A Virtual Joy-Stick Study of Emotional Responses and Social Motivation in Children with Autism Spectrum Disorder

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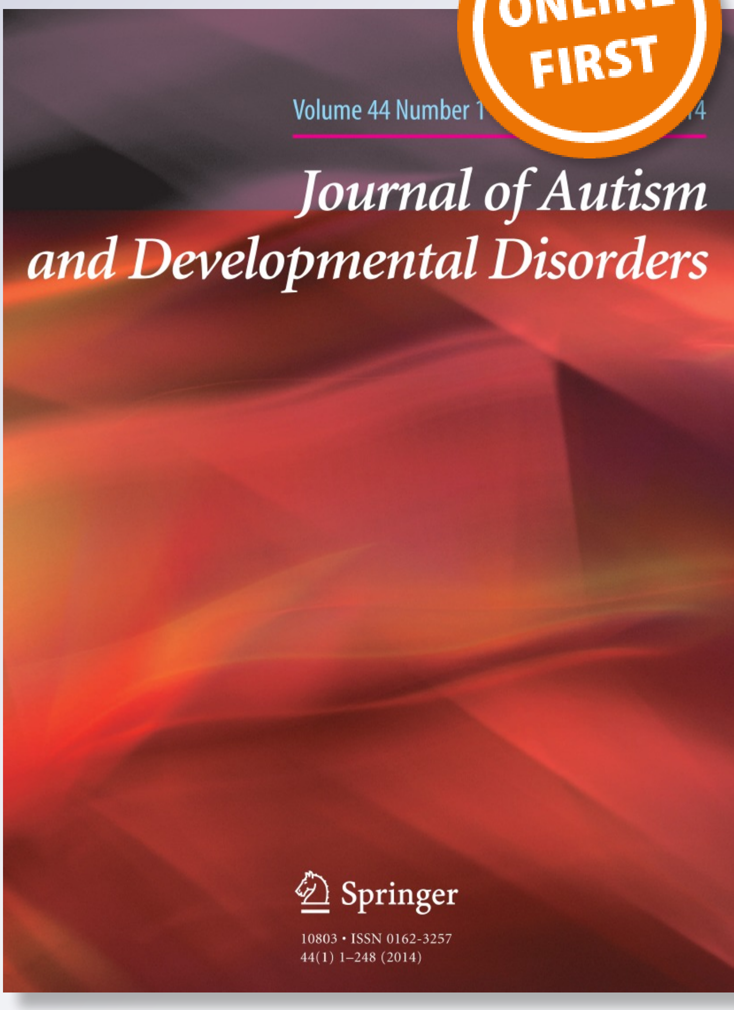

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ORIGINAL PAPER

A Virtual Joy-Stick Study of Emotional Responses and Social Motivation in Children with Autism Spectrum Disorder

Kwanguk Kim · M. Zachary Rosenthal · Mary Gwaltney · William Jarrold · Naomi Hatt · Nancy McIntyre · Lindsay Swain · Marjorie Solomon · Peter Mundy

Abstract A new virtual reality task was employed which uses preference for interpersonal distance to social stimuli to examine social motivation and emotion perception in children with Autism Spectrum Disorders. Nineteen high function children with higher functioning Autism Spectrum Disorder (HFASD) and 23 age, gender, and IQ matched children with typical development (TD) used a joy stick to position themselves closer or further from virtual avatars while attempting to identify six emotions expressed by the avatars, happiness, fear, anger, disgust, sadness, and surprise that were expressed at different levels of intensity. The results indicated that children with HFASD displayed significantly less approach behavior to the positive happy expression than did children with TD, who displayed increases in approach behavior to higher intensities of happy expressions. Alternatively, all groups tended to withdraw from negative emotions to the same extent and there were no diagnostic group differences in accuracy of recognition of any of the six emotions. This pattern of results is consistent with theory that suggests that some children with HFASD display atypical social-approach motivation, or sensitivity to the positive reward value of positive social–emotional events. Conversely, there was little evidence that a tendency to withdraw from social–emotional stimuli, or a failure to process social emotional stimuli, was a component of social behavior task performance in this sample of children with HFASD.

Keywords Interpersonal distance · Emotional accuracy · Social-motivation · Reward sensitivity · Virtual avatar · High function Autism Spectrum Disorder

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Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by abnormalities in social interaction, communication and restrictive and repetitive behaviors (American Psychiatric Association 1994). Some models of the psychological phenotype of ASD suggest that variation in the typical motivation to engage, approach or orient to other people plays a role in the impairments of social interaction the characterize ASD across the age span (Chevallier et al. 2012; Kohls et al. 2012; Mundy 1995). These models describe three possible different patterns of expression of social motivation in ASD. One is that children with ASD may experience a negative reaction to social stimuli leading to aversion and withdrawal from social engagement. A second proposal is that children with

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ASD may experience an atypically low level of reward from social stimuli, and/or an atypically high level of reward from non-social stimuli. This leads to decreased initiation of social approach and social-orienting behavior, but not necessary withdrawal or avoidance of social stimuli. A third possibility that stems from Wing subtypes (e.g., Modahl et al. 1998; Wing and Gould 1979) is that children with ASD may exhibit significant individual differences in social motivation. Some individuals with ASD display social inhibition, withdrawal or aloof behavior, yet others exhibit active but odd social engagement that may be associated with positive social motivation, and that the latter may be associated with lower social symptom intensity in children with ASD.

Although social motivation theory is potentially illuminating, a lack of precise methods has hampered it empirical evaluation in research on ASD. However, several lines of research suggest that measures of preference for interpersonal distance may provide a useful index of social approach or social avoidance tendencies among individuals with ASD. For example, Kennedy et al. (2009) have noted that preference for interpersonal distance in social interaction, assessed with digital laser measurement, is affected by amygdala lesions. This is noteworthy because previous studies have suggested that atypical amygdala functions may contribute to the ASD social phenotype (Schumann and Amaral 2006; Mosconi et al. 2009; Schumann et al. 2009). At least one study also specifically suggests that amygdala impairment may lead to a disruption of reward sensitivity that contributes to social-motivation deficits (Kohls et al. 2012). Observations of significant associations between interpersonal distance and social anxiety in typically developing individuals also support the validity of interpersonal distance assessment as an operational measure social motivation (Heuer et al. 2007; Wieser et al. 2010).

Of course, the measurement of interpersonal distance preference with individuals with ASD in vivo could be complex, costly and time consuming. One alternative is to use a joy stick metric of interpersonal distance in virtual social interaction paradigms to validly and efficiently assess individual differences in preferences for interpersonal distance (Heuer et al. 2007; Wieser et al. 2010). Such a computer based paradigms may be a relatively appealing assessment medium for children with HFASD (Bellani et al. 2011). More significantly, Parsons et al. (2004, 2005) have also shown that the use of joystick metrics provides a valid index of differences in interpersonal distance preferences among children with higher functioning ASD (HFASD). Hence, joystick measures of interpersonal distance in virtual social paradigms may offer a new methodological approach to evaluate the role of social motivation in HFASD. This study was designed and implemented to assess this hypothesis.

The paradigm used in this study provided a measure of preference for interpersonal distance exhibited by children with higher functioning HFASD in a task involving their ability to recognize different types and intensities of emotion expressed by avatars. Emotional presentations are social signals that elicit approach and withdrawal behavior in typical individuals (Marsh et al. 2005). In general, children with HFASD often display impaired emotion recognition and responses. Nevertheless, older children with HFASD often appear relatively similar to their typical counter parts with respect to emotion recognition (Harms et al. 2010). Previous studies, though, have not examined the degree to which children with HFASD may display atypical approach or avoidance of stimuli while engaged in an emotion recognition task. In this regard, social motivation theory raises three hypotheses. The aversion hypothesis suggests that children with HFASD would display a preference for greater interpersonal distance from all stimuli in the facial recognition task. The attenuated social approach hypothesis suggests that children with HFASD would only display a failure to exhibit typical levels of approach to positive social stimuli (i.e., positive facial expressions). The Wing subtype hypothesis suggests that subsets of children may display a general tendency toward withdrawal from all stimuli, while others may display a more general approach tendency and that approach may be related to differences in symptom intensity among children with HFASD.

Materials and Methods

Participants

The protocol of the current study was approved by the University Institutional Review Board prior to recruitment. Participants were recruited via the subject tracking system (STS) of the UC Davis M.I.N.D. Institute. Nineteen children who met diagnostic criteria for HFASD (13 males, 68.4 %, age = 11.1, SD = 2.5) and 23 typically developing controls (16 males, 69.6 %; age = 11.5, SD = 2.3) participated for this study. Participants in the two diagnostic groups were matched on chronological age (8–16 years-old), gender, and IQ (Table 1).

All children in the HFASD group had received a clinical diagnosis of Autism Spectrum Disorders. The diagnostic status at the time of this study of was confirmed with parent reports on the High Functioning Autism Spectrum Screening Questionnaire (ASSQ; Ehlers et al. 1999; Posserud et al. 2006), the Social Communication Questionnaire (SCQ, Berument et al. 1999, Corsello et al. 2007) and the Social Responsiveness Scale (SRS, Constantino 2004). Children in the HFASD sample met or exceeded the SCQ

Table 1 Descriptive mean statistics for the diagnostic groups with standard deviations

Variables	Controls (N = 23)	Higher Functioning Autism (N = 19)
Age	11.5 (2.3)	11.1 (2.5)
IQ full	115.2 (10.3)	110.6 (15.3)
IQ performance	110.6 (13.0)	107.2 (15.8)
IQ verbal	117.6 (10.3)	114.4 (16.3)
SCQ**	3.5 (5.5)	21.5 (5.6)
ASSQ**	1.8 (4.2)	30.8 (8.2)
SRS**	42.7 (6.3)	97.6 (24.1)
MASC social anxiety	52.8 (9.8)	57.1 (10.2)
BASC internalizing**	45.4 (8.5)	70.4 (14.2)
BASC withdrawal**	48.0 (11.9)	76.7 (12.2)
RME	19.9 (3.9)	18.2 (4.4)

SCQ Social Communication Questionnaire, *ASSQ* Autism Spectrum Screening Questionnaire, *SRS* Social Responsiveness Scale, *MASC* Manifest Anxiety Scale for Children, *BASC* Behavioral Assessment Scale for Children, *RME* Reading the Mind behind the Eyes task

** Significant diagnostic group difference, $p < .001$

criteria of 12, which is recommended for increased instrument sensitivity in studies on children with HFASD, and met or exceeded HFASD criteria scores on both the ASSQ (19 or greater) and SRS (70 or greater). Children in either diagnostic group were excluded if parent report indicated the child was affected by a disorder other than HFASD, a history of significant sensory or motor impairment or a neurological disorder or psychotic symptoms or a full scale IQ of less than 80. Sample characteristics are presented in Table 1.

Virtual Reality (VR) Measure

In the present study, we used a recently development measure for emotion recognition and interpersonal distance called the virtual-reality emotion sensitivity test (V-REST; Kim et al. 2010). In this paradigm participants were asked to identify one of six basic emotions (happiness, fear, anger, disgust, sadness, and surprise) in a simulated real-world encounter with an avatar (see Fig. 1a). Participants were directed to indicate the emotion they observed by selecting from words presented on screen on each trial (Fig. 1b). A sequence of four trials was presented for each emotion in succession with the level of the emotional intensity increasing from vague/neutral (see *happy* example, Fig. 1b top panel) to clear/strong (see *happy* example Fig. 1a top left panel). Each level had different intensities of facial expression (10, 40, 70, and 100 %), and body gesture (i.e., clasp hands, raise shoulders, shakes head, arms crossed, look down, step back). In addition lip-synch animation was used to allow the avatars to appear to verbalize increasingly more information (more words and phrases) consonant with the emotion across each level of intensity. Each of the trials lasted 10 s. On each trial participants were instructed to use a standard joystick to move as close to, or as far from, the avatar as they would if the situation was occurring in real life. The starting position of the joy stick in each task was at the mid-point between the closest possible avatar approach and furthest possible avatar withdrawal (see Fig. 1b).

Forty-eight trials were presented to each participant consisting of six emotions (happy, fear, anger, disgust, sadness, and surprise), two avatars (male and female), and four emotion intensity levels (from level 1 to level 4). The percent of trials with correct emotion recognition was calculated for each emotion and intensity level for all participants. Logitech Wingman software measured the final joystick position on each trial as an index of preferred interpersonal distance. Recall that at the start of each trial the joy stick position was calibrated to reflect 50 % of the perceived distance from the avatar. Therefore, avatar approach was reflected by final joy stick positions such that intervals 49 to 0 of the joy stick scale reflected increasing degrees of approach, while withdrawal from an avatar was measured by final joy stick intervals from 51 to 100.

The VR system hardware consisted of a Pentium PC, DirectX 3D Accelerator VGA Card, LCD Monitor (48 × 27 cm), and Joystick (Wingman, Logitech Inc., Newark, CA, USA). Participants were asked to sit in a chair in front of the monitor (53 cm distance), and the joystick was placed in the same line between the participant and monitor. The Game Studio A6 rendering engine (Conitec, Germany) was used as the VR software platform. Responses of participants were saved automatically with time stamped computer generated data records on all trials.

Symptom, Cognitive and Emotion Measures

To assess symptoms of HFASD, parent report data were collected on the Social Communication Questionnaire (SCQ; Berument et al. 1999; Corsello et al. 2007), Autism Spectrum Screening Questionnaire (ASSQ; Ehlers et al. 1999; Posserud et al. 2006), and Social Responsiveness Scale (SRS; Constantino 2004). All of these measures have well established validity in the discrimination of HFASD and typically developing samples (Corsello et al. 2007; Posserud et al. 2006; Constantino 2004).

IQ estimates were obtained with the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1999). The WASI Full Scale IQ has well established internal consistency (0.98) and test–retest reliability (0.92).

To examine the relations between emotion processing, interpersonal distance in the VR task and other measures of emotion-processing in HFASD participants were also

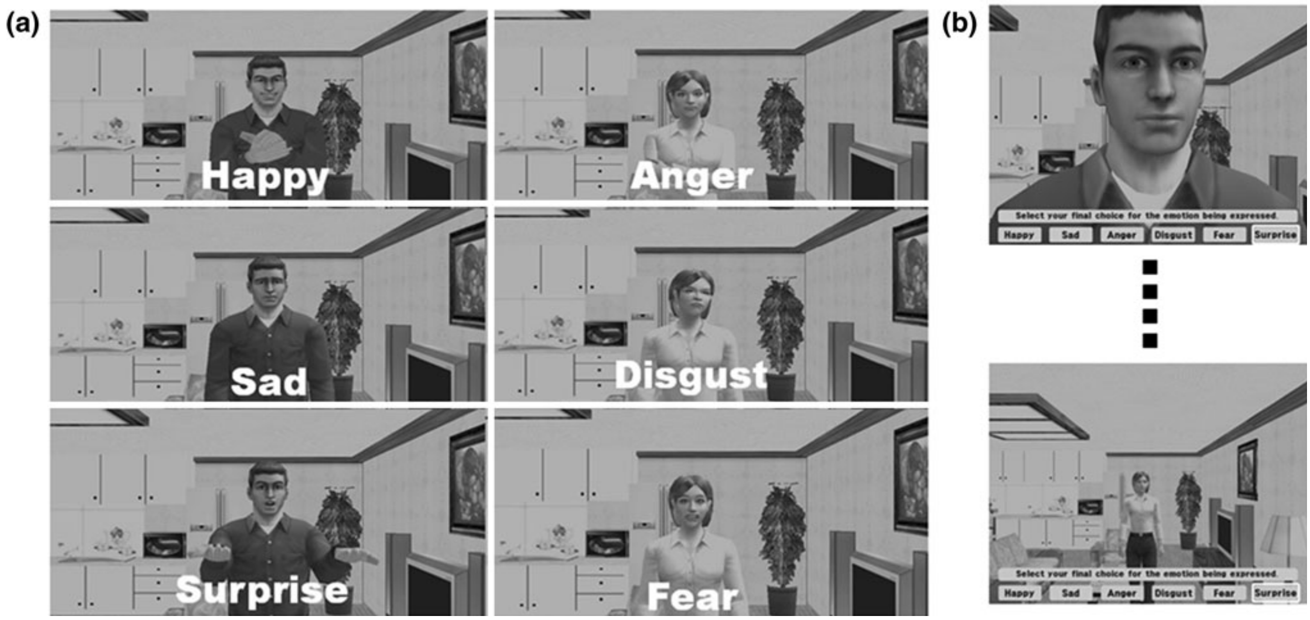

Fig. 1 Examples of the six emotions (**a**) and distances illustrating as close as possible and as far as possible (**b**) in V-REST. As a more detailed illustration in the happy emotion scenario, the subject met the avatar rising from a couch that was situated in the middle of the living room. The avatar stood and said "Hello, how was your day?" in a neutral tone and a slight smile (level 1). After the response of participant, the avatar continued to stand in the same place, and said "It's really good to have you home so early today" in a pleasant and higher tone and a slightly wider smile (level 2). The avatars continued to stand in the same place, and said "And guess what… I made us something wonderful for dinner. It's your favorite." in an excited tone while smiling broadly (level 3). The avatar continued to stand in the same place, and said in an excited tone with a broad smile "But before we eat… Congratulations! You have earned it!" The avatar clasped their hands together and raised their shoulders to show happiness (level 4)

presented with the child version of the Reading the Mind in the Eyes (RME) task (Baron-Cohen et al. 2001). The RME is an objective measure that requires participants to examine 36 different black and white pictures of eyes, and then pick from four emotion words the one that best describes the emotional and mental states expressed in each picture (Baron-Cohen et al. 2001).

Variance in interpersonal distance may be affected by differences in social-anxiety so the participants were asked to provide self-report on the Manifest Anxiety Scale for Children (MASC, March et al. 1997). The MASC is a 39 item for the assessment for use with children between the ages of 8- and 19-years, which yields a standardized Social Anxiety Scale score. The MASC has been standardized on 2,698 children and adolescents and has established validity for research with school-aged children with HFASD (Bellini 2004, 2006; Wood et al. 2009).

Finally, parent reports of children's problems and adaptive behaviors were obtained with the Behavior Assessment System for Children—2 (BASC-II; Reynolds and Kamphaus 2004). This broad-band measure has been shown to be a reliable and valid tool to identify behavior problems (Jarratt et al. 2005; Reynolds and Kamphaus 2004).

Results

Preliminary Analyses

The main dependent variables from the V-REST were the percent accuracy scores (Table 2) and the interpersonal distance scores also presented as percentages (Table 3). The V-REST is a newly developed measure (Kim et al. 2010). Therefore, we examined one aspect of its reliability and validity by correlating it with an established measure of emotion recognition in HFASD research, the Reading the Mind from the Eyes (RME) task (Baron-Cohen et al. 2001). Correlation analyses collapsing all participants indicated that that the emotional accuracy of V-REST was positively correlated with the total score of RME task, $r(41) = .33$, $p < .03$. Divergent validity for the joy-stick measure was provided by the observation that the personal distance measure of the V-REST was not correlated with the total score of RME task ($ps > .56$). In addition, the two dependent measures of the V-REST (accuracy and distance) were not correlated each other ($ps > .18$).

In the V-REST both male and female avatars presented emotion identification trials to study participants. No main effects associated with avatar gender or interactions with

Table 2 The V-REST emotional accuracy (%) at each level and emotion

	Control sample (N = 23)	Higher functioning autism (N = 19)	All participants
Level 1	15.2 (8.6)	18.0 (8.9)	16.5 (8.7)
Level 2	72.1 (18.6)	67.1 (26.9)	69.8 (22.5)
Level 3	72.1 (21.4)	78.1 (20.1)	74.8 (20.8)
Level 4	83.3 (14.2)	81.6 (17.7)	82.5 (15.7)
Anger	56.0 (18.8)	61.8 (16.9)	58.6 (18.0)
Disgust	58.2 (22.5)	57.2 (22.2)	57.7 (22.1)
Fear	52.2 (23.4)	51.3 (32.0)	51.8 (27.3)
Happy	83.2 (21.5)	78.9 (16.7)	81.3 (19.4)
Sadness	57.6 (18.0)	58.6 (24.3)	58.0 (20.8)
Surprise	57.1 (24.1)	59.2 (22.8)	58.0 (23.2)

V-REST is a virtual reality emotion sensitivity test. Accuracy data reflects the percentage of participants who correctly identified avatar expressed affect at a specific level of intensity of expression or for a specific type of emotion expression

Table 3 The V-REST personal distances (%) for each level and emotion

	Control sample (N = 23)	HFASD (N = 19)	All participants
Level 1	51.9 (7.2)	53.1 (10.8)	52.4 (8.9)
Level 2	54.2 (9.4)	53.5 (5.2)	53.9 (7.7)
Level 3	56.4 (12.2)	57.6 (7.8)	56.9 (10.3)
Level 4	57.0 (11.5)	59.8 (11.3)	58.3 (11.4)
Anger	60.4 (12.3)	62.4 (10.9)	61.3 (11.6)
Disgust	63.2 (14.9)	60.4 (13.5)	62.0 (14.2)
Fear	55.3 (14.7)	52.0 (15.0)	53.9 (14.7)
Happy*	43.8 (10.9)	50.7 (7.1)	46.7 (9.9)
Sadness	52.1 (10.3)	56.0 (9.3)	53.9 (9.9)
Surprise	54.8 (10.1)	54.4 (6.1)	54.6 (8.5)

V-REST is a virtual reality emotion sensitivity test. Personal distance greater than 50 % indicates joystick movement away from avatar and less than 50 % indicates movement toward the avatar

* Significant difference, $p < .05$

Diagnostic were observed in analyses of the data on Accuracy (all p values >.19) or Interpersonal Distance (all p values >.22). Therefore, avatar gender was not considered further in the primary analyses. In addition no effects of participant gender were observed on Accuracy (all p values >.42) or Interpersonal Distance (all p values >.91). Therefore, participant gender was not included in the subsequent analyses.

Accuracy, Emotion Type and Emotion Intensity

A 2 (diagnostic group) × 6 (emotions) mixed ANOVA for the accuracy measures revealed a significant main effect of emotion, $F(5, 200) = 12.00$, $p < .001$, $\eta^2 = .23$, but no effect of diagnostic group, $p > .90$, nor an effect of the diagnostic group by emotion interaction, $p > .89$ (See Table 2). Thus, there was no evidence of HFASD impairment in accuracy of emotion recognition on this task. There was also no evidence of emotion recognition impairment on RME task in this study ($p > .38$). The HFASD group RME mean was 18.06 (SD = 4.44) and the TD group RME mean was 19.26 (SD = 3.97).

Consistent with the manipulation of emotion intensity, a 2 (diagnostic group) × 4 (Intensities) mixed ANOVA revealed that V-RES task accuracies increased with intensity of emotion expression for the entire sample, $F(3, 120) = 223.90$, $p < .001$, $\eta^2 = .85$, but neither the main effect for diagnostic group ($p > .90$) nor the diagnostic group × intensity interaction ($p > .20$) were significant (see Table 2). Follow-up analyses revealed the following pattern of significant differences in accuracy across levels of intensity: level 1 versus level 2, $t(41) = 15.24$, $p < .001$; level 2 versus level 3, $t(41) = 1.66$, $p < .11$; and level 3 versus level 4, $t(41) = 3.60$, $p < .001$ (see Table 2).

Approach–Avoidance Motivation and Interpersonal Distances

A 2 (diagnostic group) × 6 (emotion) mixed ANOVA for the Interpersonal Distance measure revealed a significant main effect of emotion, $F(5, 200) = 13.29$, $p < .001$, $\eta^2 = .25$. Follow-up of the main effect for Interpersonal Distance revealed that approach tendency was strongest for the Happy emotion ($p < .002$, Table 3). Relatively strong joy stick indexes of withdrawal or avoidance were displayed for the emotions of Anger and Disgust emotions ($p < .005$; Table 3).

The analyses did not reveal a main effect of Diagnosis, $p > .65$, but did reveal a diagnostic group × emotion interaction, $F(1, 40) = 6.27$, $p < .02$, $\eta^2 = .14$. To explore this interaction in more detail, post hoc t tests (Tukey's HSD) for each emotion across the HFASD and TD groups were conducted. The results showed that the average HFASD group joy stick position was further from the "happy" avatar compared to the average distance of the TD group in the Happy emotion condition, $t(40) = 2.48$, $p < .017$ (see Table 3). No other significant diagnostic group differences were observed for the other five emotions (all $ps > .21$).

To determine if differences in accuracy of emotion identification had an impact on this group difference, analyses were also conducted only for trials on which the participants correctly identified the "happy" affect. In these analyses the mean interpersonal distance of Control Group was 42.8 (SD = 12.2) and 50.7 (SD = 6.4) for the

HFASD sample. The change in trials used in the analyses resulted in unequal variance across the groups, but even when this was considered there was still evidence of a diagnostic group difference, t(35.6) = 2.66 $p < .012$.

To examine the effect of intensity level on interpersonal distance a 2 (diagnostic group) × 4 (intensity) mixed ANOVA was also conducted. There was a significant main effect on the level, $F(3, 120) = 6.12$, $p < .001$, $\eta^2 = .13$, but no effects for diagnostic group ($p > .63$) or the diagnostic group × intensity interactions ($p > .73$) were observed (see Table 3). Accordingly, the diagnostic group effect on interpersonal distance on "happy" emotion trials was comparable across intensity level 1 [49. 5 (SE = 4.2) vs. 54.3 (SE = 4.6)], level 2 [(45.1 (SE = 2.4) vs. 48.8 (SE = 2.7)], level 3 [41.4 (SE = 2.8) vs. 49.4 (SE = 3.1)], and levels 4 [(40. 6 (SE = 3.2) vs. 49.1 (SE = 3.6)] for the control and HFASD groups respectively.

Individual Differences

To examine if there were meaningful individual differences in choice of interpersonal distance within the diagnostic groups correlation analyses were conducted within each group. These analyses revealed a pattern of significant convergent associations in the HFASD sample with responses to the Happy and Disgust emotions, but not with responses to any other emotions. First, the association between the ASSQ and Happy Personal Distance approached significance in the HFASD group, $r(18) = .44$, $p < .06$, but this association as non-significant in the TD group, $r(22) = -.18$, $p > .41$. The difference between these two correlations was significant ($z = 1.95$, $p = .05$), but the lower correlation in the TD group may have reflected that groups relatively restricted variance on the ASSQ (see Table 1; Fig. 2).

In the HFASD sample closer joystick proximity to the Happy emotion was associated with lower parent report ratings of HFASD symptoms on the ASSQ (see Fig. 2). To examine the possibility that this association could be explained by variance in cognitive status in the HFASD sample a partial correlation was computed. However, the correlation between ASSQ and Happy distance was unchanged after controlling for IQ ($r = .44$). It was also the case that evidence for this association was unchanged in the HFASD sample when partial correlations were computed to control for possible shared variance with child self-reports on the MASC Social Anxiety scale, $r = .46$, $p = .05$, or parent reports on the BASC Withdrawal scale, $r = .45$, $p < .06$. There were no other correlations between symptoms and emotion measures that approached significance in the HFASD sample (all $ps > .23$).

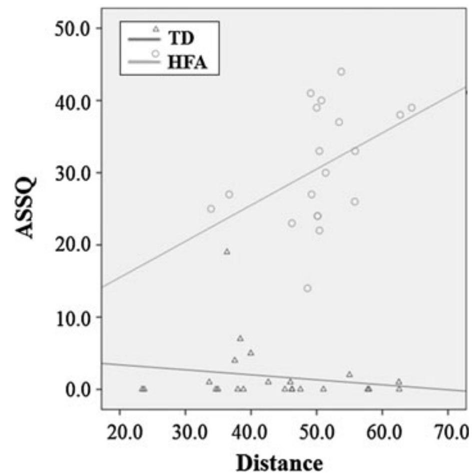

Fig. 2 Comparison of the linear relations between the ASSQ and "happy interpersonal distance in the diagnostic groups. ASSQ refers to the Autism Spectrum Screening Questionnaire; TD refers to the Typical Development group; HFASD to the Higher Functioning Autism Spectrum Disorder group

Interpersonal distance on the *Disgust* expression trials were correlated with self-reported social anxiety in children. The HFASD children with higher self-report of MASC Social Anxiety scores positioned themselves at greater Interpersonal Distance from Avatars displaying Disgust, $r = .58$, $p < .01$, and this association was not effected by covariance with IQ ($r = .55$). There was evidence of as significant correlation in the TD sample, but surprisingly the correlation was in the opposite direction, $r = -.43$, $p < .05$. Examination of the scatter plots suggested the association in the TD was non-linear, but linear in the HFASD sample. This observation was supported by non-parametric analyses, which revealed that the association between Interpersonal Distance and Disgust was not significant in the TD group, Kendal's tau = −.29, but remained significant in the HFASD sample, Kendal's tau = .44, p < .01. Additional, Convergent data indicated that the parent report on Internalizing Scale of the BASC was also correlated with greater interpersonal distance from the display of *Disgust* in the HFASD group, $r = .60$, $p < .007$, which remained significant after controlling for IQ ($r = .56$). This association was not evident in the TD sample, $r = .18$, but the group difference in these correlations was not significant, $z = -1.49$, $p = .13$.

Analyses also revealed several observations about the factors that may moderate emotion recognition accuracy in children with HFASD. Full Scale IQ were positively correlated with accuracy of Happy expression identification in the HFASD sample, $r = .68$, $p < .001$, and particularly at identifying Happy expressions at intensity level 3, $r = .63$, $p < .004$. The identification of the other five emotions was not correlated with IQ in the HFASD group. The associations between IQ and the identification of Happy expression were not observed in the TD sample, $r = -.001$. The group difference of these correlations was significant, $z = -2.40$, $p < .02$, respectively. Performance on the Eyes Test was also correlated with accuracy of identification of Happy emotion in the HFASD sample, $r = .49$, $p < .03$. This correlation remained significant after controlling IQ, $r = .48$, $p < .04$. A similar correlation was observed only for the Happy expression in the TD sample, but that correlation did not reach a conventional level of significance, $r = .37$, $p < .09$, but was not diminished by the controlling IQ, $r = .38$, $p < .08$.

Discussion

The current study provides data on a novel method for examining approach and avoidance tendencies and associated social-motivation in children with HFASD. The major new observation in this study was that children with HFASD displayed significantly less evidence of a tendency to move toward a virtual avatar expressing a positive (Happy) emotion, using a joy stick, than was observed among children with TD. Alternatively, there was little evidence that children with HFASD avoided or move away from avatars expressing positive or negative affect to a greater extent than did children with TD.

Consistent with previous findings on emotional processing, when effects of age, gender, and IQ factors were controlled there was little evidence of a robust disturbance of affect recognition among children with HFASD (Grossman et al. 2000; Harms et al. 2010; Tracy et al. 2011). Indeed, both groups displayed relatively high accuracy in the recognition of Happy emotion. This observation mitigates the possibility that approach to the Happy emotion was systematically different in the HFASD group because of emotion recognition impairment. Analyses also suggested that the variance in approach in the Happy emotion condition could not be explained by third factors such as variance associated with IQ, parent reported Internalizing symptoms or participants reports of symptoms social-anxiety. The latter observation is noteworthy because a systematic decrease in approach to Happy emotions has previously been observed in non-HFASD samples with social phobia (Heuer et al. 2007).

This pattern of results has implications for the social-motivation model of HFASD (Kohls et al. 2012; Chevallier et al. 2012). First, the results were not consistent with the aversion hypothesis that many individuals with HFASD can be characterized by a tendency to avoid or move away from social stimuli. Alternatively, the results appeared to be more consistent with the notion that some or many children with HFASD may not experience the same level of reward and approach behavior in response to positive affect or the opportunity to share positive affect with other people (Kasari et al. 1990; Kohls et al. 2012; Mundy 1995).

It was also the case, though, that the results could be construed as consistent with the possibility that children with HFASD display individual differences in social-motivation and associated social approach and avoidance tendencies (Wing and Gould 1979). Individual differences in the approach of Happy emotion was associated with level of symptom intensity as measured by the ASSQ approached a conventional level of significance in this study. Caution must be exercised in interpreting this observation. Nevertheless, this observation raises the possibility children with HFASD display social motivation differences that may moderate behavioral tendencies associated with types of symptom expression within samples children with HFASD (Mundy et al. 2007).

Stronger evidence of this possibility was provided by the observation that both self-report of social anxiety and parent report of internalizing behavior disturbance in the HFASD sample was associated with positioning the joy stick at a greater distance from avatars expressing disgust. By its very nature disgust involves the expression of a feeling of revulsion or profound disapproval. When directed toward participants by the avatar it may have posed an especially alarming and/or aversive stimulus for children with HFASD who were also affected by higher levels of with social anxiety. This type of pattern of individual differences in social-motivation supports the possibility that social motivation may moderate behavior in children with HFASD, but may not necessarily define a universal attribute of HFASD.

Although the diagnostic groups did not differ in emotion recognition accuracy the data in this study provided some insights into the factors associated with individual differences in accuracy *within* the diagnostic groups. First and foremost the data suggested that variance in IQ may relate to the accuracy of emotion recognition, even within a sample of children with HFASD. Moreover, the contribution of IQ to emotion recognition may be specific to children with HFASD, and not observed in a control sample with a similar mean and range of IQ. These results are consistent with previous observations of increased vulnerability to social impairment among HFASD children with lower IQs (Jarrold et al. 2013).

It was also the case that Happy accuracy was the one emotion recognition measure to correlate with the Eye-Task measure of recognizing emotion only from pictures of eyes. This was true for the HFASD group regardless of IQ. At least two possibilities may be considered in explaining this finding. One is that the Happy expression was more dependent on processing information from the eye and brow region of the avatars than were the other V-REST emotion recognition measures. Another equally plausible possibility is that emotion expression recognition was more limited to facial emotional expression in the Happy condition, whereas vocal and postural information had greater influence in the recognition of other emotions in the V-REST task. In either case this pattern of results suggests that the Happy condition reflected processes in common with the presumptive social-cognitive facial process of the Eyes-Task in the HFASD sample.

Study Limitations

It was not clear why diagnostic group differences in approach or avoidance of emotion expressions were only observed in the Happy condition in this study. To understand this finding replication is needed using a balanced study design that compares multiple exemplars of positive emotion with multiple exemplars of negative emotion. It was also not clear why social anxiety in the typical in the typical sample was not associated with greater interpersonal distance from negative emotions, and was even associated with approach to one negative emotion (disgust). This was contrary to observations of adults (Heuer et al. 2007). This may reflect developmental differences across studies, or the method variance. Specifically, in this study vocal, gestural and facial components of affect expression were displayed. To better understand the utility and processes involved in joy stick measures of motivation and interpersonal distance in children with HFASD it will be important to carefully examine HFASD and TD responses to avatar facial expressions alone versus avatar multi-modal expressions in future studies (cf. Grossman et al. 2000; Philip et al. 2010) .

Another limitation the sample size, which was modest, and the number of trials presented to each participant was limited because of the duration demand of presenting multiple intensity trials for each emotion. This limited the power of analyses in this study and restricted the number of analyses to aggregate measures. In future studies it may be useful reduce the number of intensity presentations to one or two in order to increase number of emotions exemplar presented and the number of avatars and trials involved in presented each emotion. It is also important to note that, although some validation of the joy stick measure was provided in this study in terms of individual difference data, more direct validation will be an important next step. This may examine the degree to which joy stick interpersonal distance measures of social motivation are associated with direct behavioral observation of social motivation or interpersonal differences among HFASD children (e.g., more or less aloof behavior styles). Lastly, it should be noted that the current findings were based on an experiment with HFASD children, and this small sample may not represent all children with HFASD. However, the task demands of the V-REST task are not high and may be informative in research with larger and more representative samples of children with HFASD.

Two other issues were noteworthy. Given the atypical language and communication development associated with HFASD, it is possible that the two diagnostic groups did not interpret the task instructions of "use a standard joystick to move as close to, or as far from, the avatar as they would if the situation was occurring in real life" in a comparable manner. This methodological issue is common to many assessments of children with HFASD that involve verbal directions. However, it's not clear why or how a lack of comparable understanding of task instructions would specifically led to a pattern of group differences in interpersonal distance to on positive stimuli, but not stimuli with negative emotions. It seems more parsimonious to conclude with study, and the previous work of Parsons et al. (2004, 2005), there are now three studies that indicate that joystick measures of preference for persona distance reveals theoretically meaning data about social emotional factors in people with HFASD.

Finally, the comparable interpersonal distance to Avatars with negative affect displayed by the groups suggested that HFASD and TD children were similar in their emotional engagement with some stimuli in this paradigm. However, we also need to recognize that the VR paradigm used in this study did not emulate binocular depth cues. Hence, the potential for relative immersion in the VR stimulus field was likely limited for both groups. Enhancing immersion potential, and ecological validity may be an important factor to consider in future VR studies of interpersonal distance studies in HFASD. Fortunately, the use of head mounted display methods, or 3D flat screen presentations, may be used to address this issue.

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