011), which served as the basis of our own procedure, both 21- and 27-month-olds were able to learn novel words from an unfamiliar voice as long as they were addressed in infant-directed speech. The fact that our 24-month-olds did not seem to learn novel words while they were addressed in infant-directed speech might therefore be surprising. However, when we look at the way in which novel word learning was assessed, we see that Ma and colleagues (2011) used the 'single longest look' at the target and the non-target over the complete seven-second test trial, whereas we used 'percentage looking time' over a specific two-second time window. We used a shorter time window for two reasons. First, due to the variety in speakers, we had no fixed trial length. Second, it is noteworthy that most infant studies use a critical time window around two seconds from target word onset (most fall between 1800 - 2500 ms). To comply with this, we therefore decided to use a two-second interval. Furthermore, looking behavior was manually coded at a lower sample rate in the study of Ma and colleagues (2011), whereas we used an eye-tracker to assess gaze behavior. Our data is therefore more precise and better timed as it excludes time spend on saccades from final calculations, which makes fixation detection more accurate. These might be possible explanations for the differences in results. Another explanation could be due to the language used: we tested in Dutch, in which the difference between infant- and adult-directed speech is less pronounced than in American-English (e.g., Benders, 2013).

We further observed that the advantage of maternal speech holds across both learning settings, and therefore our study observed no ‘video deficit’. This result implies that there is no additional advantage of the mother uttering the words directly compared to having her speech prerecorded. Consequently, it appears that the acoustic aspect of the mother’s voice is a key factor in driving the facilitation of the novel word learning processes. However, we do have to keep in mind that social interaction was rather constrained across both learning situations as we used pre-scripted texts throughout the task and discouraged direct eye-contact between speaker and child. Moreover, the mother was still present in the room in the prerecorded setting although additional social interaction between the infant and the mother was discouraged. It is possible that our two learning situations did not differ sufficiently enough to find an effect of learning setting. It is also possible that our two-year-olds have overcome the ‘video deficit’, as other studies show that infants above the age of 20 months are able to learn from video input as long as the video input is contingent with their own behavior (Krcmar et al., 2007; Myers et al., 2017; Roseberry et al., 2014). Future research should further examine the differences between the effects of live and prerecorded speech presentation on word learning.

Results from the explorative analyses

These analyses were performed with nearly all two-year-olds from the final sample of the word learning experiment. Three infants were excluded as there were no video recordings of these infants, which results in a total sample of 133 infants for these analyses. First we report whether our two indexes of infant attention differ per setting at the group level, before we report correlations between these indexes and learning outcomes.

Word repetition

We performed a univariate ANOVA with target word repetition as dependent variable and voice condition and learning setting as fixed factors. We observed a marginally significant effect of voice condition on the amount of target word repetitions ($F(1,129) = 3.33$; $p = .07$; $\eta^2 = .03$). There was a trend for infants to repeat more target words in the mother's voice condition ($M = 4.45$, $SD = 5.03$) compared to the unfamiliar voice condition ($M = 2.78$, $SD = 5.60$). There was no effect of learning setting on target word repetition, nor an interaction effect between voice condition and learning setting (ps > .24).

Pointing gestures

We performed a univariate ANOVA on the amount of pointing gestures with voice condition and learning setting as fixed factors. We observed an effect of learning setting on the amount of pointing gestures ($F(1,129) = 11.15$; $p = .001$; $\eta^2 = .08$). Infants pointed more often in the live setting ($M = 4.89$, $SD = 3.95$) compared to the prerecorded setting ($M = 2.78$, $SD = 3.17$). There was no effect of voice condition on the amount of pointing gestures nor an interaction effect between voice condition and learning setting ($ps > .32$). Figure 2.3 displays the results regarding the target word repetition and pointing gestures.

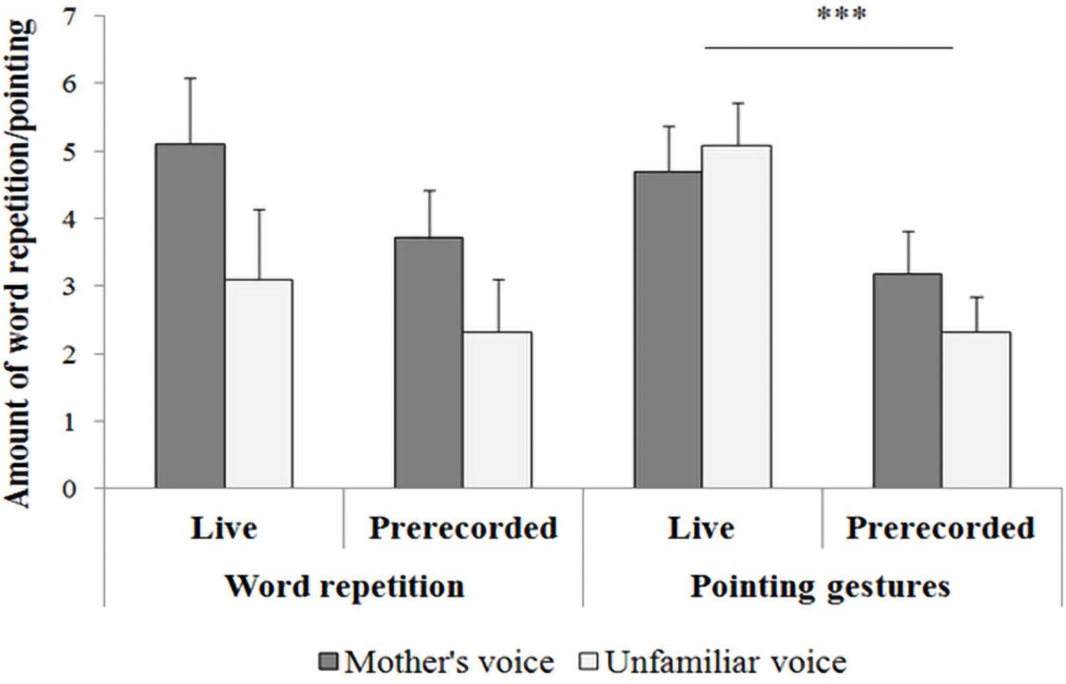

Figure 2.3. Amount of target word repetitions and pointing gestures per condition. Dark gray bars represent the mother's voice condition, light gray bars represent the unfamiliar voice condition. Error bars represent one standard error from the mean.

*** $p = .001$

Correlation analyses

Last we tested whether there is a correlation between either the amount of target word repetitions or pointing gestures on the one hand, and the word learning effect on the other. The word learning effect was defined as the difference score between the proportion target looking and the proportion non-target looking. The higher this score, the more the infants looked at the named object. In the correlation analyses, we corrected for the amount of target words spoken over the course of the experiment. We observed a significant positive correlation between the word learning effect and target word repetition (*r* = .23, *p* = .009). No such correlation was observed for the amount of pointing gestures (*r* = .08; *p* = .36). The correlations are plotted in Figure 2.4.

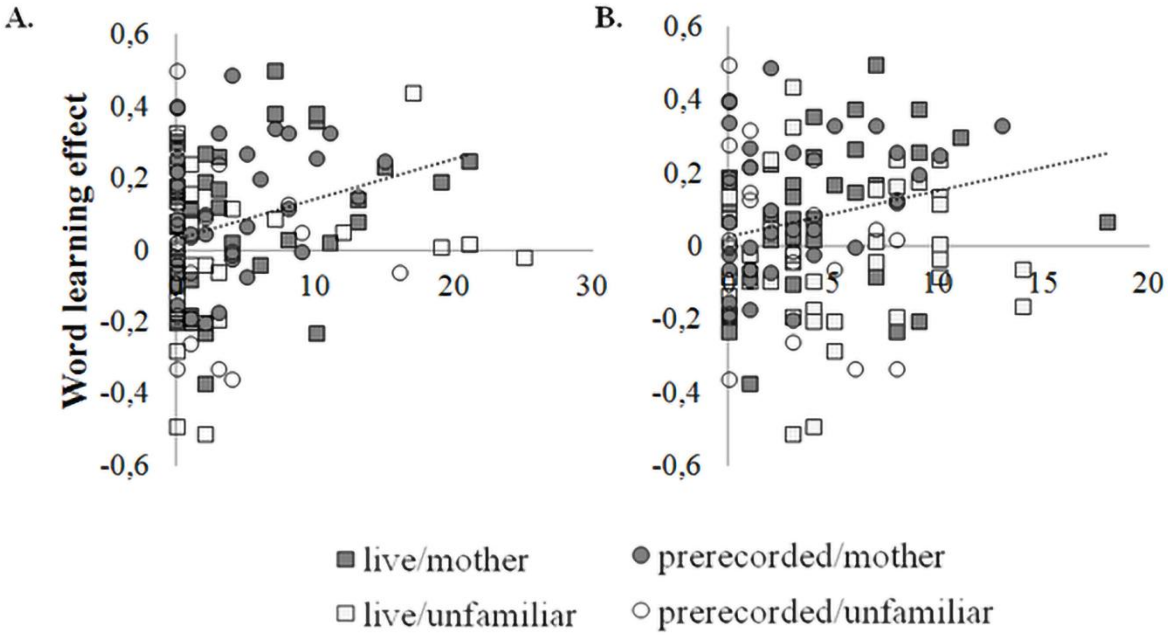

Figure 2.4. Correlations between the word learning effect on the one hand and either target word repetition (A) or the amount of pointing gestures (B) on the other hand. Word learning was defined as the difference score between the proportion target looking and the proportion non-target looking over a two-second time window after target word onset. We observed a significant positive correlation between the word learning effect and target word repetition, yet no such correlation was observed for the amount of pointing gestures.

Interim summary and discussion

With the current analyses we investigated whether an infant's own behavior (i.e., novel word repetition and pointing gestures) differed over learning settings and whether it aids novel word learning. The results showed a trend for infants repeating more target words when they heard their own mother's voice compared to an unfamiliar voice, irrespective of learning setting. This trend possibly indicates that hearing the mother's voice labeling a novel object induces the infant to repeat this label, which might further strengthen the link between label and object. However, as this was only a marginal effect, caution is needed when interpreting this result. We further observed that infants made more pointing gestures in the live setting compared to the prerecorded setting, irrespective of voice condition. Apparently, the possibility of direct social interaction induces more pointing gestures. Future research should try to explain why speech mostly influences the infants' word repetition behavior whereas social setting has more influence on the production of gestures. Does the mother's voice in some way trigger language production whereas the ability to also see a person sitting next to you in a learning situation induces more non-verbal communication as well?

Next, we looked at an individual level whether the infants' word repetition and pointing behavior on the one hand is related to their word learning ability on the other hand. We observed that the more infants repeated target words, the better they had learned the new word-object mappings, regardless of speaker familiarity. This is in accordance with previous studies which found an effect of word repetition on vocabulary size (Baddeley et al., 1998; Gathercole & Adams, 1993; Masur 1995). In contrast, the amount of pointing gestures did not correlate with the word learning effect. This is probably due to the fact that our experiment was scripted, and left no room to respond to an infant’s pointing. Consequently, the speaker could not verbally react to any utterances or gestures made by the infant. Therefore, pointing gestures in our study did not result in more object labeling by the speaker, whereas it is exactly this kind of speaker adjusting to the infant’s needs that is assumed to explain the often-observed benefit of infants’ pointing in word learning (Kishimoto et al., 2007; Wu &

Gros-Louis, 2014). Moreover, the speaker’s subsequent utterances (either live or prerecorded) were not contingent with the infant's pointing behavior, which is also very important for the facilitating effect of pointing on word-object mapping (Lucca & Wilbourn, 2018).

General Discussion & Conclusion

The central question in the current study was whether infants learn novel words easier from maternal speech, and whether this hinges on the way her speech is presented. We conclude that the mother’s voice facilitates the formation of new word-object mappings. Our findings that maternal speech induces similar improvements for infants’ word learning across live and prerecorded learning settings further bolster our conclusion that the often-observed advantage of maternal speech for early language processing also extends to novel word learning. At the same time, our finding that the advantage of maternal speech holds regardless of the way her voice is presented suggests that it is at least the acoustic aspect of the mother’s voice that aids novel word learning, although we cannot completely rule out the effect of social interaction (Bortfeld, et al., 2013).

Although the current study investigated the role of speaker familiarity on word learning solely with maternal speech, there are usually more caretakers involved. Infants also have numerous interactions with for instance the father or other caretaker, grandparents and caretakers at child care facilities. The question remains whether the current observed beneficial effect of speaker familiarity is solely attributable to the mother's voice (i.e., primary caretaker for the infants tested) or whether other familiar voices have similar effects on word learning abilities. Future research should shed more light on this issue, by investigating whether there might be a relation between the amount of exposure to a certain voice and the effect this voice has on word learning abilities.

The present study highlights that one of the factors boosting word learning is maternal speech, although an infant's own behavior could contribute to this as well. Research has shown that a child’s behavior might steer how people speak to that child. For instance, mothers subconsciously adjust the properties of their speech according to an infant's preferences (Kitamura & Lam, 2009), hearing situation (Lam & Kitamura, 2012) and their risk on dyslexia (Kalashnikova, Goswami, & Burnham, 2018), to provide optimal language input. An infant's word repetition and pointing behavior might have similar effects on language input and consecutive word learning. We therefore took a more explorative approach and evaluated whether infant word repetition and pointing serve as meaningful indexes of attentive behavior that relate to their task of word learning. Results showed that novel word repetition indeed facilitates word-object mapping. In contrast, the amount of pointing gestures infants make does not appear to be related to word-object mapping, yet the null result in the current study could also be due to limitations in the experimental set-up.

Together, these results imply that at least the mother's voice and an infant's word repetition behavior correlate with word learning abilities, yet the direction of these relations is unknown. These two factors, however, are likely to be interrelated: recall that at the group level, infants were possibly more likely to repeat words when listening to their mother than to an unfamiliar speaker. Hence, it appears that infants are at least more audibly attentive to the learning situation when they are listening to their own mothers. Our results however do not allow us to disentangle the contributions of maternal speech and the infants' target word repetitions on word learning. We therefore are unable to draw a conclusion on the direct effect of the mother's voice and word repetition on word learning abilities[2]. For instance, is word repetition a guide for later word learning and does it create a basis for the consolidation of a new word? Or is it only after the initial learning of a word-object mapping that an infant starts to produce the word which in turn might reinforce, but not guide, the learning process? Future research should try to disentangle the direction of the relation between these processes. Which processes lie at the basis of early language acquisition and which processes reinforce, but do not guide, language learning?

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[2] However, when we control for the number of target word repetitions made by the infant during the task, we still observe a beneficial effect of the mother's voice on word learning performance. This suggests a direct effect of voice familiarity on novel word learning.

Overall, we conclude that maternal speech as well as an infant's own word repetition behavior have a boosting effect in word learning processes, yet the exact influence of these factors on early language acquisition need further in depth investigation.

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Chapter 3

Two-year-olds at risk for autism can learn novel words from their parents

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RR and CJ contributed conception and design of the study; EW was involved in the data collection; RR was responsible for data processing and data analyses; RR wrote the first draft of the manuscript; All authors contributed to manuscript revision, read and approved the submitted version.

Abstract

Clinicians consider lagging behind in vocabulary size as one of the first signs of atypical behavior in infants who later develop autism. Surprisingly, on-line evidence that infants at high risk for autism are indeed limited in their vocabulary formation is still missing. The current preferential looking study therefore compares early word learning abilities in a high-risk sample of 24-month-olds (n = 18) with a low-risk sample (n = 11), while parents provided the learning input. In addition, we also collected information about their concurrent vocabulary scores and followed up on their autistic traits at three years. Results showed that both high- and low-risk infants do not differ in their ability to form new word-object mappings: they looked longer at the requested target than at the non-target item. High-risk infants however did reveal lower vocabulary scores based on parental report. Finally, we did not observe a correlation between autistic traits at three years and word learning abilities. Thus, our results reveal that despite their reported lag in vocabulary size, infants at high risk for autism do not differ in word learning abilities from low-risk infants, at least when it is a parent who provides the speech. This is vital information for the design of new autism interventions with a primary role for the infants' caregivers.

Introduction

Acquiring good language skills at an early age is key for later development. One of the main challenges infants face in language development is building a large vocabulary, where associative links between words and their referents are formed (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Research suggests that early vocabulary size is supporting for later intellectual functioning, as vocabulary size and the speed of word recognition at 25 months of age is related to linguistic and cognitive skills at eight years (Marchman & Fernald, 2008). Although the DSM-V no longer considers atypical language development a key characteristic in identifying children with autism (American Psychiatric Association, 2013; Constantino & Charman, 2016), clinicians consider lagging behind in vocabulary size between 18 and 24 months as one of the first signs of atypical behavior in infants who are later diagnosed with an autism spectrum disorder (ASD; Wheterby, Watt, Morgan, & Shumway, 2007). Impairments in both receptive and expressive language abilities are often observed in infants with ASD. These impairments are first found to emerge at 12 months of age and are still present in later childhood (Charman, Drew, Baird, & Baird, 2003; Hudry et al., 2010; Landa & Garrett-Mayer, 2006; Mitchell et al., 2006; Yirmiya, Gamliel, Shaked, & Sigman, 2007; Zwaigenbaum et al., 2005). Whereas typically-developing infants largely increase their use of complex babble and words over their second year of life, infants with ASD do not (Werner & Dawson, 2005). Moreover, there is a strong correlation between word learning performance in three-year-olds and autistic-related characteristics as measured with the ADOS (Autism Diagnostic Observation Schedule Second Edition, Lord et al., 2000), which indicates that in early childhood there is a link between ASD severity and poor language skills (Gliga et al., 2012).

The early delay in vocabulary growth in children with ASD might thus be an early marker which indicates that these children might also develop other linguistic and cognitive atypicalities later in life. It is therefore vital to investigate possibilities to improve word learning abilities in children with ASD as early as possible, to diminish negative developmental outcomes. Since ASD cannot be diagnosed reliably before the age of three years, it is becoming increasingly common to turn to prospective risk studies for information about the early development of children with this disorder (Gliga, Jones, Bedford, Charman, & Johnson, 2014; Loth et al., 2017). Compared to the typical population, who have around a 1% chance of receiving an ASD diagnosis, prospective longitudinal studies often chart development in younger siblings of children with ASD, as they have increased risk (i.e., 15-30% chance) of receiving an ASD diagnosis themselves (Ozonoff et al., 2011). Such prospective studies have started to reveal more about early predictors of ASD in infants who are yet to receive their diagnosis. Consistent with the retrospective findings in children with an ASD diagnosis, some prospective studies show that high-risk siblings, even those who continue to develop typically, also have impairments in receptive and expressive language abilities as indicated by parental questionnaires (Mitchell et al., 2006; Yirmiya, et al., 2007; Zwaigenbaum et al., 2005).

It is however noteworthy that most evidence for impairments in language abilities in infants at high risk for ASD comes from parental questionnaires, which can be prone to biases, as some parents require their infant to react explicitly as proof for word understanding (Houston-Price, Mather, & Sakkalou, 2007). Nonetheless, children may not always respond to words according to their parents’ expectations. This might specifically be true for children with ASD, who have troubles with social interactions. Parental questionnaires might therefore underestimate a child’s real vocabulary size. Surprisingly, there is little experimental evidence that infants at high risk for ASD are indeed limited in their vocabulary formation (but see Gliga et al., 2012, with three-year-olds). For example, Bedford and colleagues (2013) show similar performances in the initial formation of novel word-object pairs in infants at high- and low-risk for ASD. In this study, two-year-olds were first familiarized with both novel and familiar objects without specifically naming any of these objects. Then, three objects (either all familiar, or two familiar and one novel) were presented to the infant on a tray. The experimenter asked the infant to hand over one of the objects. Both high- and low-risk infants were able to select the novel object among the familiar objects the moment the experimenter used a word they had never heard before. This result implies that infants at high risk for ASD do not differ from typical infants in the initial formation of novel word-object pairs. However, this study still relies on an explicit reaction from the infants by handing over a certain object in response to a question. In the current study, we therefore specifically compare on-line word learning abilities of high- and low-risk infants by using eye-tracking. In this way, the infants do not need to explicitly react and interact in order to assess word learning processes. Instead, we deduct from their gaze patterns (i.e., preferential looking) whether they correctly pair novel objects with novel words.

As a first step to test on-line word learning abilities in this sample of infants, we relied on parents to teach their infants novel words. Parents are the first in line when it comes to teaching young children new skills. Consequently, early interventions for ASD usually train parents to improve the quality and quantity of their parent-child interactions (McConachie & Diggle, 2007). This training successfully improves infants’ language abilities (Rogers et al., 2014). In typically-developing children, parents can also boost early vocabulary growth, as compared to child care providers (Marulis & Neuman, 2010). A recent study revealed that typically-developing two-year-olds only show evidence of novel word learning when it is the mother who provided the accompanying speech, whereas teaching by the experiment leader did not result in significant word learning (*Chapter 2*).

To study word learning abilities in 24-month-olds at increased risk for ASD we adopt the same paradigm as used in *Chapter 2,* which was originally based on a study of Ma and colleagues (2011). In this eye-tracking paradigm, two novel objects are displayed on a computer screen in several short animations. The corresponding auditory stimuli are presented as sentences at the bottom of the screen, such that the infant’s caretaker can read these sentences aloud during the experiment. During these animations the parent names the objects several times. This training phase is followed by a test phase, in which we test the infants' word learning performance with a preferential looking paradigm: the two novel objects appear side-by-side on the screen and we record looking time at each object when one of the objects is named. We compare the word learning performance of two-year-olds at high and low risk for ASD. In addition, we also collected information about their concurrent vocabulary scores (N-CDI: Zink & Lejaegere, 2002) and followed up on their autistic symptoms at three years of age (Lord et al., 2012).

We expect that the low-risk infants show clear signs of word learning, similar to the results observed in *Chapter 2*. A possible outcome for the high-risk infants is that they perform as well as the low-risk infants on this word learning task. This result would entail that experimentally testing word learning abilities in a sample of infants at high risk for ASD does not reveal any impairments, in contrast to what is often observed in studies employing parental questionnaires to measure infants' language abilities. Another possibility is that the high-risk infants perform worse on our task than the low-risk infants. This would mean that high-risk infants are generally impaired in word learning, in accordance with parental questionnaires, even in the optimal word learning situation in which parental speech is provided. Furthermore, we will explore whether there is a correlation between two-year-olds' on-line word learning performance and both their concurrent vocabulary size (N-CDI score) and autistic symptoms one year later (ADOS score).

Materials and methods

Participants

A total of 33 full-term two-year-olds participated in this study. Four additional infants were tested but not included in the dataset as either no eye-tracking data were acquired for these infants (*n* = 2) or due to experimental errors (*n* = 2). The high-risk group consisted of 21 infants (10 boys; *M* age = 24.40 months, *SD* = 0.74, range 23.41 - 26.40 months) with an older sibling with ASD. The low-risk group contained 12 infants (7 boys; *M* age = 24.98 months, *SD* = 1.16, range 23.54 – 27.39 months) with a typically-developing older sibling. The two groups did not significantly differ in age or gender. The high-risk infants were recruited via collaborations with practitioners and via Dutch patients and parents associations, e.g., the 'Nederlandse Vereniging voor Autisme (NVA)' and 'Balans'. The low-risk infants were recruited from the existing databases of the University of Utrecht and the Radboud University Nijmegen. This study was embedded in a large multi-site prospective longitudinal cohort study looking at the development of ASD in very young high-risk infants and controls (EU-AIMS project; see Loth et al., 2017). The project was approved by the Medical Ethical Committee of the Arnhem-Nijmegen Region and the study was performed in accordance with the Helsinki Declaration. Parents signed informed consent prior to participation and received monetary compensation for their time, travel costs when applicable, and a small present for the infant in appreciation of their participation.

Stimuli

The stimuli consisted of images of two familiar and two novel objects. These stimuli were the same as used in the studies in *Chapter 2* and Ma and colleagues (2011). During familiarization, an image of an apple and a book were presented (size 500 x 480 pixels). During a training phase, the novel objects were introduced in short animations. The object first dropped into the window, moved forwards and backwards, turned 360 degrees, jumped to the right, turned around, jumped to the left and out of sight, and then reappeared from the left corner of the screen. The animations had a white background and a size of 720 x 480 pixels. During the later phases, static images of the novel objects were used (test phase: size 500 x 480 pixels; reminder phase: size 800 x 480 pixels). Images of the visual stimuli are depicted in Figure 3.1.

The two novel objects were named ‘gemer’ /ˈxemər/ and ‘miekel’ /ˈmikəl/, two Dutch pseudowords. The carrier sentences as used by Ma and colleagues (2011) were translated into Dutch. These sentences were presented on the screen below the visual stimuli, such that the infant’s parent could read them aloud during the experiment.

Procedure

The study was performed at two sites in the Netherlands: Utrecht (Utrecht University) and Nijmegen (Radboud University Nijmegen). The researchers of the Utrecht University conducted home visits. At the infants’ homes, a testing booth was assembled to minimize distraction. Infants were seated in a high-chair at approximately 65cm distance from the screen. We conducted the word learning task with a Tobii TX-300 eye-tracker (sampling rate 300 Hz, 5-point calibration; for details on calibration see Hessels, Andersson, Hooge, Nyström, & Kemner, 2015) integrated with a computer screen (1920 x 1080 pixels; size 24 inch; refresh rate 60 Hz). The task was programmed in Matlab version R2014b (MathWorks Inc., USA) and PsychToolbox (version 3.0.12, Brainard & Vision, 1997).

In Nijmegen the infants and their parents visited the lab facility at the Baby Research Center of the Radboud University. Infants were seated in a high-chair or on the parent's lap at a distance of 60-65cm from the screen. Here the task was conducted with a Tobii T-120 eye-tracker (sampling rate 60 Hz, 5-point calibration) which has an integrated computer screen (1280 x 1024 pixels, size 17 inch, refresh rate 60 Hz). The task was run in Matlab version R2013a with PsychToolbox version 3.0.11.

Figure 3.1 gives a schematic representation of the task procedure. In the familiarization phase infants were directed to look once at the apple and once at the book, which were the objects presented side-by-side on the screen. The order of which object was requested first was counterbalanced across participants. These trials were also designed for the parent to get acquainted with the procedure. The experimenter corrected the speaking rate or intonation of the speaker during these trials if needed. In the training phase, the novel objects were introduced in a short animation in which the object was named nine times. The animation of each object was presented twice during the training phase, in alternating order. Which object was paired with which novel word and the order of presentation were counterbalanced across participants. Training was followed by a test phase. In the test trials, two static images of the novel objects were presented side-by-side, and the infant was asked to look at one of the objects. The position of the objects on the screen and which object was named first were counterbalanced across participants. There were two blocks of test trials, with each block comprising two (in Utrecht) or four (in Nijmegen) test trials[1]. The two blocks were interleaved with a reminder phase showing each of the novel objects once,

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[1] Statistical tests indicated that test site had no influence on the infants' performances. Moreover, there was no block effect, which suggests that the first test block did not reinforce performances in the second test block. We therefore pooled all test trials together in the analyses.

accompanied by a reminder sentence introducing the name of the object again three times.

Each trial started with a fixation star in the middle of the screen (size 55 x 55 pixels). The experimenter manually started a trial the moment the infant was fixating the middle of the screen, and ended the trial once the speaker had finished the sentence. The familiarization, test and reminder trials all had a minimum duration of 10 s, and training trials lasted at least 20 s. However, as trial length was dependent on the speaking rate of the parent, trial duration was variable. The task had a total duration of approximately five minutes.

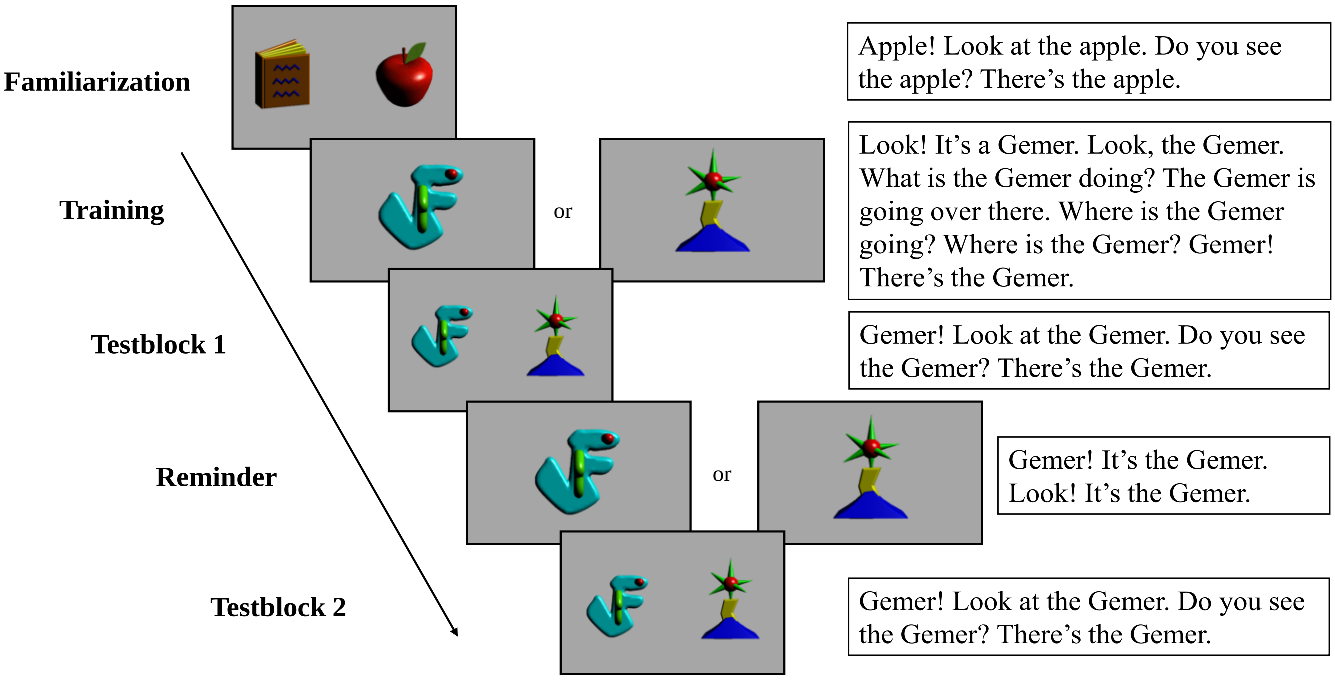

Figure 3.1. This figure shows the screen display per experimental phase. On the right, the text accompanying every trial is displayed. These sentences contain the target word 'gemer', which is replaced by the target word 'miekel' in half of the trials. Which object received which of the novel names was counterbalanced between participants.

Measures

N-CDI. We measured both infants' receptive and expressive vocabulary size with the MacArthur Communicative Development Inventory – Words and Sentences (CDI; Fenson et al., 1993; translated in Dutch: Lijsten voor communicatieve ontwikkeling (N-CDI), Zink & Lejeagere, 2002). Parents filled out this checklist, which measures both single word comprehension and production in different categories as well as the production of comprehensive sentences. We only scored the 'single word' part of the questionnaire (i.e., part A), which yields two scores (max. score 702) related to the infant's level of language development in terms of receptive and expressive vocabulary (Fenson et al., 1993).

ADOS-2. We measured autistic traits one year later, at 36 months, with the Autism Diagnostic Observation Schedule 2 (ADOS-2; Lord et al., 2012). We used ADOS scores at 36 months, instead of 24 months, as this later measure gives a more reliable indication of whether the infants indeed can be diagnosed with ASD or not (Zwaigenbaum et al., 2016). The ADOS is a 30-45 minute, semi-structured play assessment of communication, social interaction, play skills, and restricted interests/repetitive behavior (Lord et al., 2000). It was developed to diagnose ASD across a wide range of chronological and mental ages and is normed on individuals ranging from 12 months of age through 40 years. Depending on the level of expressive language of the infant, either module 1 ($n = 1$) or module 2 ($n = 25$) was administered. Because two different test modules were used we determined the comparison score for each infant, such that the scores of the two different modules were comparable with each other. The ADOS-2 was administered by a trained psychologist who met requirements for research reliability. Three of the participants (one high-risk and two low-risk infants) dropped out before the 36-month-old test session, so for these infants we have no ADOS scores.

Data reduction

For the preferential looking paradigm, we first used the Identification by 2-Means Clustering algorithm (I-2MC; Hessels, Niehorster, Kemner & Hooge, 2017) to classify fixations. This algorithm is specifically designed for noisy infant eye-tracking data. Using Steffen interpolation, we interpolated periods of data loss up to 100 ms in the raw data when at least 2 samples of valid data were available at each end. A moving window of 200 ms width was used for fixation classification. Fixations were merged when they were not more than 30 pixels apart and within a time range of 30 ms. Fixations of 40 ms or shorter were removed.

We determined the total proportion looking time to the screen during the training phase. One high-risk infant was excluded from further analysis because he/she had attended to the screen less than 25% of training time. For the test trials, we chose a critical time window of 200-2200 ms after first target word onset (cf., *Chapter 2*). For this time window, we determined total fixation time on both the target and the non-target object by adding the fixation durations of all fixations on each image (areas of interest: whole left and right side of the screen, separated by a 40-pixel wide gap in the middle of the screen). We calculated the proportion of looking time for each object by dividing the total fixation time on each object by the time window duration (i.e., 2 s). Test trials were excluded when the infant had no valid fixations on the objects on the screen over this two-second time period. Infants with less than two valid test trials were excluded from analyses (high-risk: n = 2; low-risk: n = 1). Therefore, the final sample consisted of 18 high-risk and 11 low-risk infants.

The performances of the high- and low-risk infants on this word learning task were tested with a repeated measures ANOVA, which compares the infants' proportion looking time at both the target and non-target object during test trials. Furthermore, independent samples t-tests were used to test differences in N-CDI and ADOS scores between high- and low-risk infants. We also explored whether there are correlations between on-line word learning performance on the one hand, and N-CDI and ADOS scores on the other hand. Last, we used the ADOS score to reclassify the total sample of infants in an ASD and a non-ASD group, and tested with independent samples t-tests whether these groups differ in their on-line word learning performance and N-CDI scores.[2]

Results

Preferential looking paradigm

First, we tested whether the infants in both risk groups looked equally long at the screen during the training period. We observed no difference in the percentage of time the high- and low-risk infants spent attending to the screen in the training phase (high-risk: $M = 0.73$, $SD = 0.13$; low-risk: $M = 0.70$, $SD = 0.19$, $t(27) = -0.52$, $p = .61$, Cohen's $d = 0.18$).

We performed a repeated measures ANOVA with proportion looking time at object (target object vs. non-target object) during the test trials as a within-subjects factor and risk group status as a between-subjects factor. We also included test site (Utrecht; Nijmegen) as a factor in the analysis to test for differences between the sites, but no relevant effects were observed (all *p*s > .30), so we collapsed data across sites for all analyses. There was a main effect of object which shows that, throughout test trials, infants looked significantly longer at the target than the non-target (target: $M = 0.43$, $SD = 0.12$; non-target: $M = 0.35$, $SD = 0.10$; $F(1,27) = 4.29$; $p = .048$; $\eta^2 = .14$). There was no main effect of risk for ASD ($F(1,27) = 0.15$; $p = .70$; $\eta^2 = .01$), nor was there an interaction between proportion looking time to the target and risk group status ($F(1,27) = 0.15$; $p = .71$; $\eta^2 = .01$). These results imply that both groups of infants were able to form new word-object mappings, irrespective of their risk for ASD. Figure 3.2 displays the proportion of looking time to the target and non-target for each risk group separately.

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[2] Additionally, we performed explorative analyses on infant behavior, similar to *Chapter 2*. These analyses are reported in Appendix A.

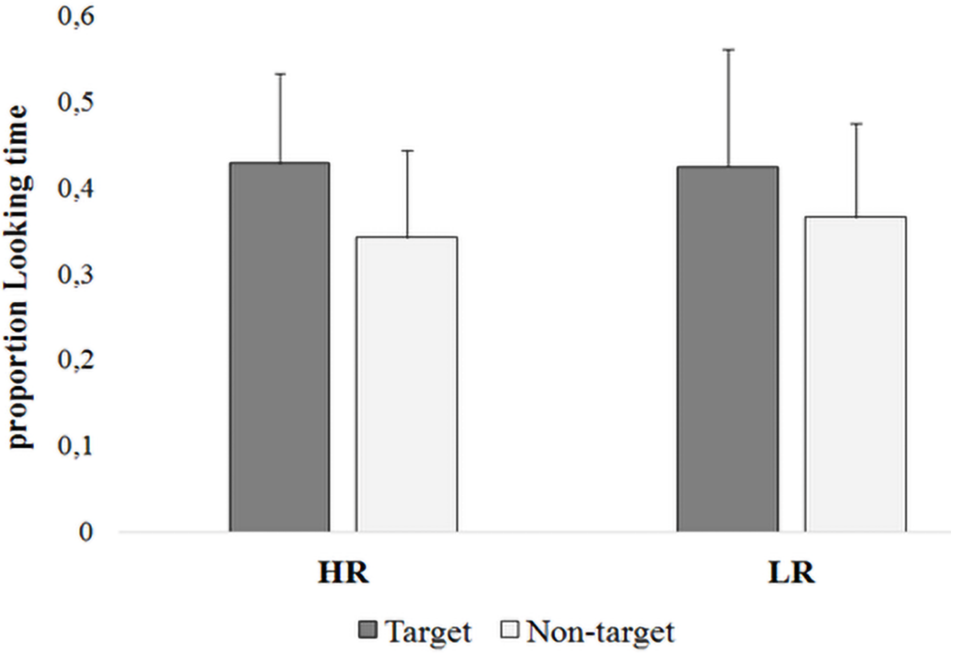

Figure 3.2. Proportion of looking time to target and non-target, per risk group (HR = high risk; LR = low risk). Dark gray bars represent the proportion of time spent looking at the target and light gray bars represent the proportion of time spent looking at the non-target. Error bars represent one standard deviation from the mean. Overall, infants looked significantly longer at the target than the non-target

N-CDI scores

An independent samples t-test indicated that compared to the low-risk infants, the high-risk infants scored lower on both receptive and expressive vocabulary scores. Means and statistical tests are presented in Table 3.1. Thus, according to parental reports, the groups differed in vocabulary size at the moment of testing. We found no correlation between the word learning effect (proportion target looking – proportion non-target looking) and receptive (r = .10, p = .63) or expressive (r = .08, p = .70) vocabulary.

Table 3.1. Means, standard deviations and statistical tests of the N-CDI scores for both high-risk (HR) and low-risk (LR) infants.

	Receptive vocabulary					**Expressive vocabulary**				
	Mean	***SD***	***t***	***p***	**Cohen's *d***	***Mean***	***SD***	***t***	***p***	**Cohen's *d***
HR	343.35	162.72	2.71	.012	1.10	148.47	105.59	3.20	.007	1.35
LR	512.60	145.62				346.60	178.09			

ADOS scores

An independent samples t-test indicated that high- and low-risk infants did not differ in their ADOS comparison scores at 36 months (high-risk: M = 3.12, SD = 2.21; low-risk: M = 2.11, SD = 0.93; $t(23.29) = -1.63$, $p = .12$, Cohen's d = 0.60; equal variances not assumed). Figure 3.3 plots the relationship between the word learning effect at 24 months and the ADOS comparison score at 36 months. As the ADOS comparison scores violated the assumption of normality, as indicated by significant Kolmogorov-Smirnov values (difference score: $D(26) = .31$, $p < .001$), we carried out a non-parametric Spearman correlation. There was no correlation between the word learning effect at 24 months (proportion target looking – proportion non-target looking) and the ADOS comparison score at 36 months ($r_s = -.17$, $p = .41$). There was also no correlation between the ADOS comparison score at 36 months and receptive ($r_s = .04$, $p = .85$) or expressive ($r_s = .19$, $p = .35$) vocabulary at 24 months.

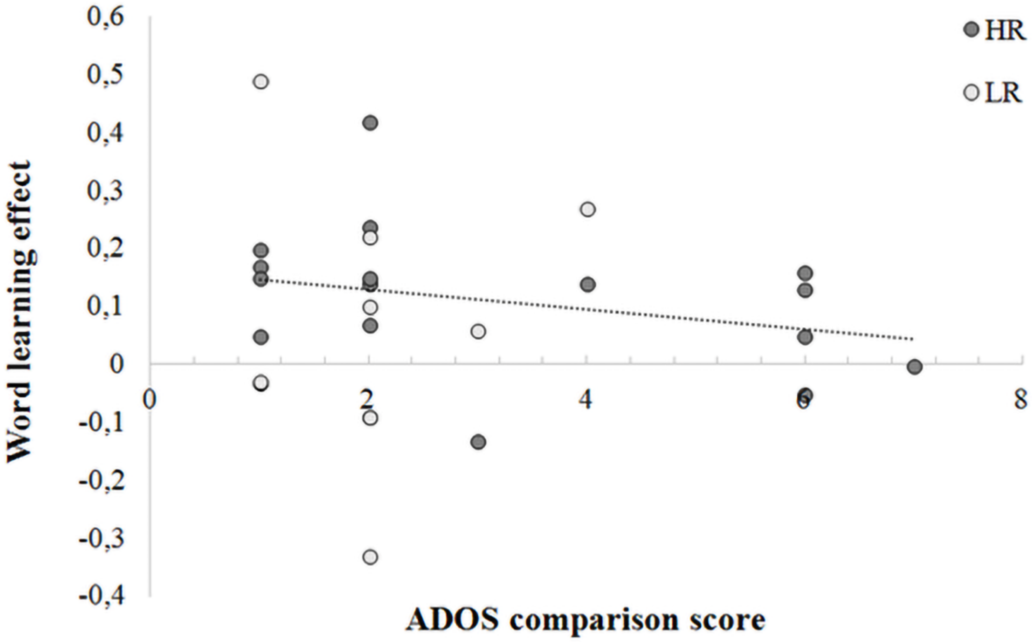

Figure 3.3. Distribution of the word learning effect at 24 months and the ADOS comparison score at 36 months. The dark gray dots represent high-risk infants (HR), the light gray dots represent low-risk infants (LR). There was no significant correlation between the two variables.

To explore differences between infants with an ADOS classification (ADOS-2 module 1 total score > 7; ADOS-2 module 2 total score > 6; *n* = 7) and the typically-developing infants from both the low- and high-risk groups (*n* = 19), we further compared these groups on word learning ability and N-CDI score. An independent samples t-test indicated that these groups did not differ in their on-line word learning abilities (ASD group: *M* = 0.10, *SD* = 0.11; non-ASD group: *M* = 0.09, *SD* = 0.19; *t*(24) = -0.09, *p* = .93, Cohen's *d* = 0.06). They also did not differ in their N-CDI scores (ASD group: *M* = 418.29, *SD* = 168.37; non-ASD group: *M* = 385.95, *SD* = 171.34; *t*(24) = -0.43, *p* = .67, Cohen's *d* = 0.19). However, we have to note that the sample size for the ASD group is too low to draw reliable conclusions.

Discussion

In the current study, we investigated whether 24-month-olds at high risk for ASD differ from low-risk infants in their word learning abilities. Parental questionnaires often indicate impairments in vocabulary size in high-risk infants, yet experimental evidence for two-year-olds had still been missing. As intervention studies highlight the important role of the caregiver in diminishing ASD symptoms (McConachie & Diggle, 2007), we relied on the parents to provide the input to the infants for learning novel word-object pairs. Our results showed no difference in on-line word learning performance between the high- and low-risk group. This suggests that when listening to their parents' voices, infants at high- and low-risk for ASD all efficiently process this familiar voice to form new word-object pairs. The language impairments often observed in autistic children and infants at high risk for ASD are therefore unlikely to originate in word learning itself, and are more likely caused by higher level social demands of interactive communication. This provides us insight into the sources of autistic children's language difficulties, and is a vital step towards the initiation of new intervention strategies with a primary role for the children's caregivers.

Yet, our results should be treated as a first step towards testing on-line word learning ability in a high-risk sample, as there are multiple paradigms available to test on-line word learning in infants. Novel word learning should be assessed with other paradigms, such as other forms of the preferential looking paradigm (Golinkoff, Ma, Song, & Hirsh-Pasek, 2013), the cross-situational word learning paradigm (Smith, Smith, & Blythe, 2011) or the switch paradigm (Werker et al., 1998), to examine whether our results are generalizable to other test situations.

Our results are in accordance with previous research which demonstrated similar word learning abilities in high- and low-risk 24-month-olds when taught by an experimenter (Bedford et al., 2013). Both risk groups showed similar performances for the initial word learning process, in which they had to grasp one out of three objects (two familiar and one unfamiliar) from a tray. However, this study also demonstrated that only low-risk infants used the provided feedback (i.e., 'Yes, this is the [*target word*]!') to store the novel words in long-term memory, whereas the high-risk infants failed to retain this information. In the present study we lack data on the long-term retainment of the novel words, and therefore we cannot comment on differences between groups in the storage of the novel words. Future research should tap further into language processes to examine whether it is indeed the long-term storage of words, instead of the initial word-object pairing, which is impaired in infants with ASD.

An alternative explanation for equal performances in both risk groups is that our group of high-risk infants does not contain many individuals who turned out to develop ASD (6 out of 18 high-risk infants and one low-risk infant reached ADOS classification at 36 months). We know from previous research that high-risk infants who eventually turn out to develop typically initially fall behind in their vocabulary size, yet they catch up over the second year of life (Hudry et al., 2014). As we tested two-year-olds, it is possible that the typically-developing infants in our high-risk group had already caught up, and therefore compensate for the weaker performances by the infants who eventually are diagnosed with ASD. However, the N-CDI scores show that the high-risk infants as a group are still behind in their vocabulary size, which makes this alternative explanation unlikely.

Another issue to keep in mind is that we need to be careful when comparing the current sample based on on-line word learning performance and their N-CDI scores. We found no correlation between the ability to form novel word-object pairs and the N-CDI scores, although both measures are related to word learning processes. When inspecting the literature, we observe that the relation between vocabulary size and infants' ability to recognize novel words appears to be inconsistent, especially when a preferential looking paradigm is used to assess word learning (e.g., Bedford et al., 2013; Swingley & Aslin, 2007; Tan & Schafer, 2005). This discrepancy can possibly be explained by the way in which the measures are acquired. We measured word learning abilities with eye-tracking, an objective behavioral measure, whereas N-CDI scores are based on parental report and therefore dependent on the parents' interpretations of their child's behavior (Houston-Price et al., 2007). More specifically, parents require their child to overtly react to object naming as proof of word understanding, which can lead to an underestimation of the actual vocabulary size. Furthermore, as children with ASD have difficulties with social interaction, it is possible that parents have troubles with interpreting their child’s behavior and consequently find it hard to determine which words their child does and does not understand. In contrast, eye-tracking studies can detect more implicit, subtle reactions to object naming. Such more objective behavioral measures might give a better insight in a child’s true language abilities.

Last, we have to note that, with the current experimental set-up, we are unable to draw conclusions on the boosting effect of a familiar voice on word learning abilities. We asked parents to provide the auditory stimuli in this study, because parents are increasingly used in interventions to mitigate autistic symptoms. However, we have no specific information on whether hearing a familiar voice allowed word learning of high-risk infants in the current set-up, although our study with a typical sample suggests that the maternal voice, compared to an unfamiliar voice, has a boosting effect (*Chapter 2*). Future studies that also include unfamiliar voices are required to specifically examine the voice familiarity effect in high-risk infants.

To conclude, our results show that infants at high-risk for ASD do not differ from low-risk infants in their on-line word learning abilities, at least when it is a parent who provides the speech. Although high-risk infants show a lag in vocabulary size according to parental questionnaires, experimentally testing their on-line word learning abilities does not reveal such a deficiency. Therefore, the communication difficulties observed in children with ASD do probably not stem from the initial process of word-object pairing, but are more likely caused by higher level social demands of interactive communication. This is vital information for understanding the source of communication difficulties in ASD, and may inform the design of new interventions with a primary role for the children’s caregivers.

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Appendix A

Similar to *Chapter 2*, we conducted several explorative analyses to examine infant behavior. We report on the same indexes of infant behavior, that is novel word repetition and pointing to the screen. Both behaviors have been shown as instances of how infant behavior itself might further propel word learning, and can arguably be taken to reflect an infant's engagement during task (e.g., Baddeley, Gathercole, & Papagno, 1998; Colonnesi, Stams, Koster, & Noom, 2010; Vihman & Keren-Portnoy, 2011).

Explorative analyses

These analyses were performed with nearly all two-year-olds from the final sample of the word learning experiment. Six infants were excluded as there were no video recordings of these infants, which results in a total sample of 23 infants for these analyses (16 high-risk; 7 low-risk). First we report whether our two indexes of infant behavior differ per setting at the group level, before we report correlations between these indexes and learning outcomes.

We quantified infant behavior based on the video recordings of the experimental session. We coded infant speech and pointing gestures (coded in ELAN version 5.2). A pointing gesture was defined as raising the arm and pointing with one finger to the screen. We counted the number of target word repetitions and the number of pointing gestures made by the infant over the entire course of the experiment.

Results

Word repetition. An independent samples t-test indicated that high- and low-risk infants did not differ in the amount of target word repetitions during the experiment (high-risk: *M* = 6.06, *SD* = 8.50; low-risk: *M* = 11.71, *SD* = 7.95; *t*(21) = 1.49, *p* = .15, Cohen's *d* = 0.69). When we divided the sample in infants with and without an ADOS classification at three years, there was also no difference between groups in target word repetitions (ASD: *M* = 9.40, *SD* = 12.03; non-ASD: *M* = 6.33, *SD* = 7.50; *t*(18) = -.68, *p* = .50, Cohen's *d* = 0.31).

Pointing gestures. We used an independent samples t-test to examine whether there is a difference in the amount of pointing gestures during task between high- and low-risk infants. There was no difference between groups (high-risk: $M = 9.69$, $SD = 6.34$; low-risk: $M = 8.14$, $SD = 7.52$; $t(21) = -.51$, $p = .62$, Cohen's $d = 0.22$). There was also no difference between groups when we divided the infants based on their ADOS classification at three years (ASD: $M = 10.0$, $SD = 5.43$; non-ASD: $M = 9.20$, $SD = 7.68$; $t(18) = -.21$, $p = .83$, Cohen's $d = 0.12$).

Correlation analyses. Last we tested whether there is a correlation between either the amount of target word repetitions (not equally distributed, $D(23) = 0.18$, $p = .046$) or pointing gestures on the one hand, and the word learning effect on the other hand. The word learning effect was defined as the difference score between the proportion target looking and the proportion non-target looking. The higher this score, the more the infants looked at the named object. We observed no correlation between the word learning effect and target word repetition ($r_s = -.29$, $p = .18$). There was also no correlation with the amount of pointing gestures ($r = .13$; $p = .57$). This data is shown in Figure 3.4.

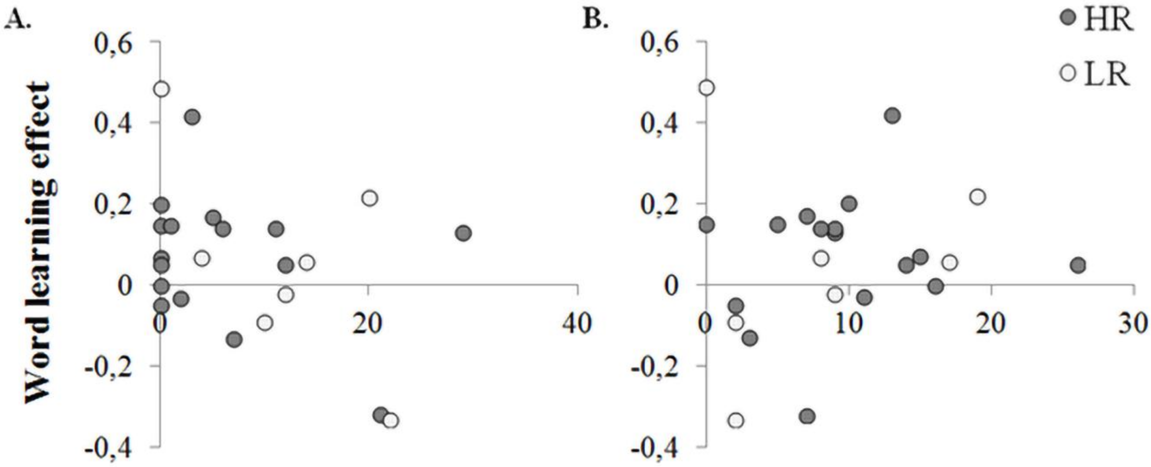

Figure 3.4. Distribution of the word learning effect on the one hand and either target word repetition (A) or the amount of pointing gestures (B) on the other hand. The dark gray dots represent high-risk infants (HR), the light gray dots represent low-risk infants (LR). Word learning was defined as the difference score between the proportion target looking and the proportion non-target looking over a two-second time window after target word onset. There were no significant correlations between variables.

Summary and discussion

With the current explorative analyses we investigated whether infant behavior during the task (i.e., novel word repetition and pointing gestures) differed between high- and low-risk infants. The results showed that there were no differences in infant behavior between groups. Both high- and low-risk infants exhibited a similar amount of target word repetitions and pointing gestures over the course of the experiment. This possibly indicates that infants in both groups were equally attentive during the task and that risk-status does not influence infant behavior in a social learning situation with the infants' own parents.

Next, we looked at an individual level whether the infants' word repetition and pointing behavior on the one hand is related to their word learning ability on the other hand. We observed no correlations between infant behavior and word learning performance, which indicates that these behaviors, at least in the current sample, are not supportive in the word learning process. This is in contrast with *Chapter 2*, where we observed a significant positive correlation between word learning performance and the amount of target word repetitions. However, the sample tested in *Chapter 2* contained only typically-developing (TD) infants, whereas the current sample consisted of both TD infants and infants at high risk for ASD. Recall that the current sample contained almost three times more high-risk infants than low-risk infants. High-risk infants might exhibit no, or just a weak, correlation between word repetition and word learning performance, which then in turn overshadows a possible positive correlation in the TD infants. Due to the low sample size, it was not possible to calculate correlations for both risk groups separately and check whether the correlations are different for both groups.

Chapter 4

The interplay between gaze following, emotion recognition and empathy across adolescence; a pubertal dip in performance?

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CJ and CC contributed to the conception and design of the study; RR was responsible for the data processing and data analyses; RR wrote the first draft of the manuscript; All authors contributed to manuscript revision, read and approved the submitted version.

Abstract

During puberty a dip in face recognition is often observed, possibly caused by heightened levels of gonadal hormones which in turn affect the re-organization of relevant cortical circuitry. In the current study we investigated whether a pubertal dip could be observed in three other abilities related to social information processing: gaze following, emotion recognition from the eyes and empathizing abilities. Across these abilities we further explored whether these measurements revealed sex differences as another way to understand how gonadal hormones affect processing of social information. Results show that across adolescence, there are improvements in emotion recognition from the eyes and in empathizing abilities. These improvements did not show a dip, but are more plateau-like. The gaze cueing effect did not change over adolescence. We only observed sex differences in empathizing abilities, with girls showing higher scores than boys. Based on these results it appears that gonadal hormones are not exerting a unified influence on higher levels of social information processing. Further research should also explore changes in (visual) information processing around puberty onset to find a more fitted explanation for changes in social behavior across adolescence.

Introduction

People’s eyes are very informative in social interactions. First, eye-gaze can direct someone's attention towards a gazed at location (e.g., Friesen & Kingstone, 1998). One demonstration that people are sensitive to shifts in eye-gaze comes from gaze cueing experiments. The first gaze cueing experiment was conducted by Friesen and Kingstone (1998) who showed that people are faster in detecting a target when a preceding face looked at the location where the target would appear (congruent condition) compared to a situation where the preceding face looked in the opposite direction (incongruent condition). This is called the gaze cueing effect. Second, eyes can express emotions as well as intentions and desires. The eye region is highly informative when deducting another's mental state (Frischen, Bayliss, & Tipper, 2007). The ability to recognize emotions from the eye region is often tested with the Read the Mind in the Eyes Task (RMET; Baren-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). During this task, participants see an image of the eye region of a person and are asked to choose one out of four options which word describes best how the person in the picture is feeling.

Closely related to gaze following and emotion recognition from the eyes is empathy. Empathy is 'the drive to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion' (Baron-Cohen, 2002). In other words, empathy enables one to give appropriate emotional responses. There is a clear connection between one’s ability to empathize and this person's eye-gaze pattern. People with high empathizing abilities fixate more on the eye-region of the people they are looking at compared to people with lower empathizing abilities (Cowan, Vanman, & Nielsen, 2014). This heightened attention for the eye-region might in turn result in better performances on gaze following and emotion recognition from the eyes.

Surprisingly, the investigation of the development of, and interplay between, empathy and sensitivity to another person’s eyes remains sparse, especially over the period of adolescence (for a review on the interplay between different sociocognitive processes, see Happé, Cook, & Bird, 2017). It is across adolescence that changes in social behavior and environment become most pronounced. The current study therefore examines the interplay between gaze following, emotion recognition from the eyes and empathy in a large group of children ranging from 8 to 16 years.

Investigating a group which contains children from pre-adolescence to adolescence further allows us to examine the influence of gonadal hormones on different social processes. Gonadal hormones released during puberty play a role in re-organizing cortical circuitry, and causally influence the neural basis of face processing, and more general social information processes (Scherf, Behrmann, & Dahl, 2012). Although one might expect a linear improvement with age from infancy to adulthood on basic face and emotion recognition, previous studies found a ‘dip’ in performance around the pubertal age: around midpubertal age (12-13 years old) children show worse performance on face and emotion recognition tasks compared to younger children and adults (e.g., Carey, Diamond, & Woods, 1980; Diamond, Carey, & Back, 1983; McGivern, Andersen, Byrd, Mutter, & Reilly, 2002; Peters & Kemner, 2017). This pubertal dip in performance might be initiated by the heightened levels of gonadal hormones, which results in a shift from a caregiver bias towards a peer bias (Scherf et al., 2012; but for other theories see Chung & Thomson, 1995). Adolescents develop specific peer-oriented behaviors which prepare them for adult social roles, such as developing peer friendships and exploring romantic relationships (Motta-Mena & Scherf, 2017). Indeed, in a face memory task adolescents show worse performance for the recognition of adult faces compared to prepubertal children and adults. However, they perform better than the other age groups for the recognition of faces which matched their own pubertal status specifically, which not necessarily matched their own age (Picci & Scherf, 2016). Thus pubertal status, irrespective of age, seems to influence the development of face processing abilities (see also Diamond et al., 1983; Lawrence, Campbell, & Skuse, 2015).

If gonadal hormones indeed influence task performance by re-organizing cortical circuitry, processes dependent on similar underlying brain structures should all be affected by this hormonal influx. Evidence from studies using functional Magnetic Resonance Imaging (fMRI) suggest that the same brain areas involved in face processing are also part of the brain circuitry involved in other social information processes such as the ones under investigation in the current study; gaze following, emotion recognition from the eyes and empathy. The core network involved in face processing is centered around the superior temporal sulcus (STS), the fusiform face area and the occipital face area (Gobbini & Haxby, 2007). Likewise, studies on eye-gaze processing highlight the involvement of the STS, together with the middle temporal gyrus and inferior parietal lobule, both in adults (e.g., Hoffman & Haxby, 2000) as well as in children (Mosconi, Mack, McCarthy, & Pelphrey, 2005; Vaidya et al., 2011). Similarly, fMRI studies looking into the RMET also show activation in the STS, as well as the temporal pole and the inferior frontal gyrus (IFG) (e.g., Adams Jr et al., 2010; Castelli et al., 2010; Gunther Moor, et al., 2012). For young adolescents (10-12 year-olds), the medial prefrontal cortex is involved as well (Gunther Moor, et al., 2012). Finally, brain-imaging studies on empathy also observe activation in the STS region (e.g., Dziobek et al., 2011; Zaki, Weber, Bolger, & Ochsner, 2009), as well as a thinner cortex in this area in people with lower empathy skills (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2005). Taking all these studies together we can conclude that brain circuitries centered around the STS are crucial in social information processes such as gaze following, emotion recognition from the eyes as well as empathy.

Coupling the findings of great overlap in brain circuitry recruited for basic face recognition and for higher levels of social processing, and the behavioral observation that there is a dip in basic face recognition in puberty, we expect to find a pubertal dip in measures that tap into other social information processes as well. We focus here on three examples of higher social information processes; gaze following, emotion recognition from the eyes and empathy. Although, as far as we know, there are no studies that examine the interplay between all three of these processes across adolescence, there are a few studies that focus on the influence of gonadal hormones on one of our measures. For instance, there is one study that reports a dip in RMET performance around pubertal age (Vetter, Leipold, Kliegel, Phillips, & Altgassen, 2013). Although this study found no reason to attribute the dip to pubertal status, note that the different pubertal groups were rather small and that the study sampled only children from 12 to 15 years old. Another study reports that for empathizing abilities there is a plateau rather than a pubertal dip, with no increase in abilities between 10 and 14 years of age (Garaigordobil, 2009). To our knowledge no study examined the developmental changes over adolescence in performance on the gaze cueing task. With the present study we will get a broader view on the effect of pubertal status on these social information processes.

To be able to take the pubertal status of the participants into account we included the Pubertal Development Scale (PDS), which is a written questionnaire that assesses multiple aspects of pubertal development (Petersen, Crockett, Richards, & Boxer, 1988). Empathizing abilities will be measured with the Interpersonal Reactivity Index (IRI; Davis, 1980), which is a written questionnaire looking into several aspects of empathizing behavior. The IRI is found to be a reliable measure of empathy as it shows correlations with several other empathy measures (Riggio, Tucker, & Coffaro, 1989).

To look even more closely at the influence of gonadal hormones we will also examine sex differences. Sex differences partly reflect, among other influences such as genes and environment, the effects of gonadal hormones on the abilities under investigation in the current study. Differences in testosterone exposure might have a causal role in sexual dimorphism in social development (Chapman et al., 2006; Knickmeyer & Baron-Cohen, 2006). During adolescence there is a tremendous increase in testosterone in boys, yet not in girls (Schulz & Sisk, 2006), which might result in the initiation or enlargement of already existing sex differences. Studying gaze following, emotion recognition and empathy in an adolescent sample allows us to further investigate the developmental time course of the sex differences found in adults, with females consistently outperforming males (e.g., Alwall, Johansson, & Hansen, 2010; Baron-Cohen et al., 2015; Bayliss, Pellegrino, & Tipper, 2005; Deaner, Shepherd, & Platt, 2007; Kirkland, Peterson, Baker, Miller, & Pulos, 2013).

In sum, our aim with the current study is to test whether a pubertal dip, caused by heightened levels of gonadal hormones which in turn affect re-organization of cortical circuitry, can be observed in higher social information processing measures such as the gaze cueing task, the RMET and the IRI. We expect to find this dip to be present across our measures as all processes rely on overlapping neural regions, which are similar to the regions involved in face recognition processes in which a pubertal dip is observed. Because of this similar underlying activation pattern we also expect that the performances on all three tasks will correlate with each other. Furthermore, we explore the influence of gonadal hormones more closely by looking at sex differences. We expect females to outperform males on all tasks.

Materials and methods

Participants

A sample of 124 adolescents participated in this study (57 boys; *M* age = 12.0 years, *SD* = 2.61, range 8–16 years). The participants were recruited through advertisements at primary and high schools in and around Utrecht, the Netherlands. This study was embedded in the first round of a larger cohort study on the development of cognition at Utrecht University, the Consortium on Individual Development (https://www.uu.nl/en/research/dynamics-of-youth/youth). The project was approved by the Medical Ethical Committee of the University Medical Center of Utrecht. Participants and their parent(s)/caregiver(s) gave informed consent at the start of the study and received 10 Euro for the test session.

Stimuli

Gaze cueing task. Stimuli consisted of faces with a neutral expression of 10 different identities, 5 male and 5 female, taken from the MacBrain Face Stimulus Set. Of each identity, three different pictures were used. One with a direct gaze, and two with an averted gaze to either the left or the right. Pictures were in grayscale and had an oval cutoff such that hair and background were not visible. The pictures had a width of 738 pixels and a height of 981 pixels, with the eyes at a height of 440 pixels. The target picture could either be a bird, cow, pink flower, red flower, or spiral (size 150 x 150 pixels).

Reading the Mind in the Eyes task. We used an adapted version of the RMET which was translated to Dutch and suitable for use with children and adolescents (Overgaauw, van Duijvenvoorde, Gunther Moor, & Crone, 2014). Stimuli consisted of 28 pictures of the eye region of a face, expressing a certain feeling or emotion (size 541 x 214 pixels). Each stimulus had a different identity. The pictures were accompanied by four words that describe possible feelings and emotions. One of these words was the target word describing the mental state of the individual in the picture.

Questionnaires

Interpersonal Reactivity Index. We used the Interpersonal Reactivity Index (IRI; Davis, 1980) as a measure of empathizing abilities. In the current study, we used a Dutch version which was adapted for use with children and adolescents (Hawk et al., 2013). The IRI consists of four scales of seven items each, which had to be answered on a five-point scale ranging from 0 (doesn’t describe me well at all) to 4 (describes me very well). We looked at three of the four subscales of this questionnaire (‘Perspective Taking’, ‘Fantasy’, and ‘Empathetic Concern’), as these subscales are related to ‘sensitivity to others’ (Davis, 1983), important in the tasks of the current study. We computed a score for every of the three subscales by adding the scores for all the seven items belonging to that subscale. Then, a total score was computed by adding the scores of the three subscales. One participant did not complete this questionnaire.

Pubertal Development Scale. To measure the pubertal status of the participants we used the Pubertal Development Scale (PDS; Petersen et al., 1988), translated in Dutch. This questionnaire assesses multiple aspects of pubertal development, focused on physical changes of the body. For each sex there are five questions which can be answered on a four-point scale ranging from 1 (maturation not started) to 4 (maturation completed). An overall pubertal development score was computed by averaging across the five items. Based on the answers children can be classified into one of five categories; prepubertal (1), early pubertal (2), midpubertal (3), late pubertal (4) or postpubertal (5). To compare our results with previous research

(Vetter et al., 2013) we reclassified the children into three groups; prepubertal (group 1 & 2; 42 boys, 24 girls), midpubertal (group 3; 13 boys, 11 girls), and postpubertal (group 4 & 5; 4 boys, 27 girls)[1]. Three participants did not complete this questionnaire.

Procedure

The participants came to our research facility for an entire testing day, consisting of several tasks to measure different aspects of cognition. The tasks described in the current chapter were two of them. The questionnaires were completed during this same testing day. Due to randomization the participants completed the two tasks at different moments during the day and in a counterbalanced order. Both tasks were programmed in Matlab version R2013a (MathWorks Inc., USA) and the PsychToolbox (version 3.0.11, Brainard & Vision, 1997) running on a MacBook Pro (OS X 10.9).

Gaze cueing task. The gaze cueing task was conducted with a Tobii TX-300 eye-tracker (sample rate 300 Hz) integrated with a computer screen (1920 x 1080 pixels; size 24 inch; refresh rate 60 Hz). Participants were seated at 65 cm distance from the screen and a chin-rest was used to stabilize head position. First, the task was explained and participants were instructed to look at the face and then look at the target as soon as it appeared on the screen. A 5-point calibration was performed and after accepted calibration or re-calibration the task started. The task consisted of 80 trials in total, 20 trials for each condition (left and right congruent/incongruent), in random order. Each face identity was shown twice for each condition. A trial started with a bouncing fixation dot in the middle of the screen (50 x 50 pixels).

The trial continued once the participant had focused on the fixation dot for a period of 36 samples. Then, a face with direct gaze was presented for 300 ms, followed by a face with an averted gaze for a random duration between 300 and 500 ms (over all trials the average duration was 400 ms). Next, a target was shown at either the right or left side of the screen, and started to spin when the participant fixated on it

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[1] We reclassified the children into three groups to be able to compare our results with those of Vetter and colleagues (2013). We also performed the analyses without this reclassification. This led to very similar results.

(i.e., three eye samples in an area of 200 pixels around the target), or after an elapsed time of 1500 ms in which the participant had not fixated on the target. The target remained spinning for 1000 ms. The task was automatically paused after 40 trials, the participants could indicate themselves when to continue.

Reading the Mind in the Eyes task. The Reading the Mind in the Eyes task consisted of 28 trials in total, preceded by one practice trial. In each trial, a picture of an eye region appeared on the screen, accompanied by four words, each describing a feeling or emotion. The participant was instructed to select the word which described the mental state of the person in the picture best. There was no time limit for answering. At the end of the task the participant received feedback on how many answers were correct. We scored on how many trials the participant had correctly interpreted the emotion in the eyes. One participant did not perform this task, so the results are based on a total sample of 123 participants.

Data reduction of the gaze cueing task

Fixations were determined with the Identification by 2-Means Clustering algorithm (I-2MC; Hessels, Niehorster, Kemner & Hooge, 2017). This algorithm is able to detect fixations in data with possibly high noise levels, both within and between participants and trials. Therefore, it is specifically useful for infant and child eye-tracking data. In the present study, periods of data loss up to 100 ms in the raw data were interpolated using Steffen interpolation if at least 2 samples of valid data were available at each end. For fixation detection we used a moving window of 200 ms width. Fixations that were not more than 30 pixels apart and that were separated by no more than 30 ms were merged. Fixations with a total duration shorter than 40 ms were removed.

In the analysis, we looked at target-driven and anticipatory saccades. A saccade was defined as I) a fixation during target presentation on the target position and II) the preceding fixation was on the face-stimulus until either target onset (i.e., target-driven saccade) or until at least 80 ms after cue-onset (i.e., anticipatory saccade). Target-driven saccades occurred in 40.5% of the trials, and 26.1% of the trials were anticipatory saccades. Participants were excluded from analysis when there were less than 10 included trials in one or more conditions (*n* = 6), eventually resulting in a total sample of 118 participants. For each participant the median latencies of the saccades per condition were calculated, defined as the time between target-onset and the start of the first fixation on target location. In addition, we calculated a difference score (RT on incongruent trials – RT on congruent trials) to examine the gaze cueing effect.

Results

Pubertal status effects

Gaze cueing task. We performed a repeated measures ANOVA with congruency as within-subjects factor and pubertal status as between-subjects factor. A main effect for congruency ($F(1,113) = 14.50$, $p < .001$, $\eta^2 = .11$) showed that the reaction times (RTs) for congruent trials ($M = 207.8$, $SD = 34.66$) were faster than RTs for incongruent trials ($M = 217.0$, $SD = 35.14$). There was a main effect for pubertal status as well ($F(2,113) = 3.77$, $p = .026$, $\eta^2 = .06$). Post-hoc tests showed that the postpubertal group showed faster overall RTs compared to the prepubertal ($t(73.56) = 3.12$, $p = .003$, Cohen's $d = 0.64$, equal variances not assumed) and midpubertal ($t(52) = 2.05$, $p = .046$, Cohen's $d = 0.57$) group. There was only a marginally significant interaction effect between congruency and pubertal status ($F(2,113) = 2.98$, $p = .055$, $\eta^2 = .05$). Figure 4.1 shows the results per pubertal group. Inspecting the graph suggests that the gaze cueing effect declines with pubertal status, but we did not further examine this as the interaction was not significant.

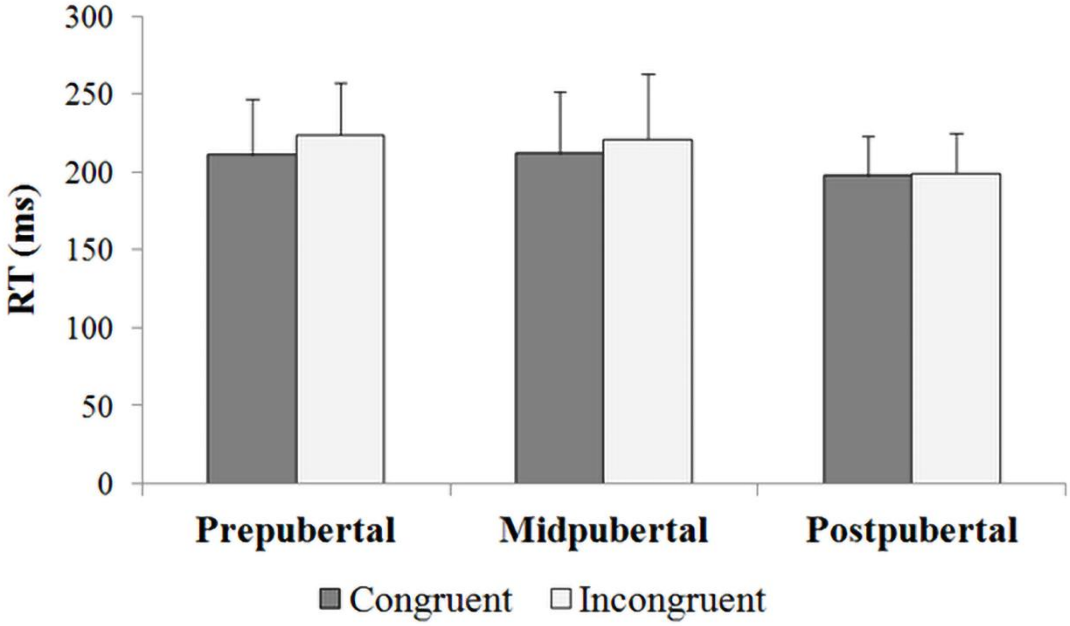

Figure 4.1. The median reaction times (RT) in ms for congruent (dark gray) and incongruent trials (light gray), per pubertal group. Error bars represent one standard deviation from the mean. Data showed a main effect for congruency with higher RTs for incongruent trials, and a main effect for pubertal status with lower overall RTs for the postpubertal group. There was no significant interaction effect.

Reading the Mind in the Eyes Task. To check for the effect of pubertal status we performed an one-way ANOVA on RMET scores with pubertal status group as between-subjects factor. There was a significant effect for pubertal status ($F(2,117) = 10.37$, $p < .001$, $\eta^2 = .15$), shown in Figure 4.2. Post-hoc analyses revealed that prepubertal children ($M = 16.8$, $SD = 3.62$) scored significantly lower compared to both midpubertal ($M = 19.2$, $SD = 2.65$; $t(87) = -2.95$, $p < .005$, Cohen’s $d = 0.71$) and postpubertal children ($M = 19.7$, $SD = 2.47$; $t(82.43) = -4.48$, $p < .001$, Cohen’s $d = 0.87$, equal variances not assumed). The scores of the midpubertal and postpubertal children did not differ significantly ($t(53) = -0.63$, $p = .53$, Cohen's $d = 0.20$).

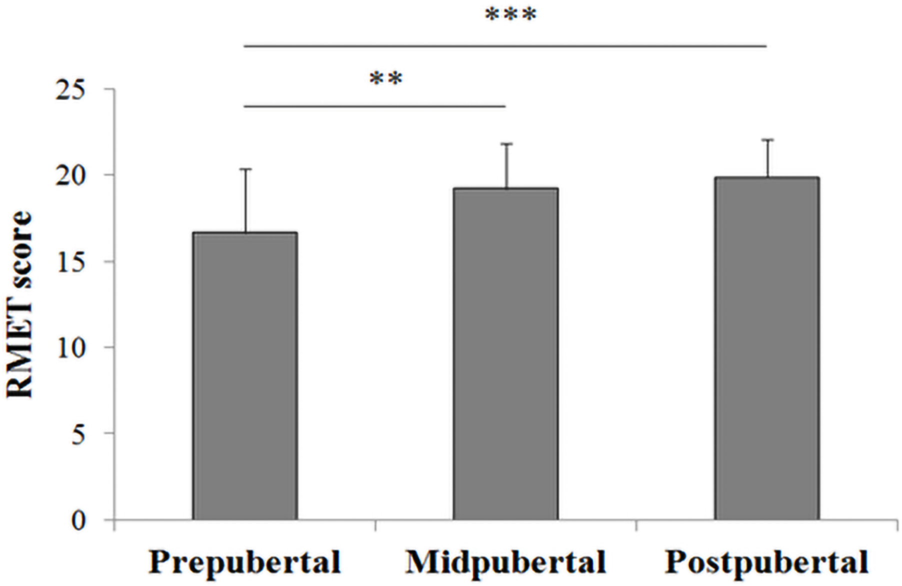

Figure 4.2. Total RMET score per pubertal group. Error bars represent one standard deviation from the mean. Data showed a main effect for pubertal group. ** $p < .005$; *** $p < .001$

Empathy. We performed an one-way ANOVA on IRI scores to examine differences in empathizing abilities between the pubertal groups. There was a significant effect for pubertal status ($F(2,117) = 6.47$, $p = .002$, $\eta^2 = .10$), shown in Figure 4.3. Post-hoc analyses showed that prepubertal children ($M = 44.3$, $SD = 11.25$) scored similar to midpubertal children ($M = 49.1$, $SD = 11.51$; $t(87) = -1.80$, $p = .08$, Cohen's $d = 0.42$) and significantly lower than postpubertal children ($M = 52.8$, $SD = 10.93$; $t(94) = -3.53$, $p = .001$, Cohen’s $d = 0.78$). Midpubertal and postpubertal children did not differ in IRI scores ($t(53) = -1.22$, $p = .23$, Cohen's $d = 0.33$).

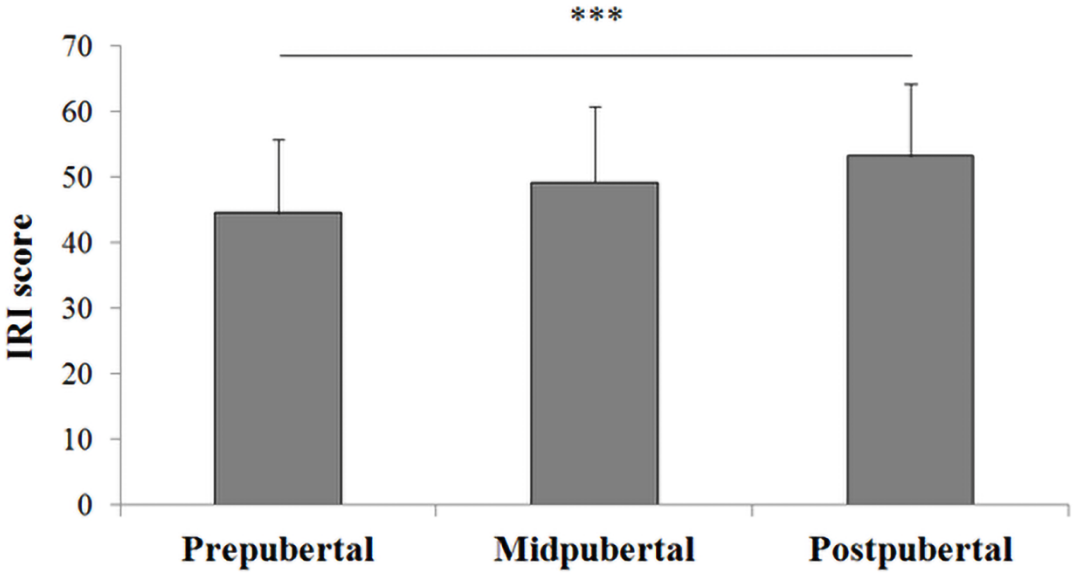

Figure 4.3. Total IRI score per pubertal group. Error bars represent one standard deviation from the mean. Data showed a main effect for pubertal group. *** p=.001

Sex differences

Gaze cueing task. To check for sex differences on the gaze cueing task we performed a repeated measures ANOVA with congruency as within-subjects factor and gender as between-subjects factor. Results showed a significant main effect for congruency ($F(1,116) = 23.24$, $p < .001$, $\eta^2 = .17$), where RTs for congruent trials (M = 208.1, SD = 34.62) were faster than RTs for incongruent trials (M = 217.1, SD = 34.95). There was no significant main effect for gender ($F(1,116) = 0.00$, $p = .98$, $\eta^2 < .001$), nor an interaction effect ($F(1,116) = 2.13$, $p = .15$, $\eta^2 = .02$).

Reading the Mind in the Eyes Task. We performed an independent samples t-test to check for gender differences on the RMET score. There was no significant difference in scores between boys (M = 17.5, SD = 3.43) and girls (M = 18.4, SD = 3.43; $t(121) = -1.50$, $p = .14$, Cohen's $d = 0.26$).

Empathy. To examine whether boys and girls differed in their empathizing abilities, we performed an independent samples t-test on the IRI score. Boys (M = 42.5, SD = 11.04) scored significantly lower on the IRI compared to girls (M = 52.0, SD = 10.37; $t(121) = -4.942$, $p < .001$, Cohen’s $d = 0.90$).

Correlations between gaze cueing, the RMET and empathy

We examined whether the three abilities tested in the current study are related, as we expected based on similar underlying brain activation and previously reported correlations between empathy measures and both gaze cueing and the RMET (Baron-Cohen, et al., 2001; Bayliss et al., 2005).

Since both the gaze cueing difference score and the RMET score violated the assumption of normality, as indicated by significant Kolmogorov-Smirnov values (difference score: $D(118) = .09$, $p = .035$; RMET score: $D(118) = .11$, $p = .001$), Spearman correlations were conducted. There was a significant negative correlation between the gaze cueing difference score and the RMET score ($r_s = -.22$, $p = .015$). This means that individuals who are highly influenced by the cue validity (i.e., who show a big difference in RT between congruent and incongruent trials) are worse in emotion recognition from the eyes compared to individuals who are less influenced by the cue validity.

There was no significant correlation between the IRI score and the gaze cueing difference score ($r_s = -.06$, $p = .54$). Thus, gaze following does not seem to be related to empathizing abilities. We found a significant positive correlation between the IRI score and the RMET score ($r_s = .36$, $p < .001$). This means that individuals who were good in emotion recognition from the eyes also show higher empathizing abilities.

Discussion

During puberty a dip in face recognition is observed (Diamond et al., 1983; Picci & Scherf, 2016), possibly caused by heightened levels of gonadal hormones which in turn affect re-organization of cortical circuitry. In the current study, we investigated whether a pubertal dip could be observed in three other abilities related to social information processing; gaze following, emotion recognition from the eyes and empathizing abilities. All of these three abilities rely on brain circuitries centered around the STS, as does face recognition, and therefore we expected that these abilities are influenced by the heightened hormone levels in puberty in similar ways. For the same reasoning, we also expected that performances on all three measurements would be correlated. We further explored the effects of gonadal hormones on these tasks by examining sex differences. In the following sections we will first discuss pubertal status effects and sex differences for each of the three measurements separately, after which we turn to the observed correlations across tasks. Last, we describe possible alternative explanations for the observed pubertal effects.

In our first task, the gaze cueing task, we observed an overall gaze cueing effect, with higher reaction times for incongruent compared to congruent trials. We observed no interaction effect with pubertal status nor a sex difference. Pubertal status influenced the overall reaction times, but not the magnitude in which the participants' attention was directed by the gaze cue. To our knowledge, this is the first study which looked at the development of the gaze cueing effect over adolescence. Our results show no development of the effect over this period, although a trend indicates a slight decline in the gaze cueing effect across adolescence. These results indicate that the gaze cueing effect is fairly robust and not easily influenced by individual factors. Previous studies reported gender differences in an adult population (Bayliss et al., 2005; Deaner et al., 2007), but we did not replicate this in the current sample of adolescents. Not many gaze cueing studies report on either the presence or absence of sex differences in their results. It is therefore hard to conclude whether sex differences arise after adolescence, whether sex differences arise during childhood but we failed to find them in the current sample or whether differences do not exist.

In our second task, the RMET, we observed a pubertal status effect, yet no sex difference was observed. The prepubertal children performed worse on this task compared to the mid- and postpubertal children, who did not differ in their performance. This result suggests that RMET performance first increases but later reaches a plateau. Whether there is more improvement at a later age cannot be determined based on the current study. Our results are in contrast with the study by Vetter and colleagues (2013) who did not find a pubertal status effect. Possibly our results are more representative as the sample size of the current study was twice as big compared to the study of Vetter et al.. However, these are the only two studies looking at the influence of pubertal status on RMET performance. Further research is needed to confirm our results.

The third measurement, the IRI questionnaire, revealed both a pubertal status effect and a sex difference. Prepubertal children showed lower empathetic abilities than postpubertal children and girls had higher scores than boys on this questionnaire. These results suggest that there is a small gradual improvement in empathizing abilities over adolescence, only reaching significance when comparing the scores of the two outer groups. This is consistent with the finding of no increase in empathizing abilities between 10 and 14 years of age, which are children who are probably in the pre- or midpubertal phase (Garaigordobil, 2009).

Our next question was whether there are correspondences between the three different tasks. Recall that other studies observed a positive link between empathy and a person’s eye-gaze pattern: high empathizing abilities are related to more fixations on the eye-region (Cowan et al., 2014). We therefore expected that empathy scores in our sample would positively correlate with the gaze cueing effect and RMET scores. Indeed, RMET scores in our study are positively related to empathizing abilities. However, we did not observe a correlation between empathy scores and the gaze cueing effect. Higher empathy does not influence a person’s attentive behavior in response to gaze cues. Third, although we observed a correlation between the gaze cueing effect and RMET scores, it turned out to be negative. Apparently, individuals who perform well in emotion recognition from the eyes, are also the individuals who are less influenced by cue validity. We expected to find a positive correlation between these two measures, as they both rely on similar brain areas and tap into similar processes. We have no direct explanation for the negative correlation observed in our data. Further research should tap deeper into both processes to find differences which may explain our observed negative correlation. Indeed, while there is reason to believe that brain circuitry involved in these processes overlap to some extent, there is also evidence highlighting that gaze following and emotion recognition are distinct abilities, each additionally recruiting different areas in the brain. A study with women with Turner’s Syndrome (lack of a complete X-chromosome) shows that these women are impaired in emotion recognition from the eyes, yet not in gaze following, possibly due to dysfunction of the amygdala (Lawrence et al., 2003). This suggests that these two processes are dissociable and that at least the affective aspect of emotion recognition is supported by a distinct brain circuitry.

When looking at the correspondences across the three measurements, especially empathy and emotion recognition from the eyes seem to be related to each other at a correlational level. The relation with gaze following remains more unclear. Also the individual characteristics such as pubertal and sex effects that could possibly bear on these measurements do not all pattern alike. For example, our results show that pubertal status effects and sex differences do not consistently co-occur and do not show the same pattern for all tasks. Based on these results it is hard to pinpoint the exact effect of gonadal hormones on higher levels of social information processing. Clearly, this study shows that different sorts of higher social processing do not reveal similar levels of involvement of gonadal hormones. There are several possibilities why this is the case. One explanation could be that the lack of consistent puberty effects across different forms of social information processing highlights that gonadal hormones play only a minor role in higher levels of social information. Another explanation could be that gonadal hormones differentially modulate processing of social information, depending on the exact configuration of the task and ability at hand. It is also possible that the way in which we could easily quantify pubertal status (i.e., via self-based questionnaires) is more prone to subjective measurement error compared to direct measures of gonadal hormones. Research with more direct measures of gonadal hormone levels and brain activation would allow us to draw firmer conclusions about the role of these hormones in social information processes.

There are some other theories which might explain our observed pubertal effects. Diamond and colleagues (1983), and Soppe (1986) argued that instead of a direct effect of gonadal hormones there is a more indirect effect of pubertal changes on face encoding. Once children become aware of their own pubertal development they may subconsciously change their interests, for example changes in which aspects of a face are in the center of attention. For example, adults and young children show a left visual field advantage for unfamiliar faces, yet this advantage was not present in 12- and 14-year-olds (Diamond et al., 1983). These differences in attentive processes might cause a period of less efficient face processing. Basic processes of joint attention, such as gaze following, could have become mature enough to be insensitive to such a shift in attention. This would explain why we observed no effect of pubertal status for this task. In contrast, a more taxing task would be one that asks people to interpret higher order emotions, such as the RMET. Here one would expect that less efficient face processing would directly lead to worse performances for this RMET task. More research into this possible change in attentive processes around the onset of puberty is needed to come up with more specific hypotheses on how this change might influence social processes.

Another possibility is that the decline in performance is unrelated to pubertal status over all, and is instead due to changes in visual information processing not influenced by puberty onset. The dip in performance might for instance occur when the knowledge about faces is reorganized once a certain level of proficiency is reached (Flin, 1985). Transition from one phase to the other results in a temporary disruption in performance. Another developmental change in visual information processing is the change in sensitivity to details (for a review, see van den Boomen, van der Smagt, & Kemner, 2012). Over development adolescents change from featural-oriented to configural-oriented face processing (Mondloch, Le Grand, & Maurer, 2002). This transition takes place as the ability to process low spatial frequency (LSF) increases with age. The use of LSF information during face processing results in better face perception and face recognition (Peters & Kemner, 2017). This switch in face processing might also explain our finding why we observe pubertal status effects in the RMET task, as emotion recognition is more reliant on LSF information (Vlamings, Goffaux, & Kemner, 2009). Maybe LSF processing was not yet fully developed in our prepubertal group, whereas it was in our midpubertal and postpubertal groups, which could explain the worse performance of the first group on the RMET. Gaze cueing on the other hand might rely less on LSF processing (Munsters, van den Boomen, Hooge, & Kemner, 2016), such that the switch in processing does not influence performance on the gaze cueing task. Therefore, we also did not observe any pubertal status effects on this task.

It is interesting to note that whenever we observed an effect of pubertal status the performances do not appear linear nor show a dip, but are more plateau-like, with improvements in performances only from prepuberty to midpuberty for the RMET and from prepuberty to postpuberty for empathizing abilities. The gaze cueing effect is more robust and does not significantly change over adolescence, although a trend was observed. The finding of plateau-like performances is also present in the face recognition literature. Various studies found a dip in performance, yet a leveling of performance was reported several times as well (for a review, see Chung & Thomson, 1995). These different findings may be due to methodological differences in the task paradigm. It therefore seems that the developmental curve for social processes indeed shows irregularities, yet inconsistency in results questions the reliability of the pubertal dip.

Further, we showed that sex differences in social behavior are not strongly present in our large sample of adolescents. Only in empathizing abilities did we observe sex differences, with girls showing higher scores than boys, but not in the gaze cueing task and the RMET. Apparently, in our results the sex difference in empathy does not extend to other social abilities such as gaze following and reading emotions from the eyes. The lack of a sex effect is in contrast with previous studies with adults which examined gaze following (Bayliss et al., 2005; Deaner et al., 2007) and emotion recognition (Alwall et al., 2010; Baron-Cohen et al., 2015; Hall, Hutton, & Morgan, 2010; Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010; Kirkland et al., 2013). An explanation may be that social and attentive processes are still under development across adolescence and only after the maturation of these processes the sex differences become prevalent in performances. However, sex differences in basic emotion recognition are previously reported in children (Lawrence et al., 2015). Clearly, these differences are inconsistent, with studies often requiring large sample sizes to find small effects. Therefore, a task that considers a wide range of complex emotions, such as the RMET, might not detect overall sex differences at this young age. In addition, adult studies into sex differences in the social domain show inconsistencies as well (for an overview, see Helgeson, 2016). Probably, a more nuanced view is needed where females excel in certain social skills whereas males excel in others, especially when aggressive stimuli are involved (for a review, see Forni-Santos & Osório, 2015). For other social skills a sex difference simply appears to be absent. More longitudinal studies into social processes are needed to unravel the developmental time course of possible sex differences.

To conclude, social behavior undergoes several changes over adolescence. This study shows improvements in emotion recognition from the eyes and empathizing abilities over pubertal development, although plateau-like. Gaze following on the other hand seems to be less influenced by pubertal status. Moreover, although girls outperformed boys on empathy abilities, sex differences were not prevalent in gaze following and emotion recognition from the eyes. Thus, we reveal developmental changes in these three abilities on social information processing across puberty, yet these do not pattern consistently across the different skills. As such, it is unlikely that gonadal hormones are exerting a simple and unified influence on all these abilities but rather that, if they do play a role in the development of these skills, the picture is more complex. Further research should therefore explore changes in (visual) information processing around puberty onset to find a more fitted explanation for changes in social behavior over adolescence.

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Chapter 5

No own-age bias in children's gaze cueing effects

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Abstract

Sensitivity to another person's eye-gaze is vital for social and language development. In the current eye-tracking study, a group of 74 children (6-14 years old) performed a gaze cueing experiment in which another person's shift in eye-gaze potentially cued the location of a peripheral target. The aim of the present study is to investigate whether children's gaze cueing effects are modulated by the other person's age. In half of the trials the gaze cue was given by adult models, in the other half of the trials by child models. Regardless of the models' ages, children displayed an overall gaze cueing effect. However, results showed no indication of an own-age bias in the performance on the gaze cueing task; the gaze cueing effect is similar for both child and adult face cues. These results did not change when we looked at the performance of a subsample of participants (n = 23) who closely matched the age of the child models. Our results do not allow us to disentangle the possibility that children are insensitive to a model's age or whether they consider models of either age as equally informative. Future research should aim at trying to disentangle these two possibilities.

Introduction

The direction of an eye-gaze of another person can be very informative. Following the gaze of someone else may lead to detection of important environmental stimuli and the initiation of joint attention (for a review, see Frischen, Bayliss, & Tipper, 2007). People's ability to shift attention in response to another's eye-gaze is often examined with the gaze cueing paradigm. The classic gaze cueing experiment shows a face which makes an eye-movement towards either the right or the left, after which a target appears on one side of the face. People are faster in detecting the target when the eye-movement correctly predicted the target location, which is called the gaze cueing effect (Friesen & Kingstone, 1998). In the current chapter we set out to examine whether children's gaze cueing effects are affected by whether the other person matches their own age or not.

Gaze cueing appears to be a crucial ability in several learning processes. For instance, shifting attention in response to gaze cues during infancy correlates with subsequent language development (Brooks & Meltzoff, 2005; Morales, Mundy, & Rojas, 1998; Morales et al., 2000). Moreover, faster gaze switching in response to gaze cues is related to less severe social and language symptoms in children with autism (Charman, 2003), and to less severe autistic traits in adults (e.g., Bayliss & Tipper, 2005). Nevertheless, gaze cueing effects are not always apparent, at least in infancy, as a comparison across gaze cueing studies with infant samples shows (Munsters, 2017). Studies with older typically-developing children show a more robust gaze cueing effect (Goldberg et al., 2008; Kylliäinen & Hietanen, 2004; Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne & Coleman, 2003; *Chapter 4*). However, when testing children with autism the results are again mixed (Goldberg et al., 2008; Kylliäinen & Hietanen, 2004; Senju et al., 2004; Swettenham et al., 2003). These discrepancies could be related to differences in task settings. This suggests that experimental factors, such as stimulus material, gaze cue presentation time or the inter-stimulus interval between gaze cue onset and target onset, contribute to the magnitude of this effect. The current study specifically aims to evaluate whether stimulus characteristics can modulate gaze cueing effects.

One possible factor of influence on the gaze cueing effect are the characteristics of the faces which are used as stimuli, such as species, race, age and gender (cf. Macchi Cassia, 2011). For example, using familiar faces as stimulus models enhances the gaze cueing effect, yet this effect is only observed in women (Deaner, Shepherd, & Platt, 2007). Moreover, young adults show larger gaze cueing effects for young adult stimulus models compared to older adult stimulus models (Slessor, Laird, Phillips, Bull, & Filippou, 2010). Although in adults both familiarity and age modulate gaze cueing, it is unclear how these face categories influence sensitivity to gaze cues across development. In particular when assessing developmental trajectories in gaze cueing from childhood to adulthood (e.g., *Chapter 4*), it is vital to understand how stimulus characteristics can affect gaze cueing effects.

The current study will therefore examine whether the age of the perceived stimulus model modulates gaze cueing in a child sample, similar to the effect observed in adults (Slessor et al., 2010). Research reveals that humans easily estimate a person’s age (Rhodes, 2009), which in turn influences the process of face encoding (e.g., Ebner, He, Fichtenholtz, McCarthy, & Johnson, 2010; Kuefner, Macchi Cassia, Picozzo, & Bricolo, 2008). When adults see other adult faces from various angles, Kuefner and colleagues (2008) observed a large inversion effect (i.e., recognition of inverted faces is less accurate than recognition of upright faces), whereas this effect is smaller for seeing child faces and even absent for newborn faces. This finding suggests that adults have difficulties in encoding configural information in other-age faces, and thus perceptual strategies are more finely tuned to adult faces. This is often referred to as the own-age bias.

Evidence for an own-age bias in face processing mainly comes from the field of face recognition (for reviews, see Macchi Cassia, 2011; Rhodes & Anastasi, 2012; Wiese, Komes, & Schweinberger, 2013). Next to research with the inverted-face paradigm, other studies test face recognition with a learning and a consecutive test phase. In this test phase the faces of the learning phase are presented, as well as new faces. Per face, participants make an old/new judgment. Meta-analyses reveal that the own-age bias is a robust effect in this field of research, with higher recognition accuracy for own-age faces compared to other-age faces (Rhodes & Anastasi, 2012). The own-age bias is not only present in adults (e.g., Kuefner et al., 2008), but also in developing populations. Indeed, children show superior recognition of child faces compared to adult faces (e.g., Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Lindholm, 2005), and also adolescents show own-age effects (Picci & Scherf, 2016). One of the explanations for the existence of an own-age bias is that people have more extensive experience with individuals of their own age and therefore perceptual processes specifically support own-age faces (Harrison & Hole, 2009; He, Ebner, & Johnson, 2011).

This own-age bias in face recognition appears to be very narrow. When faces of 8-year-old children are used as stimuli, only 7- to 9-year-old children show enhanced recognition for these faces. In contrast, 6- and 11-year-old children are less accurate in recognizing these 8-year-old stimulus faces (Hills & Lewis, 2011). A follow-up study showed that the optimal age range in which an own-age bias in face recognition can be observed might be even smaller. Children were followed from the age of seven until they were nine years old. Each year, the children performed a face recognition task in which faces of 8-year-olds were used as stimuli. Children showed better face recognition scores for this set of faces when they were 8-year-olds themselves, compared to their performance when they were seven or nine years old (Hills, 2012). Thus, in children the own-age bias in face recognition seems to be present but highly restrictive.

Although the own-age bias is often present in face recognition studies, there are only a few studies that investigated whether own-age biases are present in the gaze cueing paradigm. To our knowledge, only two previous studies looked at an own-age bias in the gaze cueing paradigm, yet both with an adult population. Slessor and colleagues (2010) investigated whether younger (mean age 20 years) and older (mean age 73 years) adults differed in their gaze cueing effect, while using younger and older adult stimulus models. There was an overall age effect, which showed that irrespective of the age of the stimulus face, older adults show a smaller gaze cueing effect than younger adults. In addition, the gaze cueing effect was influenced by an interaction with the age of the stimulus model. The younger adults expressed an own-age bias, whereas the older adults did not show such a bias (see also Ciardo, Marino, Actis-Grosso, Rossetti, & Ricciardelli, 2014). Thus, the age difference observed in this study is attributable to the fact that young adults have larger gaze cueing effects in response to young adult faces. Nonetheless, Bailey and colleagues (2014) demonstrated a different pattern of own-age biases: when seeing subliminal stimuli or happy facial expressions, only older adults (but not younger adults) exhibit an own-age bias. These studies indicate that an own-age bias can be observed in gaze cueing paradigms with adults of varying ages, yet stimulus presentation time and the addition of emotional expressions to the stimulus set seem to alter the results. As the current study is the first to examine own-age effects in gaze cueing in a child sample we will apply the more basic design, and use supraliminal stimuli with neutral expressions. In this way, we are also able to directly compare our results with the adult data of Slessor and colleagues (2010).

Surprisingly, it appears that gaze cueing studies with children employ only adult faces (e.g., Freeth, Chapman, Ropar, & Mitchell, 2010; Freeth, Ropar, Chapman, & Mitchell, 2010; Kylliäinen & Hietanen, 2004; Riby, Hancock, Jones, & Hanley, 2013; Senju et al., 2004; Swettenham, et al., 2003; *Chapter 4*). However, children might simply be more tuned towards processing faces of their own age group, as is suggested by the enhanced face recognition of own-age faces (Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Hills & Lewis, 2011; Hills, 2012; Lindholm, 2005; Picci & Scherf, 2016). This enhanced processing of own-age faces might in turn boost their performance on a gaze cueing task that uses child models as stimuli. If children indeed express an own-age bias in gaze cueing, the use of only adult stimulus models might lead to underestimation of their performance in relation to subjects of other ages, or it might mask true developmental effects in longitudinal studies. Including both child and adult stimuli in a gaze cueing task thus gives a better representation of a person’s ability to orient one's own attention in response to gaze cues from a variety of models. The present study therefore explores whether children display an own-age effect in a gaze cueing paradigm by presenting models who are either adults or children around the age of 10 years.

The current eye-tracking study first investigates whether there is an overall own-age bias in a gaze cueing paradigm in children from a wide age range (6- to 14-year-olds). As in the study of Slessor and colleagues (2010), our subjects see supraliminal faces with neutral expressions whose shift in eye-gaze either validly or invalidly cues the presence of a peripheral target. Given the literature on the own-age bias in face recognition processes, we hypothesize that children will show a stronger gaze cueing effect for child models compared to adult models. Another possibility is that own-age effects are present but rather narrow in scope; that is, only present for those children that match the child models closely in age, as is also sometimes observed in face recognition paradigms (i.e., Hills, 2012; Hills & Lewis, 2011). In a secondary set of analyses, we therefore repeat our analyses, focusing solely on children between 10 and 11 years old.

If we find evidence that children take the age of the person they look at into account when directing their attention, an own-age effect in gaze cueing would manifest itself as larger gaze cueing effects for child models: children consider gaze cues of other children more informative. Yet another possibility is that we find a larger gaze cueing effect for the adult models instead. This finding could indicate that children see adult cues as more informative, which results in faster processing and redirection of attention for this category of faces. Alternatively, if we fail to find any effect of the model’s age on children’s responses, there are at least two possibilities that could explain this: either children are insensitive to the model’s age or they find adult and child models equally informative.

Materials and methods

Participants

A total of 74 children participated in this study (40 boys; *M* age = 10.41 years, *SD* = 1.91, range 6.2-14.4 years). Another two children were tested but were excluded because of difficulties with the eye-tracker to detect the pupil. We created three age groups: compared to the age range from our child models (see stimuli descriptions below), there was a group of younger children (6-9-year-olds; *n* = 33, *M* age = 8.69, *SD* = 1.03), children of the same age (10-11-year-olds; *n* = 24, *M* age = 10.93, *SD* = 0.50), and older children (12-14-year-olds; *n* = 17, *M* age = 13.03, *SD* = 0.68). The participants were recruited at two public events in the city of Utrecht, the Netherlands, in which the general public could learn about and participate in scientific research. The project was approved by the local ethics committee, and all procedures followed were in accordance with the Helsinki Declaration of 1975, revised in 2008. Participants (when 12 years or older) or their parent(s)/caregiver(s) gave informed consent at the start of the study.

Stimuli

Stimuli consisted of faces with a neutral expression taken from the Radboud Faces Database (Langner et al., 2010). We selected six adult (no. 2, 10, 19, 23, 24 and 56) and six child (no. 39, 40, 44, 63, 64 and 65) identities (each age group had three male and three female models; adult ages {21, 22, 24, 27, 29, 35}; child ages{8, 10, 10, 11, 11}, one age unknown). Of each identity we used three different pictures; with a direct gaze, with a left averted gaze, and with a right averted gaze. The pictures had a width of 600 pixels and a height of 750 pixels, with the eyes at a height of 440 pixels. Figure 5.1 shows examples of the stimuli used. As target pictures we used several different cartoon figures (size 300 x 300 pixels).

Figure 5.1. Examples of face stimuli for both adult (top row) and child models (bottom row). Stimuli are obtained from the Radboud Faces Database (Langner et al., 2010). Written informed consent for publication was obtained.

Procedure

The participants visited a public scientific event and got directed to our testing booth when they expressed interest in participation in scientific research. Upon arrival we explained our experimental set-up, without disclosing our main hypotheses, and the children, in consultation with their parents/caregivers, could decide to participate.

We conducted the gaze cueing task with a Tobii TX-300 eye-tracker (sampling rate 300 Hz) integrated with a computer screen (1920 x 1080 pixels; size 24 inch; refresh rate 60 Hz). The task was programmed in Matlab version R2014b (MathWorks Inc., USA) and the PsychToolbox (version 3.0.12, Brainard & Vision, 1997) running on a MacBook Pro (OS X El Capitan, Version 10.11.2). We positioned the participants at 65 cm distance from the screen and a chin-rest stabilized head position. After a 5-point calibration the task started. The participants were instructed to first look at the face and then look at the target as soon as it appeared. The task consisted of 96 trials in total, 24 per condition (child/adult model; congruent/incongruent trial). First a fixation point (50 x 50 pixels) was presented in the middle of the screen jittered between 900 and 1100 ms. Then a face with a direct gaze was presented with a random duration between 300 and 500 ms. The direct face was followed by a picture of the same face with an averted gaze to either the left or right. This face (i.e., the gaze cue) was also presented for a random duration between 300 and 500 ms. Next, a target was presented at either the left or right side of the screen, which started spinning after 500 ms. It remained spinning for 1000 ms after which the next trial started.

Data reduction

We used the Identification by 2-Means Clustering algorithm (I-2MC; Hessels, Niehorster, Kemner & Hooge, 2017) to classify fixations. I-2MC is a fixation detection algorithm specifically designed for infant and child data with high noise levels. We interpolated periods of data loss up to 100 ms in the raw data using Steffen interpolation when at least 2 samples of valid data were available at each end. A moving window of 200 ms width was used for fixation classification. Fixations that were not more than 30 pixels apart and that were separated by no more than 30 ms were merged. If a fixation had a total duration shorter than 40 ms it was removed. We excluded trials when there was no fixation on either the cue or the target (30.6% of the trials), or when the participant fixated on one side of the screen before target onset (7.3% of the trials).

If participants had less than six included trials in one or more conditions they were excluded from analysis (*n* = 7). The final sample composed 67 participants (34 boys; *M* age = 10.57 years, *SD* = 1.90). For each participant the median latencies of the reaction times (RTs) per condition were calculated (in ms), defined as the time between target onset and the start of the first fixation on target location.

Results

We performed a repeated measures ANOVA with congruency and age of the stimulus model as within-subjects factors[1]. A main effect for congruency ($F(1,66) = 16.81$, $p < .001$, $\eta^2 = .20$) showed that the RTs for congruent trials ($M = 220.33$, $SD = 35.18$) were faster than RTs for incongruent trials ($M = 234.21$, $SD = 35.67$). There was no main

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[1] We also performed the repeated measures ANOVA with age as a covariate. However, age did not have a linear effect on any variable nor a main effect on RTs. We therefore decided to report the simpler analysis without age as a covariate.

effect for age of the stimulus model (*F*(1,66) = 0.09, *p* = .76, η^2 < .01) nor an interaction effect between congruency and age of the stimulus model (*F*(1,66) = 1.54, *p* = .22, η^2 = .02). These results indicate that the age of the stimulus model did not influence the participants' gaze cueing effects. Post-hoc tests showed that for both child (congruent: *M* = 218.85, *SD* = 34.16; incongruent: *M* = 235.13, *SD* = 38.76; *t*(66) = -3.95, *p* < .001, Cohen's *d* = 0.45) and adult models (congruent: *M* = 221.82, *SD* = 39.26; incongruent: *M* = 233.28, *SD* = 35.93; *t*(66) = -3.12, *p* = .003, Cohen's *d* = 0.30) RTs were significantly faster for congruent compared to incongruent trials. Figure 5.2 shows these effects.

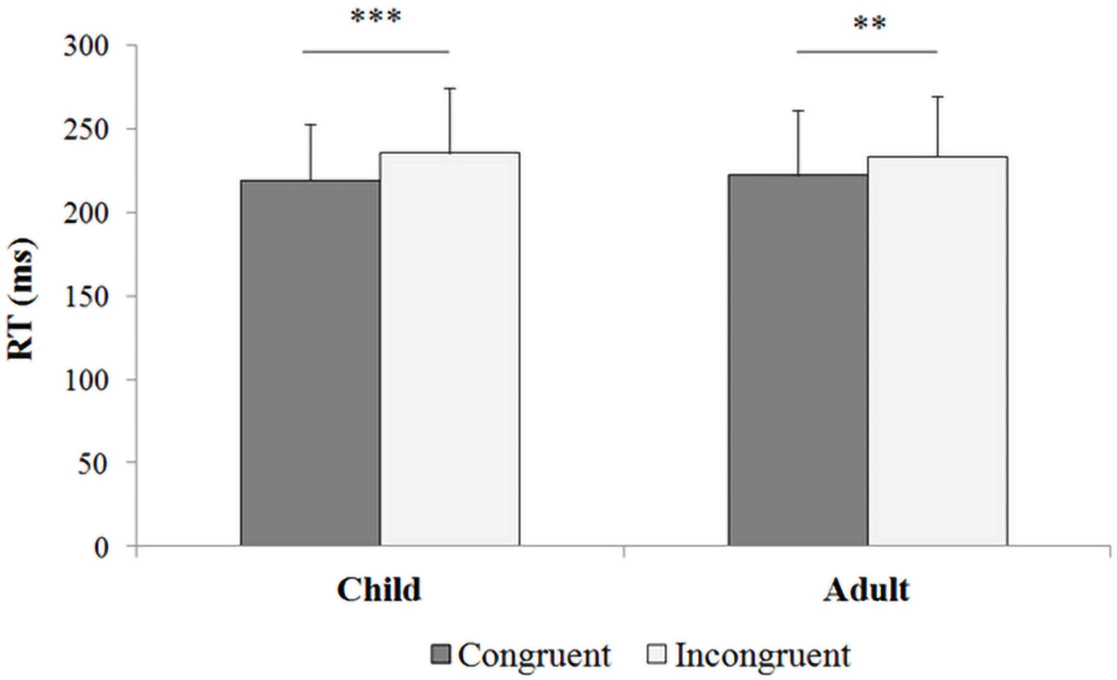

Figure 5.2. The median reaction times (RT) in ms for congruent (dark gray) and incongruent trials (light gray). Error bars represent one standard deviation from the mean. Responses are separated by type of trial (either child or adult model). The difference in reaction times between congruent and incongruent trials is significant, for both child and adult models. ***p* < .005; ****p* < .001.

As the own-age effect in face recognition can appear to be very narrow (Hills, 2012; Hills & Lewis, 2011), we wanted to closely match the age of the participants with the age of the stimulus models. We therefore performed additional analyses with only a subset of the participants, that is only the 10- and 11-year-olds (n = 23). Moreover, we only included those trials in which 10- and 11-year-old child models were shown (i.e., 2/3 of all child trials). A repeated measures ANOVA showed a main effect for congruency (F(1,22) = 5.68, p = .026, η^2 = .20) with faster RTs for congruent trials (M = 222.47, SD = 41.23) compared to incongruent trials (M = 233.53, SD = 39.67). Again, we did not observe a main effect for age of the stimulus model (F(1,22) = 1.06, p = .31, η^2 = .05) nor an interaction between congruency and age of the stimulus model (F(1,22) = 0.53, p = .53, η^2 = .02).

Last, we tested whether 10- and 11-year-old children differed from the younger and older participants in their gaze cueing effect for the 10- an 11-year-old stimulus models. We performed a one-way ANOVA on the difference score for child models (RTincongruent – RTcongruent for child trials) with age group (younger (n = 26); 10- and 11-year-old (n = 23); older (n = 17)) as fixed factor. There was no significant effect of age group on the gaze cueing effect for child trials (F(2,63) = 0.01, p = .99, η^2 < .001). Figure 5.3 shows the difference scores for child models per age group. These last two analyses indicate that even for this narrow age range there is no own-age bias in gaze cueing.

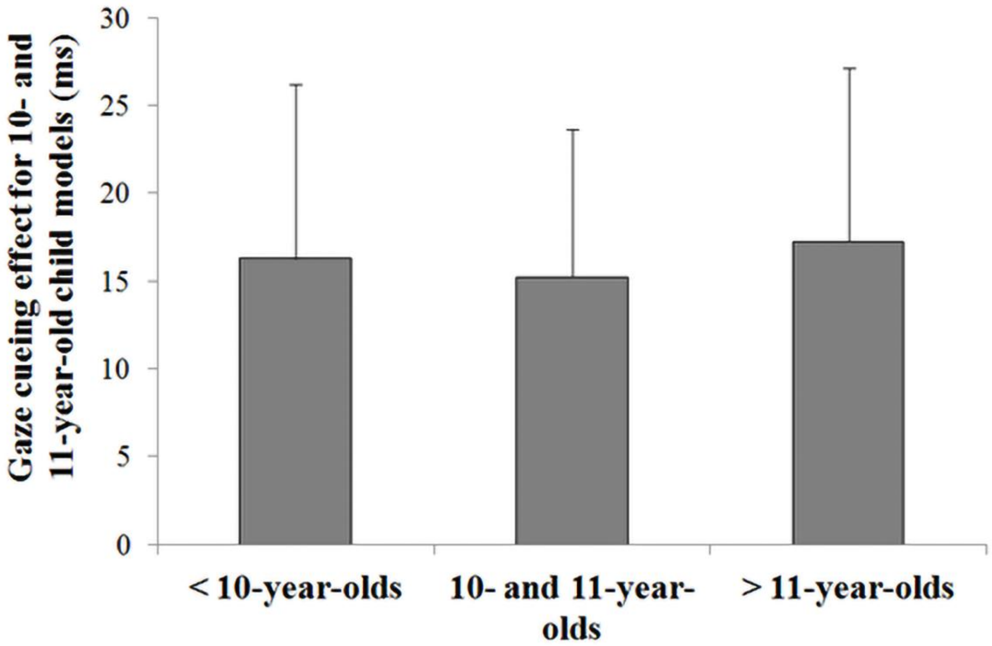

Figure 5.3. The gaze cueing effect for only the 10- and 11-year-old child models (RTincongruent – RTcongruent) per age group. Error bars represent one standard error from the mean. There is no significant difference between the groups.

Discussion

In the current study we investigated whether an own-age bias is present in children performing a gaze cueing task in which adults as well as children were our stimulus models. Evidence from literature on face recognition suggests that an own-age bias exists for visual tasks in this age group as children and adolescents show superior recognition of faces from their peers compared to adult faces (Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Lindholm, 2005; Picci & Scherf, 2016). We therefore hypothesized that an own-age effect would reveal itself as stronger gaze cueing effects for child models than for adult models. However, the present study failed to find this own-age bias in the performances on a gaze cueing task. Even when we closely matched the age of a subsample of our participants to the age of our child models, an own-age bias was absent. Below we discuss the possibilities why the own-age bias does not appear in a gaze cueing task testing children.

One of the explanations that might contribute to our lack of an own-age bias is the amount of exposure that participants have with seeing children and adults. The own-age bias is based on the idea that individuals have more extensive experience with individuals of their own age compared to other-aged individuals (Harrison & Hole, 2009; He et al., 2011). This is in accordance with the finding that greater familiarity with a stimulus face enhances the gaze cueing effect (Deaner et al., 2007). Moreover, Slessor and colleagues (2010) demonstrated an own-age bias in gaze cueing in young adults but not in older adults. They explained this finding by suggesting that older adults may have greater experience with people of different age ranges, whereas younger adults have more contact with people of their own age. Future studies should entail measures of experience with different age groups to assess the specific effect of experience on the own-age bias in gaze cueing.

Children might be in a similar situation as older adults, as they too, are surrounded by people of different age ranges. Young children are from birth focused on attachment with their primary caregiver. They are also around same-aged peers in day care and later in school, yet adult faces remain important in daily life. Much of children’s learning occurs in the context of social interactions with adults (i.e., parents, teachers, trainers), which involves joint attention processes. The coordination of one’s own perspective and another person’s perspective (based on that person’s eye-gaze) relative to a third object or event provides experiences that are fundamental to social-cognitive neurodevelopment (Mundy, 2016; Mundy & Jarrold, 2010; Mundy & Newell, 2007). Only in puberty adolescents reorient specifically from adults towards peers (Scherf & Scott, 2012). With a mean age of 10.4 years, our sample of children has possibly not reached this point of reorientation yet. In other words, while it is possible that they increasingly focus more on other children, they would still highly focus on adults as well. It is possible that this balance could contribute to the lack of an own-age bias in the present study. This would entail that social interactions with either adults or peers are equally important in learning situations during late childhood, with similar effects on social-cognitive neurodevelopment. Longitudinal designs could shed light on the moment in development where the own-age bias in gaze cueing arises, if it does at all. This would give more information about the moment in development where interactions with peers are valued as more important than interactions with adults, and thus possibly also the moment in development where interactions with peers have a larger influence on social-cognitive neurodevelopment.

Another potential explanation for the observed lack of an own-age bias in the current study is related to differences in the underlying cognitive processes of gaze cueing and face recognition. While it is in the face recognition literature that own-age biases are frequently reported, gaze cueing is a notably different process than face recognition. Evidence from studies investigating event related potentials (ERPs) highlight that both processes have different time courses. The own-age bias in face recognition is expressed in the N250, a peak around 250 ms after image presentation which reflects activation of facial representations for recognition (for a review, see Wiese et al., 2013). In contrast, gaze direction is processed slightly earlier, that is, between 150 and 200 ms after gaze motion onset (Conty, N'Diaye, Tijus, & George, 2007; Itier & Batty, 2009). It is therefore possible that the neural processes underlying the own-age bias operate too slow to affect gaze cueing. Yet such an explanation conflicts with other studies that testify to the presence of an own-age bias in gaze cueing tasks, albeit with young and older adults (Bailey et al., 2014; Slessor et al., 2010). Clearly, at least for adults, there appears to be an interaction between mechanisms underlying gaze cueing and age processing. It is possible that adults' perceptual processes have been matured enough to rapidly integrate multiple sources of information that a model possibly conveys. In other words, while adults might simultaneously integrate and evaluate a model's age with the direction of the eyes, children might only become aware of a model's age after they have processed the model's eyes. In our sample of children, perceptual processes are still expected to be developing (e.g., van den Boomen, van der Smagt, & Kemner, 2012), and therefore the effect of a model's age might not yet reach these rapid perceptual processes.

The current study has some limitations as well. First, we conducted a post-hoc power analysis to determine the reliability of our results. We have to note that the observed power for the interaction between congruency and age of the stimulus model is .23. In the analysis with only the 10- and 11-year-old participants the observed power for this interaction is .11. These values are rather low and therefore replication is key. At the moment, we cannot conclude with high certainty that there is no own-age bias in gaze cueing in children. Future studies, possibly with higher sample sizes, should replicate the current study to come to more reliable conclusions. Second, we only recorded eye-tracking data and obtained no other behavioral response times such as key presses. This makes our results comparable with infant gaze cueing studies, where it is common to calculate reaction times based on eye-gaze data. However, our results are less comparable to adult gaze cueing data, as these data are mainly acquired through key presses.

We still looked at former studies to get an indication of the magnitude of gaze cueing effects over different ages. In our own study with children we observed a gaze cueing effect of 16.28 ms (95% CI [8.06, 24.51]) for child models and an effect of 11.46 ms (95% CI [4.13, 18.79]) for adult models. The young adult participants in the study of Slessor and colleagues (2010) show a gaze cueing effect of 19.95 ms for young adult models and an effect of 12.00 ms for old adult models, whereas the older participants show gaze cueing effects of 8.73 ms and 13.19 ms respectively. Last, when only assessing the results with supraliminal neutral stimuli in the study of Bailey et al. (2014), we observe a gaze cueing effect of 14.1 ms for young adult models and an effect of 6.3 ms for old adult models in young adult participants, whereas the older participants showed effects of 4.2 ms and 5.4 ms respectively. We notice here that, although not always significantly, all age groups show the largest gaze cueing effects for stimuli of their own age. When comparing gaze cueing effects for young adult stimulus models, we notice that young adult participants display the largest gaze cueing effect. The children in our own study show a slightly smaller effect than the young adults in the other two studies, whereas the older adult participants show notably smaller gaze cueing effects for these young adult stimulus models than the other two age groups. This observation is in accordance with the theory that more extensive experience with individuals of a certain age results in a bias for this category of faces (Harrison & Hole, 2009; He et al., 2011): young adults are the ones who at this stage of their lives have most experience in viewing other young adults. However, when comparing the results of these three studies we have to keep the procedural differences between these studies in mind. Whereas we used eye-tracking data, the other two studies used key presses to calculate reaction times. It is possible that this difference in responses makes the reaction times, and therefore the gaze cueing effects, less comparable. Moreover, there are other differences in experimental set-up. First, we used a picture of a face with direct gaze before the onset of the averted gaze, which was not used in the other two studies. Second, the time between the onset of the averted gaze cue and the onset of the target differed between studies. These differences might influence reaction times as well.

Overall, the results of the present study highlight that children's responses to gaze cues are not modulated by the age of the stimulus model, similar to findings in senior adults (Slessor et al., 2010). This might indicate that children consider models of either adults or of their own age as equally informative and therefore they put the same amount of effort in processing these gaze cues. In contrast, children might also be insensitive to a model's age and disregard age information in the gaze cueing process. A gaze cue on itself might have enough relevance to be processed effectively, regardless of the person one's looking at. Future research should aim at trying to disentangle these two possibilities and shed light on the possible processes taking place when reacting to gaze cues. Yet, the current results highlight that, at least in late childhood, age of the stimulus model does not modulate gaze cueing effects.

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Chapter 6

Summary and General Discussion

Over the course of development, children master many social skills to effectively communicate with, and learn from, other people. Developing proper social skills can, for instance, influence language learning in toddlerhood, making friends in adolescence and dealing successfully with the challenges of adulthood. Although social development takes place at any age, I focused in the present dissertation on two periods in development which seem especially important in acquiring proper social skills: infancy and adolescence.

During infancy, the interactions between infants and other people are increasingly facilitated by language (Rosenblum, Dayton, & Muzik, 2009). This is why I focused on the development of language at this developmental stage, as an example of a crucial social skill that starts to develop in infancy. At 24 months, the average (American-English) child understands around 300 words, although there is considerable variation among children (Frank, Braginsky, Yurovsky, & Marchman, 2017). Even though this suggests that with increasing experience infants easily learn words, their word learning is far from robust in a laboratory setting. For example, infants find it difficult to learn words uttered in adult-directed speech (Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011) or to recognize words across different speakers (Houston & Jusczyk, 2000). It is therefore key to unravel both typical and atypical language learning processes and indicate the factors which may be beneficial in the novel word learning process. The mother’s voice could be one of these facilitating factors, as this voice is efficiently processed by the infant brain (Abrams et al., 2016; Beauchemin et al., 2011; Dehaene-Lambertz et al., 2010; Naoi et al., 2012).

Compared to earlier stages, it is during adolescence that there are again extensive changes in social behavior and environments taking place. The most notable change is that the closeness with parents diminishes (Helsen, Vollebergh, & Meeus, 2000; Steinberg & Silverberg, 1986), whereas at the same time adolescents spent more time with their peers and turn to their friends as sources of advice and comfort (Bokhorst, Sumter, & Westenberg, 2010; Gould & Mazzeo, 1982; Helsen et al., 2000). This behavioral re-orientation towards peers is reflected in neural processes as well. Adolescents are worse in adult face recognition compared to both younger children and adults, whereas they excel in recognition of peer faces (Picci & Scherf, 2016). However, the question remains whether other social processes are also influenced by this behavioral re-orientation towards peers.

In the current dissertation I examined the development of several social processes in both infants and adolescents, and I considered the role that different interaction partners might play in this social processing. More specifically, in the first part of this dissertation I investigated word learning in both typical and atypical two-year-olds using the same paradigm in which infants learned from their caregivers. In the typical infants, I further contrasted whether maternal speech is advantageous for facilitating novel word learning. In the second part of this dissertation, I focused on the development of three social processes over the course of adolescence: gaze cueing of attention, emotion recognition and empathy. Furthermore, I tried to disentangle whether the behavioral re-orientation towards peers observed in adolescence has an effect on these social processes. In the following paragraphs I will summarize and discuss the experimental findings.

Part I: Language development in two-year-olds

Summary of results

First, in *Chapter 2*, I investigated whether maternal speech boosts novel word learning processes in a typical sample of two-year-olds. This hypothesis was confirmed: the results of this study showed that infants who were taught by their own mother formed new word-object mappings, whereas infants who were taught by an unfamiliar person did not. This is in accordance with other studies which reported on beneficial effects of the mother’s voice on language processing (e.g., Barker & Newman, 2004; Parise & Csibra, 2012). *Chapter 2* thus shows that these beneficial effects extend to the process of novel word learning in 24-month-olds.

This study also examined whether the advantage of maternal speech holds across two different learning settings: a live interaction setting in which an infant is actively taught novel words, and a prerecorded setting in which the voice is played over loudspeakers. Results showed that the advantage of maternal speech holds across both learning settings. It therefore seems that there is no additional advantage of the mother uttering the words directly compared to having her speech prerecorded. This suggests that the acoustic aspects of the mother's voice aid novel word learning (Bortfeld, Shaw, & Depowski, 2012), as live interaction with her does not result in additional learning effects.

The third variable which was taken into account in this study was the infant's own behavior during the task (i.e., novel word repetition and pointing gestures). We observed a trend which indicated that infants tend to repeat more target words when they listened to their own mother compared to when they listened to an unfamiliar voice. In addition, the infants who repeated more target words showed better learning effects. When inspecting pointing behavior, results showed that infants made more pointing gestures in the live interaction learning setting compared to the prerecorded setting. However, the amount of pointing gestures made during the task was not related to learning outcomes. Taken all of these results together it appears that whereas learning setting does not seem to affect novel word learning abilities, the person who provides the speech has high impact on learning outcomes and possibly also affects child behaviors which contribute to word learning processes.

Second, in *Chapter 3*, the novel word learning abilities of two-year-olds at risk for autism spectrum disorder (ASD) were compared to word learning in typically-developing infants. Since intervention studies, as well as the study reported in *Chapter 2*, highlight the important role of caregivers in the word learning process (McConachie & Diggle, 2007), we relied on the parents to provide the learning input to the infants. We observed no difference in word learning abilities between high- and low-risk infants, although high-risk infants exhibited a lag in vocabulary size according to parental questionnaires. The language impairments observed in children with ASD are therefore unlikely to originate in the initial process of word-object mapping, but rather result from deficiencies in for example language consolidation or higher level social demands of interactive communication. This study is a vital step in assessing the sources of autistic children's language difficulties and might inform on the initiation of new intervention strategies with a primary role for the children's caregivers.

Methodological considerations

It can be difficult to determine whether an observed effect is a robust effect. Of course, replication is one way to examine robustness (Duncan, Engel, Claessens, & Dowsett, 2014). Another way is to examine results by embedding them in the existing literature and compare them with other previously published studies. Whether or not an effect is found can further be dependent on the way in which one defines or calculates the dependent variables. In a preferential looking paradigm, in which two objects are presented side-by-side on the screen and the infant is asked to look at one of the objects, there are multiple ways in which novel word learning performance can be assessed. Reported measures are percentage looking time for each object, duration of first look, position of first look, longest look at each object and total looking time for each object over the whole or a part of a test trial, calculated from word onset. Studies also differ in the time window in which they calculate these measures. The way in which word learning is assessed can alter results and might account for differences in results between studies. For example, in *Chapter 2* we observed no significant word learning in the group of infants who were taught by an unfamiliar voice. However, in the study of Ma and colleagues (2011), which served as the basis of our own procedure, both 21- and 27-month-olds were able to learn novel words from an unfamiliar voice as long as they were addressed in infant-directed speech. The fact that our 24-month-olds did not seem to learn novel words while they were addressed in infant-directed speech might therefore be surprising. However, when we look at the way in which novel word learning was assessed, we see that Ma and colleagues (2011) used the single longest look at the target and the non-target over the complete seven-second test trial, whereas we used percentage looking time over a specific two-second time window. Furthermore, looking behavior was manually coded in the study of Ma and colleagues (2011), whereas we used an eye-tracker with a high sampling rate to assess gaze behavior. Our data is therefore more precise and better timed, which makes fixation detection more accurate. These might be explanations for the differences in results. For studies to be better comparable, there should be consensus (a priori) on how to asses specific dependent variables, or multiple analyses should be reported.

Another methodological consideration to keep in mind while performing infant studies is that infants have a limited attention span. Consequently, this restricts the number of stimulus manipulations and the number of stimuli within one manipulation that could be presented. For example, all conditions of the research in *Chapter 2* (i.e., live/mother; live/unfamiliar; recorded/mother; recorded/unfamiliar) were tested using a between-subjects design, yet using a within-subjects design would comprise a more ideal test setting as the amount of confounding variables between different conditions is minimized. However, since the different groups in the study of *Chapter 2* did not differ in age or other background variables, the comparison between groups is still valid.

In addition, if it had been possible to extend testing time we also could have included an unfamiliar voice condition in the experiment with the high-risk infants. It is specifically important to keep limitations in attention span in mind when performing comparative studies with atypical samples. Estimates suggest that 31% of the children with ASD meet diagnostic criteria for attention deficit/hyperactivity disorder (ADHD) and an additional 24% of the children exhibit sub-clinical yet elevated ADHD symptoms (Leyfer et al., 2006). This suggests that ASD samples might be even more reduced in their attention span while performing experimental tasks, although such an effect was not observed in the study of *Chapter 3*.

Finally, sample sizes are not always as large as one had hoped for. Although the sample size in *Chapter 2* exceeded my expectations, because so many parents indicated their willingness to participate in this particular experiment, the reality is that often the opposite takes place: there are not as many subjects as one had anticipated for during the time span of the study. For example, in *Chapter 3* there were only 29 infants included in the final analysis, despite that fact that this project was running for four years. Similarly, *Chapter 5* (tested on a public event) included enough subjects to warrant further analysis of results, but the range of ages and the allocation of participants over different age groups was not distributed equally, making it difficult to draw firm conclusions. Both chapters observed null-findings with small sample sizes, and we cannot be sure that we would replicate these outcomes with larger samples. These results should therefore be taken as a first step, awaiting confirmation from future studies.

Future directions

The first question to answer in future research is how the word-object mapping behavior observed in *Chapter 2* and *Chapter 3* of this dissertation relates to actual word learning in real life. The studies reported in this dissertation show that two-year-olds are able to pair a certain word with a certain object in an on-line learning paradigm. It is however unclear if and for how long these words are then retained in long-term memory. Would the infants be able to store the word-object pairs and retrieve this information one hour, one week or one month after testing? And which factors contribute to effective consolidation of novel words? These are questions that I could not address with the current word learning paradigm, yet are worthy to examine.

The next question would then be to examine whether it is this storage in long-term memory which is deficient in infants at risk for ASD compared to typically-developing children. Although parent questionnaires consistently indicate deficient language development in high-risk infants (Mitchell et al., 2006; Yirmiya, Gamliel, Shaked, & Sigman, 2007; Zwaigenbaum et al., 2005; *Chapter 3*), we did not observe differences in performances between high- and low risk infants in an experimental word learning set-up (*Chapter 3*). This suggests that the initial word-object pairing - as tested with the current paradigm - is intact in high-risk infants, yet a behavioral lag in vocabulary size is observed by parents. A possible explanation is that high-risk infants, in contrast to low-risk infants, are unable to use feedback on their performance in a word learning task to store the novel words in long-term memory (Bedford et al., 2013). Future research should tap further into language processes to examine whether it is indeed the long-term storage of words, instead of the initial word-object pairing, that is impaired in children with ASD. Furthermore, novel word learning should be assessed with other paradigms, such as the cross-situational word learning paradigm

(Smith, Smith, & Blythe, 2011) or the switch paradigm (Werker, Cohen, Lloyd, Casasola, & Stager, 1998), to examine whether our results are generalizable to other test situations.

Another topic for future research would be to examine how wide-spread the effect of speaker familiarity on novel word learning is. In *Chapter 2*, I solely investigated the effect of maternal speech, but there are usually more caretakers involved. Infants also have numerous interactions with for instance the father or other caretaker, grandparents and caretakers at child care facilities. The question remains whether the current observed beneficial effect is solely attributable to the mother's voice or whether other familiar voices have similar effects on word learning abilities. Future research should investigate whether there might be a relation between the amount of exposure to a certain voice and the effect this voice has on word learning abilities.

In addition, it would be interesting for future research to examine what explains the beneficial effect of the mother’s voice as observed in *Chapter 2*. As explained in the *General Introduction*, the mother’s voice could facilitate novel word learning in at least two (not mutually exclusive) ways. The acoustic account predicts that it is the familiarity with the mother’s voice itself that results in more efficient voice processing (Purhonen, Kilpeläinen-Lees, Valkonen-Korhonen, Karhu, & Lehtonen, 2004; 2005). Indeed, research with typically-developing infants highlight their initial difficulty in recognizing words that deviate from the trained acoustic form, for instance because of a change in the speaker’s mood (Singh, 2008) or because of a change to an atypical accent (Best, Tyler, Gooding, Orlando, & Quann, 2009; Schmale, Cristia, Seidl, & Johnson, 2010). These studies suggest that infants focus on the acoustic form of a word in the initial learning process before a generalization to other speakers or accents is made.

Another explanation for the positive maternal influence on word learning could be socially motivated. As children experience so many occasions of word learning from their mother in their daily life, they might be better able to recognize the goal of the word learning situation. This awareness in turn is likely to boost their motivation, which further aids novel word learning (Bruner, 1981; Smith, 2000; Spelke, Bernier, & Skerry, 2013; Tomasello, 2003). There is indeed accumulating evidence that typically-developing children also rely on social aspects of speakers to guide their word learning. For instance, infants show better word learning abilities when there is joint attention between speaker and child (Baldwin, 1993), when there is social contingency between speaker and child (Roseberry, Hirsh-Pasek, & Golinkoff, 2014; Tamis-LeMonda, Kuchirko, & Song, 2014), or when infants learn from reliable speakers rather than unreliable speakers (Crivello, Phillips, & Poulin-Dubois, 2018).

Note that both explanations – the acoustic and the social account – are not mutually exclusive; it is likely that (for typically-developing infants) both explanations work in tandem to contribute to a facilitated word learning situation (Bortfeld et al., 2013). Although *Chapter 2* suggests that there is no additional advantage of the mother uttering the words directly to the infant compared to having her speech prerecorded, social interaction was rather constrained in both learning situations as the texts were scripted. Furthermore, the mother was still present in the room in the prerecorded setting, although social interaction between the infant and the mother was discouraged. Possibly, the two learning situations did not differ sufficiently enough to find effects. Future research should try to disentangle these two accounts even further, to examine the specific contributions of different social factors to novel word learning.

Last, we cannot discern whether the typically-developing infants and the infants at risk for ASD differ in valuing which cue (i.e., acoustic familiarity or social motivation) is more relevant to them in the word learning process, despite their equal performances in our word learning task. Although children with (increased risk for) ASD are widely regarded as socially impaired, which suggests that they minimally rely on social cues (Parish-Morris, Hirsh-Pasek, Hennon, Golinkoff, & Tager-Flasberg, 2007), this does not automatically mean that they rely only on acoustic familiarity and preclude their ability to use any social cue. Consequently, our results do not allow us to conclude that these infants must have relied predominantly on the acoustic familiarity in the word learning process. Future studies that also include unfamiliar voices are required to first examine if a familiarity effect exist in high-risk infants, and then investigate whether high- and low-risk infants differ in which cue is more relevant to them in the word learning process.

Part II: Social development in adolescence

Summary of results

In *Chapter 4* the developmental time courses of three social processes were examined: gaze cueing of attention, emotion recognition from the eyes and empathy. More specifically, it was tested whether participants’ performances in these three domains showed a ‘pubertal dip’, as is observed in basic face recognition (Diamond, Carey, & Back, 1983; Picci & Scherf, 2016). As all of the social abilities under investigation in *Chapter 4* rely on brain circuitries centered around the superior temporal sulcus (STS), as does face recognition, we expected that these abilities would also be influenced by the onset of puberty.

To our knowledge, *Chapter 4* reports on the first study which examined the development of gaze cueing of attention in a sample of adolescents. The results of the gaze cueing task indicated an overall gaze cueing effect, yet there was no interaction with pubertal status. Thus, our results showed no change in this effect over this developmental period, although a trend indicated a slight decline in the gaze cueing effect across adolescence. These results suggest that the gaze cueing effect is fairly robust and not easily influenced by individual factors such as the participant's age.

The second task discussed in *Chapter 4* assessed emotion recognition abilities. In this task a pubertal status effect was observed. The prepubertal children performed worse on this task compared to the mid- and postpubertal children, who did not differ in their performances. This result suggests that emotion recognition in the eye region first increases but later reaches a plateau. Whether the mid- and postpubertal groups performed as good as adults, or whether this ability further increases after adolescence has yet to be determined.

The last social ability under investigation in *Chapter 4* was empathy. Also in the empathy measures a pubertal status effect was observed. The prepubertal children showed lower empathetic abilities than the postpubertal children, yet no differences with the midpubertal children were observed. These results suggest a small gradual improvement in empathizing abilities over the course of adolescence. In contrast to the two previous tasks, there was also a sex difference in performances on the empathy measure. Overall, girls had higher scores than boys on the empathy questionnaire.

Taken the performances on all these tasks together, we can conclude that social behavior undergoes several changes over adolescence. Yet, a ‘pubertal dip’ as is observed in basic face recognition cannot be observed in the social processes examined in *Chapter 4*. It seems therefore unlikely that the onset of puberty, and the influx on gonadal hormones associated with this pubertal onset, has direct effects on higher order social processes.

It is noteworthy that the tasks of *Chapter 4* are all performed with adult stimuli. However, during adolescence a behavioral re-orientation from adults to peers takes place (Scherf, Behrmann, & Dahl, 2012). It is therefore possible that adolescents would perform differently on certain social tasks when child stimuli instead of adult stimuli are used. This question was addressed in *Chapter 5* for the process of gaze cueing of attention. More specifically, it was tested whether young adolescents show different gaze following behaviors when confronted with either an adult or a peer who provides the gaze cues. The study however failed to find effects of age of the stimulus model on performances on the gaze cueing task. Even when the age of the participants was closely matched to the age of the child stimulus models, an effect was absent. These results highlight that children’s responses to gaze cues are not modulated by the age of the stimulus model. This might indicate that children consider models of either adults or of their own age as equally informative and therefore they put the same amount of effort in processing these gaze cues. In contrast, children might also be insensitive to a model’s age and disregard age information in the gaze cueing process. Future research should shed light on the possible processes taking place when processing gaze information.

Methodological considerations

Social processes can be measured in many different ways. When looking at the gaze cueing task, responses can be acquired in (at least) two different ways. Reaction times are either determined based on key presses (i.e., press left or right the moment you detect a target in a certain location) or by measuring eye-movements with an eye-tracker (i.e., fixate on the target as fast as possible the moment it appears). For practical reasons, infants' reaction times are measured with an eye-tracker (or looking behavior is manually coded based on video recordings). However, in adult studies key presses are also frequently used to determine target detection times. It is therefore hard to compare results between studies, as reaction times are by definition longer when a key press is required after visual detection of the target. The cited literature in *Chapter 5* about the own-age effect in gaze cueing also reports reaction times based on key presses (Bailey et al., 2014; Slessor, Laird, Phillips, Bull, & Filippou, 2010). Although I expect that the presence of a gaze cueing effect is not dependent on the method in which responses are acquired, this is not yet explicitly tested. It is therefore unknown if and how this variable affects reaction times. This makes it impossible to directly compare our observed gaze cueing effects in children with those of adults. To be able to reliably comment on the developmental time course of social processes, similar methods should be used across different ages. As it is hard, if not impossible, for infants and young children to use button boxes or keyboards for their responses, research should shift towards the use of eye-tracking (or brain imaging techniques) as the main instrument. In this way, it becomes possible to directly compare the performances of adolescents and adults with those of infants and toddlers.

Second, the gaze cueing paradigm might not be ideal to measure how social interaction partners influence the sensitivity to gaze cues. Studies examining the influence of the characteristics of the used stimuli on gaze cueing, such as familiarity and age effects, report small or only marginally significant effects (Deaner, Shepherd, & Platt, 2007; Slessor et al., 2010; *Chapter 5*) or find effects only in one experimental manipulation (Bailey et al., 2014). A possible explanation for these small effects might be that all these experiments are conducted in a lab-setting. When performing social experiments, the question arises whether testing in such an artificial environment, in combination with the use of static stimulus material, is comparable to the myriad of different dynamic social interactions in real life. Especially for adolescents, social status and peer judgments are very important (Steinberg & Monahan, 2007). It might be possible that we find no own-age effect in *Chapter 5* because the adolescents disregard the social relevance of a static image and therefore show similar gaze behavior regardless of the stimulus material. How a child responds to a picture of either an adult or a peer cannot influence the relationship with that person. This might be different when real social interactions are at play, as it has been shown that the physical presence of social partners influences gaze behavior (Freeth, Foulsham, & Kingstone, 2013; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012). However, performing social experiments outside the lab can be challenging because of the many confounding variables which possibly influence the procedure, especially when eye-tracking or other instruments are used. Recent developments therefore aim to make social lab experiments more realistic. For example, Hessels and colleagues (2017; 2018; 2019) developed a social interaction set-up in which two participants have the ability to look at each other and engage in social interaction through a video connection while the gaze behavior of both of them is measured. This is a vital step in maintaining control of the environment while participants can freely interact with each other. This advancement is very promising for future social studies, also when examining developmental samples. It becomes possible to observe social interactions between infants and their parents, or between adolescents and their friends, while simultaneously recording their gaze behavior. Research employing these kind of measures might extend on studies with static stimulus material, such as the gaze cueing paradigm, and may inform whether the results of previous studies are generalizable to situations in which real social interaction takes place.

Future directions

First, *Chapter 5* shows that adolescents do not exhibit an own-age bias in gaze following behavior. We are however unable to pinpoint the origin of the absence of an effect. Do adolescents disregard age information when reacting to gaze cues, or are the gaze cues of both peers and adults valued equally important? Our null results cannot answer these questions, because these factors were not measurable with our gaze cueing paradigm. Future research should include additional measures on how the different stimuli are valued. Moreover, longitudinal designs could give more information about the moment in development where interactions with peers are valued as more important than interactions with adults and the moment when an own-age bias in gaze cueing arises. However, when inspecting the results of *Chapter 4*, we see that pubertal status does not affect gaze behavior in response to gaze cues. One might therefore expect that an own-age bias will also not express itself in the gaze behavior of adolescents.

All experiments reported in *Chapter 4* and *Chapter 5* of the present dissertation hint in the direction that pubertal status as well as the age of the interaction partner do not influence social information processing in adolescents. The question then arises why these factors do seem to influence basic face processing (Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Diamond et al., 1983; Hills, 2012; Hills & Lewis, 2011; Lindholm, 2005; Picci & Scherf, 2016), while other social processes remain unaffected. If the observed effects in face processing are indeed due to the influx of gonadal hormones at the onset of adolescence (Scherf et al., 2012), how is it possible that these hormones only affect face processing systems? Or is there no relation between gonadal hormones and face processing, but is there another explanation for the 'pubertal dip' and the own-age effect observed in the performances on face recognition tasks (c.f., Chung & Thomson, 1995)? Future research should aim at examining which social processes exhibit a 'pubertal dip' in performance. Once we know which exact processes change over adolescence, and in what direction, it also becomes easier to form and test hypotheses on the underlying cause.

General conclusion

The general aim of the current dissertation was to examine social information processing in infants as well as adolescents, and to investigate the possible role of different interaction partners in these social processes. Based on the research described in this dissertation, we can conclude that familiarity with the interaction partner indeed plays an important role in infants' language processing. Infants learn novel words better from their own mother compared to an unfamiliar person. Moreover, infants at risk for ASD exhibit similar novel word learning abilities as typically-developing infants when they are taught by their own parents, yet it is still unclear whether a familiar voice boosts language processing in this atypical sample. When we turn to adolescence, an influence of the type of interaction partner appears to be absent. When adult stimuli are used, adolescents do not decline in their performances on social tasks and no own-age effect was observed. These results imply that interaction partners can shape early social development, as is hypothesized in several models on the development of social systems (Rosenblum et al., 2009). However, later in development, the interaction partner does not seem to have an impact on social information processing, at least not on the processes under investigation in the present dissertation. This knowledge is fundamental for the design of early interventions for infants and children with communicative disorders, and gives information on who might be the most suitable person to provide these interventions to the children.

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Appendix I

Nederlandse Samenvatting

Doel van het onderzoek

Gedurende de ontwikkeling leren kinderen verschillende sociale vaardigheden aan, wat hen in staat stelt om te communiceren met, en te leren van, andere mensen. Hoewel sociale vaardigheden zich gedurende het hele leven door blijven ontwikkelen, zal ik in dit proefschrift focussen op twee speciale periodes in de ontwikkeling; de peutertijd en de pubertijd. In de peutertijd zal de focus van het onderzoek liggen op het aanleren van nieuwe woorden, terwijl in de pubertijd vooral gekeken zal worden naar non-verbale sociale processen.

In de peutertijd gaat taal een steeds belangrijkere rol spelen in de communicatie tussen een kind en de mensen in zijn omgeving (Rosenblum, Dayton, & Muzik, 2009). Tweejarigen begrijpen gemiddeld al 300 verschillende woorden, hoewel er grote verschillen zijn tussen kinderen (Frank, Braginsky, Yurovsky, & Marchman, 2017). Het is echter onbekend waar deze verschillen tussen kinderen vandaan komen. Om kinderen die achterlopen in hun taalontwikkeling goed te kunnen ondersteunen, is het van belang om te achterhalen welke factoren een positief effect kunnen hebben op de taalontwikkeling. Een mogelijke factor met een positief effect op het woordleerproces is de moeders stem, omdat dit de stem is waarmee kinderen het meest bekend zijn. Het is echter nog nooit onderzocht of de moeders stem kinderen inderdaad helpt om nieuwe woorden te leren. Daarom is in het eerste deel van dit proefschrift de rol van de moeders stem in het aanleren van nieuwe woorden onderzocht.

Ook in de pubertijd vinden er grote veranderingen plaats in het sociaal gedrag van kinderen. Het contact met de ouders wordt over het algemeen minder (Helsen, Vollebergh, & Meeus, 2000; Steinberg & Silverberg, 1986), terwijl tegelijkertijd steeds meer tijd doorgebracht wordt met leeftijdsgenoten (Bokhorst, Sumter, & Westenberg, 2010; Helsen et al., 2000). Het toenemende contact met leeftijdsgenoten lijkt ook invloed te hebben op de verwerking van visuele informatie, met name de verwerking van gezichten. Adolescenten zijn tijdelijk relatief slechter in het herkennen van volwassen gezichten, terwijl ze juist erg goed zijn in het herkennen van gezichten van leeftijdsgenoten (Picci & Scherf, 2016). De vraag is of andere sociale processen, naast alleen gezichtsherkenning, ook beïnvloed worden door het toenemende contact met leeftijdsgenoten. Dit is onderzocht in het tweede deel van dit proefschrift.

Deel I: Het aanleren van nieuwe woorden door tweejarigen

In het eerste deel van dit proefschrift ligt de focus op taalprocessen bij tweejarigen. Dit is een interessante leeftijdsgroep, omdat kinderen rond deze leeftijd een enorme ontwikkeling in hun taalgebruik laten zien (e.g., Goldfield, & Reznick, 1990). Deze vroege taalontwikkeling lijkt belangrijk te zijn voor de verdere ontwikkeling van het kind. De woordenschat van een kind op tweejarige leeftijd is bijvoorbeeld gerelateerd aan verschillende taal- en cognitieve vaardigheden wanneer het kind acht jaar oud is (Marchman & Fernald, 2008). Het is daarom van belang om al op vroege leeftijd zowel normale als afwijkende taalontwikkeling te onderzoeken, zodat kinderen met een achterstand al in een vroeg stadium ondersteund kunnen worden. Een mogelijk ondersteunende factor in het woordleerproces is de stem van de eigen moeder, omdat deze stem leidt tot verhoogde hersenactiviteit in zowel taal-, aandachts- en motivatiegebieden (Beauchemin et al., 2011; Dehaene-Lambertz et al., 2010; Naoi et al., 2012). Het directe effect van de moeders stem op het leren van nieuwe woorden is echter nog nooit onderzocht. Daarom is de rol van de moeders stem in het woordleerproces verder onderzocht in het eerste deel van dit proefschrift.

De invloed van de moeders stem op het aanleren van nieuwe woorden

Vanaf twee maanden oud zijn baby's in staat om verschillende stemmen te onderscheiden en te herkennen (Boyd, 1974). De stem van de eigen moeder wordt zelfs nog eerder herkend. Pasgeboren baby's laten namelijk al een voorkeur zien voor hun moeders stem en ook in de baarmoeder gaat de hartslag van de foetus omhoog tijdens het horen van de stem van de eigen moeder (Kisilevsky et al., 2003; 2009). Daarnaast is aangetoond dat zeer jonge baby's een verhoogde hersenactiviteit laten zien voor het horen van hun moeders stem vergeleken met onbekende stemmen (Beauchemin et al., 2011; Dehaene-Lambertz et al., 2010). Dit suggereert dat de moeders stem een belangrijke functie vervult, en mogelijk ook een rol speelt in het verwerken van taal.

Ondanks dat verschillende studies aantonen dat kinderen vanaf de geboorte een voorkeur hebben voor de moeders stem is het effect van haar stem op het aanleren van nieuwe woorden nog amper onderzocht. Daarom is in *Hoofdstuk 2* specifiek onderzocht of de moeders stem een positieve invloed heeft op het woordleerproces bij peuters. In dit onderzoek leerde één groep kinderen nieuwe woorden van hun eigen moeder, terwijl een andere groep woorden aangeleerd kreeg door een voor hen onbekend persoon. De resultaten laten zien dat kinderen in staat waren om snel nieuwe woorden te leren als ze het experiment samen met hun eigen moeder uitvoerden. De kinderen die het experiment uitvoerden met een voor hen onbekend persoon hadden de nieuwe woorden echter niet aangeleerd. De moeders stem lijkt dus inderdaad een positief effect te hebben in het woordleerproces. Dit resultaat komt overeen met andere studies die een positief effect van de moeders stem op verschillende taalprocessen, zoals woordvormherkenning en het herkennen van bekende woorden, laten zien (e.g., Barker & Newman, 2004; Parise & Csibra, 2012).

Dit positieve effect van de moeders stem kan op ten minste twee manieren verklaard worden. Ten eerste is het mogelijk dat de vertrouwdheid met de moeders *stem* leidt tot een efficiënte verwerking in de hersenen, waardoor het voor kinderen eenvoudiger is om te begrijpen, en op te slaan, wat er gezegd wordt (Barker & Newman, 2004; Bortfeld, Shaw, & Depowski, 2013; Purhonen, Kilpeläinen-Lees, Valkonen-Korhonen, Karhu, & Lehtonen, 2005). Bij een onbekende stem moeten ze eerst wennen aan de stem voordat deze efficiënt verwerkt kan worden. Ten tweede bestaat de mogelijkheid dat kinderen in de aanwezigheid van hun moeder een nieuwe leersituatie sneller herkennen, omdat ze immers vaker woorden van haar geleerd zullen hebben. Hierdoor kunnen ze de nieuwe informatie sneller tot zich nemen (Bruner, 1981; Smith, 2000; Spelke, Bernier, & Skerry, 2013; Tomasello, 2003).

Het is vrijwel onmogelijk om deze twee verklaringen los van elkaar te onderzoeken, want de ene verklaring sluit de andere verklaring niet uit. Om toch een indicatie te krijgen van welke verklaring het meeste bijdraagt aan het leerproces zijn in

Hoofdstuk 2 twee verschillende leersituaties toegepast. De helft van de kinderen leerden nieuwe woorden door live interactie met hun eigen moeder (i.e., bekend persoon met bekende stem) of de experimentleider (i.e., onbekend persoon met onbekende stem), terwijl de andere helft alleen de vooraf opgenomen stem van hun eigen moeder (i.e., bekende stem) of die van een andere moeder (i.e., onbekende stem) hoorden. Deze opzet stelde ons in staat om te onderzoeken of de interactie die mogelijk is in de live situatie een positieve invloed heeft op het woordleerproces. De resultaten laten echter zien dat de leereffecten in beide situaties vergelijkbaar zijn. Het lijkt er daarom op dat er geen extra voordeel is van de mogelijkheid tot live interactie tussen moeder en kind ten opzichte van het afspelen van een vooraf opgenomen stem. Deze uitkomst suggereert dat vooral de vertrouwdheid met de moeders stem, en niet zozeer de fysieke aanwezigheid van de moeder, een kind helpt om nieuwe woorden te leren.

Kinderen met een verhoogd risico op een autisme spectrum stoornis

In het hiervoor beschreven onderzoek is gekeken naar de normale taalontwikkeling, maar in het volgende onderzoek zal gekeken worden naar de afwijkende taalontwikkeling bij kinderen met een verhoogd risico op een autisme spectrum stoornis (ASS). ASS is een ontwikkelingsstoornis die zich kenmerkt door afwijkingen in sociale interactie en communicatie (DSM-V; American Psychiatric Association, 2013). Sinds kort wordt een achterstand in de taalontwikkeling niet meer gezien als een essentieel kenmerk voor de diagnose van ASS (DSM-V; Constantino & Charman, 2016), maar psychologen zien een achterstand in de woordenschat nog steeds als één van de belangrijkste eerste symptomen in kinderen met ASS (Wetherby, Watt, Morgan, & Shumway, 2007). Vanaf ongeveer 12 maanden oud beginnen kinderen met ASS achter te lopen in hun taalontwikkeling en deze achterstand blijft in de kindertijd bestaan (Charman, Drew, Baird, & Baird, 2003; Hudry et al., 2010; Landa & Garrett-Mayer, 2006; Mitchell et al., 2006; Yirmiya, Gamliel, Shaked, & Sigman, 2007; Zwaigenbaum et al., 2005). Ook is aangetoond dat kinderen meer moeite hebben met het aanleren van nieuwe woorden naarmate de ernst van de ASS symptomen toeneemt (Gliga et al., 2012).

Ondanks dat vele studies concluderen dat kinderen met ASS achterlopen in hun taalontwikkeling, is het van belang hierbij te vermelden dat deze studies woordenschat meten aan de hand van vragenlijsten ingevuld door de ouders van het kind. Deze vragenlijsten kunnen een vertekend beeld geven, omdat ouders vaak een expliciete reactie van hun kind verwachten als bewijs dat het kind een bepaald woord begrijpt (Houston-Price, Mather, & Sakkalou, 2007). Het is echter mogelijk dat een kind niet altijd reageert zoals een ouder zou verwachten. Dit zou voornamelijk het geval kunnen zijn bij kinderen met ASS, die op zichzelf al moeite hebben met sociale interacties. Als ouders het gedrag van hun kind niet juist interpreteren, dan kan dit ertoe leiden dat ze verkeerd inschatten welke woorden hun kind wel en niet begrijpt. Dit resulteert dan in een onderschatting van de werkelijke woordenschat van hun kind.

Het is opmerkelijk dat experimenteel bewijs dat kinderen met ASS achterlopen in hun taalontwikkeling grotendeels ontbreekt. Daarom is in *Hoofdstuk 3* experimenteel onderzocht, met behulp van een eye-tracker, of tweejarigen met een verhoogd risico op ASS (deze kinderen hebben een oudere broer of zus met ASS) verschillen van normaal ontwikkelende kinderen in het aanleren van nieuwe woorden. Door gebruik te maken van een eye-tracker hoeven kinderen geen expliciete reactie te geven na het noemen van een bepaald woord om vast te stellen of ze de betekenis van dit woord kennen. In plaats daarvan werd op basis van hun oogbewegingen bepaald of ze naar het goede voorwerp keken op het moment dat dit voorwerp benoemd werd. Omdat verschillende interventiestudies (McConachie & Diggle, 2007), als ook de resultaten van *Hoofdstuk 2*, aangeven dat ouders belangrijk zijn in het woordleerproces, hebben we ouders gevraagd om in dit experiment de nieuwe woorden aan te leren.

De resultaten van dit experiment laten zien dat kinderen met een verhoogd risico op ASS niet verschillen van normaal ontwikkelende kinderen in het aanleren van nieuwe woorden. De woordenschat van de kinderen met een verhoogd risico op ASS, zoals gemeten met de vragenlijst ingevuld door ouders, was echter wel lager dan de woordenschat van de normaal ontwikkelende kinderen. Dit kan aantonen dat ouders van kinderen met een verhoogd risico op ASS de woordenschat van hun kind inderdaad onderschatten. Het is echter ook mogelijk dat er wel degelijk een verschil in woordenschat is tussen beide groepen, maar het is onwaarschijnlijk dat dit verschil zijn oorsprong vindt in het proces van het koppelen van een nieuw woord aan een nieuw voorwerp, iets wat beide groepen even goed konden in het huidige experiment. Het is waarschijnlijker dat het probleem ligt in bijvoorbeeld de consolidatie van de nieuwe woorden of in meer complexe communicatieprocessen. Deze studie is een zeer belangrijke eerste stap in het achterhalen van de oorsprong van de taalachterstand in kinderen met ASS en legt een basis voor verder onderzoek naar afwijkende taalprocessen in deze groep kinderen.

Methodologische overwegingen

Wat van belang is om in gedachten te houden bij onderzoek met een eye-tracker, zoals in *Hoofdstuk 2* en *Hoofdstuk 3,* is dat de afhankelijke variabelen op verschillende manieren berekend kunnen worden. Om te onderzoeken of kinderen de nieuwe woorden geleerd hadden, hebben we gebruik gemaakt van het 'preferential looking paradigm', waarbij twee voorwerpen naast elkaar getoond worden op een scherm en het kind gevraagd wordt naar één van de objecten te kijken. Hierbij zijn er ook verschillende manieren waarop kijktijd gerapporteerd kan worden. Maten zoals percentage kijktijd per object, tijdsduur van de eerste fixatie, positie van de eerste fixatie, langste fixatie per object en totale kijktijd per object over de gehele of een deel van de trial worden gebruikt om resultaten te rapporteren. Het gebruik van verschillende maten kan onderliggend zijn aan een verschil in uiteindelijke conclusies tussen studies. Om onderzoek in de toekomst goed te kunnen vergelijken is het belangrijk dat er consensus komt over welke maat het meest geschikt is om de resultaten te berekenen en te rapporteren.

Daarnaast hebben tweejarigen vaak een gelimiteerde aandachtsspanne. Hierdoor is het aantal trials en het aantal manipulaties wat aangeboden kan worden in een experiment beperkt. Het is nog extra van belang om rekening te houden met deze gelimiteerde aandachtsspanne wanneer kinderen met een beperking getest worden. Onderzoek wijst uit dat ongeveer 31% van de kinderen met ASS ook gediagnosticeerd is met ADHD en nog eens 24% van de kinderen met ASS laat subklinische symptomen van ADHD zien (Leider et al., 2006). Het is daarom goed mogelijk dat kinderen met ASS een nog lagere aandachtsspanne hebben dan normaal ontwikkelende kinderen, wat de resultaten van vergelijkende onderzoeken kan beïnvloeden. Een extra check in *Hoofdstuk 3* laat echter zien dat er in deze groep proefpersonen tijdens de leerfase van het experiment geen aandachtsverschil (i.e., totale kijktijd naar het scherm) was tussen de hoog en laag risico kinderen.

Vervolgonderzoek

Een voorstel voor toekomstig onderzoek is om te onderzoeken hoe het aanleren van nieuwe woorden, zoals aangetoond in de experimenten van *Hoofdstuk 2* en *Hoofdstuk 3*, vergelijkbaar is met woordleerprocessen zoals deze plaatsvinden in het dagelijks leven. Onze studies laten zien dat tweejarigen in staat zijn om een onbekend woord te koppelen aan een onbekend object in een woordleer-experiment. Het is echter onbekend of de kinderen ook in staat waren om deze koppeling op te slaan in het langetermijngeheugen. Weten ze na een uur, een week, of een maand nog welk woord bij welk object hoort? En welke factoren (e.g., moeders stem, leersituatie) dragen bij aan een effectieve consolidatie in het langetermijngeheugen? Dit zijn vervolgvragen die niet beantwoord konden worden met de huidige opzet van de experimenten.

Daarnaast is het interessant om verder te onderzoeken of het effect wat gevonden werd voor de moeders stem generaliseerbaar is naar andere, voor het kind bekende, personen. In *Hoofdstuk 2* is alleen gekeken naar de rol van de moeders stem in het aanleren van nieuwe woorden. Kinderen hebben natuurlijk ook veel interactie met andere verzorgers, zoals de tweede ouder, grootouders en groepsleiders op de kinderopvang. De vraag is of deze personen ook een positief effect kunnen hebben op verschillende taalprocessen. Vervolgonderzoek kan zich richten op een mogelijk verband tussen de bekendheid van een bepaalde stem en de invloed van deze stem op het aanleren van nieuwe woorden.

Deel II: Het verwerken van sociale informatie door adolescenten

In het tweede deel van dit proefschrift verschuift de aandacht van tweejarigen naar adolescenten. De pubertijd wordt gedefinieerd als de periode tussen 13 en 19 jaar oud, al kunnen de fysieke veranderingen die horen bij deze periode al eerder starten (tussen de 9 en 12 jaar oud). Omdat de taalontwikkeling rond deze leeftijd grotendeels afgerond is, worden in deze groep non-verbale sociale processen onderzocht. De pubertijd is een zeer interessante periode voor het onderzoeken van sociale processen, vanwege de grote veranderingen die plaatsvinden in de sociale omgeving van deze kinderen. Adolescenten richten zich steeds meer op vriendschappen en romantische relaties met leeftijdsgenoten, terwijl de omgang met de ouders wat afneemt. Het doel van het tweede deel van dit proefschrift is om te onderzoeken of deze toenemende focus op leeftijdsgenoten invloed heeft op de verwerking van sociale informatie.

Puberale ‘dip’ in sociale processen

De verwerking van sociale informatie lijkt inderdaad te veranderen rond het begin van de pubertijd. Verschillende studies laten zien dat adolescenten tijdelijk relatief slechter worden in het verwerken van volwassen gezichten en emotionele gezichtsuitdrukkingen (e.g., Carey, Diamond, & Wood, 1980; Diamond, Carey, & Back, 1983; McGivern, Andersen, Byrd, Mutter, & Reilly, 2002; Peters & Kemner, 2017). Tegelijkertijd zijn ze beter in het herkennen van gezichten van leeftijdsgenoten in vergelijking met volwassenen en jongere kinderen. Dit proces lijkt gemoduleerd te worden door hoe lang kinderen al in de pubertijd zitten. Kinderen vroeg in de pubertijd herkennen het best gezichten van andere kinderen die ook nog vroeg in de pubertijd zitten, terwijl kinderen die al aan het eind van de pubertijd zijn het best gezichten herkennen van kinderen die ook aan het eind van de pubertijd zijn (Picci & Scherf, 2016). De verwerking van sociale informatie lijkt dus, onafhankelijk van leeftijd, ook afhankelijk te zijn van de fase van de pubertijd waarin kinderen zich bevinden.

Een mogelijke verklaring voor de veranderingen in de verwerking van gezichten rond de start van de pubertijd is de toename in geslachtshormonen, wat invloed heeft op verschillende lichamelijke en cognitieve processen. Er wordt gedacht dat deze toename in geslachtshormonen ervoor zorgt dat adolescenten zich meer gaan richten op leeftijdsgenoten, met als gevolg dat cognitieve verwerkingssystemen zich moeten gaan aanpassen om deze nieuwe sociale informatie beter te kunnen verwerken (Scherf, Behrmann, & Dahl, 2012). Adolescenten zullen zich bijvoorbeeld meer gaan richten op sociale kenmerken die belangrijk zijn voor hun omgang met leeftijdsgenoten, zoals betrouwbaarheid, aantrekkelijkheid en sociale status. Als gevolg van deze aanpassingen zal er een tijdelijke instabiliteit ontstaan in de reeds bestaande verwerkingssystemen, omdat er een nieuwe balans gevonden moet worden tussen verschillende processen. Deze instabiliteit uit zich dan bijvoorbeeld door een tijdelijke verslechtering van de gezichtsherkenningsprocessen. Hoewel men een lineaire ontwikkeling verwacht in gezichts- en emotieherkenning, lijkt de toename van geslachtshormonen rond de start van de pubertijd deze ontwikkeling dus tijdelijk te verstoren.

Dusver zijn alleen verstoringen in gezichts- en basale emotieherkenning onderzocht. Het is echter niet bekend of er rond de start van de pubertijd ook verstoringen waarneembaar zijn in andere, meer complexe, sociale processen. Daarom is in *Hoofdstuk 4* onderzocht of er ook verstoringen waarneembaar zijn in drie andere sociale processen; het volgen van oogbewegingen, emotieherkenning in iemands ogen en empathie. Deze sociale processen worden grotendeels aangestuurd door hersengebieden die ook betrokken zijn bij gezichts- en basale emotieherkenning, dus de verwachting is dat de toename van geslachtshormonen rond de start van de pubertijd ook een effect zal hebben op deze processen.

De eerste taak beschreven in *Hoofdstuk 4* onderzocht het volgen van oogbewegingen. Voor zover bekend is dit de eerste studie die kijkt naar de ontwikkeling van het volgen van oogbewegingen in de puberteit. De resultaten laten zien dat adolescenten gemiddeld gezien hun aandacht verplaatsen in de richting van een oogbeweging. Er was echter geen effect van de fase van de pubertijd waarin het kind zich bevond. Er is dus geen instabiliteit in deze sociale vaardigheid rond de start van de pubertijd, hoewel een trend aangeeft dat adolescenten iets minder geneigd zijn oogbewegingen te volgen naarmate ze verder in de pubertijd komen. Deze resultaten suggereren dat een aandachtsverschuiving na aanleiding van een oogbeweging een redelijk robuust effect is.

Met de tweede taak in *Hoofdstuk 4* is gekeken naar de ontwikkeling van emotieherkenning op basis van het zien van enkel iemands ogen. In deze taak is wel een effect geobserveerd van de fase van de pubertijd waarin adolescenten zich bevinden. De prepuberale kinderen scoorden lager op deze taak dan midpuberale en postpuberale kinderen. Deze laatste twee groepen verschilden niet in hun scores. Dit resultaat doet vermoeden dat emotieherkenning in iemands ogen zich in de vroege pubertijd nog ontwikkelt, maar daarna een plateau bereikt. Of er na de pubertijd nog verdere ontwikkeling plaatsvindt, valt op basis van dit onderzoek niet te zeggen.

Als laatste is in *Hoofdstuk 4* de ontwikkeling van empathie onderzocht. Ook in deze sociale vaardigheid is een effect gevonden van de fase van pubertijd waarin kinderen zich bevinden. De prepuberale kinderen scoorden lager op empathie dan de postpuberale kinderen, verder zijn er geen verschillen tussen groepen gevonden. Dit resultaat laat zien dat er een graduele toename is in empatisch vermogen over de pubertijd. In tegenstelling tot de twee andere taken is in deze taak ook een effect van geslacht geobserveerd, waarbij meisjes gemiddeld hoger scoorden op empatisch vermogen dan jongens.

Als we alle uitkomsten samen nemen kan geconcludeerd worden dat er verschillende ontwikkelingen plaatsvinden in sociale vaardigheden gedurende de pubertijd. Een tijdelijke verstoring rond de start van de pubertijd, zoals bij basale gezichtsherkenning, lijkt echter niet van toepassing te zijn op de processen onderzocht in *Hoofdstuk 4*. Het lijkt daarom onwaarschijnlijk dat de start van de pubertijd, en daarmee de toename in geslachtshormonen die hierbij hoort, een direct effect heeft op complexe sociale vaardigheden.

Het volgen van oogbewegingen

Het volgen van oogbewegingen is zeer belangrijk voor de sociale ontwikkeling. Het is bijvoorbeeld gerelateerd aan het leren van taal en het begrijpen van acties en intenties van andere mensen. De coördinatie tussen iemands eigen perspectief, het perspectief van een ander en objecten of gebeurtenissen in de omgeving levert informatie op die fundamenteel is voor de ontwikkeling van hersengebieden die betrokken zijn bij sociale processen (Mundy, 2016; Mundy & Jarrold, 2010; Mundy & Newell, 2007). Daarom is het volgen van oogbewegingen in *Hoofdstuk 5* nader onderzocht.

In hoeverre iemand geneigd is om oogbewegingen te volgen wordt getest met het 'gaze-cueing' paradigma. Hierbij verschijnt er eerst een gezicht in het midden van een scherm met de blik recht vooruit, waarna er een oogbeweging naar links of naar rechts gemaakt wordt. Hierna verschijnt er een object aan de linker- of rechterzijde van het scherm (Friesen & Kingstone, 1998). Mensen zijn over het algemeen sneller in het detecteren van dit object als de oogbeweging correct voorspelt waar het object zal verschijnen (congruente conditie) vergeleken met een situatie waar de oogbeweging in de tegenovergestelde richting wijst dan waar het object zal verschijnen (incongruente conditie). Dit wordt ook wel het 'gaze-cueing effect' genoemd.

De mate waarin dit 'gaze-cueing effect' optreedt lijkt afhankelijk te zijn van verschillende kenmerken van de gezichten die gebruikt worden als stimuli, zoals ras, leeftijd, geslacht en identiteit (Macchi Cassia, 2011). Jongvolwassenen laten bijvoorbeeld een groter 'gaze-cueing effect' zien als gezichten van leeftijdsgenoten getoond worden dan wanneer gezichten van ouderen getoond worden (Slessor, Laird, Phillips, Bull, & Filippou, 2010). Het is nog niet onderzocht of dit leeftijdseffect ook optreedt bij kinderen. Het is van belang om dit te onderzoeken, omdat dit een indicatie kan geven of het voor kinderen uitmaakt van wie sociale signalen afkomstig zijn. In *Hoofdstuk 5* is daarom getest of kinderen een verschil laten zien in het 'gaze-cueing effect' voor oogbewegingen van volwassenen en van leeftijdsgenoten.

De resultaten tonen aan dat kinderen geen verschil laten zien in het 'gaze-cueing effect' voor oogbewegingen van volwassenen en van leeftijdsgenoten. De aandacht van de kinderen wordt dus in dezelfde mate verschoven na een oogbeweging, onafhankelijk van de leeftijd van de persoon die ze zien. Dit zou kunnen betekenen dat kinderen de sociale signalen van leeftijdsgenoten en volwassenen als even informatief zien, en daardoor hetzelfde reageren op deze signalen. Het kan ook betekenen dat kinderen ongevoelig zijn voor de leeftijd van de persoon waar ze naar kijken en puur de informatie van de oogbeweging volgen. Vervolgonderzoek zou meer inzicht kunnen geven in de onderliggende processen.

Methodologische overwegingen

De effecten die gevonden worden in experimentele studies naar sociale processen zijn vaak klein. Een mogelijke verklaring hiervoor is dat de experimenten plaatsvinden in een onderzoeksruimte op een universiteit. De vraag is of het testen van sociale vaardigheden in zo'n onnatuurlijke omgeving, gecombineerd met het gebruik van statische afbeeldingen als stimuli, wel vergelijkbaar is met de complexe sociale omgeving zoals men die in het dagelijks leven aantreft. Voor adolescenten zijn sociale status en de mening van leeftijdsgenoten erg belangrijk (Steinberg & Monahan, 2007). Het is mogelijk dat in *Hoofdstuk 4* en *Hoofdstuk 5* geen effecten gevonden worden omdat de adolescenten een afbeelding van een gezicht niet als sociaal relevant ziet. Hoe een kind reageert op de stimuli heeft verder geen invloed op de relatie tussen het kind en de onbekende personen op de afbeeldingen. Experimenten met echte personen, in plaats van met afbeeldingen, zouden tot andere resultaten kunnen leiden. Eerder onderzoek heeft al aangetoond dat de aanwezigheid van een fysiek persoon kijkgedrag kan beïnvloeden (Freeth, Foulsham, & Kingstone, 2013; Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012). Daarom vindt er de laatste tijd steeds meer onderzoek plaats waarbij live interactie tussen personen mogelijk is door bijvoorbeeld een videoconnectie (Hessels et al., 2017; 2018; 2019). Op deze manier is het nog steeds mogelijk om kijkgedrag betrouwbaar te meten in een gestandaardiseerde onderzoeksruimte, maar hebben de proefpersonen wel de vrijheid om met elkaar te interacteren. Dit type onderzoek kan staven of de resultaten van experimenten met statische afbeeldingen generaliseerbaar zijn naar meer complexe sociale situaties.

Vervolgonderzoek

Alle resultaten zoals gerapporteerd in *Hoofdstuk 4* en *Hoofdstuk 5* van dit proefschrift suggereren dat zowel de fase van de pubertijd waarin adolescenten zich bevinden als de leeftijd van de interactiepartner geen invloed hebben op het verwerken van sociale informatie (buiten een normale graduele ontwikkeling in emotieherkenning en empatisch vermogen). De vraag is waarom deze factoren wel invloed lijken te hebben op meer basale processen zoals gezichts- en emotieherkenning (Anastasi & Rhodes, 2005; Crookes & McKone, 2009; Diamond et al., 1983; Hills, 2012; Hills & Lewis, 2011; Lindholm, 2005; Picci & Scherf, 2016), terwijl meer complexe processen hier niet door gestuurd lijken te worden. Als de toename in geslachtshormonen rond de start van de pubertijd een invloed heeft op de verwerking van gezichten (Scherf et al., 2012), hoe is het dan mogelijk dat dit effect beperkt blijft tot deze basale processen? Of is er toch geen relatie tussen de toename van geslachtshormonen en het verwerken van gezichten, maar is er een andere verklaring voor de tijdelijke verstoring in deze processen rond de start van de pubertijd (zie Chung & Thomson, 1995)? Vervolgonderzoek zal zich moeten richten op de vraag welke sociale processen een tijdelijke verstoring laten zien rond de start van de pubertijd. Met kennis over de exacte ontwikkeling van verschillende sociale processen gedurende de pubertijd wordt het eenvoudiger om hypotheses te vormen over mogelijke onderliggende oorzaken van eventuele verstoringen in deze processen.

Algemene conclusie

Het doel van dit proefschrift was om de verwerking van sociale informatie te onderzoeken in zowel tweejarigen als adolescenten. Daarnaast is er gekeken naar de rol die verschillende interactiepartners kunnen spelen in deze sociale processen. Op basis van de resultaten van het uitgevoerde onderzoek kan geconcludeerd worden dat taalverwerving bij tweejarigen beïnvloed wordt door de persoon die de nieuwe woorden aanleert. Kinderen leerden nieuwe woorden sneller van hun eigen moeder dan van een voor hen onbekend persoon. Daarnaast is aangetoond dat tweejarigen met een verhoogd risico op ASS niet verschillen van normaal ontwikkelende kinderen in het aanleren van nieuwe woorden wanneer hun eigen ouders deze woorden aanleren. Het is nog onduidelijk of een bekende stem hetzelfde gunstige effect heeft in het woordleerproces van kinderen met ASS zoals geobserveerd in normaal ontwikkelende kinderen.

Bij adolescenten lijken complexere non-verbale sociale processen zich gradueel te ontwikkelen. De kinderen laten geen tijdelijke verstoring zien in deze processen wanneer stimuli van volwassenen getoond worden. Daarnaast was er ook geen verschil in prestatie wanneer stimuli van volwassenen danwel stimuli van leeftijdsgenoten gebruikt werden. Het is echter nog een open vraag of er een verschil in prestatie zichtbaar is wanneer stimuli van bekende danwel onbekende personen gebruikt worden. Het positieve effect van bekendheid, zoals aangetoond bij taalprocessen in tweejarigen, zou ook aanwezig kunnen zijn in de non-verbale sociale processen in adolescenten.

Kortom, de resultaten uit dit proefschrift impliceren dat het type interactiepartner invloed heeft op de vroege sociale ontwikkeling, maar dat deze invloed gedurende de pubertijd niet meer duidelijk aanwezig is, in ieder geval niet voor de sociale processen die in dit proefschrift onderzocht zijn. Dit is cruciale informatie voor de ontwikkeling van interventies voor peuters en kinderen met communicatieproblemen en geeft meer inkijk in wie de geschikte personen zouden zijn om deze interventies uit te voeren.

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Appendix II

Dankwoord

Dit was het dan. Er zijn vier jaar voorbij gevlogen zonder dat ik het eigenlijk doorhad. Oneindig veel lezen en schrijven, uren en uren programmeren, honderden baby's en kinderen getest voor onze onderzoeken. En terwijl de analyses draaiden maar hopen dat er mooie resultaten uitkomen. Met uiteindelijk dit boek als eindresultaat, iets waar ik ontzettend trots op ben. Bedankt aan iedereen die er voor gezorgd heeft dat ik dit eindresultaat heb kunnen neerzetten!

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Janna, al vanaf dat wij bijna 10 jaar geleden begonnen met onze bachelor was jij een luisterend oor en een steun. Samen klagen, samen lachen, samen ervoor gaan. Dankjewel dat je ook nu als een steun achter mij wilt staan en al die pagina's wilde doorlezen op spelfouten en onbegrijpelijke zinnen. En zeker ook bedankt voor alle etentjes en dagjes uit om even uit de werksfeer te ontsnappen.

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Rianne van Rooijen, april 2019

Appendix III

List of Publications

Publications in this dissertation

van Rooijen, R., Bekkers, E. L., & Junge, C. M. M. (*Submitted*). Beneficial effects of the mother's voice on infants' novel word learning.

van Rooijen, R., Junge, C. M. M., & Kemner, C. (2018). The Interplay between Gaze Following, Emotion Recognition, and Empathy across Adolescence; a Pubertal Dip in Performance?. *Frontiers in Psychology, 9*, 127. doi: 10.3389/fpsyg.2018.00127

van Rooijen, R., Junge, C. M. M., & Kemner, C. (2018). No Own-Age Bias in Children's Gaze Cueing Effects. *Frontiers in Psychology*, *9*, 2484. doi: 10.3389/fpsyg.2018.02484

van Rooijen, R., Ward, E. K., de Jonge, M., Kemner, C., & Junge, C. M. M. (*Submitted*). Two-year-olds at risk for autism can learn novel words from their parents.

Publications not in this dissertation

Di Lorenzo, R., Blasi, A., Junge, C. M. M., van den Boomen, C., ***van Rooijen, R.,*** & Kemner, C. (*In press*). Brain responses to faces and facial expressions in 5-month-olds: an fNIRS study. *Frontiers in Psychology.*

Junge, C. M. M., ***van Rooijen, R.,*** & Raijmakers, M. (2018). Distributional Information Shapes Infants' Categorization of Objects. *Infancy*, *23*(6), 917-926. doi: 10.1111/infa.12258

Sprong, M., Munsters, N. M., & ***van Rooijen, R.*** (2017). *Lesbrief onderzoekend en ontwerpend leren: communiceren zonder te praten.* Wetenschapsknooppunt, Universiteit Utrecht.

van Rooijen, R. (2015). Experience-dependent suppression of mu- and beta-power in the infant motor cortex while observing others' actions. *Amsterdam Brain and Cognition Journal*, *2*, 41-47.

van Rooijen, R., Ploeger, A., & Kret, M. E. (2017). The dot-probe task to measure emotional attention: A suitable measure in comparative studies?. *Psychonomic Bulletin & Review*, *24*(6), 1686-1717. doi: 10.3758/s13423-016-1224-1

Appendix IV

Curriculum Vitae

Rianne van Rooijen is geboren op 23 december 1990 te Gouda.

In 2009 behaalde Rianne haar vwo-diploma aan het Oranje Nassau College te Zoetermeer. Daarna volgde ze de bachelor Psychobiologie (2009-2012, cum laude) en de onderzoeksmaster Brain and Cognitive Sciences (2012-2014, cum laude) aan de Universiteit van Amsterdam. Tijdens haar masteropleiding heeft Rianne twee onderzoeksstages volbracht. Haar eerste onderzoeksstage liep ze bij de afdeling Ontwikkelingspsychologie van de Universiteit van Amsterdam. Hier heeft ze onderzoek gedaan naar hoe 10 maanden oude baby’s categorieën vormen. Daarna heeft ze een half jaar stage gelopen bij de ‘*Baby Research on Action, Interaction and Neurocognition Group’* van het Donders Institute for Brain, Cognition and Behaviour te Nijmegen. In dit onderzoek heeft ze EEG-onderzoek gedaan naar veranderingen in hersenactiviteit in de periode dat kinderen leren lopen.

Rianne begon in 2015 aan haar promotieonderzoek bij de Universiteit Utrecht (afdelingen Psychologische Functieleer en Ontwikkelingspsychologie), onder begeleiding van prof. dr. Chantal Kemner en dr. Caroline Junge. In haar promotieonderzoek heeft Rianne onderzoek gedaan naar de invloed van verschillende interactiepartners op het verwerken van sociale informatie in zowel baby's als adolescenten. Als onderdeel van haar promotie werkte ze ook op het YOUth-onderzoek naar de ontwikkeling van hersenen en gedrag. In de toekomst wil ze zich graag verder ontwikkelen in het onderwijs of de klinische praktijk.