It remains unclear why individuals with autism spectrum disorder (ASD) tend to respond in an atypical manner in social situations. Investigating autonomic and subjective responses to social vs. nonsocial stimuli may help to reveal underlying mechanisms of these atypical responses. This study examined autonomic responses (skin conductance level and heart rate) and subjective responses to social vs. nonsocial pictures in 37 adolescents with an ASD and 36 typically developing (TD) adolescents. Thirty-six pictures from the International Affective Picture System were presented, divided into six categories based on social content (social vs. nonsocial) and pleasantness (pleasant, neutral, and unpleasant). Both in adolescents with ASD as well as TD adolescents, pictures with a social content resulted in higher skin conductance responses (SCRs) for pleasant and unpleasant pictures than for neutral pictures. No differences in SCRs were found for the three nonsocial picture categories. Unpleasant pictures, both with and without a social content, showed more heart rate deceleration than neutral pictures. Self-reported arousal ratings were influenced by the social and affective content of a picture. No differences were found between individuals with ASD and TD individuals in their autonomic and subjective responses to the picture categories. These results suggest that adolescents with ASD do not show atypical autonomic or subjective responses to pictures with and without a social content. These findings make it less likely that impairments in social information processing in individuals with ASD can be explained by atypical autonomic responses to social stimuli. **Autism Res 2013, ••: ••–••. © 2013 International Society for Autism Research, Wiley Periodicals, Inc.**

**Keywords:** autism spectrum disorders (ASD); affective pictures; autonomic responses; subjective ratings; heart rate; skin conductance level

**Introduction**

Individuals with autism spectrum disorder (ASD) show atypical behavioral responses in social situations [APA, 2000]. For example, in response to social stimuli, individuals with ASD look less at faces [Chawarska & Shic, 2009; Osterling & Dawson, 1994; Riby & Hancock, 2009] and tend to avoid eye contact [Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Rice, Moriuchi, Jones, & Klin, 2012]. Previous studies have suggested that atypical behavioral responses to social stimuli of individuals with ASD could be explained by the level of arousal that individuals with ASD experience when attending to social stimuli [Hutt, Hutt, Lee, & Unstred, 1964; Kyllläinen et al., 2012; Levine et al., 2012; Riby, Whittle, & Doherty-Sneddon, 2012; Rimland, 1968; Rogers & Ozonoff, 2005; Senju & Johnson, 2009; van Engeland, Roelofs, Verbaten, & Slangen, 1991]. Two distinct models have been proposed based on this idea: the hyperarousal model and the hypoarousal model [Senju & Johnson, 2009]. The hyperarousal model suggests that individuals with ASD are in a “heightened” autonomic state, in which their autonomic system is constantly on a maximum alert [Bal et al., 2010; Hirstein, Iversen, & Ramachandran, 2001]. In this state, individuals with ASD might be more easily aroused by social stimuli than typically developing (TD) individuals, and they may fail to habituate to social stimuli in the environment [Dalton et al., 2005; Hutt et al., 1964; Joseph, Ehrman, McNally, & Keehn, 2008; Rogers & Ozonoff, 2005]. On the other hand, the hypoarousal model hypothesizes that individuals with ASD experience less arousal or reward when attending to social stimuli in their environment [Mathersul, McDonald, & Rushby, 2012; Rimland, 1968]. This lack of autonomic arousal might interfere with attaching positive reward to social stimuli, which, in turn, allegedly hampers learning from the social environment [Senju & Johnson, 2009]. Albeit these suggestions...
of hyper- or hypoarousal in ASD, research on indices of arousal in reaction to social stimuli is still scarce.

Arousal can be measured at various levels: at the level of brain functioning, autonomic arousal, or subjective responses. First, at the level of brain functioning, several studies found atypical neural responses to social or affective stimuli in individuals with ASD [Adolphs, Sears, & Piven, 2001; Dalton et al., 2005; Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2007; Kleinhans et al., 2011; Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012]. The structure and connectivity of the amygdala seems to influence these arousal levels [for overview, see Senju & Johnson, 2009].

Second, levels of arousal can be measured with indices of the autonomic nervous system, e.g. skin conductance level (SCL) or heart rate (HR). SCL reflects the level of, and fluctuations in, sweat gland activity. Sweat gland activity is under control of the sympathetic branch of the autonomic nervous system, and, therefore, SCL can be considered as a good index for autonomic arousal. In individuals with ASD, both higher and lower levels skin conductance responses (SCRs) have been reported [Hirstein et al., 2001; Hubert, Wicker, Monfardini, & Deruelle, 2009; Joseph et al., 2008; Kaartinen et al., 2012; Kylliäinen & Hietanen, 2006; Kylliäinen et al., 2012; Mathersul et al., 2012; Sasson, Dichter, & Bodfish, 2012]. HR responses are also used as an indicator of autonomic activity. HR is the resultant of the combined activity of the sympathetic and parasympathetic branches of the autonomic nervous system. Only few studies investigated HR responses to social stimuli in ASD [Bal et al., 2010; Bölte, Feineis-Matthews, & Poustka, 2008; Mathersul et al., 2012; Sigman, Dissanayake, Corona, & Espinosa, 2003]. Almost all of these studies used the averaged HR response during the stimulus relative to the baseline, without taking into account the triphasic pattern of the cardiac response, which is a classical HR response to arousing pictures that consists of an initial deceleration (i.e. orienting response), an acceleration, and a second deceleration [Bradley & Lang, 2000]. The initial deceleration response (i.e. orientation response) is thought to reflect the intake of stimulus information and is part of an attention processing mechanism [Turpin, Schaefer, & Boucsein, 1999]. The initial deceleration response is primarily mediated by parasympathetic processes. The acceleration phase is interpreted as a defensive response, primarily related to sympathetic arousal. Mathersul et al. [2012] did take this HR pattern into account and reported a higher HR deceleration response for pleasant and unpleasant stimuli compared with neutral stimuli in individuals with ASD. This pronounced deceleration response for affective stimuli was not found for the TD group. However, their pleasant and unpleasant stimuli were all social stimuli, whereas their neutral stimuli contained all nonsocial pictures. Therefore, Mathersul et al. (2012) were unable to clarify whether the higher HR deceleration response in individuals with ASD was due to the affective content or to the social content of the selected stimuli. Mathersul et al. [2012] therefore argued that future studies should consider studying responses to “pleasant, unpleasant, and neutral stimuli of both a social and non-social nature” (p. 20).

Third, the level of arousal can be measured at the level of subjective report of the participant. Only few studies examined self-reported arousal ratings for stimuli with a social content vs. a nonsocial content. These studies did not find differences in self-reported arousal ratings between individuals with ASD and TD individuals [Mathersul et al., 2012; Sasson et al., 2012]. Other studies focused on the self-reported arousal ratings of affective stimuli. In TD individuals, affective (pleasant or unpleasant) pictures triggered stronger subjective arousal ratings than neutral pictures [Bradley & Lang, 2000]. Individuals with ASD reported lower levels of subjective arousal for affective pictures vs. neutral pictures than TD individuals [Ben Shalom et al., 2006; Bölte et al., 2008]. Interestingly, Bölte et al. [2008] found this lower reported arousal levels of individuals with ASD for sad pictures that were exclusively represented by social situations. Although their study did not focus on differences between social and nonsocial stimuli, the authors suggested that the atypical self-reported arousal ratings might have been influenced by the social content of the stimuli.

When combining study results at the level of brain functioning, autonomic responses, and subjective responses, there is some evidence that individuals with ASD show atypical levels of arousal while attending to social stimuli. However, with claims of both hyper- and hypoarousal, previous results are mixed. It is important to unravel which aspects of the environment trigger levels of hyper- or hypoarousal in individuals with ASD compared with TD individuals. First, the social content of the stimuli varied between studies; some studies included social and nonsocial stimuli, while others only included social stimuli (e.g. faces). Previous studies found lower levels of arousal for individuals with ASD in reaction to social stimuli vs. nonsocial stimuli, while TD individuals did show higher levels of arousal to the social stimuli [Hirstein et al., 2001; Hubert et al., 2009]. However, the results were mixed for studies that only included social stimuli, but with a varying degree of social relevance (e.g. stimuli including direct eye gaze vs. closed eyes). Some of these studies found higher levels of arousal for the more social relevant stimuli for individuals with ASD [Kylliäinen & Hietanen, 2006; Kylliäinen et al., 2012], while others did not [Joseph et al., 2008; Kaartinen et al., 2012]. Second, the affective content of the stimuli seemed to influence the level of autonomic and subjective arousal. Previous studies have indicated that looking to stimuli with an affective content (pleasant or unpleasant)
was associated with higher levels of arousal than neutral stimuli for individuals with TD [Bradley & Lang, 2000]. This typical higher response to affective compared with neutral pictures was not reported for individuals with ASD [Ben Shalom et al., 2006; Bölte et al., 2008; Hubert et al., 2009; Mathersul et al., 2012]. However, some studies did not report differences in arousal to affective stimuli in individuals with ASD compared with TD individuals [Riby et al., 2012; Sasson et al., 2012]. Thus, previous studies focused either on the social content or on the affective content of stimuli, while these concepts often overlap. This overlap makes it hard to determine whether the social content, the affective content, or both triggered autonomic and subjective responses. To our knowledge, there are no direct comparisons of stimuli with and without a social content, accounting for the affective content (i.e. pleasantness) of the stimuli. The integration of these two concepts into one study design would be beneficial because this would make it possible to detect whether either the social content or the affective content, or trigger hyper- or hypoarousal in individuals with ASD.

When measuring levels of arousal, we must bear in mind the relationship of arousal with attention [Coull, 1998]. The amount of attention paid to a stimulus might influence the level of autonomic arousal [Hajcak, Macnamara, Foti, Ferri, & Keil, 2011]. Therefore, when studying reactions to specific stimuli, not only subjective and autonomic arousal measures, but also the attention toward the stimulus should be considered [P. J. Lang, Greenwald, Bradley, & Hamm, 1993]. Attention toward the stimulus can be detected through eye-tracking. Yet, studies that combine measures of arousal and eye-tracking are currently scarce.

The aim of the current study is to determine autonomic activity, subjective experience, and fixation durations in adolescents with ASD and TD individuals, while showing social vs. nonsocial pictures, with a pleasant, neutral, and unpleasant affective content. Because several previous studies indicated that both social stimuli and affective stimuli triggered higher levels of arousal in TD individuals, we expect that looking to pleasant and unpleasant social stimuli will be associated with higher levels of autonomic and subjective responses than nonsocial neutral stimuli for TD individuals. In line with some previous studies, we expect that adolescents with ASD will show less arousal for affective vs. neutral pictures than TD individuals [Ben Shalom et al., 2006; Bölte et al., 2008; Hubert et al., 2009; Mathersul et al., 2012]. Also, we expect less arousal to social stimuli vs. nonsocial stimuli for individuals with ASD compared with TD individuals [Hirstein et al., 2001; Hubert et al., 2009]. Therefore, for the combination of a social and affective content of stimuli, we expect less differential autonomic and subjective responses in individuals with ASD compared with TD individuals. This hypothesis would underline hypo- or hyperarousal to social affective stimuli in individuals with ASD.

To be able to evaluate whether attention (i.e. visual fixation time to the total picture) was related to the autonomic and subjective responses, we simultaneously recorded eye movements during stimulus presentation.

Methods
Participants

Thirty-nine adolescents with ASD and 42 TD adolescents participated in this study, which was approved by the Medical Ethical Committee of the Erasmus MC. Informed consent was obtained from all adolescents and also from their parents if the adolescent was younger than 16 years of age. Only male adolescents with an intelligence quotient (IQ) above 70 were included. To confirm an IQ above 70, the Wechsler Abbreviated Scale of Intelligence [Wechsler, 1999] was administered. There was no significant difference regarding the mean total IQ of the adolescents with ASD (mean = 103.7, standard deviation (SD) = 13.6) and the TD adolescents (mean = 108.1, SD = 10.6; t(79) = 1.6, P = 0.11). The ages of the adolescents with ASD (mean = 16.0, SD = 1.9) and the TD adolescents (mean = 16.2, SD = 2.5) were also not significantly different (t(79) = 0.4, P = 0.71). All adolescents had normal, or corrected to normal, vision.

ASD adolescents were recruited from the outpatient’s department of Child and Adolescent Psychiatry/Psychology of the Erasmus MC-Sophia, Rotterdam, the Netherlands. All 39 adolescents with ASD met the diagnostic criteria (i.e. algorithm) of both the Autism Diagnostic Observation Schedule [Bastiaansen et al., 2011; Gotham, Risi, Pickles, & Lord, 2007; Lord et al., 2000] and the Autism Diagnostic Interview—Revised [Bildt et al., 2013; Lainhart et al., 2006; Rutter, Le Couteur, & Lord, 2003; Sung et al., 2005]. The parents of ASD adolescents were asked if their child had used medication in the week before testing. Sixteen adolescents used psychotropic medication, eight took methylphenidate, six took antipsychotics, one used an antidepressant, and one used antiepileptic medication.

The TD participants were selected from a general population sample [Tick, van der Ende, & Verhulst, 2008]. These adolescents had no history of neurodevelopmental disorders. In addition, TD individuals were excluded if their parents reported ASD problems within the clinical range of the Children’s Social Behavior Questionnaire [Hartman, Luteijn, Serra, & Minderaa, 2006].

Procedure

The experimental procedure lasted about 1.5 hr. The participant was presented with three tasks. The results
described in the current paper are based on the second task. In this task, the adolescent was presented with a series of 36 pictures. The adolescent was seated in a fixed chair approximately 60 cm from the computer screen on which the stimuli were displayed. Electrodes for the autonomic recordings (HR and SCL) were applied according to standard procedures [Greaves-Lord et al., 2007; N. J. Lang et al., 2007]. Eye movements were recorded during all tasks (please see Measurement for more information).

After instructions, a five-point calibration routine was used to ensure validity of the eye-tracking data. The examiner evaluated the calibration, and the calibration routine was repeated in case of unsatisfactory data. Subsequently, two additional pictures were shown as practice stimuli. After instructions, the calibration procedure, and the practice stimuli, the examiner sat behind a screen. The subject was instructed to look at 36 pictures and to rate his subjective impression of valence and arousal (see Subjective ratings) after the presentation of each picture.

The stimulus presentation was designed and controlled by E-Prime software (version 2.0 including extensions for Tobii: PST-100777; Psychology Software Tools, Inc., Sharpsburg, PA, USA), which is used for computerized psychological tasks. Each presentation of a stimulus lasted 6 sec, and the interval between stimuli varied between 15 and 25 sec. During this interval, a fixation cross was presented on the screen.

**Stimuli**

The stimuli consisted of 38 color pictures from the International Affective Picture System [IAPS; P. J. Lang, Bradley, & Cuthbert, 2001]; two of which were used as practice pictures, and the other 36 were used as target stimuli. The pictures were selected based on social content (social vs. nonsocial) and pleasantness (pleasant, neutral, or unpleasant). Pictures with a social content depicted humans (e.g. individuals in a rollercoaster), while pictures with a nonsocial content did not depict humans (e.g. fireworks). Pleasantness was based on normative ratings provided with the IAPS [P. J. Lang, Bradley, & Cuthbert, 2001]. There were six categories, containing six pictures each:

1. Social—pleasant
   (valence rating > 6, arousal rating > 4)
2. Social—neutral
   (valence rating 4–6, arousal rating 0–4)
3. Social—unpleasant
   (valence rating 0–4, arousal rating > 4)
4. Nonsocial—pleasant
   (valence rating > 6, arousal rating > 4)
5. Nonsocial—neutral
   (valence rating 4–6, arousal rating 0–4)
6. Nonsocial—unpleasant
   (valence rating 0–4, arousal rating > 4)

The pictures were shown in a different random order for each participant.

**Measurement**

**Eye-tracking.** Eye movements were recorded using a remote eye tracker (Tobii120; Tobii, Danderyd, Sweden) with a 17-inch display and data rate of 60 Hz. Adolescents were free to move their head throughout the tasks; the accuracy of recording was maintained as long as the adolescents kept their eyes with a virtual space measuring 44 \( \times \) 22 \( \times \) 30 cm. Eye movement data were processed using custom software written in Matlab (The Mathworks, Natick, MA, USA). For each stimulus, the total fixation time for the whole picture was determined. For each of the six stimulus categories, fixation duration was defined as the average fixation time across the pictures in that category.

**Subjective ratings.** After the presentation of each stimulus, the adolescent was asked to evaluate how pleasant or unpleasant (i.e. valence) the picture made him feel, and how calm or aroused (i.e. arousal) the picture made him feel. The instruction for the participant was to “rate each picture in terms of how they made you feel while viewing it” [Bölte et al., 2008, p. 779]. These subjective ratings were based on the Self-Assessment Manikin (SAM). The SAM is a visual nine-point rating scale with icons depicting values along the dimensions of valence and arousal [Lang et al., 2001]. The observer first reported the number on the 9-point scale that indicated his level of valence. Thereafter, he reported the number that indicated his degree of arousal. An adaptation of the instruction of the SAM, used specifically in studies with individuals with ASD, was also used in the current study [Ben Shalom et al., 2006; Bölte et al., 2008]. To give the subjective ratings, the adolescent responded with his dominant hand using a keyboard. For each of the six stimulus categories, SAM scores of valence and arousal were defined as the average valence and arousal scores across the pictures in that category.

**Autonomic measures.** Two indices of autonomic activity were measured: HR and SCL. All HR and SCL data were sampled and stored on a flashcard by means of a portable digital recorder (Vitatap System; TECME Instruments B.V., Kerkrade, the Netherlands). Upon completion of the recording, all autonomic data were imported and processed on a laptop using the Vitascore software module (TEMEC Instruments B.V.). The autonomic...
measures were visually inspected for detection and removal of artifacts.

HR was recorded continuously using a precordial lead and was sampled at 512 Hz. The interbeat intervals were calculated, using R-top detection. This resulted in HR series of beats per minute. The mean HR in the second before each picture onset was defined as the baseline value. This baseline value was subtracted from the minimum value of the HR between the first and third second of the picture, to retrieve the HR deceleration response [Hempel, Tulen, van Beveren, Mulder, & Hengeveld, 2007; P. J. Lang et al., 1993]. The HR acceleration response was defined as the maximum value between the third and sixth second of the picture, subtracted by the minimum value between the first and third second. For each adolescent, mean HR deceleration responses and mean HR acceleration responses were computed for each stimulus category.

SCL was measured using two Ag/AgCl electrodes attached to the volar surfaces of the medial phalanxes of the index and ring fingers of the nondominant hand. The level of skin conductance was sampled at 8 Hz and stored in μSiemens. The SCR was defined as the largest amplitude relative to baseline (the SCL at stimulus onset) from 1 to 6 sec after picture onset. Changes of 0.01 or higher μSiemens were considered as responses; changes below 0.01 μSiemens were marked as zero-responses. For each adolescent, the mean value of SCR amplitude was computed for each stimulus category.

Statistical Analyses

The power of the current study was calculated with G*Power 3 [Faul, Erdfelder, Lang, & Buchner, 2007]. These analyses revealed that the power was between 0.96 and 1 to detect large between-subject effects and between 0.99 and 1 to detect medium to large within-group effects. These medium and large effect sizes were based on Cohen’s population effect sizes [Cohen, 1988]. The estimation of these effect sizes should be based on the results from previous studies. However, the heterogeneity within the results of current literature hampered the estimation of a population effect size.

Because the autonomic responses (HR deceleration response, HR acceleration response, SCR) and the total fixation durations were not normally distributed, we used the Box–Cox transformation to reduce the skewness of the distributions [Osborne, 2010]. For the SCR, a lambda (λ) of −33.4 reduced skewness of the data most. For the HR deceleration response, the lambda of 2.2 fitted best, and for the amplitude of the HR acceleration response, a lambda of 0.2 was used to reduce the skewness of the distribution.

To check for possible effects of age, IQ on the main outcome variables (fixation duration, HR deceleration response, HR acceleration response, SCR, and subjective rating scores), correlations between the putative confounding variables and the outcome variables were computed. If significant correlations were found, the parameters were taken into account in further analysis as covariates. In addition, to be able to evaluate whether attention (i.e. visual fixation time to the total picture) was related to the autonomic and subjective responses, we also computed correlations between fixation duration and the outcome variables.

The outcome variables (fixation duration, HR deceleration response, HR acceleration response, SCR, self-reported valence, and self-reported arousal) were analyzed using separate repeated measures analysis of variances (ANOVAs) with social content (social vs. non-social) and pleasantness (pleasant vs. unpleasant vs. neutral) as the within-subjects factors and group (ASD vs. TD) as the between-subjects factor. If an interaction effect or a main effect of condition was found, simple contrasts were reported to clarify the nature of the effect. All factors were entered in a single model. We did not conduct further model selection steps. A univariate approach, with a compound symmetry structure of the variance-covariance matrix, was used if the assumption of sphericity was not violated. The Huynh-Feldt correction was used to adjust for sphericity violations if necessary. For each ANOVA, the results of the Box’s Tests of Equality of Covariance Matrices were reported.

For all analyses, we used SPSS software (version 20.0; IBM SPSS Statistics, Chicago, IL, USA). All analyses were two-tailed, and the alpha was set at 0.05.

Results

Preliminary Data Inspection

Because of technical problems, SCL data of two adolescents with ASD and four TD adolescents and HR data of three TD adolescents could not be analyzed. After exclusion of these participants, full data sets of 37 ASD and 36 TD adolescents were available.

IQ and fixation duration were not significantly related with the outcome measures. Age was significantly correlated with SCR (r = −0.3, P < 0.01), HR deceleration response (r = 0.3, P < 0.01), and HR acceleration response (r = −0.3, P = 0.03). Therefore, age was included as a covariate in the subsequent analyses regarding SCR and HR deceleration responses. To reduce multicollinearity between age and group, age was centered by subtracting the mean age of the total group from the age of the participants.

Fixation Duration

Fixation duration was not significantly related with the outcome variables (HR deceleration response, HR
acceleration response, SCR, and subjective rating scores). The repeated measures ANOVA revealed that adolescents with ASD fixated significantly shorter to the total set of stimuli than TD adolescents \(F(1, 71) = 10.3, P = 0.002, \eta^2_p = 0.13\); Table 1). Also, a significant interaction effect between social content and pleasantness on fixation duration was found \(F(2, 142) = 3.8, P = 0.03, \eta^2_p = 0.05\). The within-subject contrasts indicated longer fixation durations to pleasant vs. neutral pictures with a social content, but not for pictures with a nonsocial content \(F(1, 71) = 6.1, P = 0.02, \eta^2_p = 0.08\) and longer fixation durations to unpleasant vs. neutral pictures for the social pictures, but not for the nonsocial pictures \(F(1, 71) = 4.1, P = 0.05, \eta^2_p = 0.05\). The Box’s Tests of Equality of Covariance Matrices was not significant.

### Table 1. Fixation Duration in Seconds (Mean, SD) toward the Total Stimuli for Social vs. Nonsocial Pictures with a Pleasant, Neutral, and Unpleasant Affective Content, for Adolescents with ASD and TD Adolescents

<table>
<thead>
<tr>
<th>Category</th>
<th>Social</th>
<th></th>
<th>Nonsocial</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pleasant</td>
<td>Neutral</td>
<td>Unpleasant</td>
<td>Pleasant</td>
<td>Neutral</td>
</tr>
<tr>
<td>ASD</td>
<td>4.2 (0.9)</td>
<td>4.0 (0.7)</td>
<td>4.3 (0.8)</td>
<td>4.0 (0.8)</td>
<td>3.8 (1.0)</td>
</tr>
<tr>
<td>TD</td>
<td>4.7 (0.6)</td>
<td>4.4 (0.9)</td>
<td>4.8 (0.8)</td>
<td>4.5 (0.8)</td>
<td>4.5 (0.9)</td>
</tr>
</tbody>
</table>

ASD: \(n = 37\), TD: \(n = 36\). ASD, autism spectrum disorder; SD, standard deviation; TD, typically developing.

### Figure 1. Valence and arousal Self-Assessment Manikin (SAM) ratings (mean and 95% confidence intervals (CIs)) for social vs. nonsocial pictures with a pleasant, neutral, and unpleasant affective content, for adolescents with autism spectrum disorder (ASD) and typically developing (TD) adolescents.

Concerning valence ratings, a significant interaction effect between social content and pleasantness of the pictures was found \(F(2, 142) = 21.7, P < 0.001, \eta^2_p = 0.23\); Fig. 1). The within-subjects contrasts revealed that the decrease in valence rating for a neutral picture, compared with a pleasant picture, was larger for nonsocial pictures than for social pictures \(F(1, 71) = 29.7, P < 0.001, \eta^2_p = 0.26\), and that the decrease in valence rating for unpleasant pictures compared with neutral pictures was larger for social than for nonsocial pictures \(F(1, 71) = 45.8, P < 0.001, \eta^2_p = 0.39\). There was no significant main effect of group \(F(1, 71) = 0.3, P = 0.60, \eta^2_p < 0.01\).
For the arousal ratings, a significant interaction effect between social content and pleasantness was found ($F(2,142) = 28.5, P < 0.001, \eta^2 = 0.29$). The within-subjects contrast revealed that the decrease in arousal rating for a neutral picture, compared with a pleasant picture, was larger for nonsocial pictures than for social pictures ($F(1,71) = 42.7, P < 0.001, \eta^2 = 0.38$). The decrease in arousal rating for a neutral picture, compared with an unpleasant picture, was also somewhat larger for the nonsocial pictures than for the social pictures (trend significant effect: $F(1,71) = 3.1, P = 0.08, \eta^2 = 0.04$). There was no significant effect of group for arousal ratings ($F(1,71) = 2.2, P = 0.14, \eta^2 = 0.03$). For both the ANOVAs concerning valence and arousal ratings, the Box’s Tests of Equality of Covariance Matrices was not significant.

Autonomic Responses

**SCR.** There was a significant interaction effect between social content and pleasantness of the picture ($F(2,140) = 3.2, P = 0.05, \eta^2 = 0.04$). Affective pictures with a social content resulted in higher SCR than neutral social pictures (Fig. 2). Within-subjects contrasts indicated higher SCR for unpleasant vs. neutral pictures for the social pictures, vs. more similar SCR for unpleasant and neutral pictures for the nonsocial pictures ($F(1,70) = 5.6, P = 0.02, \eta^2 = 0.07$) and a trend toward higher SCR for pleasant vs. neutral pictures for social pictures, compared with more similar SCR responses to pleasant and neutral nonsocial pictures ($F(1,70) = 3.7, P = 0.06, \eta^2 = 0.05$). There was no significant effect of group ($F(1,70) = 1.0, P = 0.33, \eta^2 = 0.01$), nor any interaction involving group on SCR. The Box’s Tests of Equality of Covariance Matrices was not significant.

**HR responses.** For the HR deceleration response, a significant main effect of pleasantness was found ($F(2,140) = 18.1, P < 0.001, \eta^2 = 0.21$; Table 2). Unpleasant pictures triggered a larger HR deceleration response than neutral pictures ($F(1,70) = 29.9, P < 0.001, \eta^2 = 0.30$). No significant effects were found for social content ($F(1,70) = 3.8, P = 0.06, \eta^2 = 0.05$) or group ($F(1,70) = 0.1, P = 0.82, \eta^2 < 0.01$). The HR acceleration response was not significantly associated with social content ($F(1,70) = 0.6, P = 0.43, \eta^2 = 0.01$), pleasantness ($F(2,140) = 0.1, P = 0.93, \eta^2 < 0.01$), or group ($F(1,70) = 0.6, P = 0.44, \eta^2 = 0.01$). For the HR deceleration response, the Box’s Tests of Equality of Covariance Matrices was not significant. However, for the HR acceleration response, the Box’s Test of Equality of Covariance was significant ($P = 0.04$). To evaluate the violation of this assumption, we also looked at the Levene’s tests for the HR acceleration response in the separate categories. These Levene’s tests were not significant, suggesting no significant differences between the group variances. Therefore, we did not take further steps to equalize the variance of the HR acceleration response.

Discussion

The current study investigated whether high functioning adolescents with ASD (i.e. an IQ above 70) showed atypical autonomic and subjective responses when looking at social vs. nonsocial pictures, with a pleasant, neutral, and unpleasant affective content. For both adolescents with ASD and TD adolescents, subjective responses, autonomic responses, and fixation durations were influenced by both social content and affective content (i.e. pleasantness) of the pictures. However, no differences in autonomic and subjective arousal levels were found between the ASD and TD groups, suggesting typical subjective and autonomic responses to static social stimuli in high functioning adolescents with ASD. Thus, both the social and affective content of the picture influenced subjective and autonomic arousal levels. However, for high-functioning adolescents with ASD, these pictures did not trigger hypo- or hyperarousal compared with TD adolescents.

In line with the norm data of the IAPS, the subjective ratings of the pictures used in this study were significantly affected by the social and affective content of the pictures [P. J. Lang et al., 2001], which underlines the...
Table 2. HR Deceleration Response and HR Acceleration Response in Beats per Minute (Mean, SD) for Social vs. Nonsocial Pictures with a Pleasant, Neutral, and Unpleasant Affective Content, for Adolescents with ASD and TD Adolescents

<table>
<thead>
<tr>
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<th>Neutral</th>
<th>Unpleasant</th>
<th>Pleasant</th>
<th>Neutral</th>
<th>Unpleasant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR DR</td>
<td>ASD</td>
<td>−4.1 (3.3)</td>
<td>−4.8 (3.5)</td>
<td>−7.9 (4.7)</td>
<td>−4.4 (3.6)</td>
<td>−4.5 (4.3)</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>−4.4 (2.5)</td>
<td>−4.8 (4.1)</td>
<td>−6.8 (4.0)</td>
<td>−5.1 (3.6)</td>
<td>−4.0 (4.4)</td>
</tr>
<tr>
<td>HR AR</td>
<td>ASD</td>
<td>8.7 (3.5)</td>
<td>8.3 (3.8)</td>
<td>9.2 (3.8)</td>
<td>9.7 (5.1)</td>
<td>8.7 (3.5)</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>9.2 (3.7)</td>
<td>9.9 (5.3)</td>
<td>8.7 (3.6)</td>
<td>9.5 (4.1)</td>
<td>9.5 (4.3)</td>
</tr>
<tr>
<td>Nonsocial</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>HR DR</td>
<td>ASD</td>
<td>5.8 (4.3)</td>
<td>6.0 (4.9)</td>
<td>4.5 (4.3)</td>
<td>5.8 (4.3)</td>
<td>9.1 (3.9)</td>
</tr>
<tr>
<td></td>
<td>TD</td>
<td>6.8 (4.0)</td>
<td>7.9 (4.7)</td>
<td>5.1 (3.6)</td>
<td>5.8 (4.3)</td>
<td>9.1 (3.9)</td>
</tr>
</tbody>
</table>

ASD: n = 37, TD: n = 36.

HR DR, heart rate deceleration response; HR AR, heart rate acceleration response; ASD, autism spectrum disorders; TD, typically developing; HR, heart rate.

validity of the six selected categories (social pleasant, social neutral, social unpleasant, nonsocial pleasant, nonsocial neutral, and nonsocial unpleasant). Mathersul et al. [2012] reported higher levels of subjective arousal for social pictures vs. the nonsocial pictures. Their finding, however, might have been due to the more extreme affective pictures in the social condition (erotica, mutilations) compared with the less arousing pictures in the nonsocial category. The present study replicated the finding of higher subjective arousal ratings for social vs. nonsocial pictures in a design that accounted for the level of pleasantness. Based on previous studies [Ben Shalom et al., 2006; Bölte et al., 2008], we expected that individuals with ASD would report similar levels of arousal for the pleasant, neutral, and unpleasant pictures. However, the responses of the adolescents with ASD, like TD adolescents, did differentiate in their arousal ratings for these categories of pleasantness. This suggests that cognitively able adolescents with ASD show a typical subjective report of arousal to social and nonsocial stimuli.

The autonomic responses of both adolescents with ASD and TD adolescents were influenced by social content and pleasantness of the pictures. Both adolescents with ASD and TD adolescents displayed the typical pattern of higher SCRs to pleasant and unpleasant social pictures [Bradley, Codispoti, Cuthbert, & Lang, 2001; Mathersul et al., 2012; Phillips, Drevets, Rauch, & Lane, 2003]. These results elaborate on earlier findings by indicating that social content significantly influences the level of SCRs. Pleasant and unpleasant social pictures resulted in higher SCRs than neutral social pictures. For nonsocial pictures, no significant differences in SCR were found between pleasant, neutral, and unpleasant pictures. This typical pattern of higher SCRs for social affective pictures was not found for the HR acceleration response. Yet, the HR deceleration responses were larger for unpleasant than for neutral pictures, which was line with previous studies [Alpers, Adolph, & Pauli, 2011; Bradley et al., 2001; Mathersul et al., 2012]. This larger HR deceleration response indicates that unpleasant pictures triggered more attention and a larger initial orienting response compared with neutral pictures. This finding is in line with the eye-tracking data because unpleasant pictures also triggered significantly longer fixation durations than neutral pictures.

No significant differences in SCR and HR responses between individuals with ASD and TD individuals were found. Previous studies indicated that individuals with ASD had lowered SCRs to social stimuli but not to nonsocial stimuli than TD adolescents [Hirstein et al., 2001; Mathersul et al., 2012]. Our findings did not seem to support our hypotheses that looking to social stimuli was associated with hypoarousal in adolescents with ASD compared with TD adolescents. The models of hyper- and hyperarousal in ASD try to explain why individuals with ASD show impairment during social interactions. Both models of hyper- or hypoarousal in ASD emphasize the role of attached reward value to stimuli, i.e. negative reward in the hyperarousal model or neutral reward in the hypoarousal model. Both negative and neutral rewards hamper reinforcement learning about the environment [Senju & Johnson, 2009]. Taken together, the current study did not find significant differences in autonomic responses between adolescents with ASD and TD adolescents. However, the null hypothesis cannot be completely ruled out because we found several differences of small effect size between the groups [Cohen, 1988]. Thus, it is hard to make theoretical claims of hyper- or hypoarousal based on the current data. Mixed study results concerning autonomic responses in individuals with ASD vs. TD individuals might be due to study characteristics or to the heterogeneity of ASD.

We should keep in mind that the pictures selected in the current sample were probably not as extreme in the arousal they triggered as the stimuli used in the previous mentioned studies [i.e. extreme pictures with violent or sexual content in Mathersul et al., 2012]. This might have resulted in rather similar levels of SCR and HR in the current study between the adolescents with ASD and TD adolescents, in contrast to the results of previous studies.
Because the current study however included a clinical and adolescent sample, it was not considered ethical to use more extreme pictures from the IAPS [Lang et al. 1998]. In addition, we depicted arousal levels while individuals watched pictures of social vs. nonsocial content. These levels of arousal do not represent arousal levels during real-life interaction. Thus, these findings cannot be generalized to real-life interactions, and, therefore, further research is necessary to extend these findings to more ecological valid stimuli.

A strength of this study was that we included an eye-tracker for the registration of the total fixation duration toward the pictures. Therefore, we were able to evaluate whether arousal levels were affected by the amount of attention that individuals paid to the pictures. Total fixation durations were not significantly correlated with the autonomic and subjective arousal measures. However, individuals with ASD spend significantly less time looking toward the pictures than TD individuals. This diminished gaze duration was apparent in both social and nonsocial pictures with a pleasant, neutral, and unpleasant content. Still, one might question whether the overall shorter amount of fixation duration toward the stimuli in individuals with ASD implies a failure to optimally respond to stimuli in their environment. The interpretation of the current study results is limited to high functioning adolescents with ASD because all participants in the current study had an IQ above 70. The autonomic responses of the adolescents in the current study might have been influenced by the instruction to rate their subjective valence and arousal levels after the stimulus presentation. A previous study found that spontaneous viewing was associated with differences in responses between individuals with ASD vs. TD, whereas this difference was not apparent when a task was given to both groups [Oberman, Winkelman, & Ramachandran, 2009]. Another limitation of the current study was that we did not account for medication effects because of the small sample and the variety of psychotropic medicine use in the sample. However, the use of medicines might have influenced our results because previous studies revealed that differences in autonomic responses in individuals with ASD vs. TD individuals might be related to the effects of medication [Dalwatte et al., 2012; Mathewson et al., 2011]. The influence of SAM ratings and medication on autonomic arousal measures in individuals with ASD requires further investigation.

The present results nevertheless elucidate our understanding of autonomic responses and subjective arousal ratings to social and affective stimuli. This study underlines that autonomic and subjective responses are dependent upon both the social and affective content of a stimulus. Adolescents with ASD, like TD adolescents, do respond to both affective and social information. We did not find significant differences in autonomic and subjective responses between adolescents with ASD and an IQ above 70 and TD adolescents. Based on the current findings, we cannot make firm statements about the hyperarousal theory that suggests that individuals with ASD show higher levels of arousal than TD individuals while attending to social stimuli [Hutt et al., 1964] or the hypoarousal theory that suggests that individuals with ASD show lower levels of arousal than TD [Rimland, 1968]. Mixed study results concerning autonomic and subjective responses might be the result of study characteristics or could be related to the heterogeneity of ASD. We encourage researchers investigating hyper- and hypoarousal to social affective stimuli to pay close attention to their study designs to disentangle the different constructs.

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