Emotion processing in preschoolers with autism spectrum disorders

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Chapter 5

Development of social attention and arousal: evidence from eyetracking and heart-rate in typically developing children and children with Autism Spectrum Disorders

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Under review.

Abstract

Studying individual differences in underlying mechanisms of social behavior has substantial implications for understanding both typical development and developmental disorders that are characterized by social challenges such as Autism Spectrum Disorders (ASD). The present study aimed to gain insight into the development of emotional arousal and social attention during a critical period in child development. The role of cognitive development in areas of executive functioning and language, over a period of six months were explored in TD children. Participants included 45 typically developing children (TD; 41-75 months) and 15 children with ASD (43-71 months). Eyetracking and heart rate in response to a social-emotional clip were monitored simultaneously and measurements were repeated six months later. Results revealed stability of arousal in both TD and ASD children in contrast to significant increases in social attention for both TD and ASD children. In TD children, improvements in cognitive flexibility and inhibition, but not language were associated with being more socially attentive. We conclude that even in young children with ASD, fundamental mechanisms of social behavior that are known to be compromised show substantial development in early childhood. In TD children, this improvement was related to maturational changes in higher order cognitive functioning.

Introduction

Being able to show adaptive social behaviors already from an early age requires a child to respond to a fast-paced and ambiguous environment. Understanding social situations and adequate responding to others represent complex behaviors that heavily rely on efficient and effective information processing. As a consequence, social development is vulnerable to developmental disruptions and shows great individual variability, ranging from children who easily 'tune in' to others, to children who have substantial difficulties navigating their social environment. From a developmental perspective, studying underlying mechanisms that are closely related to social behavior during critical periods in childhood could contribute to better understanding the emergence of social behavior in children. Especially since similar social behavioral difficulties may arise from different underlying impairments. To illustrate, less engagement in social interactions may arise from high emotional arousal and related social anxiety or from low emotional arousal and related low social motivation (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Corbett et al., 2014; White et al., 2014). Studying individual differences in underlying mechanisms of social behavior has substantial implications for the understanding of developmental disorders that are characterized by social challenges such as Autism Spectrum Disorders (ASD). Core symptoms of this developmental disorder encompass persistent deficits in social communication, social interaction, and restricted, repetitive patterns of behavior, interests, or activities (APA, 2013).

From the literature we know that underlying mechanisms of social behavior such as attending to faces and eyes of others (social attention) and adequate emotional arousal responses to others are affected in children with ASD (e.g.; Benevides & Lane, 2015; Guillon, Hadjikhani, Baduel, & Roge, 2014; Papagiannopoulou, Chitty, Hermens, Hickie, & Lagopoulos, 2014; Zantinge, van Rijn, Stockmann, & Swaab, 2017b). Instead of merely focusing on group differences at a single time point, the present longitudinal study was designed to 1) gain insight into the development of social attention and emotional arousal in both TD and ASD children, and 2) to address the role of cognitive development in areas of executive functioning (EF) and language in TD development in order to take the first steps in exploring mechanisms of developmental trajectories.

From infancy, typically developing children attend preferentially towards social information such as their caregivers, faces, and biological motion also referred to as social attention (Gliga & Csibra, 2007; Haith, Bergman, & Moore, 1977; Simion, Regolin, & Bulf, 2008; Vuilleumier, Armony, Driver, & Dolan, 2003). An early social preference is believed to be largely automatic, efficient, and requires little effort (Chawarska, Macari, & Shic, 2012; Salva, Farroni, Regolin, Vallortigara, & Johnson, 2011) and is considered a crucial prerequisite for the development of social behaviors such as learning to socialize and recognizing emotions of others. As children interact in reciprocal relationships, their experience with faces and voices grows which in turn enhances cortical specialization and the fine-tuning of perceptual systems (Johnson et al., 2005; Webb, Jones, Kelly, & Dawson, 2014). As a result, social brain circuitries specialize and mature, supporting more complex behaviors such as joint attention, intentional communication, and imitation (Dawson, Webb, & McPartland, 2005).

With the emergence of new techniques such as eye tracking, objective and direct measurements have provided insight into preferential attention to social information (Jones & Klin, 2013; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Social attention in early childhood has been investigated, however longitudinal studies are scarce. Knowledge about developmental aspects is important particularly with regard to identifying opportunities to positively influence maturation in vulnerable children. Children (later diagnosed) with ASD have shown an initial intact attention towards the eyes in the first months of life, and an average decline in eye fixation from two to six months of age (Jones & Klin, 2013). While another study of infants with and without a family history of ASD showed intact gaze following behavior at both seven and 13 months (Bedford et al., 2012). These studies stress the importance of learning more about the developmental trajectory of this precursor for social development.

Crucial for understanding the dynamics of social attention is to integrate measures of underlying processes, in particular the emotional arousal response. Arousal can be conceptualized as a dimension of emotional responsiveness and is considered a prerequisite for emotionally resonating with others in a social context (Kreibig, 2010; Mauss & Robinson, 2009). An arousal response is generated by the autonomic nervous system (ANS) and causes an individual to attend and respond towards social information (Baron-Cohen & Wheelwright, 2004; Bons et al., 2013). Heart rate is an index of the ANS and varies due to the influence and interaction between both the sympathetic and parasympathetic nervous system. In children with ASD, there is evidence for normative resting state arousal but mixed results regarding arousal patterns in response to stimuli (Benevides & Lane, 2015) showing less modulation in response to social stimuli (Levine et al., 2012; Zantinge et al., 2017b) and intact modulation when it comes to their own emotions (Zantinge, van Rijn, Stockmann, & Swaab, 2017a). From a developmental perspective, there are indications that arousal patterns in typically developing children show maturational changes between 4 months and 4 years, but relative stability in middle to late childhood (Bar-Haim, Marshall, & Fox, 2000; Benevides & Lane, 2015). Studying arousal parallel to social attention, from a developmental perspective, might provide important information about which aspects of social-emotional mechanisms show continued development in early childhood as leads for possible intervention and treatment.

The way children direct their attention to others and how their arousal system responds to this social information may depend on the development of specific cognitive functions. It is therefore important to study cognitive processes such as executive functions and language, which are core to the regulation of behavior, thought, and emotion with regard to the

development of social behavior (Chita-Tegmark, 2016; Hill, 2004a; Moriguchi, 2014).
Executive function is an umbrella term for a broad range of higher order cognitive processes that are critical for efficient functioning in everyday life such as attention, cognitive flexibility, goal setting, and inhibitory control. Executive functions develop mostly stepwise through childhood and adolescence, together with the maturation of prefrontal regions of the brain (Anderson, 2008) and thus can be considered an early indicator of very early frontal brain development. Together with executive functions, communication is important to the successful establishment of relationships and peer acceptance (Beauchamp & Anderson, 2010). More specifically, the development of language is among the most complex neurocognitive functions of humans and are a result of brain development in interaction with the social environment. (Non-) verbal language evolves in the early years from the first social smile to the emergence of intentional imitative behavior and dyadic interaction with aspects of communication such as joint attention and expressive and receptive communication. Both functions are known to be vulnerable in children with ASD compared to typically developing children (APA, 2013; Groen, Zwiers, van der Gaag, & Buitelaar, 2008; Hill, 2004b; O'Hearn, Asato, Ordaz, & Luna, 2008). Together, executive functioning and language/communication reflect the ability to express, control and steer thoughts, behaviors and emotions and are important to study as they might be related to being able to attend to social cues in the environment. Studying the typical development of executive functions and language in relation to social attention and emotional arousal is a prerequisite for understanding the dynamics of these characteristics in children with ASD.
In sum, knowledge is growing about the early symptoms of ASD, indicating that both social attention (Chita-Tegmark, 2016; Frazier et al., 2017; Zantinge et al., 2017b) and emotional arousal response patterns (Benevides & Lane, 2015; Zantinge et al., 2017a) might be different in children with ASD. However, the developmental dynamics in early childhood are less clear. Early interventions could have a significant impact on daily life functioning and later quality of life. For interventions to have optimal effects on the developing brain, we need to have knowledge about the developmental aspects of social attention and emotional arousal, as this may help to identify windows of opportunity. Finally, the present study aimed to take the first steps in understanding the influence of language and executive functioning on the development of social attention and emotional arousal, in typical development only. These exploratory results might prove to be valuable leads for further studying this relationship in the development of young children with ASD.

Methods

Participants

Participants included 45 typically developing children (TD) and a matched group of 15 children with ASD. Children with ASD were recruited through the Dutch Autism Center

(Rivierduinen), the Dutch Autism Association (NVA), and the Dutch Association for Developmental Disorders (Balans). The TD group was recruited through daycare centers, elementary schools, and postings in public areas in the Netherlands. All children were invited to the lab twice. The mean duration between T0 and T1 was 6.42 months (*SD*= .87). For children with ASD, the first visit (T0) was planned as soon as possible after clinical diagnosis (mean duration between T0 and T1= 7.07 months, *SD*= .88). Children were matched on age (M_{TD}= 55.22, SD= 10.79, M_{ASD}= 56.27, *SD*= 9.57) and gender (see Table 1). Parental versions of the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005) and the Childhood Behavior Checklist (CBCL; Achenbach & Rescorla, 2000) showed normed sum scores below the clinical cut off in the TD group. Inclusion criteria for all participants were that parents and/or children were Dutch or English speaking, children had no neurological conditions, previous head injuries with loss of consciousness, and/or metabolic diseases.

Table 1. Demographic characteristics of the TD group and the ASD group at T0.

	TD (*N*= 45) **Mean (*SD*)**	**ASD (*N*= 15)** **Mean (*SD*)**	**Group differences**
Age range	41-75 months	43-71 months	$t(58)= -.33, p= .74$
Gender	M= 37, F= 8	M= 13 , F= 2	$\chi^2(1)= .16, p= .69$
FSIQ	110.62 (14.44)	86.80 (21.55)	$t(58)= 4.86, p< .01$*
PPVT-III-NL Language	110.89 (10.78)	84.07 (21.02)	$t(16.52)= 4.74, p <.01$*
SES †	2.60 (0.48)	2.33 (0.75)	$\chi^2(4)= 9.96, p= .04$*

* Group difference significant at $p <.05$
† SES: 1= low, 2= medium, 3= high

Measures

Autism diagnosis

Current symptoms of ASD according to the DSM-IV-TR criteria (APA, 1994) were evaluated using the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). Standardized severity scores were calculated according to Gotham, Pickles, & Lord (2009) to compare the three different modules of the ADOS that were administered. The diagnostic algorithm of the Autism Diagnostic Interview-Revised (ADI; Le Couteur, Lord, & Rutter, 2003) was used to assess retrospective or current functioning (depending on age) at age four to five years. All children exceeded the diagnostic threshold on both the ADI-R and the ADOS (Table 2). The diagnosis was provided by child psychiatrists and psychologists with extensive clinical experience during a multidisciplinary meeting.

Table 2. ADI and ADOS scores for the ASD group (*N*=15)

Scale		Mean *(SD)*
ADI social communication (cut-off= 10)		19.00 (6.15)
ADI communication	Verbal (*N*= 14, cut-off= 8)	14.64 (3.84)
	Non-verbal (*N*= 1, cut-off= 7)	14.00
ADI repetitive behavior (cut-off= 3)		6.07 (3.13)
ADI developmental deviance (cut-off= 1)		4.00 (1.25)
ADOS severity score		8.33 (1.67)

Intellectual functioning

Children from the TD group completed the Wechsler Non-Verbal (WNV-NL; Wechsler & Naglieri, 2006). Intellectual functioning of children with ASD was assessed using the test that matched children's verbal, motor, and developmental level. 11 children (73%) completed the WNV-NL (Wechsler & Naglieri, 2006), one child the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III-NL; Wechsler, 2006), one child the Snijders-Oomen Nonverbal Intelligence Test (SON-R 2.5-7; Tellegen, Winkel, Wijnberg-Williams, & Laros, 1998), and two children (13%) the Mullen Scales of Early Learning (MSEL; Mullen, 1995). A ratio IQ was computed in case raw scores were outside the standard range for deviation scores by taking the average age equivalents across the subtests, divided by the chronological age in months, multiplied by 100 (Bishop, Guthrie, Coffing, & Lord, 2011).

Social attention

Detailed information about the pilot study that was conducted to select the baseline and social-emotional video clip, has been reported elsewhere (Zantinge et al., 2017b). Two identical video's, that significantly elicited an arousal response displaying an angry emotion were played using the Tobii T120 eye tracker (Tobii Technology AB, Danderyd Sweden). Videos were counter balanced between T0 and T1 to account for clip-specific effects. Gaze data within specific areas of interest (AOIs) was collected at 120 Hz by using corneal reflection techniques and were processed using the Tobii I-VT fixation filter in Tobii Studio (Version 3.2.1). This filter controls for validity of the raw eyetracking data making sure only valid data was used (Olsen, 2012). With the "Dynamic AOI" tool, face and total screen AOIs were drawn, taking into account the size and the margins around the AOIs (Hessels, Kemner, van den Boomen, & Hooge, 2015; Hooge & Camps, 2013). A "relative" total fixation duration was calculated by taking the total fixation duration within the AOI, divided by the total duration of the clip, multiplied by 100 (Zantinge et al., 2017b). The relative total fixation duration reflected the percentage of time children were attending to the AOI. In the present study, the development of social attention was operationalized in terms of the difference between relative fixation duration towards the face at T1 minus T0, expressed in Δ-scores.

Executive functioning

The Behavior Rating Inventory of Executive Function-Preschool version (BRIEF-P; Gioia, Espy, & Isquith, 2001) was used to evaluate executive functioning. This parent report questionnaire consists of 5 scales; inhibition, cognitive flexibility, emotion regulation, working memory, and planning and organizing. The Dutch translation showed sufficient to high internal consistency, interrater reliability, construct validity, and test-retest reliability indicating suitability for research purposes (Van der Heijden, Suurland, De Sonneville, & Swaab, 2013). High scores represented lower levels of executive functioning. In the present study, Δ-scores represented the development over a period of six months, calculated by subtracting the scores at T0 from the scores at T1.

The Amsterdam Neuropsychological Tasks (ANT; De Sonneville, 2014) were used to assess inhibition and attention in the TD group. This computerized test battery has demonstrated satisfactory validity and test-retest reliability (De Sonneville, 2005) and has been used in a variety of clinical and non-clinical samples with young children (e.g.; Rommelse et al., 2008; Swaab et al., 2000; van Rijn & Swaab, 2015). After instructions and a practice trial, children were instructed to work as quickly and accurately as possible by clicking the mouse button with their index finger.

ANT: Inhibition was measured with the Go/NoGo subtest (De Sonneville, 2014). Each of the 48 trials (24 Go- and 24 NoGo) began with a fixation period (500 ms) and was followed by the presentation of the target stimulus, either the Go-stimulus (a green walking man) or the NoGo-stimulus (a red standing man). A higher amount of false alarms (pressing the mouse key on a NoGo stimulus) indicated problems with inhibition. The development of inhibition was expressed in Δ-scores which represented the number of false alarms at T1 minus T0.

ANT: Attentional control was measured with the Sustained Attention subtest (De Sonneville, 2014) operationalized in terms of stability in attentional control over a longer period of time. In this task, a house was continuously presented on the screen in which one animal randomly appeared in one of the three windows. During the 20 series of 12 trials children were instructed only to press the key in case they saw that target animal (a mouse) and to wait in case another animal was presented. A higher standard deviation in response time indicated problems with attentional control. Development in attention was expressed in Δ-scores which represented the difference score between T1 minus T0.

Language

Receptive language was measured with the Dutch version of the widely used Peabody Picture Vocabulary Test-III-NL (PPVT-III-NL; Schlichting, 2005). Each item of this non-verbal multiple choice test consists of four pictures from which the child is asked to pick the one that corresponds with the examiner's stimulus word. Delta (Δ) scores represented the development of receptive language from T0 through T1.

Expressive language was assessed with body part naming subtest of the NEPSY-II-NL (Korkman, Kirk, & Kemp, 2007. Dutch translation by; Zijlstra, Kingma, Swaab, & Brouwer, 2010). A comprehensive child neuropsychological assessment for ages 3–12 years. This task required the child to identify different body parts on a stimulus card that were read aloud by the experimenter. Delta (Δ) scores represented the development of expressive language.

Physiologic measurement

Data were recorded continuously with AcqKnowledge (Version 4.3.1 BIOPAC Systems Inc.). Electrodes were attached at the top center of the chest, (10 cm below the suprasternal notch) the bottom left, and right of the ribs (10 cm above the bottom of the rib cage). Recordings were acquired through an Electrocardiogram amplifier (ECG100C) and BIOPAC data acquisition system (MP150 Windows) with a sampling rate of 200 Hz. Physiological monitoring equipment was synchronized with Tobii software by event markers representing the start of the social-emotional clip. In AcqKnowledge a 0.5 Hz high pass filter and a 50 Hz notch filter were applied to stabilize the ECG signal. Recorded physiological data was further processed by manually inspecting the detected R peaks and valid interbeat intervals in MATLAB Release 2012b (The MathWorks, Inc., Natick, Massachusetts, United States). Motion artifacts were visually identified and excluded from the data.

Procedures

Both the TD group and ASD group followed same procedures. Preparations for the lab visit included an information brochure and a copy set of the electrodes to practice at home. During assessment, children completed cognitive tasks while the parent was in the room next to the child filling out questionnaires. After a break, the session continued in the lab in the presence of the parent (who was out of direct sight). Electrodes were applied after which children played an easy exploration game on a touch screen to familiarize and for the electrodes to adjust to the skin. After 10 minutes, children sat in an adapted car seat to have a stable position and to minimize distraction with the head protection on the side. After baseline, the anger clip was played. Children were instructed to watch the clips while trying to sit quietly (Zantinge et al., 2017b). Tests were completed at the Center for Autism by a certified child psychologist and trained experimenters who used written protocols detailing all procedures and verbal instructions.

Statistical analyses

After a missing data inspection, data was checked for normality. For both groups separately, the development of arousal and social attention was analyzed using paired samples *t*-tests including T0 and T1. Linear regression analyses (with a backward procedure) were done to study associations between executive functioning, language, and social attention. Finally, group comparisons using independent samples *t*-test were performed to investigate whether developmental effects were different between groups. Effect sizes were calculated according to Cohen's *d* with 0.2 being a small, 0.5 medium, and 0.8 a large effect.

Ethics statement

This study was approved by the Ethical Committee of the Department of Education and Child Studies at the Faculty of Social and Behavioral Sciences, Leiden University, and by the Medical Research Ethics Committee at Leiden University Medical Center. A written informed consent according to the declaration of Helsinki was signed by parents/ legal caretakers.

Results

Intellectual functioning

Within the TD group there was no significant relationship between IQ and Δ heart rate (r= -.21, p= .17) nor between IQ and Δ social attention (r= -.05, p= .77). Within the ASD group, there were also no significant relationships between IQ and the outcome measures (IQ and Δ heart rate r= -.02, p= .95, IQ and Δ social attention r= .02, p= .96).

Developmental trajectory in TD children

Development of arousal response in TD children

A paired samples t-test revealed that heart rate, as expressed in peak arousal during video clips, was not significantly different between T0 (M= 3,25, SD= 7,02) and T1 (M= 2,84, SD= 6,50) ($t(44)$= .29, p= .78). In other words, for TD children, peak in arousal while watching a social-emotional clip was stable over a period of 6 months (see Figure 1).

Development of social attention in TD children

A paired samples t-test showed that social attention, as expressed in percentage of fixation duration towards the face including the eyes, increased significantly between T0 (M= 34,56, SD= 9,54) and T1 (M= 45.66, SD= 15,23) ($t(39)$= -3.77, p< .01). Cohen's d was 0.9, indicating a large effect size (see Figure 1). Within the TD group, 72,5% of the children showed higher scores at T1 as compared to T0 in attention towards the face. The other 27,5% of the children attended towards the face equally or less. The percentage total visit duration total screen was 98% at both T0 and T1 indicating that children looked at the screen equally at both time points so increases in social attention were not a consequence of looking more at the screen in general.

Predictors of social attention in TD children

A linear regression analysis with a backwards procedure was done to investigate the relationship between the increase in social attention and executive functioning within the TD group. The increase in social attention (Δ T0 and T1) was entered as dependent variable. IQ and Age were entered in block one, the five Δ BRIEF-P scales and the two Δ ANT measures of executive functioning were entered in block two as independent variables. This resulted in a significant model (R^2= .21, F(2, 29)= 3,90, p< .05) with the combination of the Cognitive flexibility scale of the BRIEF-P (β= -3.20, p= .03) and Inhibition (β= -1.36, p= .08) as measured with the ANT as significant predictors. This indicated that the increase in social attention within the TD group was best predicted by increases in Cognitive flexibility and Inhibitory control. Both IQ and Age were no significant predictors within this model. Next, the Δ PPVT-III-NL (receptive language), Δ NEPSY body part naming (expressive language) were entered as independent variables, in addition to IQ and Age, to investigate the relationship between the increase in social attention and language within the TD group, controlled for intellectual functioning and age. No significant model was found (R^2= .02, F(1, 34)= .56, p= .46).

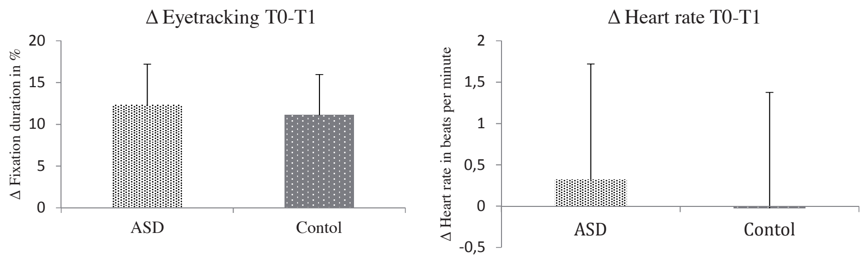

Figure 1. Developmental difference of social attention (left) and arousal response (right) in ASD and TD children between T0 and T1expressed in Delta (Δ) scores.

Developmental trajectory in ASD children

Development of arousal response in ASD children

A paired samples *t*-test revealed that the peak in arousal response did not change between T0 (M= 1,08, SD= 8,46) and T1 (M= 1,40, SD= 6,59) (t(10)= -.088, p= .93). In other words, for children with ASD, emotional arousal in response to a social-emotional clip was stable over a period of 6 months (see Figure 1).

Development of social attention in ASD children

A paired samples *t*-test showed that social attention increased significantly between T0 (M= 28,18, SD= 13,80) and T1 (M= 40.51, SD= 19,22) (t(15)= -2.53, p= .024). Cohen's d was 0.7, indicating a medium effect size (see Figure 1). Within the ASD group, 80% of the children showed an increase in attention towards the face from T0 to T1, and 20% of the children attended equally or less at the face. The percentage total visit duration total screen was 97% at T0 and 96% at T1, which indicated that children attended to the screen equally at both time points and results were not due to looking more at the screen in general.

Group comparisons of social attention development

Both TD and ASD children showed significant increases in social attention over a period of six months. An independent samples *t*-test was performed to investigate whether the increase in social attention was different between groups. Results showed that Δ social attention between TD children (*M*= 11,10, *SD*= 18,60) and children with ASD (*M*= 12,33, *SD*= 18,85) was not significantly different ($t(53)= -.217$, $p=.83$). In other words, the increase in attention towards the face over a period of six months was equal.

Discussion

The present study investigated developmental changes in social attention and emotional arousal in typically developing children (TD) and children with Autism Spectrum Disorders (ASD). The role of cognitive development in areas of executive functioning and language, over a period of six months was explored in TD children.

Measures of the development of emotional arousal in response to a social-emotional stimuli revealed stable heart rate responses over a period of six months in both TD children and children with ASD. Longitudinal measurements of emotional responding to social stimuli in young children with ASD, to our knowledge, has not been investigated before so the present results have to be seen in light of the available literature in TD children and older children with ASD. In the TD population, there is evidence that heart rate is indeed a relatively stable measure during middle to late childhood (For a review see; Benevides & Lane, 2015), also in response to behavioral stress between childhood and adolescence (Matthews, Woodall, & Stoney, 1990). The results regarding developmental stability in heart rate from the present study, together with previous studies, suggest that maturation of the parasympathetic nervous system may contribute to children's increasing ability to self-regulate (Bar-Haim et al., 2000). This is an important concept in the study of autism (Benevides & Lane, 2015). With regard to the development of arousal states (measured with heart rate) during rest, daily life activities, and sleep in children between 3 and 15 years, research shows age related changes, with a slow decline over time (Alkon et al., 2003; El-Sheikh & Buckhalt, 2005; Fleming et al., 2011; Hinnant, Elmore-Staton, & El-Sheikh, 2011). However, results reported in the present study showed that age was not of influence on the development of arousal in the current sample. In sum, our data shows that during this developmental stage there are no *changes* in arousal response over time.

In contrast to the stability in arousal response, social attention improved in both TD children and children with ASD. Previous research has revealed that initial social attention towards social cues (mainly the face, specifically the eyes) in children with ASD is not different from that of TD children before six months, but starts to shows a decline at six to twelve months (Bedford et al., 2012; Jones & Klin, 2013). In sum, our results show that there is substantial development in social attention to the same extend as TD children within a relatively short period of six months.

The results of the present study suggest that even though arousal levels in response to social-emotional information remain very similar over time, social attention can become more coordinated towards the relevant social-emotional cues. From an evolutionary perspective, an affective arousal response can be considered a primitive and fundamental predisposition of the human body which responds to complex triggers already at an early age. Arousal is a reflection of the autonomic nervous system in interaction with the subcortical and limbic brain processes. With regard to development, it is hypothesized that such primary processes are quite innate and possibly less prone to developmental changes over relatively short periods of time (Calkins & Keane, 2004; Jemerin & Boyce, 1990). Higher order cognitive processes however, show continued and rapid development during early childhood as a consequence of brain maturation and environmental influences.

Studying the influence of language (both expressive and receptive) and executive functioning on the improvement of this social attention in TD children revealed that a combination of inhibitory control and cognitive flexibility were the most important predictors of improvement in social attention. This suggests that the development of being able to socially attend to others is associated with higher order cognitive functioning. At this age, rapid maturations of frontal brain regions drive the increases in being able to socially orient toward others, even in a relatively short period of six months. Executive functioning in young children is an essential precursor for the development of social skills such as theory of mind (Hughes & Leekam, 2004; Perner & Lang, 2000). Being able to resonate with other persons and to understand their thoughts, feelings, and emotions is an essential aspect of brain maturation. The current study was limited to investigating these mechanisms in TD children only, but the results provide interesting leads for further research and possible interventions into these relating mechanisms in children with ASD. Existing research suggests that differences in the autonomic nervous system (both sympathetic and parasympathetic) are observed among individuals with ASD during social interaction, which correlates with severity of social difficulties (e.g.; Benevides & Lane, 2015; Neuhaus, Bernier, & Beauchaine, 2016; Zantinge et al., 2017b).

The present study has limitations that are important to address. The role of cognitive development in areas of executive functioning and language could only be explored in the typically developing children. Related to this was the sample size of the ASD group, causing restrictions with regard to the complexity and comprehensiveness of the analyses that could be done. However, we were able to study development by operationalizing development in difference (Δ)-scores as a pure measure of development. The results of the present study need to be replicated, preferably in a larger sample, including a condition with intellectually matched children without ASD considering the difference in IQ between TD and ASD children in the current sample. Heart rate was analyzed in beats per minute as indicator of both the sympatric as the parasympathetic response. Using a larger repertoire of ANS indices is recommended, as studies including indices such as PEP and HRV have yielded complementary results. Even though IQ cannot be separated from the effects of the condition (Dennis et al., 2009), IQ was significantly lower in children with ASD, therefore we decided to investigate the role of IQ in the relationship between cognitive functioning and social attention.

In conclusion, the present study revealed that in young children with ASD, fundamental mechanisms of social behavior develop in early childhood during a relatively short period. In TD children, this improvement is related to maturational changes in behavioral and cognitive repertoires of understanding more and being able to show adaptive social behavior. Even though it is hypothesized that early ASD symptoms might represent a vulnerability in the development social brain systems that fail to become specialized and functionally integrated (Johnson et al., 2005; Webb et al., 2014), the present study highlights that even in six months there certainly is evidence for improvements and that intervening at this age might be warranted. Studying sensitive and direct indices of social-emotional mechanisms, such as eyetracking and heart rate, are anticipated to fuel ASD screening, diagnosis, and treatment (Bölte et al., 2016). With this knowledge, early experiences in this sensitive period can be targeted which could have a long-term impact on development and potentially improve developmental trajectories (Bradshaw, Steiner, Gengoux, & Koegel, 2015).

References

Achenbach, T. M., & Rescorla, L. A. (2000). Manual for the ASEBA Preschool forms and Profiles. . Burlington, VT: University of Vermont Department of Psychiatry.

Alkon, A., Goldstein, L. H., Smider, N., Essex, M. J., Kupfer, D. J., & Boyce, W. T. (2003). Developmental and contextual influences on autonomic reactivity in young children. Developmental Psychobiology, 42(1), 64-78.

Anderson, P. (2008). Towards a developmental model of executive function. In V. A. Anderson, R. Jacobs, & P. J. Anderson (Eds.), Executive functions and the frontal lobes: A lifespan perspective (pp. 3-22). Hove, England: Psychology Press.

APA. (1994). DSM-IV: Diagnostic and Statistical Manual of Mental Disorders.

APA. (2013). Diagnostic and statistical manual of mental disorders (DSM-5®): American Psychiatric Pub.

Bar-Haim, Y., Marshall, P. J., & Fox, N. A. (2000). Developmental changes in heart period and high-frequency heart period variability from 4 months to 4 years of age. Developmental Psychobiology, 37(1), 44-56.

Baron-Cohen, S., & Wheelwright, S. (2004). The empathy quotient: An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. Journal of Autism and Developmental Disorders, 34(2), 163-175. doi: 10.1023/b:jadd.0000022607.19833.00

Beauchamp, M. H., & Anderson, V. (2010). SOCIAL: An Integrative Framework for the Development of Social Skills. Psychological Bulletin, 136(1), 39-64.

Bedford, R., Elsabbagh, M., Gliga, T., Pickles, A., Senju, A., Charman, T., & Johnson, M. H. (2012). Precursors to social and communication difficulties in infants at-risk for autism: Gaze following and attentional engagement. Journal of Autism and Developmental Disorders, 42(10), 2208-2218.

Benevides, T. W., & Lane, S. J. (2015). A review of cardiac autonomic measures: considerations for examination of physiological response in children with autism spectrum disorder. Journal of Autism and Developmental Disorders, 45(2), 560-575.

Bishop, S. L., Guthrie, W., Coffing, M., & Lord, C. (2011). Convergent validity of the Mullen Scales of Early Learning and the differential ability scales in children with autism spectrum disorders. American Journal on Intellectual and Developmental Disabilities, 116(5), 331-343.

Bölte, S., Bartl-Pokorny, K., Jonsson, U., Berggren, S., Zhang, D., Kostrzewa, E., . . . Jones, E. (2016). How can clinicians detect and treat autism early? Methodological trends of technology use in research. Acta Paediatrica, 105(2), 137-144.

Bons, D., van den Broek, E., Scheepers, F., Herpers, P., Rommelse, N., & Buitelaaar, J. K. (2013). Motor, emotional, and cognitive empathy in children and adolescents with autism spectrum disorder and conduct disorder. Journal of abnormal child psychology, 41(3), 425-443.

Bradshaw, J., Steiner, A. M., Gengoux, G., & Koegel, L. K. (2015). Feasibility and effectiveness of very early intervention for infants at-risk for autism spectrum disorder: A systematic review. Journal of Autism and Developmental Disorders, 45(3), 778-794.

Calkins, S. D., & Keane, S. P. (2004). Cardiac vagal regulation across the preschool period: Stability, continuity, and implications for childhood adjustment. Developmental Psychobiology, 45(3), 101-112.

Chawarska, K., Macari, S., & Shic, F. (2012). Context modulates attention to social scenes in toddlers with autism. Journal of Child Psychology and Psychiatry, 53(8), 903-913.

Chevallier, C., Kohls, G., Troiani, V., Brodkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. Trends in cognitive sciences, 16(4), 231-239.

Chita-Tegmark, M. (2016). Social attention in ASD: A review and meta-analysis of eye-tracking studies. Research in developmental disabilities, 48, 79-93.

Constantino, J. N., & Gruber, C. P. (2005). The Social Responsiveness Scale. Los Angeles: Western Psychological Services.

Corbett, B. A., Swain, D. M., Newsom, C., Wang, L., Song, Y., & Edgerton, D. (2014). Biobehavioral profiles of arousal and social motivation in autism spectrum disorders. Journal of Child Psychology and Psychiatry, 55(8), 924-934.

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioral and electrophysiological studies. Developmental Neuropsychology, 27(3), 403.

De Sonneville, L. (2005). Amsterdamse Neuropsychologische Taken: Wetenschappelijke en klinische toepassingen. Tijdschrift voor Neuropsychologie, 0, 27-41.

De Sonneville, L. S. (2014). Amsterdam Neuropsychological Tests: Manual. Amsterdam: Boom.

Dennis, M., Francis, D. J., Cirino, P. T., Schachar, R., Barnes, M. A., & Fletcher, J. M. (2009). Why IQ is not a covariate in cognitive studies of neurodevelopmental disorders. Journal of the International Neuropsychological Society, 15(03), 331-343. doi: doi:10.1017/S1355617709090481

El-Sheikh, M., & Buckhalt, J. A. (2005). Vagal regulation and emotional intensity predict children's sleep problems. Developmental Psychobiology, 46(4), 307-317.

Fleming, S., Thompson, M., Stevens, R., Heneghan, C., Plüddemann, A., Maconochie, I., . . . Mant, D. (2011). Normal ranges of heart rate and respiratory rate in children from birth to 18 years of age: a systematic review of observational studies. The Lancet, 377(9770), 1011-1018.

Frazier, T. W., Strauss, M., Klingemier, E. W., Zetzer, E. E., Hardan, A. Y., Eng, C., & Youngstrom, E. A. (2017). A Meta-Analysis of Gaze Differences to Social and Nonsocial Information Between Individuals With and Without Autism. Journal of the American Academy of Child & Adolescent Psychiatry.

Gioia, G. A., Espy, K. A., & Isquith, P. K. (2001). Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P). Psychological Assessment Resources.

Gliga, T., & Csibra, G. (2007). Seeing the face through the eyes: a developmental perspective on face expertise Progress in Brain Research (Vol. 164, pp. 323).

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. Journal of Autism and Developmental Disorders, 39(5), 693-705.

Groen, W. B., Zwiers, M. P., van der Gaag, R.-J., & Buitelaar, J. K. (2008). The phenotype and neural correlates of language in autism: an integrative review. Neuroscience & Biobehavioral Reviews, 32(8), 1416-1425.

Guillon, Q., Hadjikhani, N., Baduel, S., & Roge, B. (2014). Visual social attention in autism spectrum disorder: Insights from eye tracking studies. Neuroscience and Biobehavioral Reviews, 42, 279-297. doi: 10.1016/j.neubiorev.2014.03.013

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. Science, 198(4319), 853.

Hessels, R. S., Kemner, C., van den Boomen, C., & Hooge, I. T. (2015). The area-of-interest problem in eyetracking research: A noise-robust solution for face and sparse stimuli. Behavior research methods, 1-19.

Hill, E. L. (2004a). Evaluating the theory of executive dysfunction in autism. Developmental Review, 24(2), 189-233.

Hill, E. L. (2004b). Executive dysfunction in autism. Trends in cognitive sciences, 8(1), 26-32.

Hinnant, J. B., Elmore-Staton, L., & El-Sheikh, M. (2011). Developmental trajectories of respiratory sinus arrhythmia and preejection period in middle childhood. Developmental Psychobiology, 53(1), 59-68.

Hooge, I., & Camps, G. (2013). Scan path entropy and arrow plots: capturing scanning behavior of multiple observers. Frontiers in psychology, 4.

Hughes, C., & Leekam, S. (2004). What are the links between theory of mind and social relations? Review, reflections and new directions for studies of typical and atypical development. Social development, 13(4), 590-619.

Jemerin, J. M., & Boyce, W. T. (1990). Psychobiological differences in childhood stress response. II. Cardiovascular markers of vulnerability. Journal of Developmental & Behavioral Pediatrics, 11(3), 140-150.

Johnson, M. H., Griffin, R., Csibra, G., Halit, H., Farroni, T., De Haan, M., . . . Richards, J. (2005). The emergence of the social brain network: Evidence from typical and atypical development. Development and psychopathology, 17(3), 599.

Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2-6-month-old infants later diagnosed with autism. Nature, 504(7480), 427-431.

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. Nature, 459(7244), 257-261. doi: http://www.nature.com/nature/journal/v459/n7244/suppinfo/nature07868_S1.html

Korkman, M., Kirk, U., & Kemp, S. (2007). The Developmental Neuropsychological Assessment II (NEPSY-II). San Antonio, Texas, USA: Harcourt Assessment.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. Biological psychology, 84(3), 394-421.

Le Couteur, A., Lord, C., & Rutter, M. (2003). The Autism Diagnostic Interview-Revised (ADI-R). Los Angeles: Western Psychological Services.

Levine, T. P., Sheinkopf, S. J., Pescosolido, M., Rodino, A., Elia, G., & Lester, B. (2012). Physiologic arousal to social stress in children with autism spectrum disorders: a pilot study. Research in Autism Spectrum Disorders, 6(1), 177-183.

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., . . . Rutter, M. (2000). The Autism Diagnostic Observation Schedule-Generic: A standard measure of social and communication deficits associated with the spectrum of autism. Journal of Autism and Developmental Disorders, 30(3), 205-223. doi: 10.1023/a:1005592401947

Matthews, K. A., Woodall, K. L., & Stoney, C. M. (1990). Changes in and Stability of Cardiovascular Responses to Behavioral Stress: Results from a Four-Year Longitudinal Study of Children. Child development, 61(4), 1134-1144.

Mauss, I. B., & Robinson, M. D. (2009). Measures of emotion: A review. Cognition and emotion, 23(2), 209-237.

Moriguchi, Y. (2014). The early development of executive function and its relation to social interaction: a brief review. Frontiers in psychology, 5.

Mullen, E. M. (1995). Mullen Scales of Early Learning. Circle Pines, MN: American Guidance Service.

Neuhaus, E., Bernier, R. A., & Beauchaine, T. P. (2016). Children with autism show altered autonomic adaptation to novel and familiar social partners. Autism Research, 9(5), 579-591.

O'Hearn, K., Asato, M., Ordaz, S., & Luna, B. (2008). Neurodevelopment and executive function in autism. Development and psychopathology, 20(4), 1103-1132.

Olsen, A. (2012). The tobii i-vt fixation filter. Tobii Technology.

Papagiannopoulou, E. A., Chitty, K. M., Hermens, D. F., Hickie, I. B., & Lagopoulos, J. (2014). A systematic review and meta-analysis of eye-tracking studies in children with autism spectrum disorders. Social Neuroscience, 9(6), 610-632. doi: 10.1080/17470919.2014.934966

Perner, J., & Lang, B. (2000). Theory of mind and executive function: is there a developmental relationship?

Rommelse, N. N. J., Altink, M. E., Oosterlaan, J., Buschgens, C. J. M., Buitelaar, J., & Sergeant, J. A. (2008). Support for an independent familial segregation of executive and intelligence endophenotypes in ADHD families. Psychological Medicine, 38(11), 1595-1606.

Salva, O. R., Farroni, T., Regolin, L., Vallortigara, G., & Johnson, M. H. (2011). The evolution of social orienting: evidence from chicks (Gallus gallus) and human newborns. PLoS One, 6(4), e18802.

Schlichting, L. (2005). Peabody picture vocabulary test-III-NL. Amsterdam, the Netherlands: Hartcourt Assessment BV.

Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. Proceedings of the National Academy of Sciences, 105(2), 809-813.

Swaab, H., de Sonneville, L., Cohen-Kettenis, P., Gielen, A., Buitelaar, J., & van Engeland, H. (2000). Visual sustained attention in a child psychiatric population. Journal of the American Academy of Child and Adolescent Psychiatry, 39(5), 651-659. doi: 10.1097/00004583-200005000-00020

Tellegen, P. J., Winkel, M., Wijnberg-Williams, B., & Laros, J. A. (1998). SON-R 2,5-7: Manual and research report. Amsterdam: Hogrefe uitgevers.

Van der Heijden, K. B., Suurland, J., De Sonneville, L. M. J., & Swaab, H. (2013). BRIEF–P Executive Functioning Questionnaire for Preschoolers. Amsterdam, the Netherlands: Hogrefe.

van Rijn, S., & Swaab, H. (2015). Executive dysfunction and the relation with behavioral problems in children with 47,XXY and 47,XXX. Genes Brain and Behavior, 14(2), 200-208. doi: 10.1111/gbb.12203

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. Nat Neurosci, 6(6), 624-631.

Webb, S. J., Jones, E. J., Kelly, J., & Dawson, G. (2014). The motivation for very early intervention for infants at high risk for autism spectrum disorders. International journal of speech-language pathology, 16(1), 36-42.

Wechsler, D. (2006). WPPSI-R manual: Wechsler preschool and primary scale of intelligence-revised. San Antonio: Psychological Corporation.

Wechsler, D., & Naglieri, J. A. (2006). Wechsler Nonverbal Scale of Ability (WNV). San Antonio, TX: Harcourt Assessment.

White, S. W., Mazefsky, C. A., Dichter, G. S., Chiu, P. H., Richey, J. A., & Ollendick, T. H. (2014). Social-cognitive, physiological, and neural mechanisms underlying emotion regulation impairments: Understanding anxiety in autism spectrum disorder. International Journal of Developmental Neuroscience, 39, 22-36.

Zantinge, G., van Rijn, S., Stockmann, L., & Swaab, H. (2017a). Physiological Arousal and Emotion Regulation Strategies in Young Children with Autism Spectrum Disorders. Journal of Autism and Developmental Disorders, 1-10.

Zantinge, G., van Rijn, S., Stockmann, L., & Swaab, H. (2017b). Psychophysiological responses to emotions of others in young children with autism spectrum disorders: Correlates of social functioning. Autism Research.

Zijlstra, H., Kingma, A., Swaab, H., & Brouwer, W. (2010). Nepsy-II-nl. Enschede: Ipskamp.