

# Collaborative Problem Solving in Young Typical Development and HFASD

Yael Kimhi · Nirit Bauminger-Zviely

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**Abstract** Collaborative problem solving (CPS) requires sharing goals/attention and coordinating actions—all deficient in HFASD. Group differences were examined in CPS (HFASD/typical), with a friend versus with a non-friend. Participants included 28 HFASD and 30 typical children aged 3–6 years and their 58 friends and 58 non-friends. Groups were matched on CA, MA, IQ, and maternal education. The CPS task was placing pairs of blocks to balance scales. HFASD preschoolers solved the problem slower, showed more irrelevant behaviors, shared less, and used fewer coordinative gestures than TYP. But they were more responsive and had more fun with friends versus non-friends. In addition, they solved the problem more efficiently during their second attempt. Implications are discussed, regarding the social deficit of HFASD.

**Keywords** HFASD · Collaborative problem solving · Peer relations · Preschool

## Introduction

Collaborative problem solving is the ability to work together to solve a problem leading to a joint outcome (Fawcett and Garton 2005; Kumpulainen and Kaartinen 2003). While two children collaborate to solve a problem, they must cooperate with one another and coordinate their behaviors. Such a task requires mutual engagement and the ability to share goals, attention, and intentions. Therefore, the partners need an array of cognitive and socio-cognitive

abilities such as theory of mind, which is the ability to take into account the partner's knowledge while sharing intentions and goals (Liebal et al. 2008), and executive functions, which enable higher order planning abilities (Carlson et al. 2004; Hughes 1998; McAlister and Peterson 2006; Razza and Blair 2009). Educators view CPS as a valuable strategy to foster learning via active participation; therefore, it is widely used in the classroom (Kutnick and Kington 2005; Zajac and Hartup 1997) to enhance children's cognitive and social growth (Johnson-Pynn and Nisbet 2002).

ASD is a neurobiological disorder that significantly impairs children's social interaction, verbal and nonverbal communication, and behaviors (*DSM-IV-TR*, American Psychiatric Association 2000). Collaboration is thus viewed as a major difficulty for children with autism spectrum disorders (ASD) because it requires shared acts, intentions, and planning, which are all considered to be lacking in autism (Bishop et al. 2001; Hill 2004; Pellicano 2007; Tager-Flusberg 2001). Despite the importance of CPS for social development and cognitive growth, research concerning children with ASD is very limited. In the current study, we aimed to shed light on collaborative capabilities in high functioning children with ASD (HFASD) through CPS. We will first review theoretical assumptions of CPS development, followed by studies that investigated CPS in typical development, concluding with studies that examined CPS in ASD.

## CPS-Conceptual Basis

Both the Piagetian (1959) and the Vygotskian (1978) theories of cognitive development led to the conceptual frameworks outlining the cognitive and social benefits of CPS. However, the two theories differ in defining the

Y. Kimhi · N. Bauminger-Zviely (✉)  
School of Education, Bar Ilan University,  
52900 Ramat-Gan, Israel  
e-mail: nirit.bauminger@biu.ac.il

partner's role and the type of social interaction that lead to cognitive growth during the joint problem-solving process. According to Piaget, cognitive growth occurs during active interaction with one's surroundings and with partners of equal (symmetrical) status. During the partners' social interaction process, as they encounter various problems, they try to solve them together, with each child posing different questions and relaying knowledge and views. Thus, the cognitive growth of both partners is likely to occur (Johnson-Pynn and Nisbet 2002; Thornton 1995). In contrast, according to Vygotsky, cognitive growth occurs when the partners are asymmetrical, where one child (the "expert") has more knowledge about the problem than the other (the "novice"). During such problem-solving interactions, each partner uses various communicative skills such as asking, explaining, listening, and responding, which facilitate the cognitive growth of both the "expert" and the "novice" (Fawcett and Garton 2005; Johnson-Pynn and Nisbet 2002). In light of the Vygotskian and Piagetian theories of CPS development, research concerning young children with typical development, including toddlers (1–3 years) and preschoolers (3–6 years) examined collaboration with same-age peers; with friends (only in preschoolers; e.g., Piaget); as well as master-novice dyads (e.g., Vygotsky), as will be reviewed in the next section.

## Research on CPS in Typical Development

### Toddler Peer Dyads

To examine the development of toddlers' ability to cooperate with same-age peers, Brownell et al. (2006) gave two simple cooperation tasks to toddler dyads over the age range of 12–27 months. In the first task, the pair had to pull a handle simultaneously in order to activate a toy, and in the second task they needed to pull the handle sequentially. Brownell et al. found that the toddlers' ability to coordinate their activity to achieve a single goal improved between the second and third year. At the age of 19 months, the toddlers' cooperation was sporadic, the 2-year-olds cooperated more actively and explicitly, and by 27 months the dyads cooperated readily and more skillfully, repeating their success several times. The toddlers in the older dyads accommodated their behaviors to the peer's activities, and tended to pull the handle when their partner was near his/her handle and available as a partner, as opposed to the toddlers in the younger dyads, who pulled the handle regardless of their partner's availability. Nevertheless, the 27-month-olds continued to show limited CPS abilities; nearly half of their efforts remained uncoordinated with their partners. Furthermore, the older toddlers continued to leave their side of the apparatus often, going to the

partner's side, and thereby revealing a lack of awareness that they were expected to share goals and intentions cooperatively or that the two partners held different roles and perspectives. According to the authors, age-related growth in social understanding, which includes joint attention and the ability to understand and use language concerning self and others, enabled better CPS abilities.

### Tutor-Novice Dyads

Two separate studies examined the role of the young child as a tutor for novices performing CPS (Ashley and Tomasello 1998; Johnson-Pynn and Nisbet 2002). In the first study, toddler/preschool aged dyads (ages 24–42 months) were presented with an apparatus through which they could access stickers, if they coordinated two complementary actions (Ashley and Tomasello 1998). This two-stage study was designed to explore both CPS and teaching abilities of young children over their early development, while examining their problem-solving skills and their communicative abilities. First, in the study's cooperation stage, the partners learned how to solve the problem proficiently. Then, in the tutoring stage, each experienced child (master/tutor) was paired with a naïve (novice) partner who had no knowledge of the task, and the pairs were asked to jointly solve the problem. Results showed a clear developmental trend in CPS abilities. Two-year-old toddler dyads did not succeed in the task, whereas 2.5- and 3-year-olds could coordinate behavior with their partner, and some "masters" even showed some understanding as to the novice partner's lack of knowledge in the tutoring stage. During the tutoring stage, the 3-year-old dyads used more coordinated attempts, spending less time idly or separately investigating the apparatus compared to the 2.5-year-olds. The group of 3.5-year-old dyads solved the problem faster than the younger toddler dyads, and they also displayed a higher number of coordinated attempts, especially because the tutors monitored the partner's behaviors. The tutors used more specific directives and explicit demonstrations in order to show the partner how to solve the problem. According to the authors, these findings are consistent with the development of theory-of-mind abilities at this age. Therefore, the younger toddler dyads' less coordinated behaviors reflected their earlier developmental stage, where they could not yet fully grasp the partner's different role and different perspective in their joint task.

In the second study, according to the Vygotskian conceptualization of asymmetrical partners, Johnson-Pynn and Nisbet (2002) examined the assistance given by a preschool-aged trained tutor to an untrained novice peer (ages 3–5 years) on a block construction task. Findings showed that "expert" preschoolers assisted their peers spontaneously in a variety of ways, without being instructed to do

so, both verbally and nonverbally. Verbal assistance included encouraging remarks and prompts to look at the house, and nonverbal assistance included mostly modeling behaviors as to how to combine the blocks. According to the authors, the development of executive functions at this age enhanced the tutoring capacities of the expert preschoolers, by enabling the children to plan and to hold multiple task demands in mind concurrently.

#### Friend Dyads

Cooper (1980) examined the communicative behaviors of 3–5-year-old dyads of preschool friends during a CPS task (using balance scales to locate matching pairs of blocks that varied in weight and surface design, similar to the current study's task). Cooper expected that friendship would permit the most familiar, and perhaps the most advanced, form of communicative interchange. However, in Cooper's study all 32 dyads consisted of friends; hence, a comparison of friends versus non-friend dyads was not executed, thus the differential role of the friend versus a non-friend remains unexplored and will be examined in the current study. Cooper investigated the differences between two age groups within the dyads—the younger group comprised of 16 dyads mean age 3.5, and the older group comprised of 16 dyads mean age 4.5. Results demonstrated a significant development in problem-solving abilities between the ages of 3 and 5, manifested mostly in a larger array of communicative skills displayed by the older children. They used communicative behaviors such as attention focusing, questions, directives, and verbal responses. The older group (mean age of 4.5 years) was more efficient at solving the problem, spending less time and making fewer false attempts in comparison to the younger group (mean age of 3.5 years).

In summary, prior research revealed a developmental sequence in typically developing toddlers' and preschoolers' ability to solve problems collaboratively. Collaboration with a peer, especially if that peer is a friend, is considered to be an advanced form of collaboration, and first emerges at the age of 27 months. By 36–42 months, toddlers can share their intentions with their peer's intentions and solve a problem collaboratively. By 5 years of age, preschoolers can already utilize a repertoire of communicative skills to efficiently solve problems collaboratively. Furthermore, a master-novice profile can be found within dyads ages 3 years and older, meaning that the expert partners are capable of adjusting their behaviors to the novice partner's behaviors, and can spontaneously monitor their mutual progress during the problem-solving task. It is possible that the more mature theory-of-mind and executive-function capabilities at older ages facilitate preschoolers' problem-solving abilities.

#### Research on CPS in ASD

Although CPS may pose a serious challenge for children with autism, research on CPS in such peer dyads is lacking. The only study available to date on CPS in toddlers and preschoolers with autism (Liebal et al. 2008) examined collaboration between 2- and 5-year-olds and adults rather than peers, did not include a control group of typically developing preschoolers, and did not investigate high functioning children. In Liebal et al.'s study, toddlers and preschoolers with ASD had to coordinate their actions with those of an adult partner (by positioning themselves at the openings of a movable cylinder) in order to retrieve an object that was placed in the cylinder. The dyads were presented with four cooperative activities: two problem-solving tasks and two social games in which success depended on the toddler's ability to operate apparatus in a complementary or parallel fashion to the adult partner. The toddlers and preschoolers with ASD performed poorly compared to a group of toddlers and preschoolers with developmental delay who were matched on CA and on overall MA (24–31 months).

Several other autism studies examined participants' decisions to cooperate with a partner, but these studies focused only on participants' actual decisions to cooperate (rather than compete with their partner), without investigating any direct CPS interactions with a peer that would involve behavioral coordination (such as described above and scrutinized in the current study). In these three studies, using the Prisoner Dilemma paradigm (a paradigm which confronts individuals with gains and losses resulting from cooperation vs. non-cooperation), older participants with HFASD (children aged 6–10 years and adults with CA = 34 years) were asked to choose to either compete or cooperate with their partner, thus winning points individually (in a competitive mode) or sharing points with their partner (in a cooperative mode). The partner in the various studies was either human or computerized (Downs and Smith 2004; Hill et al. 2004; Sally and Hill 2006). Findings demonstrated that children and adults with HFASD made as many cooperative decisions as children and adults with typical development in all three studies, and a higher number compared to children with attention-deficit hyperactivity disorder or oppositional defiance disorder (Downs and Smith 2004). However, based on semi-structured interviews with the participants, Hill et al. (2004) suggested that such decisions could have been based on purely logical strategies rather than on mentalizing the partner's intentions.

In light of the paucity of research as surveyed above, the question remains open regarding HFASD preschoolers' ability to cooperate on a CPS task that requires the coordination of actions with a peer partner. The present study

strives to close this gap in the literature, by examining CPS in peer dyads consisting of preschoolers with HFASD and preschoolers with typical development.

### Current Study Objectives

This study on CPS aimed to compare preschoolers with HFASD versus preschoolers with typical development (TYP) and to compare peer-friend dyads versus peer-non-friend dyads. Furthermore, children in the current study solved the same problem twice, once with a friend and once with a non-friend; thus, we also explored whether a novice-master profile, following Vygotsky's theory of CPS, would emerge for both HFASD and TYP, where experienced dyads (comprised of novice-master partners) would be able to solve the problem more efficiently than inexperienced dyads (comprised of novice-novice partners). Finally, the link between CPS and CA was measured to evaluate the contribution of maturation to success in CPS, in light of former findings showing improvement in CPS with age for children with typical development. Thus, the study hypotheses were as follows: (1) Despite the paucity of data on CPS between peer dyads in HFASD, we hypothesized that these preschoolers would show poorer performance on CPS than their TYP counterparts due to their core deficit in cooperative skills. (2) We expected that CPS with a friend would permit more advanced forms of communicative interchanges in the TYP group. (3) We assumed that a master-novice profile would appear for the children in the TYP group, showing better CPS performance in their second experience. (4) We also presumed that older children would show better CPS performance in the TYP group. In sum, the current study is novel in at least four major ways: (a) by examining CPS in preschool HFASD peer dyads; (b) by exploring CPS in preschool dyads consisting of friends and of non-friends among same-age peers in HFASD and in TYP; (c) by evaluating the contribution of learning to CPS in HFASD and in TYP; and (d) by assessing the contribution of maturation to CPS in HFASD and in TYP.

### Method

#### Participants

A total of 177 children aged 3–6 years participated in the study, comprising three groups: (a) 58 recruited target participants, divided into two subgroups, HFASD ( $n = 28$ ) and TYP ( $n = 30$ ), with 4 girls in each subgroup; (b) 58 children who were the target children's friends, and (c) 58

non-friend same-age peers, all from the target children's preschools.

#### HFASD Target Group

All target children with HFASD were previously diagnosed by licensed psychologists unassociated with the current study, based on the *DSM-IV-TR* (American Psychiatric Association 2000). Clinical diagnoses were as follows: PDD-NOS (3.6%,  $n = 1$ ), HFASD (35.7%,  $n = 10$ ), and Asperger syndrome (60.7%,  $n = 17$ ). In addition, all 28 children met criteria for autism on the Autism Diagnostic Interview-Revised (ADI-R; Lord et al. 1994), which was completed with the parents to verify diagnosis. To assess children's IQ and MA scores, the Mullen Scales of Early Learning (Mullen 1995) were administered to all target children, except for 5 children with ASD who came to the study with prior IQ scores based on recent testing from less than 1 year earlier using the Wechsler Intelligence Scale for Children-Revised (*WISC-R*; Wechsler 1974) or the Wechsler Preschool and Primary Scale of Intelligence (*WPPSI-III*; Wechsler 2002). Only participants with an IQ of 75 or above were included, to denote high functioning in ASD. Sixty-three percent of the HFASD group studied in self-contained settings, and 37% of the HFASD group studied in inclusive education settings.

#### TYP Target Group

This TYP group was matched to the HFASD group (see Table 1) on maternal education, CA, and several indices derived from the Mullen Scales: IQ, full MA, verbal MA (VMA), and nonverbal MA (NVMA).

#### Friends

For each target child (in both groups), a close friendship of at least 4 months duration was identified according to reports by the child's teacher and verification by the child's mother. Howes's (1996) criteria for friendship were utilized: (1) mutual preference during spontaneous interaction along different activities (i.e., on playground); (2) demonstration of mutual interest; (3) staying in close proximity; (4) showing affection (eye contact and smile, touch); (5) shared fun; and (6) sharing objects during play. Children in both groups had same-age friendships, but the friends' disability status differed between the groups, with 62% of the friends of children with HFASD having a disability (18 pairs), whereas no friends of the children with TYP had a disability. More detailed information about the friends is outside the scope of the current paper and is presented more extensively in a separate article (Bauminer and Agam-Ben-Artzi 2011).

**Table 1** Sample characteristics for high-functioning preschoolers with autism spectrum disorder (HFASD) and children with typical development (TYP)

	HFASD ( <i>n</i> = 28)		TYP ( <i>n</i> = 30)		Group diff ( <i>t</i> )
	<i>M</i>	SD	<i>M</i>	SD	
CA (in months)	59.57	11.25	55.30	10.97	1.45
Verbal MA <sup>a</sup>	59.41	11.30	58.68	10.53	.25
Nonverbal MA <sup>a</sup>	60.63	11.16	55.87	11.66	1.59
MA <sup>a</sup>	60.05	10.90	57.27	10.83	.97
IQ	103.67	17.50	107.60	14.13	.99
Mother's education <sup>b</sup>	4.90	1.01	5.23	0.94	1.33

<sup>a</sup> Based on the Mullen Scales of Early Learning (1995)

<sup>b</sup> Calculated on a 6-point scale: 1 = less than 8th grade; 2 = some high school; 3 = high school with diploma; 4 = some college; 5 = college degree (e.g., BA); 6 = graduate degree (e.g., master's or above)

### Non-friends

Each target child's friend was matched with a non-friend (defined using Howes's friendship criteria) by age and diagnostic status. That is, TYP non-friends matched the TYP friends, and HFASD non-friends matched the HFASD friends, in both age and presence of disability. All friends and non-friends were from the same preschool of the target children.

### CPS Experimental Scenarios

To examine CPS, we evoked a scenario based on Cooper (1980) where the children needed to work together placing pairs of blocks in order to balance a two-sided weighing scale. Each child received 6 blocks that varied in color (2 pink blocks, 2 blue blocks, and 2 green blocks) and weight (each block was a different weight), therefore, partners could not match the blocks only according to color. Each child could only place one block at a time on his/her side of the scale, requiring the partners' collaboration to succeed in attaining balance. The children were expected to balance the scales a total of six times minimum, once for each matching pair of blocks. If the children did not find any matching pair within the first 3 min, the research assistant intervened and helped the children find the matching pairs. Each target child (HFASD, TYP) performed this task twice: with a friend and with a non-friend in counterbalanced order. Children's interactions were videotaped.

### CPS Coding

Children's videotaped interactions, problem-solving behaviors, verbalizations, and affects with their friend and non-friend were assessed using two measures: (a) level of success (based on Holmes-Lonergan 2003); and (b) assessments of behaviors exhibited during the CPS

interactions (based on Ashley and Tomasello 1998; Cooper 1980).

### Level of success

This measure was developed to assess children's success in solving the problem according to three main categories: (1) efficacy level; (2) level of problem understanding; and (3) time to solution.

**Efficacy Level** Based on Holmes-Lonergan (2003), the efficacy of the problem-solving procedure was calculated by dividing the number of correct attempts (a maximum of six) by that same number multiplied by 100. Higher scores indicated higher efficacy levels. Children who could not complete the task successfully even once ( $n = 7$ , 25% in HFASD; and  $n = 6$ , 20% in TYP) received a 0 on this scale.

**Level of Problem Understanding** This measure assessed children's ability to understand the dimensions of color, weight, and combined color and weight along the following 4-point scale: 0 = does not understand either dimension; 1 = understands the dimension of color; 2 = understands the dimension of weight; 3 = understands both dimensions. The coder determined the target child's level of understanding, according to the child's references to the various dimensions (i.e., understanding of color was coded when the child used expressions describing the blocks' color or when the child followed the partner's lead by placing the same color of block as placed by the partner).

**Solution Time** The time required to solve the problem fully (balancing the scales collaboratively for all six block pairs) was measured in seconds, from the beginning to the completion of the task. Shorter time durations indicated faster problem-solving, therefore a higher level of success.

### *Behaviors Exhibited During the Problem-Solving Scenario*

In an adaptation of Cooper (1980) and Ashley and Tomasello (1998), the frequency and quality of the target child's problem-solving behaviors were assessed, including actions, verbalizations, and affects in three categories. General evaluation of dyadic quality was assessed based on Bauminger et al. (2008a).

*Individual Behaviors by the Target Child* Such behaviors were not directed toward the partner and included three indices: (1) independent investigation of the scales and blocks (without placing the blocks on the scales); (2) independent manipulation of the scales and blocks (placing blocks on the scales or trying to balance the scales with one's hands, but without cooperating with the partner to reach the joint solution); and (3) irrelevant behaviors (e.g., banging blocks on the table or walls). The coder watched the target child's videotaped behaviors along the entire interaction period, stopping every 20 s to record the presence or absence of each of these three indices. For each index, the total number of observations in which it was detected was then divided by the total scenario duration. Higher scores indicated a higher quantity of behaviors for that index.

*Behaviors Directed by Target Child Toward the Partner* These behaviors on the part of the target child included five categories: (1) directing the attention of the partner (e.g., calling the partner's name or saying "hey"); (2) sharing comments related to the success or failure of the solution; (3) actively coordinating actions with the partner through words (e.g., telling the partner "put the blue block on now"); (4) actively coordinating actions with the partner through gestures (e.g., pointing to a specific block); and (5) responsiveness to the partner (actively responding to the partner's comments or instructions through words, gestures, or actions). In the same coding procedure as described for the individual behaviors, the presence or absence of each of these five categories was assessed by the coder once every 20 s, along the entire videotaped interaction period. For each category, the number of observations in which it was detected was summed and then divided by the total scenario duration. Higher scores indicated a higher quantity of behaviors for that category.

*General Dyadic Quality Evaluation* Based on Bauminger et al. (2008a), this global evaluation assessed the quality of the interaction between the children throughout the whole problem-solving scenario, along two main categories, rated on a 5-point scale. The "shared fun" category was rated from *Not having fun at all* (1) to *Having a lot of fun—including laughing, smiling, cries of joy* (5). The "reciprocity"

category was rated from *Low reciprocity—egocentricity* (1) to *High reciprocity—including high levels of shared work and planning* (5).

For coding, an observer specializing in special education and autism who was blind to the study aims and to children's group affiliation underwent training to code the interaction indices using videotapes of problem-solving scenarios that were not associated with the current study, together with the first author. An inter-observer agreement level of 85% was obtained for all items on the final scale. The coder then worked independently and coded the current CPS scenarios, first for the independent behaviors, then for the behaviors directed at the partner, and then for the global dyadic quality.

### Procedure

This study was part of a large project investigating social-emotional aspects of preschoolers with HFASD. Parents were contacted through their child's preschool teachers, after receiving permission from the Israeli Ministry of Education. After obtaining written parental consent for participation, we advised the parents and the teachers about the nature of the research by telephone, and interviewed them regarding the friendship status of the target child, according to Howes's (1996) criteria. After the children were found eligible for the study, we arranged four meetings for the children with HFASD and three meetings for the children with TYP. The first meeting for children with HFASD comprised the ADI-R interview of at least one parent. In the second meeting (first for TYP), the Mullen Scales were administered for all participants but 5 (who had taken IQ tests within the past year). Finally, the CPS scenarios were held in the target children's preschools over two different meetings (third and fourth meetings for HFASD; second and third for TYP), one meeting with the friend and one with the non-friend, in counterbalanced order.

### Results

This section reports on differences between target children in the two diagnostic groups (HFASD/TYP), between interactions of the two friendship types (friend/non-friend), and between interactions that occurred in a different order (Order A = CPS first with a friend, then with a non-friend/ Order B = CPS first with a non-friend, then with a friend). These differences were examined regarding the three categories of success level (efficacy, problem understanding, and solution time) and regarding the three behavioral measures, which included (a) individual behaviors

(investigative behaviors; independent manipulation of objects; irrelevant behaviors); (b) behaviors directed toward the partner (attention directing; sharing comments; coordinating by words; coordinating by gestures; responsiveness to partner); and (c) general evaluation of dyadic interaction quality (shared fun, reciprocity).

#### Level of Success

##### *Efficacy and Problem Understanding*

A 2 (group)  $\times$  2 (friendship status)  $\times$  2 (order) MANOVA was computed for level of success, with repeated measures on friend/non-friend and on order, to examine target children's differences in efficacy level and problem understanding. Findings were non-significant for the group effect,  $F(2, 52) = .67, p > .05, \eta^2 = .03$ ; for the friendship status effect,  $F(2, 52) = .69, p > .05, \eta^2 = .03$ ; and for the order effect,  $F(2, 52) = 1.69, p > .05, \eta^2 = .06$ . The interaction for friendship status  $\times$  order was significant,  $F(2, 52) = 13.18, p < .001, \eta^2 = .34$ . Univariate ANOVAs revealed significant interactions of friendship status  $\times$  order for both categories of success (see Table 2 for  $M$ s,  $SD$ s, and  $F$  values). Clarification of the interaction through simple effect tests (see Table 4 for  $F$  and  $\eta^2$  values) revealed that the target children were more efficient (requiring fewer attempts) in their second CPS experience, regardless of partner type (both with friends and with non-friends). Understanding of the problem improved during the second CPS experience only in the interaction with a non-friend. Children were able to achieve better understanding when they worked with a non-friend second, after a prior experience with a friend, than when they worked with a non-friend first. In contrast, no differences emerged in the understanding they gleaned while working with friends as a function of order.

##### *Solution Time*

Next, a 2 (group)  $\times$  2 (friendship status)  $\times$  2 (order) ANOVA with repeated measure on friendship status and order was computed to examine target children's differences in the amount of time necessary to achieve full success. Only children who were able to match all 6 pairs of blocks were included in this analysis (HFASD:  $n = 21, 75\%$ ; TYP:  $n = 24, 80\%$ ). Univariate ANOVA revealed significant group differences in solution time,  $F(1, 41) = 8.13, p < .01, \eta^2 = .16$ . Children with TYP solved the problem significantly faster ( $M = 141.83; SD = 70.6$ ) than children with HFASD ( $M = 193.54; SD = 77.54$ ). The interaction of friendship status  $\times$  order was also significant (see Table 2 for  $M$ s,  $SD$ s, and  $F$  values). Clarification of the interaction found that, overall, children were faster in their second experience, regardless of partner type (see Table 4 for  $F$  and  $\eta^2$  values).

#### Behavioral Measures

##### *Individual Behaviors*

A 2 (group)  $\times$  2 (friendship status)  $\times$  2 (order) MANOVA, with repeated measures on friendship status and order, was computed to examine target children's differences on the following individual behaviors: investigative behaviors, object manipulation, and irrelevant behaviors. A significant group effect emerged,  $F(3, 52) = 2.77, p = .05, \eta^2 = .14$ , and a significant friendship status effect emerged,  $F(3, 52) = 5.65, p < .01, \eta^2 = .25$ . As can be seen in Table 3, children with HFASD performed a higher number of irrelevant behaviors when solving the problem compared to children with TYP. Likewise, the target children demonstrated a higher frequency of object manipulation when working with a non-friend partner than a friend partner. The interaction of order  $\times$  friendship status was also

**Table 2** Friendship status (friend/non-friend)  $\times$  order (A/B) for differences on CPS level of success

CPS level of success	Order A		Order B		$\eta^2$
	Friend (1st task)	Non-friend (2nd task)	Friend (2nd task)	Non-friend (1st task)	
Efficacy $F(1,54)$					
$M$	38.89	56.60	56.36	38.89	17.15**
$SD$	26.34	24.60	19.23	28.71	.24
Problem understanding $F(1,54)$					
$M$	0.80	1.25	0.80	0.57	11.14*
$SD$	0.66	0.91	0.51	0.59	.17
Solution time $F(1,41)$					
$M$	194.41	134.65	145.75	191.37	12.89**
$SD$	96.89	62.09	39.34	72.93	.24

\*  $p < .05$ ; \*\*  $p < .01$

**Table 3** Group (HFASD/TYP) and friendship status differences for CPS behavioral measures

CPS behavioral measures	Group		Friendship status		<i>F</i> (1,54) Group $\eta^2$	<i>F</i> (1,54) Friendship status $\eta^2$
	HFASD ( <i>n</i> = 28)	TYP ( <i>n</i> = 30)	Friend	Non-friend		
<i>Individual behaviors</i>						
<i>Investigating</i>						
<i>M</i>	1.36	1.37	1.35	1.37	0.69	1.36
<i>SD</i>	0.36	0.50	0.42	0.47	0.01	0.02
<i>Object manipulation</i>						
<i>M</i>	1.53	1.39	1.31	1.61	0.71	12.44***
<i>SD</i>	0.68	0.45	0.46	0.70	0.01	0.19
<i>Irrelevant behaviors</i>						
<i>M</i>	1.26	1.07	1.15	1.18	8.49**	0.36
<i>SD</i>	0.40	0.20	0.26	0.41	0.14	0.01
<i>Behaviors toward partner</i>						
<i>Attention directing</i>						
<i>M</i>	1.16	1.19	1.17	1.18	0.30	0.00
<i>SD</i>	0.39	0.34	0.40	0.34	0.01	0.00
<i>Sharing comments</i>						
<i>M</i>	2.12	2.57	2.23	2.43	4.50*	1.32
<i>SD</i>	0.99	1.01	0.98	1.08	0.08	0.02
<i>Coordinating with words</i>						
<i>M</i>	1.37	1.53	1.42	1.49	0.27	0.04
<i>SD</i>	0.52	0.83	0.68	0.73	0.00	0.00
<i>Coordinating with gestures</i>						
<i>M</i>	1.63	2.33	2.04	1.98	15.80***	0.72
<i>SD</i>	0.62	1.02	1.00	0.83	0.27	0.01
<i>Responsiveness</i>						
<i>M</i>	1.41	1.18	1.46	1.14	8.05**	13.85***
<i>SD</i>	0.50	0.37	0.61	0.25	0.13	0.20
<i>General evaluation: dyadic interaction</i>						
<i>Shared fun</i>						
<i>M</i>	2.53	2.88	2.94	2.48	2.12	10.92**
<i>SD</i>	1.15	1.08	1.22	1.04	0.04	0.17
<i>Reciprocity</i>						
<i>M</i>	2.98	3.45	3.48	2.96	2.22	15.47***
<i>SD</i>	1.24	1.08	1.27	1.09	0.04	0.22

HFASD high-functioning children with autism spectrum disorder, TYP children with typical development

\* *p* < .05. \*\* *p* < .01. \*\*\* *p* < .001

significant  $F(3, 52) = 3.58, p < .05, \eta^2 = .17$ . Univariate ANOVAs revealed a significant interaction of order X friendship status only for investigative behavior,  $F(1, 54) = 7.41, p < .01, \eta^2 = .12$ . Simple effect tests executed to examine the source of the interaction revealed that when interacting with a friend, fewer investigative behaviors were noted in the second CPS experience than the first; investigative behaviors when interacting with a non-friend were independent of order (Friend in first task:  $M = 1.46$ ;  $SD = 0.43$ ; Friend in second task:  $M = 1.18$ ;  $SD = 0.33$ ; Non-friend in first task:  $M = 1.48$ ;  $SD = .39$ ; Non-friend in second task:  $M = 1.31$ ;  $SD = 0.50$ ) (see Table 4 for *F* and  $\eta^2$  values).

*Behaviors Towards Partner*

A 2 (group) × 2 (friendship status) × 2 (order) MANOVA, with repeated measures on friendship status and order, was computed to examine target children’s differences on the following behaviors toward the partner: attention directing; sharing comments; coordinating through words; coordinating through gestures; and responsiveness to partner. Significant main effects were found for group,  $F(5, 50) = 4.27, p < .01, \eta^2 = .30$ , as well as for friendship status,  $F(5, 50) = 3.43, p < .01, \eta^2 = .25$ . As can be seen in Table 3, compared to children with HFASD, children with TYP coordinated more with gestures and



**Table 4** Simple effect test for the differences between order A and order B in interaction with friends and non-friends:  $F$  and  $\eta^2$  values

CPS behavioral scale	Friend $\eta^2$	Non-friend $\eta^2$	$F$
<i>Level of success</i>			
Efficacy			
$M$	6.12*	7.72*	(1,56)
SD	0.10	0.12	
Problem understanding			
$M$	0.01	9.35*	(1,56)
SD	0.00	0.14	
Solution time			
$M$	3.67 <sup>†</sup>	7.59*	(1,43)
SD	0.08	0.15	
<i>Individual behaviors</i>			
Investigating			
$M$	6.34*	1.83	(1,56)
SD	0.10	0.03	

Order A, CPS first with a friend, then with a non-friend

Order B, CPS first with a non-friend, then with a friend

\*  $p < .01$ ; <sup>†</sup>  $p = .06$

used more sharing comments during CPS. Surprisingly, children with HFASD were more responsive toward their partner compared to children with TYP during CPS. However, children in both study groups were more responsive when solving the problem with a friend partner than with a non-friend partner (see Table 3 for  $M$ s, SDs, and  $F$  values).

#### General Evaluation of Dyadic Interaction Quality

A 2 (group)  $\times$  2 (friendship status)  $\times$  2 (order) MANOVA, with repeated measure on friendship status and order, was computed to examine differences in the dyadic qualities during CPS on the dimensions of shared fun and reciprocity. Only the main effect of friendship status was found significant,  $F(2, 53) = 8.06$ ,  $p < .001$ ,  $\eta^2 = .23$ . For children with HFASD as well as for children with TYP, interactions with friends during CPS were more fun and included a higher level of reciprocity than interactions with a non-friend (see Table 3 for  $M$ s, SDs, and  $F$  values).

#### Correlations Between CPS and CA

The correlations between CPS categories (level of success and behavioral measures) and CA were examined in each study group. A larger number of significant correlations appeared in the TYP group compared to the HFASD group; however, the directions of the correlations in both groups were similar, in which the older children did better than the younger ones. Regarding level of success, older children

with TYP showed a higher level of efficacy in solving the problem with a friend ( $r = .43$ ,  $p < .01$ ); were faster in solving the problem (in interaction with a friend) ( $r = -.71$ ,  $p < .001$ ); and understood the problem better when solving it with a friend ( $r = .48$ ,  $p < .01$ ); and with a non-friend partner ( $r = .42$ ,  $p < .01$ ), compared to their younger counterparts. Older children with HFASD revealed a higher level of understanding in non-friend interactions ( $r = .42$ ,  $p < .01$ ).

Regarding the behavioral measures, older children with TYP manipulated objects independently less often (in interactions with a friend) ( $r = -.46$ ,  $p < .01$ ); shared comments with their friends ( $r = .44$ ,  $p < .01$ ) and non-friends ( $r = .34$ ,  $p < .05$ ) more often than younger children; and showed higher levels of shared fun ( $r = .58$ ,  $p < .001$ ) and reciprocity ( $r = .51$ ,  $p < .001$ ) in interactions with friends, compared to younger children. Reciprocity was also higher in older than younger children with TYP in non-friend interactions ( $r = .34$ ,  $p < .05$ ). Older children with HFASD revealed less individual manipulation ( $r = -.46$ ,  $p < .01$ ), as well as higher reciprocity levels in non-friend interactions ( $r = .35$ ,  $p < .05$ ), compared to younger children with HFASD. In addition, children with HFASD performed fewer attention-directing behaviors in interactions with a friend ( $r = -.30$ ,  $p < .05$ ) and with a non-friend ( $r = -.32$ ,  $p < .05$ ). Overall, in both groups, older children demonstrated higher CPS capabilities and higher interaction qualities than younger children.

#### Discussion

As far as we know, this is the first study to examine CPS in preschoolers with HFASD and the first CPS study to compare dyads with a friend versus a non-friend both in HFASD and in TYP. To solve a problem together, children must work in collaboration and to be attuned to each other's attitudes, plans, and actions. The CPS interaction between peers is more goal-oriented than it is a free-form, non-structured, or spontaneous social interaction. Successful CPS involves cognitive skills (e.g., planning; inferences about the set of "game rules" characterizing the particular problem-solving situation, Hope 2002), socio-cognitive skills (taking the partner's point of view while working to achieve a joint solution), and social skills (e.g., peer interaction; listening to the partner; communication of identified "rules" to the partner verbally or nonverbally). In the current study on CPS, the preschoolers with TYP and the preschoolers with HFASD had to identify the "rules for balancing the scales" by recognizing the two block sets' similarities in color and weight and then communicating that understanding efficiently to coordinate the timing of their actions.

We explored three aspects of children's CPS performance. The first aspect—level of success—measured the children's goal-oriented behaviors toward the problem's solution. The efficacy measure on the one hand, meaning how many correct or incorrect attempts were made during the problem-solving process, and the solution time on the other hand, may be seen as indirect measures of the partners' level of coordination efficacy, because better communication with the partner regarding the solution could lead to fewer unsuccessful attempts to solve the problem and to faster achievement of the full, successful task performance.

The second aspect analyzed minute-by-minute interactive and non-interactive behaviors that characterized the preschoolers throughout the process of CPS. Non-interactive behaviors included both efficient investigation and manipulation behaviors (regarding the scales and blocks) and non-efficient (irrelevant) behaviors that appeared. Interactive behaviors comprised helpful, coordinated steps taken toward the solution of the problem, such as coordinating actions by using gestures or words, sharing experiences and feelings, and attention directing.

Due to the fact that we compared CPS with a friend versus a non-friend, the third aspect was the general evaluation scale that tapped the quality of the partners' interaction in terms of their shared fun and reciprocity.

We predicted poorer CPS performance in children with HFASD than in children with TYP, based on the former's core deficit in collaboration (American Psychiatric Association 2000). Our prediction was only partially supported. Group differences did emerge, but interesting and informative similarities also emerged between the groups.

#### Group Differences and Similarities

With regard to level of performance success, interestingly, children with HFASD understood the problem as well as children with TYP, and they used a similar percentage of incorrect attempts while solving the problem; however, children with TYP were faster than children with HFASD in reaching a full solution. One possible explanation for the longer solution time may be the higher preoccupation with irrelevant, non-interactive behaviors evidenced among the children with HFASD. Such behaviors included banging the blocks on the wall, playing with insignificant objects such as the chair or table, and so on. This finding not only attests to the neuropsychological profile of autism denoting preoccupation with objects (American Psychiatric Association 2000), but also coincides with prior research showing (a) a higher frequency of off-task and purposeless activities in HFASD than in TYP during peer social interactions (e.g., Lord and Magill-Evans 1995) and (b) a higher frequency of maladaptive behaviors in ASD than in TYP or in

children with intellectual disability (ages 1.5–5.8 years; Hartley et al. 2008). Irrelevant behaviors unrelated to the given CPS task were also found in younger children with TYP (i.e., in 30-month-olds but much less so in 42-month-olds; Ashley and Tomasello 1998). In sum, the higher frequency of irrelevant behaviors in the current sample of preschoolers with autism revealed a similar pattern to prior samples of younger toddlers with TYP and of children with ASD at various ages.

Another possible explanation for the slower solution time in HFASD versus TYP may be slower processing speed. Several recent findings indicated slower processing speed in children with HFASD, as found in the WISC-IV (Wechsler 1974) and WAIS-III (Wechsler 1989) processing speed indexes subtests in general, and in the coding subtest specifically (e.g., Calhoun and Mayes 2005; Mayes and Calhoun 2008; Spek et al. 2008). This explanation suggests that the current preschoolers with HFASD indeed did extract the balancing problem's rule; however, it took them longer to grasp the rule (a cognitive skill), or else it took them longer to communicate and coordinate it with their partners (a social or socio-cognitive skill). In support of a social deficit explanation, Dawson et al. (1998) found, for example, that children with autism took longer to orient to social stimuli (i.e., name calling and hand clapping) than children with Down syndrome or children with TYP. Dawson et al. (2004) suggested that children with autism have a specific difficulty in processing social stimuli, possibly due to their complexity, unpredictability, and/or lower reward for these children (e.g., Dawson et al. 2004).

Group differences appeared also in three interactive behaviors: coordinating through gestures, sharing, and responsiveness. Children with TYP outperformed children with HFASD on both gesture coordination (e.g., pointing or showing) and sharing behaviors. The literature on is replete with reports that children with autism exhibit: (a) limited use of multiple nonverbal gestures to regulate social interaction (e.g., Osterling and Dawson 2004); (b) atypical joint attention behaviors—coordination of attention between social partners with respect to a third object or event (e.g., Dawson et al. 2004); (c) disturbances in affective sharing in the context of joint attention (e.g., Kasari et al. 1990); and (d) deficits in gaze sharing (e.g., Hobson and Hobson 2007). Thus, the group differences in these two main categories support former findings and attest to the centrality of the core deficit in autism regarding use of nonverbal communication to coordinate social interaction as well as sharing behaviors.

The direction of the group differences found for preschoolers' responsiveness was surprising. We expected that HFASD children would demonstrate less responsiveness toward their partners than would their TYP counterparts; however, the opposite findings emerged. There is some prior

research evidence indicating that children on the autism spectrum are better responders than initiators. Data from studies on spontaneous social interactions reported that older children with ASD presented a higher frequency of social responses than social initiations (e.g., Sigman and Ruskin 1999). Studies on joint attention (see review in, Mundy and Newell 2007) reported that children with autism demonstrated better responsive joint attention skills (RJA; i.e., following the direction of others' gazes and gestures to share a common point of reference) compared to initiative joint attention skills (IJA; i.e., spontaneously seeking to share interest or pleasure from an experience with others by using gesture and eye contact to direct others' attention).

Coinciding with the notion of better responsive than initiative capabilities in children with autism, Kasari et al. (1993) demonstrated that in a "low-involved" non-structured free-play situation (in which the adult did not initiate interaction with the target child), preschoolers with autism showed less focused attention to toys and exhibited fewer social bids to the adult and fewer social looks, compared to both children with TYP and children with mental retardation. In contrast, in a "high-involved" social-game situation that was guided by an adult, children with autism were as responsive to the adult as the other children. Also, interestingly, only for the autism group, children with higher language and cognitive capabilities surpassed their peers with lower language and cognitive abilities, both by making more efforts to involve the "low-involved" adult (through giving, pointing, and showing) and by offering more appropriate responses to the "high-involved" adult. The latter findings from Kasari et al. stating better responsiveness for children with higher cognitive capabilities comparable to the children in the current study, hold specific implications for the current study on high-functioning preschoolers, although the partners differed. Other studies have also shown that less severely affected children on the spectrum are capable of higher joint attention capabilities (e.g., Chawarska et al. 2007).

Nevertheless, the findings indicating that HFASD children are better responders than initiators do not fully explain why they surpassed the children with TYP. Perhaps responsiveness in a more structured, goal-directed situation, while striving to reach a solution to a problem, extracted better attunement from these children as to their partner's point of view. It may also be that solving a "given quiz" was highly motivating for the HFASD children and that reaching the solution functioned as a reward (e.g., Dawson et al. 2004). The level of responsiveness as a function of the scenario characteristics should be further examined because they may have important clinical implications for intervention.

Interestingly, no group differences emerged regarding the extent of coordination through words, thereby highlighting a

more specific deficit in the nonverbal forms of coordination (gestures) than in the verbal forms. This similarity in verbal coordination between children in the two groups may hint that coordinating with words may be easier than coordinating with gestures, because words directly state the social meaning of communication, whereas gestures require extraction of the social meaning and the other's viewpoint based on the partner's bodily posture, expressions, and movements (Hobson and Hobson 2007). Hobson and Hobson termed the impairment in conveying gestures as a deficit in identification—the inability to assimilate to others' orientation toward the world through the registration of their bodily anchored psychological stance.

### Friendship Status

To the best of our knowledge, the current study is novel in its differential examination of a friend versus a non-friend, as a partner in the context of CPS. Interestingly, in both study groups, interaction with a friend did not lead to a higher level of task success or to more complex CPS behaviors. Higher level of success was linked more with learning from experience, as discussed below, than with partner type. However, by examining not only the problem-solving product (level of success) but also its process (specific and global behaviors), we could obtain a wider perspective on the partners' interaction qualities. Findings revealed that when solving the problem with a friend rather than a non-friend, children in both groups were more responsive toward their partner, showed higher levels of shared enjoyment, exhibited greater reciprocity, and demonstrated less independent object manipulation. Reciprocity, shared enjoyment, and responsiveness are considered significant markers of friendship relationships and usually signify the differentiation from friend and non-friend interactions (Bukowski et al. 2009). Higher levels of reciprocity and responsiveness with friends versus non-friends meant better attunement to each other's actions; for example, reciprocity included shared attempts to coordinate behaviors through joint work and planning (i.e., a boy waits for his friend to choose the same colored block, then both children place the blocks in the balancing cups together). Higher levels of shared fun meant that the children enjoyed working with each other, as evidenced by shared smiles, laughter, exclamations of joy, and gestures that indicated fun. Less object manipulation may mean less preoccupation with objects and therefore more time devoted to collaborating with the partner.

These findings hold significant theoretical and practical implications for both preschoolers with TYP and with HFASD. The basis of CPS is the ability to maintain mutual social interaction (Brownell et al. 2006; Kumpulainen and

Kaartinen 2003), and the current outcomes suggest that this interaction may be more socially and emotionally rewarding when solving the problem with a friend versus a non-friend, in both study groups. Moreover, these findings are in line with the literature on friendship in TYP preschoolers, which showed differences between interactions with friends and interactions with non-friends (see review in Newcomb and Bagwell 1995; Bukowski et al. 2009). Children with TYP as young as 3.5 years were previously shown to demonstrate better conflict-resolution strategies (e.g., Hartup et al. 1988) and to direct more social overtures, engage at higher levels, express more positive affect, and reveal more complex play behaviors and cooperative capabilities when interacting with a friend versus a non-friend (e.g., Dunn and Cutting 1999; Dunn et al. 2002). The increased reciprocity, shared enjoyment, and responsiveness (and decreased object manipulation) in the current preschoolers suggest that CPS with friends may maximize the participants' learning and cognitive growth. For example, according to Lemerise and Arsenio (2000), children embark on more complex social information processes when interacting with a friend.

Furthermore, the present findings have particular implications for HFASD. First, Kanner (1943) identified autism as a disorder in affective contact, thus questioning the feasibility of friendship in autism. The current outcomes support other empirical data indicating that even if probably different in quality, friendship does indeed exist in children with HFASD (e.g., Bauminger et al. 2008a, b; Carrington et al. 2003; Daniel and Billingsley 2010). A broader description of friendship characteristics outside the CPS context is beyond the focus of current study (see Bauminger and Agam-Ben-Artzi 2011); however, the current intriguing findings can inform us about peer friendships in preschoolers with HFASD. Second, the current data show that despite core difficulties in intersubjective engagement and socio-cognitive capabilities such as understanding another's perspective (e.g., Baron Cohen 1988; Rogers and Pennington 1991; Steele et al. 2003), these young children with HFASD could demonstrate higher qualities of collaboration skills when working with a friend. Thus, friend dyads may be an important potential framework and context for enhancing different social and cognitive skills in these preschoolers.

### Learning from Experience

To date, no study has examined the learning effect (first vs. second task) together with the varying role of the partner (friend/non friend), although some prior studies did investigate master/novice interactions among preschoolers with TYP (Ashley and Tomasello 1998; Johnson-Pynn and

Nisbet 2002). In these earlier studies, the masters evidenced more cooperative attempts, using both verbal and nonverbal cues than the novices, showing that they understood, albeit partly, their novice partner's need for assistance in the problem-solving task. In the current study, the second trial could be considered a novice/master situation, in which the target child, who had already solved the problem in the first trial, was the master partner. Interestingly, the current success rates (efficacy, time) reflected a master/novice profile, where partners were more efficient and faster in their second experience with the problem, regardless of partner type (friend or non-friend), in accord with the Vygotskian theory. Better understanding of the problem emerged in the second trial than in the first only in interaction with a non-friend; thus, experience was more helpful in guiding target children in their interaction with a non-friend than with a friend. The less fun and less reciprocal interactions with a non-friend found in the current study possibly required more efforts on the part of the target children; hence, having prior experience was probably more helpful in this seemingly more demanding interaction type. However, experience also emerged as important for interactions with friends because only in interactions with friends did preschoolers demonstrate fewer independent, non-social investigative behaviors in the second task trial.

In sum, spontaneous learning from experience was an important factor for both groups, leading to preschoolers' higher level of task success (more efficient and faster solutions), but it also played a differential role in relation to partner type (friend/non-friend). This finding is surprising, especially within the HFASD group, for it is generally assumed that children with ASD reveal difficulties in the generalization and transfer of newly acquired knowledge (Hwang and Hughes 2000).

### Age and Cognitive Functioning: Contribution to CPS

The correlations between the preschoolers' CPS abilities and their age were examined in each study group. On the whole, more correlations emerged in the TYP group in comparison to the HFASD group. However, a trend emerged where the older children in both study groups showed better rates of success at solving the problem. This finding replicates those of previous studies, in which developmental trends were highlighted in CPS in toddlers and preschoolers with TYP (Ashley and Tomasello 1998; Brownell et al. 2006; Cooper 1980; Warneken et al. 2006). In these studies, younger toddlers could not efficiently solve a problem collaboratively with a peer (at age 12–24 months), whereas preschool-age children (age 36 months) could do so at varying levels of success.

## Conclusions and Limitations

The current study has several limitations. First, we selected our ASD participants because of their high functioning, which includes higher cognitive abilities and their attainment of friendship. It remains unclear whether the current findings apply only to this specific subgroup or can be generalized to the larger group of children with ASD. The role of a friend in CPS should be further examined in a wider age range. In addition, it is important to examine CPS with a friend in comparison to a non-friend in pre-adolescence and adolescence, when children's verbal abilities are supposedly stronger.

Second, although the sample studied here is considered appropriate in size for in autism research, it nevertheless remains small. This may have limited the power of our analyses to detect associations; therefore, caution must be taken in interpreting the present outcomes, and replication studies are needed to verify the current findings. Future research should investigate CPS with larger samples.

Despite these limitations, this study's findings hold important clinical and theoretical implications, highlighting the importance of a friend for children with HFASD and emphasizing their ability to learn from experience. The findings in the present study demonstrate that preschoolers with HFASD possess a capacity for CPS and a social preference for a partner who is a friend. Therefore, one should take this into consideration when planning dyadic interventions and collaborative learning in educative situations, such as peer training. As found in the current study, children with HFASD can learn from experience with peer partners, but have more fun and show more reciprocity with a partner who is a friend. This finding sheds light on a completely different form of intervention, in which the peer has an important and definite role.

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