Emotion Expression and Emotional Arousal in Children with Autism Spectrum Disorder

Tessel Bazelmans, 0906689

Leiden University

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Faculty of Social and Behavioral Sciences

Supervisors: Dr. S. van Rijn, Prof. Hanna Swaab

Abstract

Children with autism spectrum disorder (ASD) are characterized by communication deficits. Emotions are part of interpersonal communication and adequate use of emotions are vital for successful interaction. To see if children with ASD express emotions to the same extent, we compared 17 children with ASD (age range: 3-6 years) to 33 typically developing children of the same age on both on behavioral emotion expression and on psychophysiological arousal. The behavioral expression and psychophysiological parameters of emotion (heart rate and skin conductance level) were continuously measured during rest and a fear inducing paradigm. The groups did not differ on the intensity of negative or positive emotion expression. The ASD group had lower skin conductance levels during rest compared to the typically developing children and a more pronounced increase in psychophysiological arousal in response to a fear paradigm. To integrate these two separate measures of emotion, the concordance between the behavioral and psychophysiological components was evaluated. Negative emotions were related to heart rate in the ASD group and to skin conductance in the control group, but the strength of the correlation did not differ significantly between the two groups. Considering the health and behavioral risks associated with abnormal levels of emotional arousal, the specific effects of deviant emotional arousal in children with ASD need to be further explored. Targeting psychophysiological levels of arousal in interventions might be an effective approach to ameliorate challenging behavior in children with ASD.

Keywords: Autism Spectrum Disorder, Concordance, Emotion expression, Fear, Psychophysiology

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder that affects approximately 0.5-1.0 percent of the population, particularly boys (American Psychiatric Association, 2013; Elsabbagh et al., 2012). ASD is characterized among other things by deficits in social communication and interaction, i.e. the verbal and non-verbal sharing of information between people (American Psychiatric Association, 2013). One of the factors that contributes to these deficits is the impediment in the sharing of emotion which individuals with ASD encounter (Kanner, 1943).

The concept of emotion can be approached from a multi-componential view. Two of these components presented in the literature are expressive behavior and psychophysiology (e.g. Ekman, 1992; Frijda, 2008; Sander, 2013; Scherer, 1984, 2005). The expressive behavior component, encompassing bodily and facial expression, is important for the communication with, and the signaling of others (Sullivan & Lewis, 2003). From birth, children are directly capable of expressing emotion which become more discrete through development (Begeer, Koot, Rieffe, Terwogt, & Stegge, 2008; Sullivan, & Lewis, 2003). Accurate expression and interpretation of social signals is vital for successful interaction and, accordingly, deficits in expression may result in misapprehension by others, for instance parents, hampering the communication (Begeer et al., 2008; Ekman, Friesen, & Ancoli, 1980; Kasari & Sigman, 1996). For young children, being accurately understood is even more essential than for adolescents or adults, as they heavily depend on the care of others.

One of the other components, psychophysiology, is important for system regulation of the body (Levenson, 2014; Scherer, 2005). The autonomic nervous system (ANS) serves to maintain homeostasis, but also to prepare the body for challenges (Charmandari, Tsigos, & Chrousos, 2005). For example, when someone encounters a change in the environment which elicits fear, the body responds by increasing heart rate and skin conductance, enabling the body to respond appropriately (Kreibig, 2010). Failure of the ANS to accurately adapt the inner body state can impede a correct response to the situation. Furthermore, excessive activation of the ANS is associated with health problems (Bauer, Quas, & Boyce, 2002).

For emotions to emerge there needs to be some degree of coordination between the different components of emotion (e.g. Ekman, 1992; Scherer, 1984). This ‘emotional concordance’ is necessary for an adaptive response to the demands of the environment, which requires social interaction as well as internal changes and preparation for physical action (Scherer, 2009). Insight into emotional concordance can possibly help to elucidate the emotional processes in children with ASD (Goodwin et al., 2006). Therefore in the present research we look at both expressive behavior and psychophysiological data and incorporate the two by looking at the concordance between them.

Although a lack of facial expressions is considered one of the traits of ASD (American Psychiatric Association, 2013), scientific studies find that young children with ASD display emotions as much as typically developing children (Baranek, 1999; McGee, Feldman, & Chernin, 1991; Yirmiya, Kasari, Mundy, & Sigman, 1989). Parent rate their children with ASD also as highly expressive (Capps, Kasari, Yirmiya, & Marian, 1993). The nature of expression on the other hand does often differ; facial expressions are described as blended, mechanical and bizarre (Loveland, et al., 1994; Yirmiya, et al., 1989). Their expression of emotion in various situations also differs from what is to be expected based on typically developing children (McGee, Feldman, & Chernin, 1991). For instance, they show high levels of distress and low expressions of positive emotion during interaction, which is opposite to the emotions observed in children without ASD (Capps et al., 1993; Dawson, Hill, Spencer, Galpert, & Watson, 1990; Gulsrud, Jahromi, & Kasari, 2010; Kasari, Sigman, Mundy, & Yirmiya, 1990; Snow, Hertzig, & Shapiro, 1987). Expressive behavior has been extensively studied in social situations, but less in response to non-social stressors (e.g. pictures, objects). A study by Jahromi, Meek, and Ober-Reynolds (2012) used a frustration paradigm and found that children with ASD showed similar levels of negative emotions to the typically developing children. In sum, these studies imply that although children with ASD are inclined to express more negative emotions during social situations, they are capable of expressing emotions with similar intensity as typically developing children. This however does not necessarily indicate that they experience comparable levels of arousal. This emphasizes the urge to include psychophysiological measures in research (Capps et al., 1993).

Evidence regarding emotional arousal of people with ASD is elusive, both in response to emotion inducing stimuli and for resting levels of arousal (Lydon et al., 2014). Lower cardiovascular and electrodermal activity in the ASD group was found in studies using social stressors with adults (Hubert, Wicker, Monfardini, Deruelle, 2009; Jansen et al., 2006) and children (Jansen, Gispen-de Wied, Van der Gaag, & Van Engeland, 2003; Kushki, Brian, Dupuis, & Anagnostou, 2014; Stagg, Davis, & Heaton, 2013; Van Hecke et al., 2009). This was true even when the levels of reported stress were similar. The deviant pattern was specific for the psychosocial stress; no difference in heart rate (HR) was noted during physical exercise (Jansen et al., 2003). Others however found increased HR (Hollocks, Howlin, Papadopoulos, Khondoker, & Simonoff, 2014) or non-significant results (Klusek, Martin, & Losh, 2013; Levine et al., 2012). Results regarding cardiovascular or electrodermal activity in response to non-social stimuli are just as divided. There are indications for no differences (Bölte, Feineis-Matthews, & Poustka, 2008; Shalom et al. 2006), higher HR and skin conductance level (SCL; Kushki et al., 2013), and less response to these stressors compared to controls (Goodwin et al., 2006).

For the interpretation of arousal levels it is critical to contemplate the differences during rest between children with ASD and typically developing children, as high basal levels could for instance flatten the response (Goodwin et al., 2006). There are indications for comparable levels of electrodermal (Kushki et al., 2014; Levine et al., 2012) and cardiac activity (Klusek et al., 2013) during rest, while others found elevated resting levels of cardiac activity (Bal et al., 2010; Goodwin et al., 2006; Kushki, et al., 2013; Kushki et al., 2014) for children with ASD. In sum, about half of the studies suggest no differences during rest or provoked levels of psychophysiological arousal, whereas the other half of the studies report hyper-arousal at rest and either hypo-arousal or hyper-arousal in response to social and non-social stimuli (for review, see Lydon et al., 2014). The majority of these studies however included participants over the age of six with high-functioning ASD. The emotional arousal of younger children needs to be clarified.

The behavioral and physiological components are both vital for the existence of emotion (Scherer, 1984). Although theoretically there is much support for the emotional concordance theory, empirical evidence is lacking (Hollenstein & Lanteigne, 2014). When assessing emotional concordance during induced emotions, the relationship between psychophysiology and behavior is found to be weak at best (Hollenstein & Langteigne, 2014). Moderate levels of concordance were found for positive emotion expression with psychophysiological arousal, however negative emotion expression was only related to increased electrodermal activity and not to cardiovascular activity (Mauss et al., 2005). Evidence from experimental studies shows that there is a certain degree of coordination between emotional expression and psychophysiology; consciously altering one of the components also influences other subsystems. For example, voluntary facial expressions of emotion alter a person’s psychophysiological state (Levenson, Ekman, & Friesen, 1990). To our knowledge, there is only one study looking at the correlation between the components of behavior and psychophysiology within the ASD population. In this study, SCL was not related to observed behavioral distress during a visit to the dentist in children with ASD, and was negatively related to behavioral distress in the control group (Stein et al., 2014). No direct comparison of the concordance rates between the ASD and control groups has been made before.

The current study aimed to evaluate the emotion processes in young children aged three to six years with ASD in comparison to typically developing children. The first objective was to investigate whether young children with ASD differ from typically developing children in their emotional response, both in their expression of emotion and their psychophysiology. The second objective concerns the concordance between the behavioral expression and psychophysiological components. The question is whether the concordance between the facial/bodily expression and the HR and SCL is the same in children with and without ASD. The answers to these questions might clarify what causes the difficulties with processing and expressing emotions in young children with ASD. Knowing what underlies these difficulties could lead to more targeted early interventions for the children and better support for parents/caregivers to enhance the communication with their child.

Method

The study was approved by the Ethics Review Board of Leiden University. The results of this study are preliminary and data collection is proceeding in order to obtain a larger sample.

Participants

The current study is part of a longitudinal research project on emotion regulation in young children with ASD. Children were excluded if the paradigm did not last longer than thirty seconds or if the physiological data was invalid due to technical problems or movement artifacts in the signal. Also if children showed excessive movements they were not included in the study. This is because physical effort can influence the arousal levels and this cannot be separated from the arousal induced by emotion. Excessive movement was established by visual inspection of the video material. The final sample consists of 17 children with ASD, 16 boys and 1 girl, with an average age of 5.1 years (*SD* = 0.80) and 32 typically developing children, 26 boys and 6 girls, with an average age of 4.7 years (*SD* = 1.00). The two groups did not differ in age ($t(47) = -1.35$, $p = .184$) nor gender ratio ($\chi^2(1) = 1.50$, $p = .220$). The control group was recruited through elementary schools, libraries, and informal advertisement. The children in the clinical sample either attended *Centrum Autisme*, an autism clinic situated in Zuid-Holland, The Netherlands, or were recruited through local institutions supporting children with ASD. Exclusion criteria for all participants were neurological conditions, severe head trauma, and/or a metabolic conditions. Additionally, the clinical group needed a clinical diagnosis of an ASD according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; APA 2000) before participating. All diagnoses were provided by a psychiatrist based on diagnostic assessment within a multi-disciplinary team. The Autism Diagnostic Observation Scale (ADOS; Lord et al., 2000) and Autism Diagnostic Interview – Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003), conducted by trained clinicians, were part of the ASD diagnosis of all children included in the clinical sample of the study.

Instruments

Rest. To measure HR and SCL during rest, the children were asked to watch a three-minute video clip. They were instructed to sit still and to not talk to the experimenter while watching a clip showing fish swimming in an aquarium.

Fear paradigm. In this paradigm, derived from the Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith & Rothbart, 1999), a toy robot approached the child several times to induce fear. The child was seated in a car seat with the parent sitting in the corner of the room behind the child. Two cameras were placed, one aimed at the child from the front, with the parent in the background; and one next to the parent, recording the child from behind and facing the robot. The children were asked to remain seated in the chair and to wait for the next task to begin directly before the start of the paradigm. Experimenter 1 was standing behind the child operating the computer with the physiology equipment, while experimenter 2, dressed in a lab coat and glasses, entered the room carrying the robot. The robot was set on the floor in front of the child. The second experimenter used the control device to let the robot approach the child for twelve seconds. Here, the robot moved his arms making a growling sound, and then walked back to the starting position in fifteen seconds. This was repeated two more times, followed by the robot moving his arms and growling one last time positioned on its starting position. Next, experimenter 2 switched off the robot using the button on the back of the robot before leaving the room. Experimenter 1 asked the parent to approach the child and give support as needed. The parent was instructed to withhold from interaction with the child. However, at any point during the paradigm, the parent was allowed to interfere and break off the paradigm if the parent thought the task was too stressful for the child. The paradigm from the first approach until the robot was switched off took approximately three minutes. Because the purpose of the current study is to observe emotional reactions in children and not their emotion regulation strategies, only the first 30 seconds of data was used. This way, the initial reaction of the child in response to the stressor is measured as expressed in their behavioral expression and psychophysiological arousal. An average score was calculated for positivity and negativity over the three 10 second blocks in these first 30 seconds.

Physiology. Using the Biopac MP150 system (Biopac Systems, Inc.) heart rate and skin conductance were continuously acquired during a three-minute rest period and during the fear paradigm. HR, reported in beats per minute (BPM), was measured using the ECG100C amplifier (gain = 1000 Hz, output = normal, low-pass filter = off, high-pass filter = 0.5Hz).

Two electrodes were attached to the child’s chest, one in the middle of the upper chest and the other one ten centimeters above the lower rib on the left side. SCL, reported in µS, was measured using the GSR100C amplifier (gain = 10µS/V, low-pass filter = 10 Hz, both high-pass filters = DC). Pre-gelled, isotonic Ag/AgCl-electrodes were attached to the middle phalanges of the index finger and ring finger of the non-dominant hand.

Procedure

Before participation, parents and/or caregivers of the child had to give written informed consent. Via the mail, parents received an information letter beforehand which included the electrodes used in the study to familiarize the children. The research environment was kept simple with limited external stimuli to avoid overstimulation or distraction, which is especially important since sensory processing in children with ASD is deviant (Baker, Lane, Angley, & Young, 2009). During the first part of the day, several aspects of the child’s development were assessed. After a short break the child and parent were brought into a room together. The parent was asked to fill out questionnaires and to withhold from interaction with the child. The experimenter working with the child was kept the same throughout the day. Alcohol wipes were used to clean the child’s chest prior to attaching the HR electrodes and children were asked to wash their hands before placing the SCL electrodes. The start-markers and end-markers of the rest period and fear paradigm were given manually in AcqKnowledge (Biopac Systems, Inc.).

Data analysis

Behavioral coding. Facial and bodily negativity and positivity were coded from the videos in 10 second intervals on a four-point scale (0-3) by two independent coders. The observation scale was based on the facial indicators of emotion as outlined in the FACS (Fear

Action Coding Scale; Ekman & Friesen, 1978) and the Lab-TAB scoring system (Goldsmith & Rothbart, 1999). Although negativity was the expected emotion in this paradigm, many children also showed signs of positivity, such as smiling. Because positive emotions are also related to psychophysiological levels of arousal, positive emotion expressions of the children were measured and analyzed in this study as well. Three emotion categories (fear, sadness/anger, and positivity) were coded independently for all children. A score of ‘0’ was given if there was no sign of fear, sadness/anger, or positivity, ‘1’ if there was minimal emotion expression (one facial/bodily indicator of negativity/positivity), ‘2’ if there was moderate emotion expression (more than one, or heightened level of one indicator of facial/bodily expression), and ‘3’ if the emotion expression was very intense (e.g. crying). Because of simultaneous occurrence of fear and sadness/anger features in the videos, it was decided to calculate a composite score of negativity instead of using the separate categories of fear and sadness/anger. The highest score on either fear or sadness/anger was taken per ten seconds, resulting in a scale for negativity ranging from 0 to 3. Interrater reliability (IRR) was estimated using the single measures of a two-way mixed, absolute agreement interclass correlation model (Hallgren, 2012). The IRR, calculated on the 10s intervals of 12 videos, is substantial for negativity (ICC = .79, $p < .001$) and high for positivity (ICC =.92, $p <.001$). All discrepancies on these double coded videos were discussed within the team to obtain a final score. Next, average scores over the three 10s-intervals were calculated for both positivity and negativity. The observed skewness of positive ($z = 3.30$) and negative ($z = 3.96$) emotion expression in the control group was corrected by applying a log-transformation to the observational data of the total sample. As scores of zero cannot be log-transformed, a score of one was added to the average score before log-transforming.

Physiology. After data acquisition, a lowpass digital Buttherworth filter with a cutoff frequency of 0.33 Hz was applied to the raw skin conductance signal in MATLAB (The

MathWorks, Inc.). Skin conductance data was inspected for anomalies (e.g. sudden drops below zero) indicating measurement artifacts. The R-waves were visually inspected to see if all peaks were detected. Missing peaks and anomalies were deleted using AcqKnowledge. The mean HR (in BPM) and SCL (in µS) over the three minute rest period and the first thirty seconds of the fear paradigm were calculated using MATLAB.

Statistical analysis. For the statistical analyses, the IBM software Statistical Package for the Social Sciences (SPSS; version 21) was used. After data-transformation, all variables approached the normal distribution and therefore parametric tests were used. Four separate t-tests were conducted to compare the groups (ASD, control) on emotional expression (positive and negative) during the fear paradigm and emotional arousal (HR and SCL) during rest. To examine the effect of condition (rest, fear paradigm) and to look at group differences, a mixed design analysis of variance (ANOVA) was performed twice with HR and SCL as dependent variables. In both ANOVAs, the independent variables were the condition as within-subject factor and the group as between-subject factor. Finally, to look at the concordance between the behavioral and physiological components of emotion, Pearson correlations were used. Partial correlations were calculated for correlations between emotion expression (positive and negative) and psychophysiology (HR and SCL during the fear paradigm), controlled for HR and SCL during rest respectively. The Pearson correlations were repeated without controlling for resting levels as it was found in previous research that absolute values of physiology correlated better with emotion, compared to scores controlled for resting levels (Golland, Keissar, & Levit-Binnun, 2014). Correlations of the ASD group were compared to the control group by calculating the Fisher's *z*-scores and these were used to compute the *z*-score of the difference.

Results

The descriptive statistics of the variables can be found in Table 1. To inspect the data on outliers, the data was standardized by converting the rest and fear paradigm physiology data to *z*-scores for the two groups separately. None of the children had extreme *z*-scores ($z > 2.5$) on either the HR or SCL measures compared to their respective groups.

Table 1
Descriptive Statistics

	Control				ASD			
	N	*M* (*SD*)	Min	Max	*N*	*M* (*SD*)	Min	Max
Expression								
Positive	32	0.41 (0.58)	0	2.00	17	0.73 (0.91)	0	2.67
Negative	32	0.71 (0.76)	0	3.00	17	1.02 (0.95)	0	3.00
Physiology - rest								
HR	32	93.16 (12.51)	70.60	120.50	17	96.32 (9.26)	84.25	113.88
SCL	30	8.25 (5.30)	0.92	21.22	14	4.51 (2.21)	1.10	8.03
Physiology - robot								
HR	32	95.14 (13.55)	67.82	122.25	17	102.98 (11.67)	83.63	125.32
SCL	30	12.76 (4.96)	2.70	21.68	14	13.21 (5.46)	6.03	25.19

Note. Heart rate is given in beats per minute, skin conductance level is given in µS.

Behavioral emotion expression. After data-transformation, the average intensity of positive emotion expression was 0.12 (*SD* = 0.16) for the control group and 0.19 (*SD* = 0.22) for the ASD group. The intensity of negative emotion expression was on average 0.20 (*SD* = 0.17) for the controls and 0.26 (*SD* = 0.20) for the ASD group. The two groups did not differ significantly on either the intensity of positive ($t(47) = -1.29$, $p = .204$) or negative ($t(47) = -1.18$, $p = .245$) emotion expression.

Psychophysiology. During the rest period the two groups did not differ significantly on HR ($t(47) = -.91$, $p = .365$). The mixed design ANOVA indicated a main effect of condition ($F(1,47) = 10.10$, $p = .003$, $\eta^2 = .18$; Figure 1a), with higher HR during the fear paradigm compared to rest. There was no main effect of group ($F(1) = 2.60$, $p = .114$, $\eta^2 = .05$). The condition by group interaction effect was borderline significant ($F(1,47) = 2.96$, $p = .092$, $\eta^2 = .06$). The ASD group showed a larger increase in HR from rest to the fear paradigm compared to the control group. For post-hoc comparison, two separate paired t-tests were conducted.

These showed that the increase in HR from rest to the fear paradigm was significant for the ASD group (*t*(28) = -6.93, *p* < .001), but not for the control group (*t*(31) = -1.49, *p* = .145).

For SCL, the ASD group had a significantly lower levels during rest compared to the control group (*t*(42) = 3.30, *p* = .002, Cohen's *d* = 0.92). Not all assumptions for the mixed design ANOVA were met; the Levene's test for equality of error variance was significant for rest SCL (*F*(1,40) = 8.04, *p* = .007), with a larger standard error for the ASD group (SE = 1.15) compared to the controls (SE = 0.77). Therefore these results should be interpreted with caution. There was a significant effect of condition (*F*(1,40) = 85.14, *p* < .001, η^2 = .68), resulting in higher levels during the fear paradigm compared to the rest condition (Figure 1b). The main effect of group was not significant (*F*(1) = 2.18, *p* = .148, η^2 = .05). There was a borderline group by condition interaction effect (*F*(1,40) = 3.65, *p* = .063, η^2 = .08). The increase in SCL from rest to the fear paradigm was larger in the ASD group than the control group. Post-hoc comparison, using paired t-tests, showed that the increase in SCL was

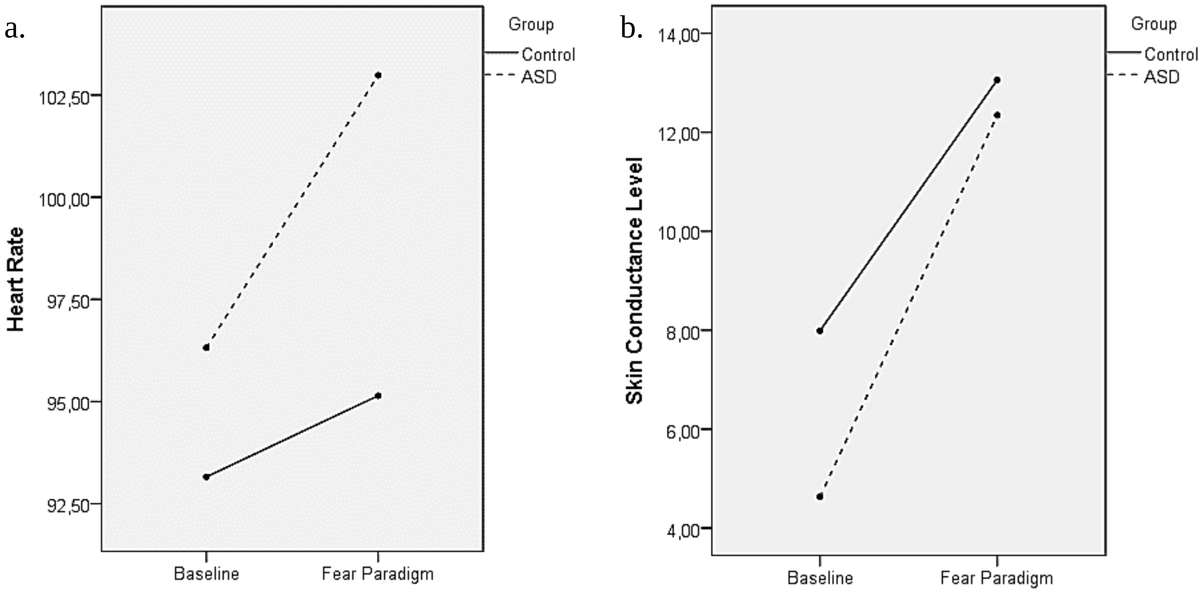

Figure 1. Mixed design ANOVA with group and condition as independent variables and (a) heart rate and (b) skin conductance level as dependent variables.

significant for both the ASD group (*t*(12) = -6.04, *p* <.001) and the control group (*t*(28) = -2.39, *p* = .030).

Concordance. Partial correlations were used to examine the concordance between emotion expression and psychophysiology, while controlling for resting levels. There was a significant correlation for the ASD group between intensity of negativity and HR (*r* = .63, *p* = .008), but not SCL (*r* = .35, *p* = .260). For the control group, the correlation between the intensity of negative expression and SCL was significant (*r* = .53, *p* = .003) and the correlation with HR was borderline significant (*r* = .32, *p* = .084). There were no significant correlations between positivity and either of the two physiology measures when controlled for the respective resting levels. When we did not control for resting levels, none of the correlations were significant. Because we were interested in the group differences in concordance the Fisher's *z* was used to compare the two groups. The ASD group did not differ from the control group in the concordance between the intensity of negative emotion expression and HR (*z* = 1.26, *p* = .209) nor SCL (*z* = 0.59, *p* = .558). This suggests that the relation between the intensity of negative expression and HR is not significantly higher and the relation with SCL not significantly lower for the ASD group compared to the control group.

Discussion

In this study, we investigated the emotional response of children with Autism Spectrum Disorder (ASD) to a fear paradigm by looking at the behavioral and psychophysiological components of emotion. The group of children with ASD was compared to typically developing children on facial/bodily emotion expressions (the behavioral component) and heart rate and skin conductance level (the psychophysiological component). Additionally, we compared the children on the autonomic parameters during rest. Next, we explored the relation between the intensity of behavioral emotion expression and the intensity of emotional arousal as measured in heart rate and skin conductance level.

The two groups of children did not show differences in the intensity of behavioral emotion expression; the children with ASD and the typically developing children had similar intensity levels of facial/bodily negativity and positivity during the fear paradigm. Regarding the autonomic parameters, the level of arousal as expressed in heart rate was similar in both groups during rest, but they did differ in skin conductance level. The results indicated that the ASD group scored almost one standard deviation (Cohen's $d = 0.96$) below the control group on the latter. An increase in arousal was seen during the fear paradigm, reflected in heightened heart rate in the ASD group and heightened skin conductance levels in both groups compared to the resting state. The results for group differences in the increase from rest to the fear paradigm were borderline for both heart rate and skin conductance level. Compared to the typically developing children, the children with ASD showed hyper-arousal in terms of a larger increase from rest to the fear paradigm in both heart rate and skin conductance level. The concordance between expressive behavior and psychophysiology shows different patterns in both groups. Whereas the intensity of negative emotions was related to SCL in the control group, for the children with ASD there was a relation between negativity and heart rate. These relations were only found when we covaried for resting states of heart rate and skin conductance. This indicates that it is the increase in arousal from rest that is related to the intensity of negative emotion expression and not the absolute level of arousal of an individual. None of the physiology measures were related to the intensity of positive expression.

According to our results, when children with ASD are in a non-social stressful situation, they are capable of expressing their emotions to the same extent as typically developing children. This is in line with the conclusions of Jahromi, Meek, and Ober-

Reynolds (2012). The results appear to suggest that parents of children with ASD can depend on their child's signals in non-social stressful situations, which is beneficial for the communication. Merely looking at differences in behavioral expression does however not imply that the intensity of the expressed emotion in a child's body and face is consistent with the inner state (Ekman, 1992). Therefore we also looked at the psychophysiological response of the children to a stimulus.

When comparing the children with ASD to the typically developing children on the autonomic parameters, we found lower levels of skin conductance in the children with ASD during rest and more pronounced reactions in heart rate and skin conductance level in response to the fear paradigm. Although the group differences in response to the fear paradigm were borderline, the sample size was small. A lack of power could underlie the non-significant results and the medium effect size emphasizes the group differences. Together these results imply dysregulation of the autonomic nervous system in children with ASD. This suggests that interventions aiming to help children regulate their emotional arousal might be most beneficial for children with ASD.

Stimulation-seeking theories argue that because of the uncomfortably low levels, people with low arousal levels seek to stimulate these (Ortiz, & Raine, 2004). Low chronic levels of arousal have been associated with being restless and easily distracted (Satterfield et al., 1974), as well as disruptive and externalizing behavior (Posthumus, Böcker, Raaijmakers, Van Engeland, & Matthys, 2009; Van Goozen, Matthys, Cohen-Kettenis, Buitelaar, & Van Engeland, 2000); such symptoms are associated with attention deficit hyperactivity disorder (ADHD; American Psychiatric Association, 2013). Given the high comorbidity of ASD and ADHD, these behaviors are not uncommon in the ASD population (Russell et al., 2014). It would be of interest to see if low levels of arousal are associated with these similar types of behaviors in children with ASD.

The more extreme response to novelty in comparison to typically developing children might lead children with ASD to avoid novel environments and stimuli as presented in restricted interests and difficulty with change (Kinsbourne, 2011). High levels of stress in children with ASD is associated with stereotypic and even self-injurious behaviors (Morgan, 2006) and this association might be mediated by levels of arousal (McDonnell et al., 2015). Hypothetically, reducing the emotional arousal of children with ASD could decrease their avoidance of new situations and reduce the stress associated with change to alleviate stereotypic behavior.

A hypothesis of the more extreme response to fearful stimuli within children with ASD comes from the intense world theory. This theory states that children with ASD experience their surroundings as more stressful because of an overly active limbic system (Markram & Markram, 2010). Putatively, the role of the amygdala, a part of the limbic system, in fear and the perception of threatening stimuli (see LeDoux, 2002) and moreover the relation between amygdala activation and cardiac activity (Yang et al., 2007), could explain the hyper-arousal as observed in the ASD group. The possible effect of heightened amygdala activity on the extreme psychophysiological response in reaction to a threatening stimulus is something that should be addressed in future research.

Our results of hypo-arousal are in contrast with previous studies showing similar or heightened levels during rest (Lydon et al., 2014). An explanation for these opposing results could be a division within the ASD group in physiological levels at rest (Mathersul, McDonald, & Rushby, 2013; Schoen, Miller, Brett-Green, & Hepburn, 2008). Besides the hyper-arousal often found, some studies suggest that there is a subgroup of children with ASD showing hypo-arousal during rest. In the development of interventions, these subgroups should be considered as they might respond differently to treatment. What is most effective in treating children showing hypo-arousal during rest might not be beneficial for the group showing hyper-arousal.

Integrating the behavioral and physiological components, both groups show concordance, however the pattern differs. Extrapolating the results of Moskowitz et al. (2013), this shows that if children with ASD are more aroused, as reflected in their heart rate, they also show more negative expression. The relationship between negative expression and heart rate explained four times more variance in the ASD group compared to the control group, for whom the relationship was not significant. However, when comparing the concordance no significant group differences were found. For skin conductance, the results were reversed; there was a relation between the intensity of negative expression and skin conductance for the control group, but not the ASD group. The latter is in line with the results by Stein et al. (2014). Again, direct comparison of the relations did not yield any differences between the groups.

In the typically developing children concordance was found between negative emotion expression and skin conductance, but not between negative emotion expression and heart rate, which is similar to the results by Mauss et al. (2005). This pattern could perhaps be explained by the defense cascade model (Lang et al., 1997). This model proposes that during moderate activation of the defense system the heart rate decelerates first in reaction to negative stimuli (Bradley et al., 2001). In this stage there is heightened attention and orientation toward the stimulus. In contrast, the skin conductance level would be expected to show a steady increase from rest to the paradigm. This would explain that the intensity of negative expression is related to skin conductance in the typically developing children, but that the relation with heart rate in this initial response to the fearful stimulus is somewhat lower. Hypothetically, this initial deceleration during the first few seconds could also be a reason no increase in heart rate for the typically developing children was found. Moment-to-moment changes could elucidate whether this same defense system exists in the ASD group. If the children with ASD do not show this initial deceleration, they might not anticipate the situation and always show an immediate response to relatively harmless stimuli, causing excessive activation of the autonomic nervous system.

The results of the current study give implications for further research; they can be used as a foundation for studies of emotion regulation in individuals with ASD. In the general population emotion regulation is found to moderate the level of concordance (Hollenstein & Langteigne, 2010). Butler, Gross, and Barnard (2014), for example, showed that expressive suppression or expressive reappraisal lowers the level of concordance between emotional arousal and facial expression. Individuals with ASD differ in the way they try to regulate emotions compared to typically developing people and these strategies might not be as effective (Mazefsky, Borue, Day, & Minshew, 2014). Speculatively, if persons with ASD are unable to regulate their emotions effectively, they would show no decrease in emotional concordance during emotion regulation, which is in contrast with what we do expect in typically developing individuals (Hollenstein & Langteigne, 2010). Extending this research by including emotion regulation could test the plausibility of this theory and evaluate the emotion regulation strategies used by children with ASD.

There are several limitations of the study that should be noted. Firstly, the sample size was small, preventing the inclusion of covariates such as intelligence. A larger sample should also be obtained to gain more power and to enable the use of more accommodating statistics for comparing the groups on concordance. For example, a linear regression with group as moderator would suit better to compare the differences found in concordance between expressive behavior and psychophysiology for the two groups. Secondly, the results might be biased by excluding children who did not finish the paradigm due to extreme reactions or who showed excessive movements, as observed in the videos and in the physiology data. The movements could be related to higher intensity of expression, thus filtering out the most expressive children. The number of children excluded based on these criteria was however comparable in both groups (three in the control group, two in the ASD group). For the remaining children there was a specific relation between psychophysiological arousal and the intensity of negative, not positive, emotion expression. This accentuates that arousal was not induced by expressiveness in general but restricted to negative emotions. Thirdly, we did not control for medication use, which could influence arousal levels (Satterfield et al., 1974), although these results are not always replicated (Schoen et al., 2007). Because not enough is known to ignore the possible effect medication can have on either resting levels or psychophysiological responses, the use of medicine should be controlled for in future studies. Another drawback is that observational scores were given based on ten second intervals and afterwards averaged over thirty seconds, losing fluctuations over time. Analyzing the data using shorter intervals could be beneficial to understand the concordance between psychophysiology and behavioral expression and the differences in patterns between the two groups. This however would have required a larger sample and more advanced techniques to control for the different reaction times of the physiology markers, for example as used by Golland, Keissar, & Levit-Binnun (2014).

Despite these limitations, the fear paradigm appears to be suitable for young children, also with developmental difficulties. The increase seen in psychophysiological arousal in both groups from rest to the fear paradigm supports the use of the robot task as a fear inducing paradigm. Furthermore, the psychophysiological arousal was specifically related to the intensity of negative emotion expression in this paradigm. Positivity was measured to include all expressed emotions, however the paradigm was designed to evoke negative emotions. The fact that the link between psychophysiology and emotion expression was specific to negative emotions therefore strengthens the validity of the paradigm.

To conclude, young children with ASD are capable of expressing facial/bodily emotions to a non-social stressor to the same extent as typically developing children. There do however appear to be differences in psychophysiological arousal. Children with ASD are under-aroused in rest as indicated by their low skin conductance level. There is a trend for over-arousal in response to a stressful stimulus. For children showing deviant arousal patterns, interventions aiming to change psychophysiological functioning might be most effective in dealing with challenging behaviors. Concerning the concordance between behavioral emotion expression and psychophysiological arousal, no differences were found between the two groups. This suggests that the behavioral emotion expression of children with ASD is similarly related to their psychophysiological response as found in typically developing children. Future research should integrate emotion regulation measures to evaluate the strategies used by children with ASD to regulate their emotions.

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