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Examining the reinforcing value of stimuli within social and non-social contexts in children with and without high-functioning autism

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Abstract

One of the key diagnostic criteria for autism spectrum disorder includes impairments in social interactions. This study compared the extent to which boys with high-functioning autism and typically developing boys "value" engaging in activities with a parent or alone. Two different assessments that can empirically determine the relative reinforcing value of social and non-social stimuli were employed: paired-choice preference assessments and progressive-ratio schedules. There were no significant differences between boys with high-functioning autism and typically developing boys on either measure. Moreover, there was a strong correspondence in performance across these two measures for participants in each group. These results suggest that the relative reinforcing value of engaging in activities with a primary caregiver is not diminished for children with autism spectrum disorder.

Keywords

autism spectrum disorder, high-functioning autism, mother–child interaction, preference, progressive-ratio, reward, social, value

Introduction

Autism spectrum disorder (ASD) is characterized by qualitative impairments in social interaction and social communication and by the presence of restricted, repetitive patterns of behavior, interests or activities, and sensory differences (American Psychiatric Association, 2013). Some have suggested that impairments in social affiliation, a lack of interest in others, and deficits in social interaction may arise from a lack of sensitivity to social reward early in development in individuals with ASD (Dawson et al., 2001, 2002; Scott-Van Zeeland et al. 2010). That is, these types of behaviors are less rewarding or valuable to the individual, such that the behavior is not supported and is not more likely to re-occur. This possibility seems to be supported by early differences in social behavior and interaction. For example, impairments in looking at faces, joint attention, social timing, and visual gaze patterns have even been reported in young infants who have later gone on to receive a diagnosis of ASD (Merin et al., 2007; Osterling and Dawson, 1994; Trevarthen and Daniel, 2005). Any resultant differences in the potency of parent–infant interactions as a reinforcer for learning and behavior would likely have profound consequences upon social development.

Neuroimaging studies reveal that children with ASD show diminished activation in reward centers in the brain (e.g. ventral striatum, a region that is sensitive to the potency of particular rewards) during a learning task employing both social (smiling vs frowning faces) and

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monetary reward feedback, with a more marked reduction in activation shown particularly for social rewards (Scott-Van Zeeland et al., 2010). Kohls et al. (2011) revealed that although there were no group differences (ASD or control) in behavior between the ability of social and monetary reinforcers to support performance during a Go/No-Go task, children with ASD show reduced event-related potentials (P3) to cues associated with both social and monetary reinforcers. In addition, on a Go/No-Go functional magnetic resonance imaging (fMRI) task, children with ASD show diminished activation in reward centers in the brain in response to monetary rewards (less activation in the ventral striatum/nucleus accumbens, as well as reductions in other reward-related regions including the midbrain, thalamus, amygdala, and anterior cingulate) and reduced activation in the amygdala and ventral anterior cingulate to social rewards (Kohls et al., 2013). These findings by Kohls et al. (2011, 2013) suggest more of a generalized reward-processing deficit in ASD, which might extend to social and non-social events.

At the behavioral level, Garretson et al. (1990) revealed that behavior during a continuous performance task was better supported by the delivery of tangible items (pennies, pretzels) than social attention and praise ("Good Job!") in low-functioning children with ASD compared to mental age–matched controls. Demurie et al. (2011) found that unlike typically developing (TD) children and adolescents, children and adolescents with ASD responded slower on a variant of a monetary incentive delay task when their behavior (performance) was supported by a context of social reinforcers (a pictogram of two people, one approving the performance of the other with a thumbs-up and a compliment in a text bubble, for example, "You're a champion!") compared to monetary reinforcers. Ingersoll et al. (2003) used an imitation task to reveal that children with ASD display fewer social behaviors (reduced coordinated joint attention and positive affect with an investigator and less social initiations), but the same object-orienting behaviors (time spent engaging with the object and directing positive affect toward it) as TD children.

Additional researchers have also directly examined preference for social and non-social stimuli in children with ASD. Celani (2002) used a forced-choice sorting-by-preference procedure to reveal that children with autism (unlike TD children and children with Down syndrome) show greater preferences for pictures of inanimate objects (e.g. table, chair) than for pictures of human beings (e.g. baby, child, adolescent, young person, and older person) and prefer drawings of a child handling an object more than a drawing of the same child in contact with another person. Using a free operant preference assessment, Prothmann et al. (2009) observed that children with ASD exhibit a greater preference (measured by duration of engagement and frequency of contact) for interactions with an animal (a dog) than for interactions with an unfamiliar adult and then followed by a smaller preference (indicated by infrequent contact) for self-engagement with inanimate objects.

Collectively, the findings from the studies by Celani (2002) and Prothmann et al. (2009) suggest that children with ASD may show reduced preferences for contexts involving (human) social interaction. However, inconsistent findings between the two studies pertaining to preference for inanimate objects (non-social events) and limitations to both studies examining preferences for social and non-social stimuli among persons with ASD warrant caution when interpreting their results. Specifically, results from the study conducted by Celani (2002) suggested that children with ASD prefer interaction with objects to interaction with humans, whereas the study by Prothmann et al. (2009) indicated that children with ASD prefer social interaction with an adult to self-occupation with objects. In addition, Prothmann et al. (2009) did not include a comparison control group, and Celani (2002) only used photographs of the various stimuli and failed to provide access to the selected items. Previous research has suggested that not providing access to selected stimuli during preference assessments may result in undifferentiated preferences (e.g. Hanley et al., 1999) or may identify stimuli that function as less effective reinforcers than those identified during preference assessments in which access to the stimuli is provided following a selection (e.g. Kuhn et al., 2006). Furthermore, neither study assessed whether the stimuli identified as highly preferred actually functioned as reinforcers. Thus, additional research on the preference for and the reinforcing efficacy of social and non-social stimuli in individuals with ASD remains necessary.

In this study, we examined the reinforcing value of activities embedded in social and solitary contexts in boys with and without high-functioning autism (HFA) using two behavioral assessment procedures: (a) a stimulus preference assessment (SPA) and (b) progressive-ratio (PR) schedules.

The SPA measures *preference*, defined as the extent to which the individual will select one stimulus over others, when all are freely available. The preparation requires a choice between concurrently presented alternatives, often presented in pairs. Many iterations encompassing all possible pairwise permutations result in selection percentages (i.e. the number of times each stimulus is selected given the number of times it is available). The stimuli are then ordered according to selection percentages, resulting in a preference hierarchy that suggests that higher ranked stimuli (i.e. those stimuli with higher selection percentages) will be more effective reinforcers than lower ranked stimuli. This hierarchy is known to have a direct correspondence to the utility of the items in reinforcing behavior (DeLeon et al., 2001, Piazza et al., 1996).

The term reinforcer is reserved for a stimulus or stimulus change that demonstrably strengthens the behavior

that produces it (e.g. increases the frequency or rate of responses relative to a no-reinforcement control condition). Thus, if a stimulus is consistently delivered contingent upon a response, but *does not* strengthen that response, it is not considered a reinforcer. SPAs are predictive tools that suggest which stimuli might function as reinforcers, but the true test of whether or not a stimulus is a reinforcer is a *reinforcer assessment*—a direct test of whether the putative reinforcer does, in fact, strengthen behavior (see DeLeon et al., 2013 for further elaboration of the relation between preference and reinforcer assessments).

Instructional and therapeutic approaches for children with ASD often rely on reinforcement arrangements. Parents, teachers, clinicians, and other caregivers use reinforcement-based procedures to both increase the frequency of desirable behavior and decrease the frequency of aberrant behavior. Thus, the success of these procedures rests on the careful selection of reinforcers and arrangement of reinforcement contingencies (see DeLeon et al., 2014a for a review and further discussion).

One way to evaluate stimuli as reinforcers (i.e. a reinforcer assessment) is through the use of PR schedules. A PR schedule (Hodos, 1961) is a type of reinforcer assessment that involves increasing amounts of work to obtain a stimulus. PR schedules have been used for decades in basic research to gauge relative reinforcer effectiveness and have been used increasingly in applied settings as a means to determine the potency of reinforcers for children with ASD and other developmental disabilities (e.g. DeLeon et al., 2009, 2011; Francisco et al., 2008; Glover et al., 2008; Kenzer et al., 2013; Tiger et al., 2010). The procedure yields a break point (BP) as a measure of *reinforcer efficacy*, defined as the extent to which an individual will work to gain access a stimulus. This procedure is based on the premise that the relative strength of a reinforcer can be measured by how its consumption changes with increasing effort required to produce it. Prior research has shown good correspondence between SPA and PR assessments of stimulus value. For example, DeLeon et al. (2009) conducted preference assessments to identify stimuli of high, moderate, and low preference for four children with developmental disabilities. Each of these 12 stimuli (one from each of the three categories for each of the four children) was then subjected to PR analysis to validate the predictions of the preference assessment. The results revealed that higher preference stimuli resulted in higher BPs than lower preference stimuli in 10 of 12 possible comparisons. The correlation between selection percentages in the preference assessments and mean BPs in the PR analyses was positive and significant ($r = 0.62$, $p = 0.03$). One aim of this study was to extend the generality of this correspondence.

Based on the literature, we predicted that these two behavioral measures (SPA and PR assessments) would yield consistent effects and reveal reduced reinforcing value (preference and reinforcer efficacy) for social compared to solitary activities in boys with ASD, but not in a control sample of TD children. In our method, some of the same types of activity (i.e. videogames and building) were allowed to occur in each context, permitting an investigation of differences between groups in the consumption of a stimulus, as the amount of behavior required to produce it increases, by examining demand curves between groups, a technique adopted from the field of behavioral economics (Hursh et al., 2013). As a first step in a line of investigation on the relative value of social and non-social reward, the social context in this study was specifically designed to be highly familiar, involving the child and his mother. In an attempt to reduce any potential confounding differences in child age and/or gender combinations of primary caregiver–child interactions, this study focused specifically on boys (aged 8–10 years) with their mothers.

Methods

Pre-study: developing a list of potential social and solitary activities

Prior to the main experiment, we interviewed 24 mothers of 8- to 10-year-old boys with HFA ($n = 12$) and TD controls ($n = 12$) who met our study eligibility criteria for each diagnostic group (see the following for more details on eligibility criteria) to develop a list of potential activities to include in the two behavioral assessments (i.e. the SPA and PR analyses). Mothers were contacted based upon their previous involvement with other research studies at the institution (all procedures and protocols were approved by the pertinent institutional review board). Mothers were first interviewed (over the telephone) using a modified version of the parental questionnaire, the Reinforcer Assessment for Individuals with Severe Disabilities (RAISD; Fisher et al., 1996). Then, we selected the most frequently nominated items and also included activities that are held to be (anecdotally, clinically) of particularly unusual or specific interest to children with ASD (e.g. playing with or watching things that spin, such as a pin wheel, fan, toy top) in an attempt to capture some potential esoteric, unusual, and idiosyncratic interests of individuals with ASD. At the conclusion of the nomination process, a revised list of potential activities was then administered to the mothers, containing selected activities that we believed should serve as high-preference social and solitary activities as well as possible low-preference social and solitary activities. Mothers were at that time asked to rank how much they considered their child would "value" the opportunity to engage in each activity using a 5-point Likert scale. We used this information to compile a final list of 12 hypothesized high-preference

Table 1. Activities included in social and solitary stimulus preference assessments.

Social preference assessment		Solitary preference assessment	
Hypothesized high preference	Hypothesized low preference	Hypothesized high preference	Hypothesized low preference
Videogames[a]	Sort silverware	Videogames[a]	String beads
Read books[a]	Stuff envelopes	Read books[a]	Wash face
Build/put things together[a]	Wash hands together	Build/put things together[a]	Clean floor and table
Board games	Mom brush hair	Computer	Trace with stencil
Physical attention (e.g. tickles, hugs, kisses, snuggles)	Put together Tupperware	Watch movie	Lace string through objects
Toys (e.g. cars, action figures)	Play peek-a-boo	Listen to music	Brush teeth

[a]The same activity was included in both the social and solitary preference assessments.

activities (6 social and 6 solitary) and 12 hypothesized low-preference activities (6 social and 6 solitary).

The list of the activities used in this study is provided in Table 1. Some examples of potentially rewarding social activities included the following: playing board games, building activities together (e.g. involving Legos), playing videogames, and reading a book. Some examples of potentially rewarding solitary activities included the following: going on the computer, building activities alone, playing videogames alone, reading a book alone, and listening to music. Several of the same type of activity (i.e. playing a videogame game, building activities, and reading) could be presented in each context (social and solitary), although the identity of the specific videogame, building activity, or book could be unique to each context (e.g. the book selected to read with mom could differ from the book read alone). Social and solitary versions of the same type of activity were included to further assess participants' sensitivity to the main manipulation of interest, the presence or absence of the mother. For the relatively less preferred (social and solitary) activities, the social activities tended to involve reciprocal interaction (e.g. peek-a-boo), whereas the solitary activities tended to be more mechanical (e.g. cleaning, stringing beads, lacing).

We allowed participants to select the specific stimulus they used across certain well-defined categories of activities. We felt that this was important for certain activities (e.g. listening to music and watching movies) as preferences are highly individualized. Although the exact stimulus for some activities varied across participants, all stimuli had to be approved by a study team member and the stimuli had to fit certain requirements of the activity category (e.g. "read books" had to be a physical book rather than an audio book). Furthermore, many of the materials used for social and solitary activities were held constant across participants (i.e. the social videogame and materials used in sorting silverware, stuffing envelopes, putting Tupperware together, type of computer used, stringing beads, cleaning, tracing, lacing, brushing teeth, brushing hair, washing hands, and washing face were all the same across participants).

Main experiment

Participants. In total, 21 boys with HFA (HFA group) and 20 TD boys, aged 8–10 years, participated in this study. Participants were recruited through their involvement with other research studies at the institution, advertisements, and postings in local parent magazines and websites, local chapters of the Autism Society of America (ASA), other autism parent support groups, flyers and distributions at area schools, and online listservs for homeschoolers. Written consent was obtained from a parent/guardian and written assent was obtained from all participating children.

Demographic characteristics for the two diagnostic groups, including mean scores and standard deviations, are presented in Table 2. As can be seen from Table 2, the two groups did not differ significantly in age. The mean age for the HFA group was 9.56 years, and the mean age for the TD control group was 9.43 years ($t(39) = -0.44$, $p > 0.6$). All participants had Full-Scale IQ scores of 73 or higher (Wechsler Intelligence Scale for Children-IV (WISC-IV), Wechsler, 2003). Of the 41 participants, 37 had Full-Scale IQ scores of 81 or above. Full-Scale IQ scores were significantly lower for children in the HFA group ($M = 97.61$, $t(39) = 4.03$, $p < 0.001$) than for children in the TD control group ($M = 114.75$). There were no significant differences between groups in terms of socio-economic status (SES) based on the study by Hollingshead (1975).

Inclusion criteria

HFA group. All children in the HFA group met *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; DSM-IV-TR) criteria for autism based on the Autism Diagnostic Interview–Revised (ADI-R; Le Couteur et al., 2003 or Lord et al., 1994), the Autism Diagnostic Observation Schedule–Generic (ADOS-G; Lord et al., 2000; 19 participants met the criteria cut-off for autism and 2 participants met the criteria cut-off for autism spectrum) and all participants were also judged clinically to have ASD. The evaluations of participants for inclusion in the HFA group were conducted by study team members S.H.M. (child neurologist) and M.C.G. (psychologist),

Table 2. Diagnostic group characteristics mean (±1 standard deviation).

Measure	Control group	HFA group
Age (years)	9.43 (0.97)	9.56 (0.85)
Full-Scale Intelligence Quotient***	114.75 (15.53)	97.61 (16.00)
Verbal Comprehension Index*	116.55 (13.43)	101.52 (21.32)
Perceptual Reasoning Index**	117.75 (8.19)	105.433 (16.92)
Working Memory Index**	106.25 (13.08)	93.62 (14.42)
Processing Speed Index**	98 (11.49)	87.14 (13.24)
Socio-economic status	53.5 (9.95)	58.79 (8.60)
ADI-R–Social Interaction Score	–	20.48 (4.76)
ADI-R–Communication Score	–	16.52 (3.92)
ADI-R–Restricted, Repetitive, Stereotyped Behavior Score	–	7.76 (2.79)
ADI-R Abnormality Present <36-Month Score	–	3.71 (1.10)
ADOS-G communication	–	4.61 (1.53)
ADOS-G Reciprocal Social Interaction	–	9.76 (2.34)
ADOS-G communication + social interaction total	–	14.38 (3.71)
ADOS-G imagination/creativity	–	1.05 (0.76)
ADOS-G stereotyped behaviors and restricted interests	–	3.24 (2.05)
SRS total score	40.00 (4.54)	80.05 (9.79)
SRS Social Awareness T-Score***	40.10 (6.63)	73.81 (12.05)
SRS Social Cognition T-Score***	40.60 (4.72)	76.00 (8.71)
SRS Social Communication T-Score***	40.20 (4.61)	77.05 (11.37)
SRS Social Motivation T-Score***	42.75 (5.43)	70.57 (7.26)
SRS Autistic Mannerisms T-Score***	42.85 (4.33)	80.76 (9.44)
SCQ total score current	2.65 (2.43)	–
SCQ total score lifetime	2.40 (2.52)	–

HFA: high-functioning autism; ADI-R: Autism Diagnostic Interview–Revised; ADOS-G: Autism Diagnostic Observation Schedule–Generic; SRS: Social Responsiveness Scale; SCQ: Social Communication Questionnaire.
*$p < 0.05$; **$p < 0.01$;***$p < 0.001$.

reliably trained in administering assessment tools for the diagnosis of autism. The HFA group included only individuals with idiopathic autism (e.g. no history of Fragile X, encephalitis, or other known medical conditions associated with autism). The clinician-administered Diagnostic Interview for Children and Adolescents-IV (DICA-IV; Reich et al., 1997) was also used to assess the presence of co-morbid psychiatric symptoms. Out of the 21 children, 17 with HFA were determined to meet criteria for co-morbid diagnoses, including attention-deficit hyperactivity disorder (ADHD, n=10), obsessive–compulsive disorder (OCD, n=3), oppositional defiant disorder (ODD, n=5), major depressive disorder–past (n=3), generalized anxiety disorder (GAD, n=2), and/or phobias (n=6). There were four participants in the HFA group who were taking stimulant medications (e.g. Focalin, Concerta, Risperdal) and one participant taking Celexa at the time of the study. These medications were not withheld on the day of testing.

Control group. Parents were interviewed and were asked to complete rating scales to ensure that children were eligible for enrollment in the TD control group. Children were included in the TD control group as long as they showed no evidence of impairments in social communication based on parent reports on the Social Responsiveness Scale (SRS; Constantino, 2005) and the Social Communication Questionnaire (SCQ), Current and Lifetime forms (Rutter et al., 2003). Children were included in the TD control group as long as they showed no evidence of a psychiatric diagnosis on the DICA-IV (e.g. ADHD, OCD, ODD, depression, anxiety), with the exception of a specific phobia. Children were also excluded from the TD control group if they met criteria for ADHD based on the following parent and teacher ADHD rating scales: Conners' Parent Rating Scale–Revised (CPRS-R; Conners, 1997), Conners' Teacher Rating Scale–Revised (CTRS-R; Conners, 1997), and the Attention Deficit Disorder–Hyperactivity Disorder Rating Scale (DuPaul, 1991). Children were also excluded from the TD control group if they had a history or current use of any psychoactive medication, history of seizures or other major neurological disorder, history of learning disabilities, and/or a sibling or parent with autism or other pervasive developmental disorder.

Procedure and stimuli. Prior to enrolling in the study, parents of potential study participants were questioned over the telephone regarding whether their child liked the proposed high-preference activities in each of the two contexts

(social and solitary). A report of liking at least four of the six hypothesized high-preference activities in each category in Table 1 was required in order to qualify for enrollment into the study. (All potential participants met this requirement, and none were excluded on this basis.) Study participants were asked to bring with them to the laboratory some of their favorite activities from home from the specified categories (e.g. a favorite game, music, movie they like to watch by themselves and with their mom).

Stimulus pre-session exposure. When each participant came into the laboratory, pre-identified items brought in from home were collected and participants were also allowed to select items from attractive games and toys in the laboratory for the remaining activities. A photo session was then conducted in order to obtain photographs of the participant engaging in the 12 social activities with his mother and 12 solitary activities (see Table 1). For the social stimulus pictures, the child and mother were asked to "pretend" to interact with the items together as they would typically do at home and were photographed accordingly. For the solitary stimulus pictures, photographs were taken of each individual item representing each activity (e.g. a photograph was taken of a book the child likes to read; the child was not present in the photograph for solitary activities). Once all 24 pictures were taken, 3×5 in color pictures were printed. Each of the 24 pictures was then paired with 30 s of access time with each of the activities. For the 12 social activities, the child engaged with his mother in each of the social activities for 30 s. For each of the 12 solitary activities, the child engaged in the activity by himself for 30 s (without the presence of his mother).

SPAs. We used a computerized version of the paired-choice preference assessment described by Fisher et al. (1992), which identifies a hierarchy of preference among activities. For each participant, the preference assessment was conducted three times: the first two administrations involved either only the 12 social activities or only the 12 solitary activities, with each assessment containing the context-relevant "supposed" high- or low- preference activities (n = 66 trials per assessment). The order of exposure to the social and solitary SPAs was counterbalanced across participants. The third administration of 12 items consisted of the combination of the 3 highest and 3 lowest ranked items from the prior two context-specific assessments (i.e. it specifically included the 3 highest and 3 least preferred activities from the social-context SPA and the 3 highest and 3 least preferred activities from the solitary-context SPA).

For all administrations, selection percentages (relative preference) were calculated for each specific activity by dividing the number of times the activity was selected by the number of times it was presented. The activities were then arranged in descending order according to their selection percentages (i.e. the activity selected with the greatest percentage was ranked number 1, the activity with the second highest selection percentage was ranked 2, and so on).

During each SPA, an examiner sat next to the participant and read the instructions verbatim to each subject at the beginning of the testing (instructions are available upon request). The participant's mother was not present in the testing room during the administration of the SPAs. In each administration, the pictures of two activities were concurrently presented side-by-side on a computer touchscreen. Participants were instructed to decide which of the two activities they wanted to choose to do by touching the picture of the given activity on the computer screen. Participants were informed that the more times they selected an activity, the more time they would accumulate to engage in the activity at the end of the session. Participants were given a brief period of time to practice touching the screen and making choices before exposure to the first SPA. A selection was counted when the participant touched anywhere within a given picture on the touchscreen and then the next trial was initiated (a new pair of stimuli was presented). Attempts to touch both pictures simultaneously were blocked by the experimenter, and the participant was again instructed to select only one activity. If participants did not respond within 20 s of the presentation of a given pair of pictures, the next trial consisting of a new pair of stimuli was presented (trials on which no response was made were not re-presented). The participants earned 30 s of time engaging with an activity at the end of the session each time that activity was selected. For example, if a photograph depicting reading with mom was selected 6 times on the touchscreen, the participant was provided with this photograph along with 3 min of time to read with mom at the end of the session. Thus, at the end of each session, participants spent time engaging in each of the 12 activities in each SPA for the amount of time selected (if an item was not selected, the participant did not engage with that item after the SPA was complete). Stimuli were delivered in ascending order according to rank (i.e. the stimulus ranked 1 was delivered first, the stimulus ranked 2 was delivered second, and so on until all stimuli that were selected were delivered). If two or more stimuli were equally ranked, the order of delivery was determined by examining which items were selected when the tied items were presented together as a pair in the SPA. The item selected when the stimuli were presented together as a pair was delivered first. If the activity was not selected, the participant was shown the picture of the activity and informed that he did not select the activity and would therefore not engage with the activity. A handheld timer was set for the appropriate amount of time and placed in view of the participant along with the photograph of the corresponding activity while he engaged in each activity. For social activities, the mother was instructed to interact with the participant in the activity during the duration of access. For solitary activities, the

child engaged in each activity by himself (without the presence of the mother or the examiner).

PR reinforcer assessment. A separate PR schedule assessment was conducted with each participant, using the same touchscreen computer and stimuli, to examine the relative value of social and solitary activities as reinforcers. This assessment was conducted after the completion of all three of the SPAs. The PR assessment included the 12 social and solitary activities that were used in the third (combined) SPA. Each of the 12 activities was tested individually. Thus, the PR schedule assessment consisted of 12 sessions. The order in which the PR sessions were conducted was randomly determined prior to initiating the PR assessment. Each session included a period of time in which the child performed the task and then a period of time in which the child was permitted to engage with the activity (duration of access to the activity was determined by how many schedules he completed within the session).

At the beginning of each PR session, a picture of an activity was presented for 5 s on a computer touchscreen to signal to the participant the activity he could earn in that given session. The experimenter instructed the participant to touch a box on the screen in order for tokens (small pictures of the activity) to appear. Each token he earned was worth 30 s of time performing the activity once the session ended. Participants were informed that the more pictures earned, the more time they could accrue to engage in the activity. Furthermore, participants were instructed that they could work as little or as much as they wanted to and could stop at any time. Each PR session continued until the participant ceased to respond for 30 consecutive seconds or the participant requested to stop. In PR schedule arrangements, the schedule of reinforcement associated with accessing a reinforcer increases in a progressive fashion throughout a given session. In this study, a PR schedule with a step size of 10 was used. Initially, only one response (i.e. touching the picture of the activity in the center of the touchscreen) was required to produce the first token. The number of touches then increased by 10 in an additive progression thereafter (i.e. 11 touches produced the second token, 21 touches produced the third token, and so on). The last completed schedule value before the participant stopped responding (i.e. 30 consecutives without a response) was used as the BP and provided an index of reinforcer potency. At the end of each PR session, the participant received access to the corresponding activity (social or solitary) for the accumulated amount of time earned during the session (e.g. five pictures of a videogame was worth 2.5 min of time engaging in that activity). As in the SPA procedure, a photograph of the activity was presented and a timer was set and placed in view of the participant while he engaged in each social activity (with his mother) and each solitary activity (alone). Items for which the participant did not complete any responses (and thus did not earn a single token) were not presented for engagement following the PR session.

The testing took place in a laboratory space within a medical institute that provides inpatient and outpatient services for children with developmental disabilities. Experimental contingencies and data collection were managed using a computer program written in Visual Basic that were run using a laptop computer attached to an Elo touchscreen (1725L/1727L 43 cm LCD Desktop Touchmonitor 3000 series). During experimental sessions, the touchscreen was placed on a table in front of the participant and the laptop was placed in front of the experimenter with the screen and keypad turned such that the participant could not access either. Two chairs were arranged side by side such that the experimenter sat next to the participant during experimental sessions. Post-session access to the stimuli was provided at a separate table with two chairs arranged side by side; one of these chairs was used for the mother and the other for the participant to sit in when they engaged in the stimuli embedded in a social context. The child was seated alone at the table when he engaged in the stimuli embedded in a solitary context. The stimulus the participant selected during the SPA or worked for during the PR assessment was then placed on the table in front of the participant or, in the case of the video and social videogame, on a cart that was rolled into the center of the room.

The SPA and PR assessments were completed during one study visit. Each SPA took between 3 and 15 min to administer and the maximum duration of reinforcer access following each SPA was 33 min. Thus, each SPA took approximately <1 h to complete. The social and solitary SPAs were conducted in the morning with the order of administration counterbalanced across participants in each group and were followed by a lunch break. After lunch, participants completed the combined SPA and the 12 PR assessment sessions. The duration of each PR session and reinforcer access varied based on the amount of work the participant completed for a given activity. Participants were required to touch the picture for 0.5 s for a response to be recorded. If the participant did not engage in a single response, the PR session lasted 30 s (the BP was met) and the next session was immediately initiated. The average number of responses emitted in a given session was 26.5. Those sessions could be completed in approximately 45 s (including the 30 s of no responding required to meet the BP criterion) and were followed by (on average) 1.5 min of reinforcer access time. The maximum number of responses emitted was 191. Thus, PR sessions sometimes lasted over 2 min and were followed by up to 10 min of reinforcer access time.

Results

SPAs

Social and solitary stimuli included in the third combined SPA were labeled as H (high preference) and L (low

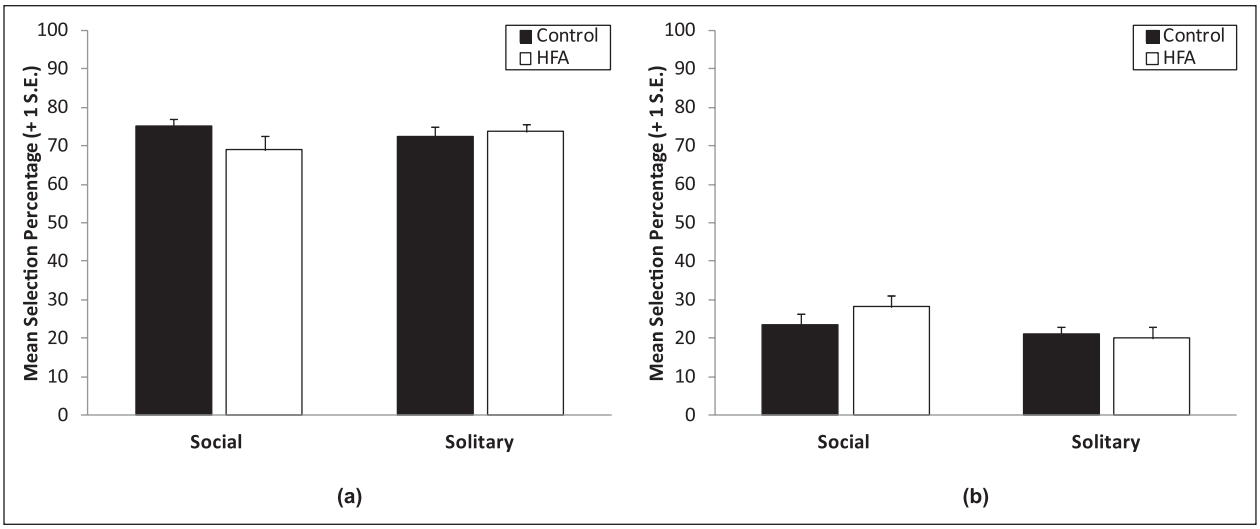

Figure 1. Mean (±1 SE) selection percentage for social and solitary activities for the HFA group (white bars) and TD control group (black bars) for (a) hypothesized high-preference stimuli (b) and hypothesized low-preference stimuli from the combined stimulus preference assessment (SPA) procedure.

preference) based on their relative rankings in the initial social (S) and solitary (or non-social, N) SPAs. Specifically, the first, second, and third highest ranked stimuli from the social SPA were labeled as HS1, HS2, and HS3, respectively; the first, second, and third highest ranked stimuli from the solitary SPA were labeled as HN1, HN2, and HN3, respectively; the lowest, second lowest, and third lowest ranked stimuli from the social SPA were labeled as LS1, LS2, and LS3, respectively; and the lowest, second lowest, and third lowest ranked stimuli from the solitary SPA were labeled as LN1, LN2, and LN3, respectively. Based on their rankings from the individual social and solitary SPAs, it was hypothesized that the HS and HN stimuli would be highly preferred and the LS and LN stimuli would be of low preference when the 12 items were presented together in the combined SPA (i.e. that the HS and HN items would be among the top six ranked items and the LS and LN items would be among the bottom six ranked items in the combined SPA). However, because the SPA assesses *relative* preference (i.e. preference for a given item relative to those other items to which it is compared) and because preferences are known to change over time (e.g. Ciccone et al., 2007; Zhou et al., 2001), it was certainly possible that an item labeled as LS or LN may actually have been higher preferred than one labeled as HS or HN when presented in the combined SPA. And, this was in fact observed on some occasions. Therefore, when we refer to the stimuli included in the combined preference assessment below as being "hypothesized high preference" or "hypothesized low preference," we are referring to the stimuli we labeled as HS, HN, LS, and LN based on whether they were of high or low preference in the individual social and solitary context–specific SPAs.

An analysis of variance (ANOVA) on the mean selection percentages for activities in the third (combined) SPA with context (social or solitary) and value (hypothesized high- or low-preference stimuli, those labeled as HS, HN, LS, and LN) as within-subject factors and a between-subject factor of group (HFA or control) revealed (based on Greenhouse–Geisser corrections) the following: no effect of context ($F(1, 39) = < 1$, $p > 0.34$), an effect of value ($F(1, 39) = 719.91$, $p < 0.001$), no effect of group ($F(1, 39) = < 1$, $p > 0.76$), and no significant interactions between these factors (largest $F = 2.87$). The absence of any significant group differences in selection percentages for social and solitary activities is illustrated in Figure 1(a) for hypothesized high-preference stimuli and in Figure 1(b) for hypothesized low-preference stimuli. Both TD controls (black bars) and boys with HFA (white bars) showed nearly equivalent selection percentages for social and solitary activities. In particular, boys with HFA did not reveal a reduction in selection percentages for social activities compared to solitary activities, as indicated by the similarity in the height of the two white bars in Figure 1(a) and (b), respectively. Finally, as expected and indicated by the significant main effect of value, higher selection percentages were shown overall for hypothesized high-preference stimuli (Figure 1(a)) compared to hypothesized low-preference stimuli (Figure 1(b)).

In order to examine whether there were any differences between the two diagnostic groups that could be accounted for by differences in IQ, we also conducted analyses of covariance by including IQ as a factor in the analyses. An analysis of covariance (ANCOVA) with Full-Scale IQ as a covariate and the same factors as in the ANOVA above indicated a significant effect of context (Wilks' Lambda, $F(1, 38) = 11.86$, $p < 0.001$), no effect of

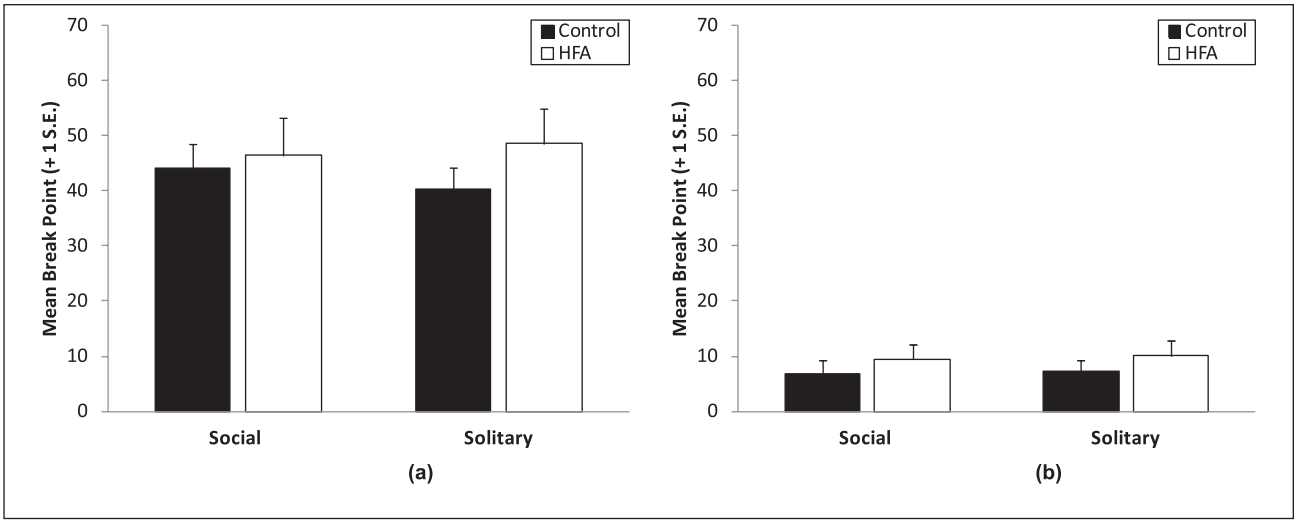

Figure 2. Mean (±1 SE) break point (BP) for social and solitary activities for the HFA group (white bars) and TD control group (black bars) for (a) hypothesized high-preference stimuli and (b) hypothesized low-preference stimuli from the progressive-ratio (PR) procedure.

value ($F(1, 38) = 3.08$, $p > 0.05$), no effect of group ($F(1, 38) = < 1$, $p > 0.59$), and no significant interactions between these factors (largest $F = 3.1$). The results of the significant effect of context revealed that across the entire group of subjects, when Full-Scale IQ is taken into account, selection percentages are greater over all subjects for social activities compared to solitary activities.

Non-parametric statistics (Wilcoxon signed-rank test) were also used to examine whether there were any differences in relative preference for social activities between boys with and without HFA. We examined the relative distribution of preference ratios for social and solitary activities across the entire set of 12 items. Children in both groups preserved the approximate (default) distribution of 50% social and solitary activities in the top and bottom halves (corresponding to the six highest and lowest preferred items from the previous two administrations of the social and solitary SPAs), even when the boundaries that defined the top (top ranked, second ranked, third ranked, etc) were varied (largest $Z = -1.00$, $p > 0.3$). For example, social activities were just as likely to be among the top three preferred activities for participants with HFA as they were for control participants. Collectively this pattern of results suggests that opportunities to engage in social activities with their mothers are no less appealing to boys with HFA compared to TD boys.

PR reinforcer assessment

Data analyses for the PR procedure were based on 18 of the 21 participants with HFA (3 of the 21 boys with HFA were unable to complete the entire PR procedures because of time restraints, difficulties with emotional behavior, and/or fatigue; this was understandable given that the PR assessments were always conducted in the afternoon of a full-day of involvement in testing procedures and the testing could run into the late afternoon).

An ANOVA conducted on the mean BPs with the same factors as above revealed no effect of context (social or solitary; $F(1, 36) = 0.008$, $p > 0.9$), an effect of value (hypothesized high- or low-preference; $F(1, 36) = 139.16$, $p < 0.001$), no effect of group (HFA or control; $F(1, 36) = < 1$, $p > 0.34$), and no significant interactions between any of these factors ($Fs < 1$). These findings suggest that boys with HFA were willing to emit an increasing number of responses in order to gain access to increasing amounts of time engaging in an activity with their mother, to an extent that was comparable to TD boys; this is indicated in Figure 2(a) by the similarity in the height of the black bar for TD controls and white bar for boys with HFA for social activities. In addition, there were no significant differences between groups in terms of effort to engage in solitary activities. Furthermore, the similarity in the height of the two white bars in Figure 2(a) illustrates our finding that boys with HFA were willing to emit a similar amount of effort to engage in social activities as they were for solitary activities. Finally, when Full-Scale IQ was included as a covariate in an ANCOVA, there were no significant effects of IQ on any of these factors.

Correspondence analyses

To extend the generality of findings from a previous study (DeLeon et al., 2009), we examined the extent of the correlation, or predictiveness, between the SPA and PR schedule assessments. The plots displayed in Figure 3(a) and (b) illustrate that there was a high level of

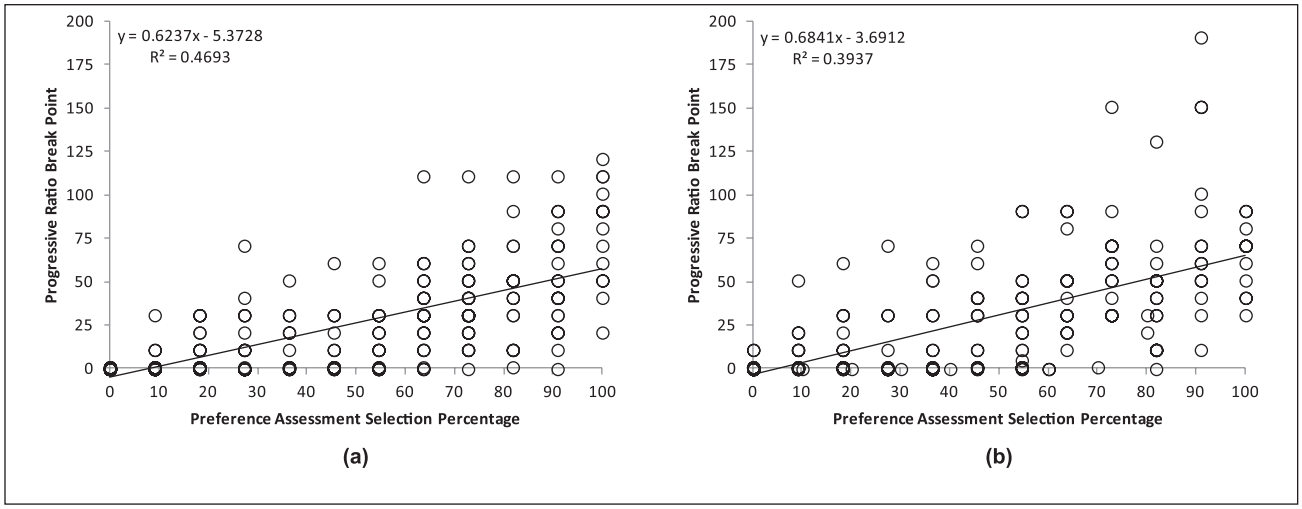

Figure 3. Correspondence between the progressive-ratio (PR) break point (y-axis) and selection percentage from the third, combined preference assessment (SPA; x-axis) is shown in (a) for the TD control group and in (b) for the HFA group. It should be noted that some data points may be hidden behind other data points that fall on the same area of the plot.

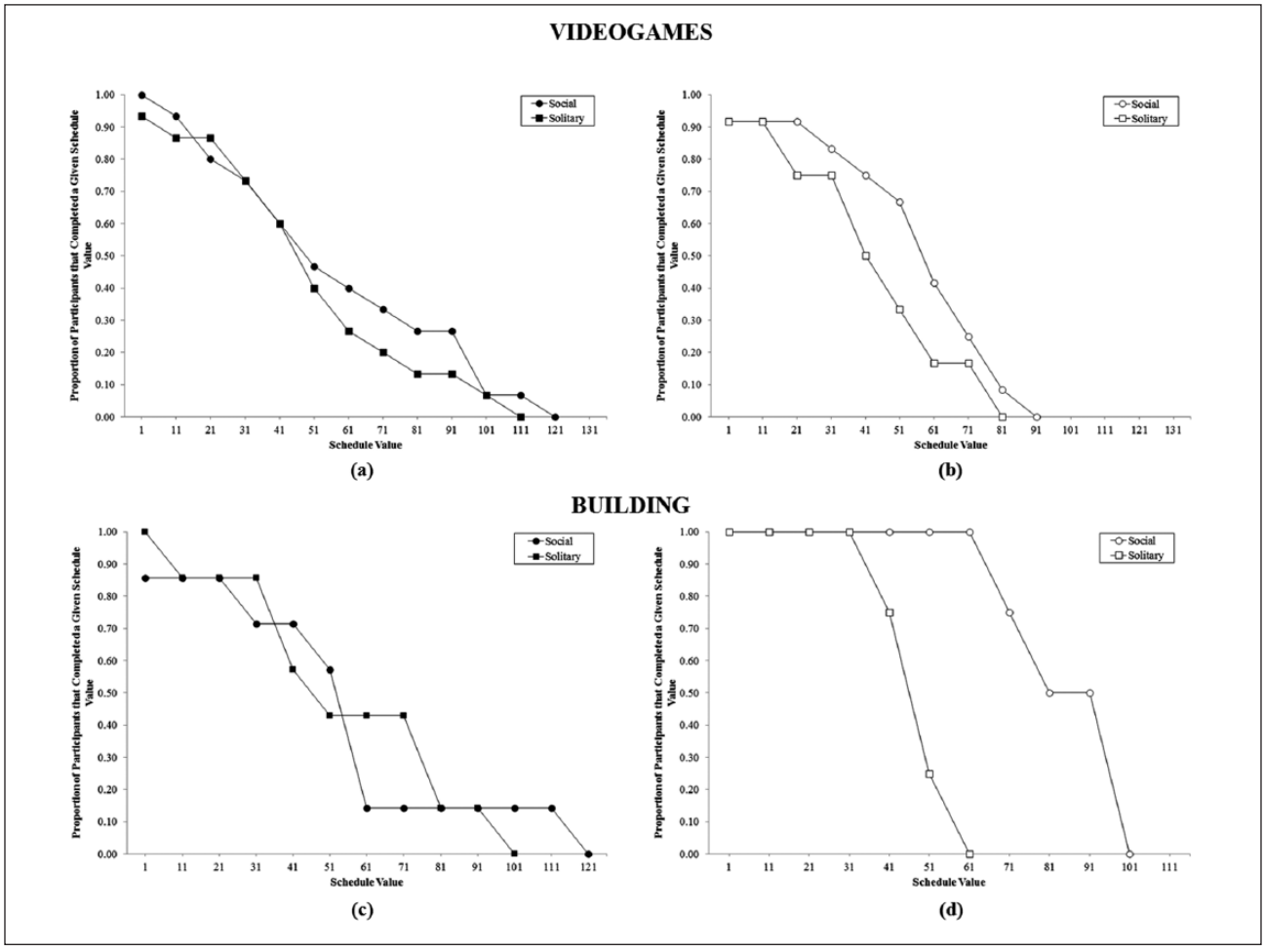

Figure 4. Population demand curves that depict the proportion of participants who completed a given schedule value for videogames in social (circles) and solitary contexts (squares) (a) for TD control and (b) for HFA participants and for building in social and solitary contexts (c) for TD control and (d) for HFA. The HFA group is illustrated by open symbols and the TD group by closed symbols.

correspondence between selection percentages on the SPA and BPs from the PR procedures for the controls (Figure 3(a); $y = 0.6237x - 5.3728$, $R^2 = 0.46934$) and the HFA group (Figure 3(b); $y = 0.6841x - 3.6912$, $R^2 = 0.39373$). That is, one measure appears to be predictive of the outcome of the other (they are valid). Furthermore, the similarity in the slopes of the lines in Figure 3(a) and (b) illustrates the similarity in performance between the two groups (i.e. absence of any group effects in both of the two measures).

Demand curves

In this study, there were several activities that were included in both social and solitary contexts, therefore allowing a direct comparison with respect to the reinforcing efficacy of the social and solitary versions of these activities. Activities were included if both the social and solitary versions of the activity were included in the PR schedule assessment and the sample size was sufficient to create population-based demand curves (i.e. activities were excluded if there were fewer than five participants in either group). Using the results from the PR assessment, we plotted population-based demand curves, depicting the proportion of participants in each group who completed a given schedule value in each context. Examination of the demand curves for videogames (n = 15 control, n = 12 HFA) and building (n = 7 control, n = 5 HFA) allowed us to compare the amount of work that boys with and without HFA were willing to emit to engage in the same activities embedded in a social context compared to a solitary context. Inspection of the demand curves for videogames in Figure 4(a) for control participants (closed symbols) and in Figure 4(b) for boys with HFA (open symbols) reveals that the demand curve for social activities (circles) is shifted to the right relative to the demand curve for the solitary version of this same activity (denoted by squares) for both groups, indicating that a greater proportion of children in both groups worked more for the social version of this activity. It should be noted, however, that these differences in the demand curves for social and solitary activities for videogames were modest (one step size differences). A pattern of greater responses emitted to engage in the social version than the solitary version of an activity was also found for building as depicted in Figure 4(c) and (d) for control participants and boys with HFA, respectively. Figure 4(d) depicts that boys with HFA showed a four-step size difference in the amount of work they were willing to emit to engage in the same building activity embedded in a social context compared to when it was in a solitary context. These results, which directly compared the presence or absence of a parent in an activity, suggest that certain activities embedded in a social context may possibly be able to serve as effective reinforcers for children with HFA.

Discussion

We observed that there was a high degree of correspondence between our two methods (SPA and PR schedule assessment) of establishing the relative reinforcing effectiveness of activities. Both measures, coupled with analysis of demand curves with the same activity in each of the two contexts (social and solitary), indicate that boys with HFA prefer and emit responses for the opportunity to engage in certain activities with their mother, at least as much as they do alone. In fact, boys with HFA reveal a similar degree of preference for social and solitary activities as TD boys of the same age. Groups were also similar with respect to their willingness to produce responses to gain access to social or solitary activities. The demand curves revealed that children may work harder to engage in certain activities when they are embedded in a social context. That is, our findings do not suggest that social stimuli are less "rewarding," as there is no reduction in the effectiveness of social activities to function as reinforcers, at least for high-functioning boys with ASD.

It is important to note that any conclusions drawn from this study cannot be generalized toward understanding the extent to which boys with and without HFA actually "enjoy" engaging in activities with their mother (compared to alone), as this study did not specifically measure the quality/extent to which participants actually engaged with their mothers during the post-session access to social activities. This additional measure of examining the quality of social engagement between boys with and without HFA and their mothers remains ripe for future investigations of social interaction in autism.

Some limitations to this study merit discussion. First, as is often a limitation in research with this population, we found a significant group difference in Full-Scale IQ between the HFA and TD groups, making group effects more difficult to interpret. Given that both of these two behavioral procedures are widely used in intervention settings for children with moderate and profound developmental and intellectual disabilities, there is little reason to suppose any behavioral differences on either measure reflect insensitivity to this type of assessment per se. While there are no group differences, we nevertheless observed an interaction with higher IQs being associated with a preference for social activities for all children (with and without HFA).

Another limitation is that the type of social interaction was deliberately focused (boy with mother, boy alone). In this study, the nature of the activities was specifically intended to be highly familiar and was deliberately individualized for each participant; favorite games, books, movies, and music, specific for each child, were brought into the laboratory from home. Therefore, the results of this study do not inform theoretical conclusions about the relative reinforcing ability of social interactions for

individuals with ASD at a more general level and the implications of any potential differences to our understanding of the disorder. It is also possible that there are other stimulus differences that could influence responding. For example, certain types of activity (e.g. videogames) are more likely than other types of activity (e.g. lacing) to require longer (accumulated) periods of access for adequate engagement (DeLeon et al., 2014b).

It would be of particular interest to examine the performance of children with ASD if the types of social interaction were otherwise manipulated, for example, if the social context comprised interactions with unfamiliar peers or adults. Results of the study by Prothmann et al. (2009) showed that children with ASD engaged more frequently with a dog, followed by an unfamiliar person, and finally followed by self-interaction with objects, and they interacted longer with a dog than with an adult or with objects. However, without the inclusion of an unaffected comparison group, it remains uncertain whether this pattern of responses in autism differs from "normal." Our findings extend on the general findings from the Prothmann et al. (2009) study as they suggest that some aspects of social interaction and social motivation related to joint social engagement are functional in boys with HFA.

Our results are in contrast to a previous report by Celani (2002) that demonstrated that children with autism (unlike TD children and children with Down syndrome) showed greater preferences for pictures of non-social stimuli compared to social stimuli. The differences in findings could possibly be due to methodological differences between studies. That is, unlike the methods in the study by Celani (2002), in this study, a photograph of each social and solitary activity was presented along with access to its corresponding activity at the beginning of the testing procedures (by pairing each picture with 30 s of time engaging in each activity) and during engagement in each activity in the SPA and PR schedule assessments in this study. Thus, in our study, the pictures were directly and associatively linked to access to the activity. Perhaps these differences in methodology contributed to the differences in findings between the two studies. As previously noted, prior research has suggested that failing to provide access to selected stimuli during preference assessments may affect preference assessment (e.g. Hanley et al., 1999) and reinforcer assessment (e.g. Kuhn et al., 2006) outcomes.

Behavioral researchers have long established that delays to delivery after a response will degrade the effectiveness of the reinforcer, a phenomenon well-characterized as temporal discounting (see Critchfield and Kollins, 2001 for a review). The responding of children with developmental disabilities is no less susceptible to delays (e.g. Leon et al., 2016). The procedures of the present experiment imposed a delay to the reinforcer by requiring that the children wait to access the reinforcer after they had completed all their work. In this respect, it may be surprising that the children responded as much as they did on the PR schedules, since cessation of responding would necessarily lead to more rapid access to the actual items or activities. However, the pictorial stimuli presented after each completed ratio may have mitigated the tendency to cease responding by functioning as conditioned reinforcers. Tokens and other sorts of conditioned reinforcers are known to help "bridge" the temporal gap between responses and delayed reinforcers (Stromer et al., 2000). Furthermore, recent work in our lab and others' has shown that children with ASD will choose delayed reinforcement if those delays are associated with accumulated (i.e. uninterrupted) access to the reinforcer (Bukala et al., 2015; DeLeon et al., 2014b), rather than smaller units of the reinforcer following the completion of each response requirement. The former arrangement is consistent with the procedures we used.

These results contribute to a growing literature demonstrating the promise of behavior economic measures of reinforcer value. Our results support prior studies with persons with neurodevelopmental disorders demonstrating good correspondence between preference assessment outcomes and reinforcer-value metrics based on increasing "cost" (PR schedules or demand curves; Call et al., 2012; DeLeon, et al. 2009; Reed et al., 2009). Some studies have shown that economic analyses might actually *better* predict the utility of reinforcers than preference assessments when use under naturalistic arrangements is considered (e.g. Roane et al., 2001). Our results are consistent with this possibility. Demand curves in this study predict that stimuli embedded in social and non-social contexts would be effective for equally as many children when the requirements for reinforcement are low (i.e. 10 responses), but stimuli embedded in the social context would remain effective for a greater number of children if those response requirements are higher. Economic analyses of this sort are being used increasingly in this population and others (see Hursh and Roma, 2013) to predict or enhance therapeutic outcomes.

Our results are in relative contrast to neuroimaging findings of deficits in autism in "reward" centers of the brain in response to social rewards (Scott-Van Zeeland et al., 2010) and rewards in general (both social and non-social, Kohls et al., 2011, 2013). Our findings revealed that boys with HFA did not show a deficit for stimuli embedded in a social context. This was indicated by the absence of a significant group by context interaction on the ANOVAs from both the SPA and PR assessment procedures. In addition, the bar graphs in Figures 1 and 2 illustrate for the SPA and PR data that responses for activities embedded in a social context were not reduced for boys with HFA. In addition, our results did not support a pattern of a general deficit in reward processing. If there was an overall deficit in reward processing, then we would have expected to see overall lower BPs for both social and solitary stimuli

(participants with HFA would not be willing to work much to earn access to rewards at all) and a significant main effect of group. We would also expect to see more variability in the data and less correspondence between the results from the SPA and PR procedures for the HFA group.

Our findings also extend the results of Nuernberger et al. (2012) as we included both high- and low-preferred social (and solitary) activities. In addition to employing presumably the "best" form of social interaction for a child (parent–child), we also individualized and deliberately targeted the highest preference activities (social and solitary), which may be favorite activities regardless of whether performed alone or with someone else (the same activity could be in each context). Future studies might examine whether there are differences in preferences for social and non-social activities that are more mundane or that are available in open and closed economies. It might also be of interest to otherwise quantify the quality of the social interaction through direct observational assessment (e.g. examine whether the child is using the mother as a prop, or whether there is reciprocal social interaction). This form of assessment might be better suited to identifying nuances in the social behavior of children with ASD. The study of lower functioning children with ASD as well as with other age ranges might provide a broader framework to assess any differences in preferences and motivation for social interactions, as reported in previous studies. Replication studies involving additional samples of HFA and TD controls as well as studies involving larger samples are also warranted.

In conclusion, our findings should be encouraging to those who work with and care for individuals with ASD. Under certain "best case" conditions (parent–child), our results show that certain types of highly familiar social interactions (with their mothers) can serve as effective reinforcers for children (boys) with HFA as much as performing these activities alone. This should inform research and clinical training and treatment protocols for children with ASD, as these types of events (parent–child interactions) appear to have utility as potential reinforcers and naturally have reinforcing effects for the parents. Ultimately (and beyond the scope of this study), a better understanding of the specific types of social interactions that are effective reinforcers to a child with ASD may inform our understanding of aspects of the disorder itself and its care.

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