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Private Speech and Executive Functioning among High-Functioning Children with Autistic Spectrum Disorders

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Abstract Private speech used by high-functioning children with autistic spectrum disorders (ASD) ($n = 33$) during two executive functioning tasks was compared to that of typically developing children ($n = 28$), and children with ADHD ($n = 21$). Children with ASD were as likely as others to talk to themselves and their speech was similarly relevant and likely to appear in moments of task difficulty. Unlike others, children with ASD were more likely to get items correct when they were talking than when they were silent. Group differences in performance were observed when children were silent but not when children were talking. Findings suggest that autistic children talk to themselves in relevant ways during problem-solving and that such speech is helpful in normalizing their executive performance relative to controls.

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Introduction

This study explores the use and self-regulatory quality of self-talk [private speech (PS)] among high-functioning children with autistic spectrum disorders (ASD). Although on first glance, one might wonder why the things that children with autism might be saying to themselves as they go about their daily activities are of any interest, upon further reflection and as will be described below, whether or not children with autism are effective in using language (a cultural tool originating from their social world) as a tool for thinking, internal self-organization, and behavioral and/or cognitive self-regulation is a question of considerable theoretical and practical import. From a theoretical standpoint, self-directed language is a phenomenon at the intersection of several of the prominent theories of autism as language has been found to be a critical mediator in both executive functioning (EF) (Russell, Jarrold, & Hood, 1999) and theory of mind (Tager-Flusberg, 2000). Further, children's self-talk represents the overlap between the social world and the private mental world of the child (Diaz & Berk, 1992), two very different realms for autistic children. From a practical standpoint, knowledge about whether the verbal self-regulatory system of autistic children is intact will help guide intervention efforts. If children with ASD do talk to themselves and their PS is helpful in attaining cognitive or behavioral control, then such speech, rather than needing remedial training itself, might be useful in the service of other EF or self-regulation interventions for children with ASD (Dawson & Guare, 2004; Mesibov, Shea, & Schopler, 2005).

EF and Role of Language in ASD

Children with ASD have particular difficulties with EF (Hill, 2004; Hughes, Russell, & Robbins, 1994; Ozonoff, Pennington, & Rogers, 1991), leading EF to be one of the major theories of the core deficit present in autism (Russell, 1997). EF refers to a cluster of skills, thought to be mediated by the frontal lobes of the brain (Luria, 1980; Stuss & Benson, 1986), that have to do with the organization and self-regulation of goal-directed, future-oriented behavior (Ozonoff, 1998; Welsh & Pennington, 1988). These skills include planning, cognitive flexibility, set-shifting, inhibition of prepotent responses, and monitoring of the environment for feedback on progress toward goal attainment (Hughes et al., 1994; Ozonoff & McEvoy, 1994). Because the construct of EF is broad, encompassing many potentially different abilities, and because deficits in EF are not specific to autism [also found for those with ADHD (Barkley, 1997; Sergeant, Geurts, & Oosterlaan, 2002) and Tourette's syndrome (Pennington & Ozonoff, 1996)], many investigators have explored subcomponents of EF in various groups of children. By using tasks that tap different aspects of EF in systematically different groups of children, investigators have come to a clearer picture of the executive troubles of children with ASD.

Planning and cognitive flexibility are the two components of EF most consistently reported to be impaired among autistic individuals. Using either Tower of Hanoi or Tower of London tasks, numerous investigators have found children with ASD to be distinguishable from normal and clinical control children in terms of planning skills (Hughes et al., 1994; Ozonoff, 1997; Ozonoff & McEvoy, 1994; Ozonoff et al., 1991). Cognitive flexibility, or the ability to shift from one problem-solving ''set'' or strategy to another, as measured by the Wisconsin Card-Sorting Task (WCST), also reliably distinguishes children with ASD from other groups of children (Hughes et al., 1994; Ozonoff & McEvoy, 1994; Shu, Lung, & Tien, 2001). Noting that successful performance on the WCST also requires cognitive inhibition in addition to flexibility, Hughes et al., (1994), using a modified computerized version of the WCST that controls for inhibition, have shown that it is set-shifting in particular that causes trouble for children with ASD while cognitive inhibition appears relatively spared.

Indeed, others have found, using inhibition tasks, such as cognitive priming and Stroop tasks, that cognitive inhibition (having to keep one relevant aspect of the task in mind while ignoring or inhibiting another salient aspect) is not consistently disturbed among individuals with autism (Hill, 2004; Ozonoff, 1997; Ozonoff & Strayer, 1997; Russell et al., 1999). Interestingly, what appears to determine whether autistic children will have trouble with inhibition tasks, and possibly with other executive tasks as well, is the extent to which verbal mediation in the form of arbitrary (or even meaningful) rules is either required, provided, or possible.

Russell and colleagues (Biro & Russell, 2001; Russell et al., 1999) have shown that children with ASD have trouble specifically with executive tasks that require following arbitrary, novel rules (i.e., ''if it is red, put it here''), and those with nonverbal response modes. When executive tasks do not involve following arbitrary rules and/or when tasks require children to respond verbally, high-functioning autistic children do not appear to be impaired. These authors suggest that rule-bound executive tasks require children to verbally remind themselves of the rule and that children with ASD may be deficient in their spontaneous ability to self-instruct using private or inner speech. Thus, it is implied that children with autism can be helped by encouraging or requiring them to respond verbally and use speech to encode and rehearse rules (Russell et al., 1999). Other evidence that language is key in autistic children's EF is that differences in EF between autistic children and controls often go away or are considerably reduced after controlling for children's language skills (Liss et al., 2001; Russo et al., 2003). Others, after observing that language ability was related to executive performance for other children but not for verbal children with autism, have suggested that perhaps autistic children do not use language for self-regulation (Joseph, McGrath, & Tager-Flusberg, 2005). Autistic children appear to be less likely to use verbal mediation to strengthen working memory (Joseph, Steele, Meyer, & Tager-Flusberg, 2005). That is, whereas the working memory performance of normally developing children benefits from using to-be-recalled stimuli that have readily available verbal labels, autistic children do not appear to benefit from the use of verbally encodable stimuli, even when groups are comparable on general language (Russell, 1997).

Private Speech

Children's use of language, in the form of PS or self-talk, as a tool for cognitive and behavioral self-regulation has been studied fairly extensively within normally developing children, and to some extent in children with behavior problems and ADHD, but it has, surprisingly, not been examined directly yet among children with ASD. PS within the context of typical development is seen as an important tool that children use to plan, organize goals, guide attention, and regulate behavior during problem-solving (Diaz & Berk, 1992). Within the Vygotskian, socio-historical theoretical perspective that has typically guided work in this area, children's overt PS is seen as an important intermediate step in the developmental process of internalizing language. That is, important for self-regulation is the merging of language with thought and the resulting shift from language being used by the child socially for communication with others to language being used internally as a tool for thinking, guiding, and mastering behavior (Diaz & Berk, 1992; Vygotsky, 1978; Winsler, Diaz, & Montero, 1997).

Research with normally developing children reveals that PS (a) appears systematically during moments of cognitive challenge and/or situations which require executive or self-regulatory functioning (Fernyhough & Fradley, 2005; Winsler & Diaz, 1995), (b) undergoes a developmental transition from being more overt, elaborate, and task-irrelevant, to being more internalized, fragmented, and relevant over time (Bivens & Berk, 1990; Winsler, Diaz, Atencio, McCarthy, & Adams Chabay, 2000; Winsler & Naglieri, 2003), (c) is influenced by the quality of children's concurrent and previous social interactions with others (Behrend, Rosengren, & Perlmutter, 1992; Berk & Spuhl, 1995; Winsler et al., 1997), (d) is associated with greater EF and increased behavioral regulation in the early childhood years (Muller et al., 2004; Winsler et al., 2000), and (e) is related with task performance in predictable yet complex ways throughout childhood and adulthood (Duncan & Cheyne, 2001; Winsler et al., 1997; Winsler & Naglieri, 2003).

The PS of children diagnosed with ADHD [another disorder thought to involve impaired EF and self-regulation (Barkley, 1997; Pennington & Ozonoff, 1996; Schachar, Mota, Logan, Tannock, & Klim, 2000)] and children with behavior problems at risk for ADHD has been explored in a number of studies. These studies are consistent in finding that such children are not impaired in the spontaneous production of PS. That is, children diagnosed with, or at risk for, ADHD are found to use the same amount of, if not more, overt PS during problem-solving tasks compared to age-matched controls (Berk & Potts, 1991; Lawrence et al., 2002; Winsler, 1998; Winsler et al., 2000). Also, the PS of children with ADHD, like that of typically developing children, includes both task-relevant, self-regulatory speech and irrelevant, off-task speech. What appears to be different about the self-talk of children with ADHD is that it is proportionally more irrelevant to the task at hand, and more importantly, less internalized than the self-speech of typical children. That is, while control children of the same age are more likely to use partially internalized PS (whispers and inaudible muttering) or fully internalized, silent, inner speech during problem-solving activities, children with ADHD tend to use more overt, full-volume PS (Berk & Potts, 1991; Winsler, 1998). The delay observed in the internalization of PS among children with ADHD suggests that internalization of PS may be important for effective behavioral self-regulation and EF.

Practically nothing is known at the current time about the quantity and self-regulatory quality of PS among children with ASD, despite the considerable research attention given individually to both EF and to general language functioning within the autistic population. The way in which autistic children spontaneously use language as a self-regulatory tool during executive tasks, however, has not been systematically explored. In addition to Russell et al. (1999), numerous others have suggested, typically in passing, while exploring other phenomena, that children with ASD may be impaired in their use of language for self-regulation. Hughes (1996), for example, while studying cognitive and behavioral inhibition on simplified executive tasks, noted that autistic children differed from others in their comments made during a delay of gratification task and suggested that perhaps autistic children do not use language to control thought and behavior in the same way as controls. Similarly, Minshew, Siegel, Goldstein, and Weldy (1994) found that high-functioning autistic children, in the context of a social game of 20 questions, were less efficient and proficient than controls in their strategic use of questions to solve the problem, suggesting that general deficits in verbal problem-solving might characterize children with autism. One early investigation (Baltaxe & Simmons, 1977) analyzed the bedtime soliloquies of an 8-year-old autistic girl to learn about the structural and syntactic features of her early language acquisition. The autistic child did talk to herself at bedtime in a manner similar to that observed in typical children, especially in terms of her word play (Weir, 1962). However, more grammatical errors and inflexibilities were found in her crib speech compared to others' and her soliloquies contained no imaginary conversational, dialogic features, unlike that of normal children. Finally, Hurlburt, Happé, and Frith (1994), in a study exploring the self-reported inner experiences of adults with Asperger syndrome, curiously reported that none of their three participants engaged in silent, inner speech (verbal thinking) whereas reporting of inner speech is typical among normal adults.

Language, Theory of Mind, and ASD

Evidence that something special might be going on in the way that autistic children use language for cognitive and/or behavioral self-regulation also comes from the literature on pragmatic language impairment and on theory of mind in children with ASD. Although impairments in multiple aspects of language are well known among autistic children (Tager-Flusberg, 1996), a central focus among children with ASD has been on the pragmatic functions of language, that is, how individuals use language to meet interpersonal communicative goals (Bara, Bosco, & Bucciarelli, 1999; Ramberg, Ehlers, Nyden, Johanssen, & Gilberg, 1996; Wilkinson, 1998). The central question of interest explored in the present study is to what extent are the various pragmatic deficits that have been found in the social speech of autistic individuals also present in autistic children's PS, and if so, does this appear to interfere with such children's effective use of PS for intra-personal communication and self-regulation?

Given that the social speech of high-functioning autistic children has been found to be less relevant to topics of ongoing conversation (Loveland, McEvoy, Tunali, & Kelly, 1990), it is possible that autistic children's use of self-talk is similarly irrelevant to their problem-solving task at hand. Autistic youth have been shown, in communicative and unconstrained free play contexts, to use language for a smaller number of functions (Wetherby & Prutting, 1984) than other children. Perhaps the PS of such children is similarly constrained in the variety of self-regulatory functions it serves. Further, children with Asperger syndrome show more pragmatic language problems (relevance, responsiveness, turn-taking, and conversational balance) in their social speech compared to controls, especially when the topic of conversation involves emotions (Adams, Green, Gilchrist, & Cox, 2002). Perhaps, during frustrating moments of task difficulty, the PS of autistic children is less effective at emotional regulation. Autistic children also have difficulty distinguishing between given and new information in conversational settings (Baltaxe & Simmons, 1977; Fine, Bartolucci, Szatmari, & Ginsberg, 1994). One of the central psycholinguistic processes observed in the normative successful internalization from PS to silent, inner speech is predication which involves a transition toward emphasizing new information in children's PS utterances and the systematic exclusion of given information over time (Berk, 1992; Wertsch, 1979). Without the given–new distinction, the process of speech internalization could be disrupted in autistic children. Finally, if children with ASD rarely talk about the mental states in themselves and others in their social speech (Tager-Flusberg, 1992), and they have considerable trouble with theory of mind and understanding mentalizing abilities (Baron-Cohen, Tager-Flusberg, & Cohen, 2000; Hobson & Meyer, 2005), and language is intimately linked with children's theory of mind (Tager-Flusberg, 2000), it is likely that they also are limited in their meta-cognitive use of self-talk as a means to monitor and regulate their own cognitive problem-solving activities.

Given that language, EF, and theory of mind are all inter-related (Joseph & Tager-Flusberg, 2004) and PS is at their intersection, there is a need for empirical investigation into autistic children's use of language in the form of self-talk for self-reflection and executive control. Indeed, several scholars from different traditions have called for studies to be conducted on the PS of children with ASD (Fernyhough, 1996; Hughes, 1996; Russell et al., 1999; Tomasello, Kruger, & Ratner, 1993). From a Vygotskian perspective, PS represents what children take from their history of social interactions with others to become part of their own mental world and what they then use to mediate and regulate their own cognition and behavior (Vygotsky, 1978). Such speech, because of its origin in the social world, is fundamentally dialogic, containing essential elements of interpersonal interaction and understanding (Fernyhough, 1996), thus making the mind similarly dialogic after speech internalization. If children with ASD have trouble with interpersonal relations and understanding how language is used in conversational contexts, and if PS is indeed internalized from children's prior social interactions, then the PS used by such children within their intra-personal world may well be similarly impaired.

In the present study, high-functioning children with ASD were videotaped as they individually completed two computer-administered tasks of EF, and their PS use during the tasks was carefully analyzed and compared to normally developing children of the same age, as well as a clinical control group of age-matched children diagnosed with ADHD. Given the literature reviewed above, we expected to see less PS use in general during the EF of autistic children relative to both other groups, and we expected the PS of autistic children to be characterized as less relevant to the task, less internalized and not as related to behavior and performance as that in the other two groups of children. In addition to using the classic WCST, to tap the executive dimensions of cognitive flexibility, set-shifting, and to a lesser extent cognitive inhibition, we also administered a relatively new executive task from the cognitive psychology literature, called the Building Sticks Task (BST), that taps children's ability to notice changes in their problem-solving environment and adapt their strategies to such changes (Lovett & Schunn, 1999; Schunn & Reder, 1998). These components of EF, namely monitoring and adapting to the environment, are relatively understudied executive skills within the developmental and autism literature (Russell & Jarrold, 1998; Russell et al., 1999; Zelazo, Carter, Reznick, & Frye, 1997). Thus, we also had the goal in the present study to provide data on autistic (and other) children's performance on this novel task. To the extent that different cognitive/executive processes are going on during the two tasks, we also wanted to explore whether autistic children's use of language for self-regulation differed as a function of task demands in ways different to that of other children. Also, in addition to exploring global relations between PS and task performance, we were also interested in examining at the more micro- or trial level, in which types of task contexts (successes, perseverations, errors) were children likely to use PS and in which situations does such speech appear to be helpful. Finally, group differences in age-related trends in PS use were examined.

Method

Participants

Eighty-two children (18 females) between the ages of 7 and 18 ($\overline{X}_{age}$ = 11.0, SD = 2.9) from a large, mid-Atlantic, metropolitan area participated in this study. Twenty-one of the children (8 females) were clinically diagnosed with ADHD ($\overline{X}_{age}$ = 11.6, SD = 2.8), 33 children (1 female) were diagnosed with an ASD ($\overline{X}_{age}$ = 11.0, SD = 2.3), and 28 typically developing children (9 females; $\overline{X}_{age}$ = 10.3, SD = 3.2) served as a control group. Of the 33 children with ASD, 27% (*n*=9) were diagnosed with high-functioning autism (HFA), 61% (*n*=20) were diagnosed with Asperger syndrome, and 12% (*n*=4) were diagnosed with pervasive developmental disorder not otherwise specified (PDD/NOS). The majority (95%) of children attended public schools (4% private and 1% home schooled). Forty percent of the ADHD children and 75% of those with ASD received some type of special education services (either self-contained special classrooms or pull out services).

The average annual family income of the participants was slightly over $100,000, with 67% coming from dual-income families, which is average for the geographic region in which the study took place. Also, 79% of the parents/guardians had at least a college degree, and the majority (89%) of the parents/guardians were married. In terms of ethnicity, 92% of the children were Caucasian, 4% were African-American, and the remaining 4% indicated "other/mixed" ethnicities. There were no significant group differences in child and family demographics, with the exception that parents of ADHD children were slightly older and wealthier than parents of the other child groups.

Children with ASD and ADHD were recruited from a variety of community agencies and clinics, including a well-known, hospital-based, pediatric neuropsychology clinic specializing in ASD, university psychological clinics, public school district special education services, and relevant online support groups and listservs. Fliers describing the study were distributed at such places, and emails or announcements of invitation were distributed through the electronic listservs and newsletters of several local support groups for parents and children diagnosed with ASD or ADHD, and through the county school systems' email support lists for children with special needs. Control children were recruited via the above mechanisms as well plus informal contacts were utilized along with the university's established child development research lab database of families who have expressed interest in participating in research studies.

Initial contact consisted of a phone call with the primary researcher that served as an initial intake/screening interview, after which families who fit inclusion criteria were scheduled to come to campus for their approximately 1–1.5 h, one-time session. Inclusion criteria for the clinical cases included a satisfactory, rigorous, clinical, and primary DSM-IV diagnosis (as documented by formal psycho-educational or neuropsychological assessment reports which we required parents to bring with them as part of their participation) of either ADHD (combined or predominantly hyperactive-impulsive types), Asperger syndrome, autism, or PDD/NOS. Diagnoses typically included full neuropsychological or psycho-educational assessment batteries, child observations/interviews by one or two independent clinicians, and parent interviews. Additional secondary diagnoses held by ten of the clinically diagnosed children included such disorders as LD, ODD, OCD, depression, and anxiety. Children were excluded if they held a secondary diagnosis that included psychotic features, their IQ was lower than 85, or their language comprehension and expression skills in English were not adequate for understanding and completing the experimental directions (as estimated by the child's parent). Nineteen (57%) of the children with ASD and 19 (90%) of the ADHD children were currently taking medication for some kind of mental health/behavioral concern. Children who were currently taking medication for ADHD symptoms were seen during a wash out period, a day that their parents had agreed not to administer the medication for at least 24-h before the visit. Other medications taken by the children for other conditions such as anxiety, mood disorders, or social skill difficulties (i.e., Prozac) where not disrupted. Participants were given $25 cash and offered a copy of the videotape of their child's participation as incentives for participating in the study.

Procedure

Data collection took place on campus in two laboratory rooms that contained a small table, two chairs, a touch-screen laptop computer (on the table), and a video camera mounted on a tripod in a far corner of the room. Two graduate students served as experimenters. Upon arriving at the site, researchers greeted the parent–child dyad, and a 5-min rapport-building session took place in which the experimenters explained the contents of the session to the parent and child, and parents (and adolescents 16 and over) signed the informed consent/assent document. The researchers also engaged in a coloring activity with the younger children who chose to do so before feeling comfortable to begin. When the child and adult were ready, the researchers lead the child and adult into separate, adjacent rooms where children began with the computerized BST (see below) and a brief post-task BST interview, which together took about 30 min. During this time, the parent/guardian completed questionnaires in the other room. After this, children and adults were given a 5- to 10-min break during which time youth were offered a drink and snack. After this, children were administered the Peabody Picture Vocabulary Test-III (PPVT-III), which lasted about 10 min and then the computerized Wisconsin Card Sort Task: Computer Version (WCST: CV), which took about 5 min. All sessions were videotaped and a flat, high-quality microphone on the table was used as audio input.

Measures

Wisconsin Card Sort Task: Computer Version (Dunbar & Bub, 1990; Harris, 1990)

The WCST has long been used as a measure of cognitive flexibility, set-shifting, and executive processing in typical adults and children and those with special needs (Heaton, Thompson, & Gomez, 1999; Ozonoff & McEvoy, 1994; Robinson, Heaton, Lehman, & Stilson, 1980). Lately, standard practice has been to administer this task on the computer, a format found to be equally valid and reliable as the original manual version (Artiola-Fortuny & Heaton, 1996). A touch-screen Macintosh laptop computer was used for this administration. In this 64-card task, children are presented with four key cards presented horizontally at the top of the computer screen. One card had a red triangle on it, one had two green stars, one had three yellow plus signs, and the final key card had four blue circles. At the bottom of the screen, response cards appear one at a time to be matched to the key cards based on one of the stimulus parameters (color, shape, or number of figures). The response cards to be sorted displayed one to four, red, yellow, blue, or green, squares, triangles, plus signs, or circles. The computer gave voice instructions for the task and children controlled the rate at which these instructions were given by pressing the space bar to proceed from sentence to sentence. After listening to the directions, participants were asked by the experimenter whether they had any questions, and after all questions were answered, they began the task. The investigator sat in the corner of the room for the first several cards to make sure the participants grasped the object of, and touch-screen controls for, the task. After the first few cards were sorted and all seemed well, the investigator left the room. This short task was completed by the participants in about 3–4 min on average.

Since the correct-sorting principle is not disclosed to the participants, they must use the responses provided by the computer (correct or incorrect) to decipher which sorting criterion is correct. After ten consecutive correct matches, the computer covertly changes the sorting criterion. Participants utilize the computer feedback to deduce that the previously used sorting category is no longer in effect. The task is completed after the participant successfully matches 10 consecutive cards in the three matching categories, which proceed from color, to form, to number, or when all 63 response cards have been utilized. Thus, a minimum of 30 and a maximum of 63 response cards can be used to complete the task. Variables used included the proportion of cards correctly sorted, and the proportion of items/cards that were perseverative errors (incorrectly placed into a pile known to be incorrect from the previous card's feedback).

Building Stick Task (Schunn & Reder, 1998)

This task, also administered via the same touch-screen computer, was designed to test individuals' awareness of, and adaptivity to, changing environmental circumstances in the context of problem-solving. The BST is similar to the classic water jars task (Luchins & Luchins, 1950). For a given BST problem, participants must add and subtract two sets of three different-sized building sticks to create a stick of desired length. The desired length is visually represented by a red "goal stick" presented at the top of the computer screen, while the six white building sticks of three lengths (small, medium, and large) are positioned at the bottom of the screen. BST problems can be solved by one of two strategies. The undershoot strategy involves starting with a building stick that is shorter than the desired stick and then lengthening that stick by additional stick lengths until the desired stick's length is reached. In contrast, the overshoot strategy involves starting with the building stick that is longer than the desired stick and then shortening that stick by the other building stick lengths. For example, suppose the desired stick is of length 14 units, and the three building sticks A, B, and C, are of lengths 2, 17, and 10 respectively (note that participants are not given the numerical lengths of the sticks). To obtain the desired stick length of 14 units, participant might start with a stick B of 17 units and subtract segments (the overshoot strategy), or a participant might start with stick C of 10 units and add more segments (the undershoot strategy). In this particular example item, a solution can only be obtained by the undershoot strategy (C + A + A = 10 + 2 + 2 = 14). The overshoot strategy will not work because subtracting the lengths of A and C from B will never lead exactly to a stick of 14 units. Each item is solvable by either undershoot or overshoot (but not both) and the proportion of problems with each solution type varies across blocks of time. In this way, success base-rates of the two strategies are directly controlled, thereby measuring individual differences in children's adaptivity to changing success rates for the strategies.

Participants were given 40 BST problems or sticks to solve, during which time the base-rate of success of the overshoot and undershoot problems was manipulated. In the first 20 problems, overshoot is the correct strategy for 80% of the problems. In the second 20, undershoot is the correct strategy for 80% of the problems. Thus, if a participant adapts, they would initially develop a preference for selecting the overshoot strategy, and then toward the end of the task, shift to the undershoot strategy. Strategy adaptivity, the primary dependent measure calculated from this task, is defined as the amount of change in use of the overshoot strategy in the response to the change in success base-rates (i.e., the mean overshoot use in the first half minus the mean overshoot use in the second block of problems). The other performance variables used were percentage of sticks solved correctly in five moves or less, and whether or not the participant completed all 40 items of the task.

As on the WCST task, verbal instructions for the task were given from the computer at a rate controlled by the child. The investigator answered all questions before participants began the game and then sat in the corner of the room for the first two problems to make sure the participants grasped the object of, and controls for, the task. After the first few initial problems, the investigator left the room. Participants took 22 min to complete this task on average.

Building Sticks Task Interview

Participant awareness of the changing base-rates of building up vs. taking away strategies on the BST was assessed by a short post-task interview. Each child was asked a series of multiple choice questions that asked about the participants' perception of what strategies seem to work best, and whether the best strategy seemed to be consistent throughout the task. Children were also queried about the types of strategies they believe they used the most and whether they felt they were successful.

Peabody Picture Vocabulary Test-III (Dunn & Dunn, 1997)

The PPVT-III is a widely used measure of children's receptive language competence found to have high reliability (Dunn & Dunn, 1997), convergent (Bell, Lassiter, Matthews, & Hutchinson, 2001), and concurrent validity (Campbell, Bell, & Keith, 2001). Each child was read a vocabulary word accompanied by a series of four pictures and then asked to point to the picture that best represented the word (e.g., "Can you show me the truck?"). Raw scores and age-normed standard scores were used.

Controlled Oral Word Association Test (Spreen & Strauss, 1998)

As a potential control variable, participants' verbal and semantic fluency were assessed via the Controlled Oral Word Association Test (COWA). This assessment simply involved asking children to name as many X's as they could think of in 1 min. There were two verbal fluency items (words that start with the letter F, words that start with the letter S) and two semantic fluency items (animals, things you eat or drink) administered. Performance was simply the total number of appropriate items named.

Behavior Rating Inventory of Executive Function (Gioia, Isquith, Guy, & Kenworthy, 2000)

The Behavior Rating Inventory of Executive Function (BRIEF) was completed by parents to measure children's general EF in social and behavioral contexts. The BRIEF contains 86 items, which parents use to rate their child's behavior on a three-point Likert scale (never, sometimes, and often). Scores on these items were used to calculate scores on the eight clinical subscales (inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, and monitor) that make up the Behavior Regulation Index (BRI; Inhibit, Shift, and Emotional Control) and the Metacognition Index (MCI; working memory, plan/organize, organization of materials, and monitor). The Global Executive Composite (GEC) score that was used here reflects children's overall EF and it is the sum of BRI and MCI scores. Higher ratings are indicative of greater perceived impairment. The BRIEF Parent Form was normed on parents of 1,419 control children and 852 children from referred clinical groups and shown to have high internal consistency reliability (.82–.98) and high 3-week test–retest reliability (.72–.84) (Gioia et al., 2000). The validity of this measurement is supported by the correlations with other behavior rating measures (Mahone et al., 2002). Internal consistency with the present sample for the GEC composite was .95, and did not vary by group.

Private Speech

The videotapes of children completing the BST and WCST were carefully transcribed so that children's private and social speech during these tasks could be assessed. The unit of analysis for speech was the utterance, defined as either a complete sentence, a sentence fragment or clause with intentional markers of termination, a conversational turn, or any string of speech which is temporally separated from another by at least three seconds (Winsler, 1998). First, child speech utterances were classified as either social or private, with PS being defined as any verbalization by the child which was not explicitly addressed to another person, as indicated by either a pronoun reference, a gaze to another person, or other signals of social intent, such as physical contact, argumentation, repetition, loudness/intonation, or conversational turn-taking (Winsler, 1998; Winsler, Fernyhough, McClaren, & Way, 2004).

Private speech utterances were classified according to Berk's (1986) three category coding system, which distinguishes children's utterances on the basis of overtness (volume) and task-relevance. Level I, task-irrelevant PS includes word play, affect expressions, comments to imaginary others, and other utterances that appear unrelated to the task at hand. Examples of actual utterances coded as irrelevant included ''Purple Rain,'' ''I've been drinking all day,'' and ''I know what you did last summer.'' Level II, overt (regular volume) task-relevant PS, includes statements about the task or the child's ongoing or future task-related activity (i.e., ''I can do that,'' ''This one over there,'' ''Color,'' ''Blue stars''). Level III, partially internalized PS, includes inaudible muttering, whispers, and silent, verbal lip movements. Inter-rater reliability was estimated by having two independent and naïve research assistants code the same random 10% subset of transcripts. Kappa estimates and percent agreement for the distinction between private and social speech were .75 and .91, respectively. For the three-level PS category system or utterance type, Kappa was .86 and percent agreement was .95. All discrepancies in coding of transcripts for the reliability estimates were resolved via consensus by the two coders.

A variety of different metrics and variables were used in the analyses to obtain a comprehensive view of children's speech use during the EF tasks. First of all, to control for differences in the amount of time children took to complete the tasks, number of utterances per minute was calculated for each of the PS categories and for total PS. Overall number of social speech utterances per minute was also calculated. In addition, the proportion of the child's total PS that was made up of each category was calculated. At the item level, percentage of items that contained different types of speech was also calculated.

Speech and Performance

In order to examine the task context of speech use, children's speech use categories and performance categories on individual items of the tasks were also coded and tabulated. For BST item performance, items were considered correct if the child solved the item in 5 or less moves (in which case the child received audible feedback as such from the computer), and incorrect if the child eventually solved the item in 6–19 moves, or never solved the item. The total number and percentage of correct BST items that contained various types of speech was calculated. Also calculated was the total number and percentage of items containing speech that were either correctly or incorrectly solved. Similar indices of the intersection between speech events and item performance events were calculated for the WCST. Number and percentage of various types of items (items that were correct, incorrect, or perseverative errors) that contained different types of PS was tabulated. Also, the proportion of items containing speech with different performance outcomes (correct, perseverative error...) was also calculated.

Results

Preliminary analyses were conducted to see if there were gender differences in any of the major dependent measures, group differences on child demographic variables, or differences as a function of subtype of ASD diagnosis. There were no gender differences on any of the variables so gender will be ignored for the remainder of the analyses. Consistent with previous research that finds few differences between children with autism and Asperger's in these areas (Howlin, 2003; Jarrold, Boucher, & Russell, 1997; Ozonoff, 1998; Schopler, Mesibov, & Kunce, 1998) we found minimal differences in speech and performance as a function of type of PDD diagnosis. PDD/NOS children showed proportionately more task-irrelevant speech on the BST than children with HFA ($F(2, 21) = 4.24$, $p < .05$) and children with Asperger's got proportionately more items correct on the WCST ($F(2, 28)=3.63$, $p < .05$) than those with HFA. Given few differences and small effect sizes, ASD children were considered together as one group for purposes of the analyses. Because of a significant difference in children's PPVT vocabulary percentile scores, $F(2, 74) = 5.75$, $p < .01$, with typical children higher than children with ASD, PPVT scores are often used as a covariate in analyses below. There were no group differences on measures of semantic and verbal fluency and thus these measures will not be considered further.

Executive Functioning

Table 1 lists the means (and standard deviations) for children's performance on the WCST and BST tasks, separately by group. Also included in the table are children's parent-reported global EF scores from the BRIEF. Children with ASD showed impaired EF in the form of poorer set-shifting and cognitive flexibility, as indicated by significant group differences on percentage of items correct on the WCST, $F(2, 77) = 5.92$, $p < .01$, and on percentage of perseverative errors made on the WCST, $\chi^2(2) = 10.94$, $p < .01$. In both cases, post hoc contrasts showed that children with ASD scored significantly lower than controls, with the ADHD children scoring somewhere in between not significantly different from either of the other two groups. The group difference on WCST percentage correct remained significant even when controlling for PPVT in an ANCOVA, $F(2, 73) = 4.60$, $p < .05$.

On the BST, although there were no group differences in overall performance for those children who completed the task and for those task items that were completed, as seen in Table 1, a significant proportion of the ASD group (39%) found the BST to be difficult, lengthy, and frustrating and they quit before the 40 items of the task were completed, $\chi^2(2) = 14.17$,

Table 1 Group Differences in Executive Functioning

Performance	ASD (n = 33)	ADHD (n = 21)	Typical (n = 28)
WCST % correct*			
(Mean)	54.57	62.50	68.4
(SD)	(16.38)	(15.92)	(14.36)
WCST % perseverative errors*			
Mean	16.79	14.27	10.03
(SD)	(12.69)	(11.60)	(7.41)
BST % correct (in five moves)			
Mean	54.18	56.25	55.44
(SD)	(14.88)	(10.34)	(8.99)
BST strategy adaptivity[a]			
Mean	.28	.28	.19
(SD)	(.22)	(.27)	(.22)
BST failed to complete task*			
N	13	2	1
(%)	39%	9%	4%
BST self-reported awareness of shift[a]			
N	9	8	17
%	(35%)	(42%)	(50%)
BRIEF executive dysfunction*			
Mean	165.51	168.10	106.84
(SD)	(20.34)	(14.05)	(21.28)

*ANOVA or Chi-Square $p < .05$

[a] Calculated only for those who fully completed the task/interview

$p < .01$, compared to 9 and 4% for the ADHD and control groups, respectively. For those items that were completed, there appeared to be no differences, compared to other children, in autistic children's ability to solve the problems, nor in their ability to recognize changes in the problem-solving environment (probability of strategy effectiveness) and adapt their problem-solving strategy accordingly. Nevertheless, a significant minority of specifically the ASD group had trouble completing the task. Those who quit before finishing the task were performing more poorly on the BST task than those who finished in terms of percentage of items correct within five moves, $t(76) = -6.04$, $p < .001$. Furthermore, there were no significant group differences in children's post-task self-report of their explicit awareness of changes in overshoot and undershoot strategy effectiveness throughout the task, although the percentages are in the direction of children with ASD showing less awareness.

Parent report on the BRIEF indicated that both the ASD and ADHD group have significantly greater problems with EF in social and behavioral domains in the home setting compared to normally developing controls, $F(2, 79) = 88.26$, $p < .001$, and the same finding is obtained when controlling for PPVT scores in an ANCOVA.

Overall Speech Use

Table 2 summarizes children's overall private and social speech during the two tasks, by group. In order to maximize the sample size in each case (i.e., not lose the six participants who for a variety of reasons had data on one of the tasks but not the other), speech use on the tasks was generally analyzed within task rather including task as a within-subjects factor in a larger ANOVA. The first thing to note from Table 2 is that the vast majority of children in all groups used self-talk

Table 2 Children's Overall Social and PS Use During the Tasks, by Group

	WCST			BST		
	ASD (n = 29)	ADHD (n = 21)	Typical (n = 26)	ASD (n = 30)	ADHD (n = 20)	Typical (n = 27)
Tot. social speech/min						
Mean	.64	.92	.91	.41	.24	.22
(SD)	(.99)	(.84)	(1.40)	(.57)	(.38)	(.39)
Tot. PS/min						
Mean	2.13	1.23	2.73	1.48	1.19	1.45
(SD)	(3.17)	(1.91)	(3.66)	(1.85)	(1.80)	(2.54)
% of children exhibiting	(69%)	(62%)	(85%)	(73%)	(90%)	(82%)
Irrelevant PS/min						
Mean	0	0	0	.06	.20*	.01*
(SD)	–	–	–	(.16)	(.46)	(.01)
% of children exhibiting	0%	0%	0%	30%	25%	11%
Relevant PS/min						
Mean	1.80	1.08	2.13	1.09	.78	1.08
(SD)	(2.83)	(1.56)	(3.09)	(1.51)	(1.19)	(2.19)
% of children exhibiting	65%	62%	69%	73%	85%	78%
Relevant PS/min						
Mean	.33*[,a]	.16*[,a]	.59*[,a]	.33	.21	.35
(SD)	(.92)	(.45)	(1.35)	(.59)	(.30)	(.83)
% of children exhibiting	24%	14%	50%	60%	75%	70%
Proportion PS irrelevant[b]						
Mean	0	0	0	.05	.03	.01
(SD)	–	–	–	.09	.09	.01
Proportion PS relevant[b]						
Mean	.84	.92+[a]	.68+[a]	.66	.68	.68
(SD)	(.28)	(.16)	(.41)	(.28)	(.31)	(.26)
Proportion PS internalized[b]						
Mean	.16	.08+[a]	.32+[a]	.29	.29	.32
(SD)	(.28)	(.16)	(.41)	(.28)	(.33)	(.26)
Proportion items with PS						
Mean	.10	.05	.13	.31	.23	.25
(SD)	(.16)	(.07)	(.17)	(.31)	(.29)	(.31)

*$p < .05$

+ $p < .10$

[a] Not sig. when controlling for verbal ability

[b] Subset of only those children who spoke

during the EF tasks. About 70% of the autistic children used PS on the tasks, which was not significantly different from the 62–90% of the children in the normal and ADHD groups that used PS. In terms of the amount of PS used, children with ASD used 1–3 utterances per minute overall, and these figures were not statistically different than the other groups in an ANOVA for either the WCST, $F(2, 73) = 1.38$, $p = .26$, nor the BST, $F(2, 74) = .12$, $p = .89$. It is also important to note that there were no significant differences in the amount of social speech used by the groups during either the WCST, $F(2, 73) = .56$, $p = .58$, or the BST, $F(2, 74) = 1.31$, $p = .28$.

Also listed in Table 2 are the numbers for the three specific categories of PS explored (irrelevant, task-relevant, and partially internalized whispers/muttering), both in frequencies per minute and proportions of total PS. Although all children are included in the utterance per minute measures (with children who never spoke in that category getting a zero), for the proportional measures, only those children who engaged in at least some PS are included (62–90% of the sample depending on task and group). Also provided in Table 2 is the percentage of children with nonzero values for each category. Proportionately speaking, during the BST, which tapped children's problem-solving, strategy adaptivity, and awareness of the environment, most (66–68%) of the children's PS was overt and relevant to the task at hand, with another third of the speech (29–32%) being relevant yet partially internalized in the form of whispers or inaudible muttering. Only a small proportion of children's speech (1–5%) was completely irrelevant to the task at hand. None of these proportions varied significantly by group according to one-way ANOVAs. In terms of the number of utterances per minute during the BST, there were no group differences in the number of task-relevant or partially internalized utterances used by the children during the task. However, significant group differences were seen in the frequency of irrelevant PS utterances per minute, $F(2, 74) = 3.42$, $p < .05$. LSD post hocs tests revealed that the ADHD children showed significantly greater amounts of this type of speech compared to controls, and the ASD group, who fell in between, were not significantly different from the other two groups. This difference continued to be significant even when PPVT language scores were entered as a covariate.

During the relatively brief WCST, requiring set-shifting and cognitive flexibility, none of the children engaged in irrelevant PS. ASD children's self-talk during this task was 84% overt and relevant and 16% partially internalized, compared to 68/32% relevant/irrelevant for the controls and 92/8% for the ADHD children, $F(2, 52) = 2.57$, $p = .08$. Post hoc tests revealed that the ADHD group was different from the controls while the children with ASD fell nonsignificantly from any group in the middle. This contrast, however, failed to maintain statistical significance when controlling for PPVT scores. In terms of frequency of PS during this task, there were no group differences in the amount of relevant self-talk; however, partially internalized speech per minute did vary by group. This variable was particularly skewed, however, with very large and unequal standard deviations that grossly violated the assumptions for ANOVA. Thus, the nonparametric median test was performed instead, $\chi^2(2) = 7.86$, $p < .05$.[1] Both the ASD and ADHD groups used less partially internalized speech than the control children on this task.

Private Speech in Relation to Overall Performance and Item Context

We explored relations between children's speech and task performance in a number of ways. First, we ran global, zero-order correlations between the amount of PS used by the children during the entire task and their performance on that same task, separately by group. Positive correlations would indicate that youngsters that talk a lot to themselves are the ones who do better on the task, negative correlations would suggest that it is the children who are struggling with the task that tend to talk to themselves more, and no global association between amount of talk and performance suggests that PS occurs in many different task contexts and/or perhaps is related to performance in different ways for different people. In practically all cases for all groups, no significant global associations between amount of PS and performance were found. The exception was that children with ASD that used frequent self-talk tended to be the ones who made more perseverative errors on the WCST (raw number of utterances with perseverative errors $r(27) = .45$, $p < .05$; total utterances per minute with perseverative errors $r(27) = .36$, $p = .06$; relevant PS utterances per minute with perseverative errors $r(27) = .35$, $p = .07$), and got fewer items correct on the BST (raw number of utterances $r(27) = .33$, $p = .08$). Correlations for the other groups were in the same direction but smaller

[1] Nonparametric analyses were also run on other analyses involving highly skewed data to confirm the results of the parametric procedures that were conducted. For simplicity and consistency, only the parametric results are reported unless differing results dictated the exclusive use of nonparametric procedures.

(.08–.30, ns). To explore this further, comparisons were made on speech use between those children who struggled and eventually gave up with the BST and those who finished the task. Quitters showed a trend to engage in more PS per item overall, $t(12.19) = 1.95$, $p = .07$, more relevant PS per item, $t(11.7) = 2.08$, $p = .06$, and less partially internalized PS per minute, $t(64.15) = 1.74$, $p = .08$, compared to completers. Thus, it would appear that overt task-relevant PS was a common strategy used by ASD children having difficulty with the BST task.

Moving beyond simple, global associations, we also wanted to see during which task contexts or item performance events children were likely to talk to themselves. That is, we wanted to know more specifically, whether the children were talking while they were making errors, while they were getting items correct, or while they were making perseverative errors. The proportions of each of these three types of item events (correct, incorrect, perseverative error) in which children used PS are listed in Table 3. Recall from Table 2 that overall across all items (forgetting about performance on the item), children used PS on 5–13% of items (depending on group) during the WCST, and between 23 and 31% of items on average during the BST. Although there were no group differences in the likelihood of speaking while getting BST items correct (children from all groups spoke on about 20% of their correct BST items), $F(2, 74) = .29$, $p = .75$, there were marginal group differences in the likelihood that children used PS during successfully sorted items on the WCST, Median test $\chi^2(2) = 5.55$, $p = .07$. Typical children, on average, spoke on 12% of their correct WCST trials, however, children with ADHD spoke on only 4% of their successful WCST items, and children with ASD spoke on 10% of their correct WCST items. Also listed in this table is the proportion of children within each group that had at least one occurrence of that particular speech/performance event. A larger percentage of typical children (77%) were found to speak at least once during correct WCST items, whereas this was true for only 65% of children with ASD and 43% of ADHD children, $\chi^2(2) = 5.91$, $p = .05$.

When children were making errors on the WCST, there were similarly between 7 and 15% likely to talk to themselves, with no significant group differences, $F(2, 73) = 1.42$, $p = .25$. However, during the BST, children from all groups were more likely (29–39%) to talk to themselves on items on which they were struggling and ultimately got incorrect. Group differences on this variable were not significant, $F(2, 74) = .43$, $p = .65$. This suggests that children from all groups use PS when they encounter challenges or obstacles during problem-solving and when they have time to reflect on multi-step problems, such as those found on the BST.

When children were making perseverative errors on the WCST, they were just as likely to talk to themselves (7–16%) as they were during successes and all errors combined, with no group differences found, $F(1.59, 68) = 1.99$, $p = .15$. Thus, during the WCST, children were just as likely to talk to themselves on successful as unsuccessful items, likely because it is not until children have (irrevocably) sorted the card that they get feedback as to whether it was right or wrong. However, during the longer BST task items, children have multiple steps within the

Table 3 Probability of Children's Speech, Given Performance (when performing well or poorly, what speech are they using?)

Concurrent speech–performance event[a]	WCST			BST		
	ASD ($n = 30$)	ADHD ($n = 21$)	Typical ($n = 27$)	ASD ($n = 30$)	ADHD ($n = 21$)	Typical ($n = 27$)
Proportion of correct items with PS/total correct items						
Mean	.10	.04+	.12+	.22	.18	.17
(SD)	(.15)	(.08)	(.16)	(.25)	(.27)	(.27)
% of children with at least one correct item with speech	65%*	43%*	77%*	60%	70%	67%
Proportion of incorrect items with PS/total incorrect items						
Mean	.12	.07	.15	.39	.29	.36
(SD)	(.18)	(.09)	(.20)	(.37)	(.31)	(.38)
% of children with at least one incorrect item with speech	52	57	58	71	90	78
Proportion of perseverative errors with PS/total perseverative errors						
Mean	.11	.07	.16	NA	NA	NA
(SD)	(.20)	(.14)	(.30)	NA	NA	NA
% of children with at least one perseverative error with speech	32	24	39	NA	NA	NA

*$p < .05$

+ $p < .10$

[a] Subset of only those children who exhibited that performance/error outcome at least once

item, feedback on progress toward goal, and time to think/speak about how they are doing before the item is completed. In that context, children from all groups tend to talk on items when struggling.

Whereas the above analyses essentially reported on the probability of speaking given child task performance, the next set of analyses explored the probability that children succeeded or failed (or made a perseverative error) on task items, given that they either talked to themselves or were silent on the item. These figures were calculated within child [i.e., (*N* correct items with PS)/(total *N* items with PS)] and then averages were taken across participants within group and these are listed in Table 4. These could only be calculated for children who spoke during at least one item and the percentage of children included for each variable is included in the table. When ASD children were talking on the card-sorting task, the probability of getting the item correct was .59, which was not different from that of controls (.62). The average probability of getting a WCST item wrong while talking for ASD children was .42, which was slightly but not significantly greater than that for controls (.35) and less than that for ADHD children (.57). Comparing vertically across the first two rows of Table 4, we see that children with ASD were more likely to get WCST items correct (.59) than wrong (.42) while they were talking, a pattern which is the same as that of controls, but interestingly reversed for children with ADHD. Finally, the probability of making specifically a perseverative error while talking was low (.09–.15) for all groups, not unlike the overall rates of making a perseverative error reported in Table 1 when ignoring children's speech activity.

Table 5 reports the probability that children will get WCST items correct or wrong given that they were silent on the item. Children with ASD got 56% of WCST items correct when they were silent, which is significantly lower than the probability of getting items correct with silence for the typical children, which was .69 ($F(2, 73) = 4.71$, $p < .01$, LSD contrast $p < .05$). ADHD children were nonsignificantly in between these two groups. More interesting comparisons, however, are made when comparing vertically within Table 5 or when comparing results from Table 4 to those in Table 5. All three groups were more likely to get items correct than wrong when they were silent, however, this differential was weaker for children with autism (.56/.44) than for controls (.69/.31) and children with ADHD (.63/.37). When comparing across Tables 4 and 5, we see that whereas typical children were more likely to get an item correct if they were silent (.69) than if they talked (.62), the opposite was true for children with ASD, who were more likely to get WCST items correct while talking (.59) than when silent (.56). Significant group differences in performance are observed when children are NOT talking to themselves (Table 5), but not seen when children are talking. This suggests not only that autistic children talk to themselves, but that such speech is helpful in normalizing their performance relative to controls.

A similar pattern is seen for perseverative errors. In Table 5, we see that children with ASD were significantly more likely than controls to make a perseverative error on the WCST when they were silent, $F(2, 73) = 3.04$, $p < .05$ (this finding moves to marginal significance when controlling for PPVT, $F(2, 69) = 2.69$, $p = .07$). However, the same group differ-

Table 4 Probability of Performance Given Speech (when they are speaking, how are they doing?)

Concurrent speech–performance event[a]	WCST			BST		
	ASD (n = 30)	ADHD (n = 21)	Typical (n = 27)	ASD (n = 30)	ADHD (n = 21)	Typical (n = 27)
Proportion of items with PS that were correct/total items with PS						
Mean	.59	.42	.62	.35	.30	.30
(SD)	(.29)	(.33)	(.31)	(.21)	(.22)	(.23)
% of children with at least one item with speech correct	95%	69%	91%	82%	78%	82%
Proportion of items with PS that were incorrect						
Mean	.42	.57	.35	.62	.69	.70
(SD)	(.50)	(.33)	(.32)	(.25)	(.23)	(.24)
% of children with at least one item with speech incorrect	96%	92%	68%	41%	100%	96%
Proportion of items with PS that were perseverative errors						
Mean	.15	.11	.09	NA	NA	NA
(SD)	(.21)	(.16)	(.13)	NA	NA	NA
% of children with at least one item with speech that was a perseverative error	45%	39%	41%	NA	NA	NA

[a] Subset of only those children who spoke

Table 5 WCST Performance Given Lack of Speech (when they aren't speaking, how are they doing?)

	WCST			BST		
	ASD (*n*=30)	ADHD (*n*=21)	Typical (*n*=27)	ASD (*n*=30)	ADHD (*n*=21)	Typical (*n*=27)
% Correct						
Mean	.56*	.63	.69*	.67	.62	.68
(SD)	(.17)	(.17)	(.15)	(.16)	(.09)	(.16)
% Incorrect						
Mean	.44*	.37	.31*	.33	.38	.32
(SD)	(.17)	(.17)	(.15)	(.18)	(.09)	(.16)
% Perseverative errors						
Mean	.17*,[a]	.14	.09*,[a]	NA	NA	NA
(SD)	(.13)	(.12)	(.07)	NA	NA	NA

*$p < .05$

[a] Not sig. when controlling for verbal ability

ence is not observed when children are talking, as seen in Table 4. Focusing on children with ASD, from Table 1, we see that overall (ignoring whether or not they are talking), they make perseverative errors on 17% of WCST items. When they are talking, the pattern changes with that figure going down slightly to 15% (Table 4), but when they are silent, it stays at 17% (Table 5). Thus, autistic children are slightly less likely to make perseverative errors when they use PS than when they do not.

Age-Related Trends in Speech Use, by Group

The final set of analyses was designed to shed light on age-related trends in children's PS use and whether different developmental patterns were observed as a function of children's group. Table 6 shows the correlations between children's age in years and PS use on the two tasks, separately by group. What is notable from the correlations is that for typical children, age is negatively associated with PS use. As normally developing children get older, they engage in less of all types of self-talk when engaged in EF tasks perhaps because with advancing age they no longer need to use the tool of overt PS to complete such tasks. However, this was not the case for children with ASD, whose PS did not decrease at all with increased age during the WCST (task tapping cognitive flexibility) and only decreased somewhat with age during the BST problem-solving task. In fact, for both tasks, there were modest *positive* associations between age and partially internalized whispered PS for autistic children.

Finally, age was positively associated with both WCST and BST task performance similarly for all groups (r's = .28–.38, $p < .10$). Interestingly, ASD children's PPVT percentile scores were strongly associated ($r = .58$, $r = .60$, $p < .001$) with increased task performance for both the WCST and BST tasks respectively, but were not associated with performance on the tasks for the other two groups, r's = -.07–.14, ns. Thus verbal ability did not appear to be important for the EF for other groups of children, but verbal skills were critical for EF among high-functioning children with ASD.

Table 6 Associations Between Age and Private Speech Use, by Group

Correlations between age and private speech use	ASD (*n*=33)	ADHD (*n*=21)	Typical (*n*=28)
While set-shifting, inhibiting (WCST)			
Overall PS/min	.06	.12	–.41*
Irrelevant PS/min	–	–	–
Relevant PS/min	.00	.13	–.35+
Internalized PS/min	.21	.09	–.32
While monitoring and adapting to changes in problem-solving (BST)			
Overall PS/min	–.15	–.38+	–.37+
Irrelevant PS/min	–.17	–.42+	–.25
Relevant PS/min	–.26	–.39+	–.31
Internalized PS/min	.24	–.06	–.30

*$p < .05$

+ $p < .10$

Discussion

The goal of the present investigation was to explore the quantitative and qualitative nature of the PS used by high-functioning children with ASD while they were engaged in EF tasks. Autistic children's difficulties with EF are well known (Hill, 2004) and indeed were replicated here, both at the cognitive and behavioral levels, in that the children with ASD showed poorer cognitive flexibility and set-shifting ability on the WCST, had more difficulty completing the BST which tapped children's adaptivity during problem-solving, and were rated by their parents as having greater behavioral and social difficulties with organization, regulation, and EF according to the BRIEF, relative to controls. The question asked here, however, was whether children with HFA used self-directed language as a tool for self-regulation during these activities requiring executive skills, and if so, did they do so in a manner similar to other children. The present study responds to recent calls for work to be done in this area (Fernyhough, 1996; Russell et al., 1999) and represents the first investigation to examine directly the nature of PS during problem-solving activities among high-functioning children with autism.

Given recent theory on the role of language in executive control for autistic children (Fernyhough, 1996; Russell et al., 1999), evidence from the literature on the pragmatic and functional deficits found in autistic children's social speech (Adams et al., 2002; Loveland et al., 1990), and the speculative observations made by others in passing while investigating related phenomena (Hughes, 1996), we expected children with ASD would use less PS in general during executive tasks, that such speech would be less relevant and useful to the tasks at hand, that it would be less internalized and less related to performance for autistic children relative to both clinical and nonclinical control children. This was not the case, however. About 70% of the ASD children used self-talk during the tasks, which was not significantly different from the proportion of control and ADHD children who used self-talk. Similarly, there were neither group differences in the overall quantity of PS used during the tasks, nor in the frequency of relevant and irrelevant speech utterances. Proportionately speaking, the majority of autistic children's self-talk was overt and relevant to the tasks in terms of content (66–84% depending on task), with another 16–29% of the speech being partially internalized or whispered, and less than 1% of the speech being irrelevant. These proportions were not different from that seen in normally developing children. The only notable difference found in terms of overall quantity of speech during the tasks was that children with ASD engaged in less partially internalized PS (whispers and inaudible muttering) compared to normal controls during the WCST. This difference was not found during the other BST task, and was no longer statistically significant when language (PPVT) was included as a covariate. Thus, and importantly, when directly examined, high-functioning children with ASD do *not* appear to have a deficit in the spontaneous production of relevant, potentially helpful PS during EF. Further research is needed to determine if there are other specific task or child conditions where deficits in autistic children's self-speech are observed.

Also explored here were the item and task contexts in which speech was likely to appear. When children are doing well or making errors on items, what children of speech are they using? During the multi-step, problem-solving BST task, children from all groups used self-speech on 17–22% of the BST items that they got correct, and they all used such speech more often (29–39%) on items that were more difficult. This clearly suggests that children from all groups are more likely to use self-talk systematically during moments of task difficulty, especially when there is time to evaluate one's progress and determine the next course of action as in the BST. During the one-response-per-trial WCST task, children from all groups were similarly likely to talk to themselves both on items they sorted correctly, items they sorted incorrectly for whatever reason, and items they sorted incorrectly due specifically to a perseverative error. There were no group differences in children's speech behavior during WCST items on which they were making perseverative errors. The fact that global correlations between the amount of PS used and overall task performance were significant (and negative) for the ASD group and not as strong for the other groups, suggests that this "use speech when the going gets tough" phenomena often found in the PS literature is clearly present for children with HFA.

Another way we assessed speech–performance contexts and relations was to calculate the conditional probability that the child got items correct given that they spoke or were silent. When children are talking (or quiet), how are they doing? Children with ASD, similar to typical children, were more likely to get WCST items correct than wrong when talking to themselves. However, whereas typical children were more likely to get a WCST item correct if they were silent than if they talked, the opposite was true for children with ASD, who were more likely to get WCST items correct while talking than while silent. Thus, group differences in performance were observed when children were silent, but not seen when children are talking. This suggests not only that autistic children talk to themselves, but that such speech is indeed helpful in normalizing their performance relative to controls at least during some tasks. Other evidence from this study that speaks to the importance of language for EF among high-functioning autistic children is that language skill was strongly related to autistic children's performance on the EF tasks but not particularly related to performance for the other two groups.

Although there were more similarities than differences across groups in terms of the overall amount and type of PS used, during one of the tasks, the WCST, children with ASD (and those with ADHD) used relatively less partially internalized PS compared to controls. This has been observed before with younger children with ADHD and this together with age-related increases in whispers and muttering and age-related decreases in overt speech has been interpreted as indicating a delay in the internalization of PS for ADHD children (Berk & Potts, 1991; Winsler, 1998). Although age-related decreases in all forms of PS use were observed for the typical children in this study, this was not the case for the high-functioning children with ASD. Perhaps, children with ASD, who continue to struggle with EF throughout childhood, keep using self-talk as the get older when their executive system is stressed. Although these small sample correlations clearly need to be replicated with larger samples, the pattern of findings suggests that continued investigation of age-related trends in PS use and internalization among children with autism is needed. It is important also to note in this connection that the children studied here were older than the participants in most of the previous research on PS that has examined age-related changes in speech. Research with younger children diagnosed with a variety of ASD is clearly needed.

The use of the BST (Schunn & Reder, 1998) allowed us to investigate aspects of autistic children's EF that have been understudied in the past (Russell & Jarrold, 1998; Russell et al., 1999; Zelazo et al., 1997), namely, monitoring the task environment (implicit or explicit awareness of changing base-rate effectiveness of strategies) and corresponding strategy adaptivity. Unfortunately, the evidence here is mixed and difficult to interpret because of the autistic children's mix of reactions to the task. More than a third of the children with ASD struggled, became frustrated, and failed to complete this rather long task, suggesting that it was particularly difficult for them. However, the other 61% of the children with ASD who completed the task showed no differences relative to the other groups in performance, in awareness of changes in the base-rate probability of strategy success, or in strategy adaptation to take advantage of such information. The BST may need to be adapted to become more developmentally appropriate for a diverse group of high-functioning children with ASD.

The findings here suggest that the verbal self-regulatory system of children with high-functioning ASD appears to be largely intact. ASD children do talk to themselves during EF tasks, such speech is similar in content and relevance to that of control children, such PS tends to emerge in moments of task difficulty, and its use appears to help such children in some ways with executive control. Such findings are not what we expected and pose a challenge to the otherwise very compelling accounts of likely impaired processes of PS and inner dialog among children with autism (Fernyhough, 1996; Russell et al., 1999). Perhaps a disturbance in the use of speech for self-direction is only found among lower-functioning children with classic, full-blown, autistic symptoms, or perhaps such a deficit as hypothesized by others is only true for fully internalized, silent, inner speech and not true of overt self-speech. It is important to recall that the children studied here, by design, were relatively high functioning, older youth with generally intact language. It appears possible for higher-functioning autistic children to have relatively unimpaired PS as evidenced here yet continue to have significant difficulties with the pragmatic uses of social speech. If indeed, however, a significant disturbance in the use of overt speech for self-direction were central to the autistic experience then we would have expected to see more group differences than we did even in our high-functioning sample. The links between language, EF, PS, and psychopathology and their social and developmental origins appear to be complex and in need of additional study.

These findings have implications for intervention efforts that are beginning to surface that are designed to teach or train improved self-regulatory skill or EF in children with ASD (Dawson & Guare, 2004; Mesibov et al., 2005). Similar to what was discovered within the area of young children with behavior problems and/or ADHD, namely that such children do indeed naturally talk to themselves and that the speech is helpful to them (Berk & Potts, 1991; Diaz & Berk, 1995; Winsler, 1998), intervention efforts likely do not need to spend time trying to get high-functioning children with ASD and generally strong language skills to talk to themselves. Instead, self-talk can perhaps be used as an adjunct or an additional tool together with other therapeutic techniques to work together to improve the executive control skills of at least high-functioning children with autism.

It is important to point out the limitations of this first direct examination of the PS of children with ASD so future investigations can improve upon the present study. First, because the clinical presentation for children with ASD is highly variable, and different clinics may use different criteria for diagnosis, future work in this area would be strengthened by using research-based assessments of the ASD diagnosis (which were not possible here) to better understand or control for the heterogeneity of functioning of children on the autistic spectrum. Also, future work should consider systematically exploring more homogenous subtypes of children with ASD with larger samples. The present study included only very high-functioning children with ASD with intact general language skills. The extent to which PS is used appropriately among autistic children who are lower functioning and whose language is more disturbed is unclear from these data and needs to be investigated. Finally, given that PS has social origins (Diaz & Berk, 1992), investigation into the process of parent–child interaction and language use and internalization during joint collaborative activities would be helpful to further understand the role that PS may play in bridging the social and private worlds of children with ASD.

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