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Weak Central Coherence, Poor Joint Attention, and Low Verbal Ability: Independent Deficits in Early Autism

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C. Jarrold, W. Butler, E. M. Cottington, and F. Jiminez (2000) proposed that weak central coherence is a primary cognitive deficit in autism and speculated that it may even account for theory of mind impairments. The current study investigated whether weak central coherence could account for deficits in 2 behaviors purported to tap capabilities fundamental to a theory of mind: joint attention and pretend play. Twenty-one children (ages 3–5 years) with autism spectrum disorders were matched to 21 control children on chronological age, nonverbal ability, and gender. Pretend play did not differentiate the groups. Weak central coherence, poor joint attention, and low verbal ability contributed significantly and independently to the prediction of autism group membership, a finding consistent with 3 independent cognitive deficits underlying autism.

Autism is one of the most disabling of childhood developmental disorders and is characterized by severe impairments in communication, social cognition, and behavioral flexibility, with signs detected before 3 years of age (see the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* [*DSM–IV*], American Psychiatric Association, 1994). The cognitive profile of children with autism is an intriguing pattern of strengths and weaknesses. Most children with autism score substantially below average on IQ tests and demonstrate deficits in working memory, planning, sequencing, set-shifting, and verbal ability (Frith & Happé, 1994a; Happé & Frith, 1996; Joseph, 1999; Leslie & Frith, 1990). Yet these same children consistently outperform typically developing children on embedded figures (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983) and block design (Shah & Frith, 1993) tests, have excellent rote memory (Frith & Happé, 1994a), and sometimes demonstrate exceptional skills in music and drawing.

A deficit in theory of mind has been the most influential explanation for autism (Baron-Cohen, 1989, 1995a, 1995b). In typical development, a theory of mind is apparent in children between 3 and 5 years of age as they begin to appreciate that a person can hold a false belief. However, children of comparable mental age with autism typically fail theory of mind tasks, such as the Sally–Ann false-belief task (Baron-Cohen, 1991; Wimmer & Perner, 1983). Although children with other developmental disorders may show impairments on standard theory of mind tasks, the impairments are not as pronounced as in children with autism (Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998). A deficit in theory of mind is particularly useful for explaining social deficits in autism. Without a theory of mind, a child cannot predict the behavior of others, relate to others effectively, or empathize (Baron-Cohen, 1995b).

Debate continues over the question of how pervasive a theory of mind deficit is in individuals with autism. Some researchers have reported that between 15% and 55% of children with autism pass first-order (usually false-belief) theory of mind tasks (Happé & Frith, 1996), and some children with autism also pass second-order theory of mind tasks (Tager-Flusberg & Sullivan, 1994). Thus, substantial numbers of children with autism develop some theory of mind capabilities, although such development is delayed compared with that of typically developing children. However, on other mind-reading tasks, such as recognition of faux pas (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999), children with autism show impairments relative to typically developing peers, and tests of adults with autism indicate continuing difficulties with mental state understanding and social sensitivity (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Heavey, Phillips, Baron-Cohen, & Rutter, 2000; Jolliffe & Baron-Cohen, 1999a). There is also debate over how adequately a theory of mind explanation of autism can account for other symptoms of autism, such as repetitive and stereotypic behaviors (however, see Baron-Cohen, 1992), and for cognitive strengths as well as weaknesses.

Central coherence theory (Frith, 1989; Frith & Happé, 1994a) offers a plausible explanation for several features of autism not addressed by a theory of mind account. In typical development, coherent processing is purported to be implicit and automatic, enabling rapid interpretation of information (Frith, 1989). It provides integrated rather than piecemeal representations and is the means by which context influences the interpretation of individual elements or events. By contrast, children with autism demonstrate weak central coherence, or a bias toward "local" cognitive pro-

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cessing, meaning that children with autism focus on individual pieces of information rather than the "global" context.

The superior performance of children with autism compared with that of typically developing children on block design and embedded figures tasks may occur because these tasks favor local processing. Studies have shown that children with autism also demonstrated a local advantage and local interference in the Navon task (Plaisted, Swettenham, & Rees, 1999), produced more local features than did control children in a copying task (Mottron, Belleville, & Menard, 1999), failed to use context to disambiguate homographs (Happé, 1997; Jolliffe & Baron-Cohen, 1999b), and failed to use context to arrange sentences coherently or to make global inferences (Jolliffe & Baron-Cohen, 2000). These studies indicate that individuals with autism are advantaged by tasks for which information can be processed piecemeal but are disadvantaged by tasks that require holistic processing—that is, they have weak central coherence.

Weak central coherence may also account for social problems in autism. Indeed, Jarrold, Butler, Cottington, and Jiminez (2000) found a relationship between weak central coherence and theory of mind deficits in autism and proposed that it was more likely that weak central coherence led to theory of mind deficits than vice versa. Jarrold et al. found that superior embedded figures performance, indicating weak central coherence, was associated with poor performance on theory of mind tasks in separate studies of children with and without autism. Jarrold et al. suggested that the poor performance of children with autism on theory of mind tasks may be due to the children's failure to integrate separate local cues into a cohesive understanding of the social situation. Even if a theory of mind is available, weak central coherence may limit a child's ability to use it (Frith, 1989; Happé, 1997).

The hypothesis that theory of mind deficits in autism are mediated by weak central coherence, as espoused by Jarrold et al. (2000), is referred to here as the *linked deficit hypothesis*. This view emerged from Frith's (1989) proposal that a weakness in central coherence alone could account for theory of mind impairments in autism. An alternative hypothesis, espoused by Frith and Happé (1994a), is that weak central coherence coexists with a specific theory of mind deficit in autism. This alternative hypothesis is referred to here as the *independent cognitive deficit hypothesis.*

One implication of Jarrold et al.'s (2000) hypothesis that weak central coherence may account for theory of mind impairments in autism is that weak central coherence should also account for deficits in behaviors that tap capabilities fundamental to a theory of mind. This implication was the basis for the current investigation, in which we considered two behaviors that purportedly tap capabilities that are fundamental to the development of a theory of mind, namely, joint attention and pretend play. If joint attention is a precursor of a theory of mind, and central coherence bias is causally linked to theory of mind, then measures of joint attention in young children should relate to central coherence bias (as suggested by Jarrold et al., 2000).

Joint attention typically emerges around 9 months of age as children learn to use eye contact to derive information about another person's goal-directed behavior. The two most common joint attention behaviors are pointing to signal interest in an object (protodeclarative pointing) and alternating eye gaze to verify that the self and another agent are attending to the same event.

Joint attention can be classified as *dyadic*—between self and another agent—or *triadic*—between self, another agent, and an object. Currently, the evidence is inconclusive regarding whether early dyadic interactions require the representation of another person's mental state (Leekam, Hunnisett, & Moore, 1998). Triadic interactions, on the other hand, almost certainly involve some early understanding of mental state in order to triangulate attention between self, other, and object. Three tasks measuring triadic joint attention are blocking, teasing, and active-toy tasks. In the blocking task, the researcher covers the child's hands while he or she is playing with a toy (Phillips, Baron-Cohen, & Rutter, 1992). In the teasing task, the researcher offers the child a toy and then withdraws the toy as the child reaches for it (Phillips et al., 1992). In the active-toy task, the researcher activates a mechanical toy and then stops it (Mundy, Sigman, Ungerer, & Sherman, 1986). In each task, a joint attention response is recorded if the child achieves eye contact with the researcher. By attending to the researcher's eyes, a child signals that he or she wants to change the researcher's behavior so that person will provide a toy, stop blocking the child's hand, or reactivate a mechanical toy. An implicit assumption in this behavior is that the researcher is an intentional agent and that intentions can be changed.

Children with autism consistently demonstrate impairments on joint attention tasks (Charman, 1997; Phillips et al., 1992; Roeyers, Van Oost, & Bothuyne, 1998), and several authors have argued that this is because joint attention taps capabilities fundamental to the development of a theory of mind (Baron-Cohen, 1995a; Leslie, 1987; Mundy, Sigman, & Kasari, 1994). Children with autism rarely point when indicating interest in something, look at their mothers' faces for information before approaching novel objects, or use gaze when communicating (Baron-Cohen, 1995b; Frith, 1989). Moreover, joint attention deficits in autism are not due to a preference for avoiding eye contact, motor deficits, or attention problems (Leekam, Lopez, & Moore, 2000; Phillips et al., 1992). Note that joint attention requires more than local processing. The child must not only attend to details of the environment but also integrate this information in a dynamic interchange with another cognizing being; children with autism do not generally perform well in such tasks.

It is also the case that children with autism do not perform well on pretend play tasks, and some researchers have suggested that pretend play may itself be a precursor of theory of mind (e.g., Baron-Cohen, 1995a; Charman et al., 2000; Leslie, 1987; Yirmiya, Pilowsky, Solomonica-Levi, & Shulman, 1999). Pretend play typically emerges by 2 years of age and, according to Leslie (1987), includes (a) using an object as if it were another object (substitution), (b) attributing properties to an object that it does not have, and (c) referring to absent objects as if they were present. Again, this activity entails the integration of different pieces of information. Children with autism perform significantly fewer spontaneous pretend play acts than developmentally delayed or typically developing children of comparable mental age (Charman et al., 1997; Lewis & Boucher, 1988; Libby, Powell, Messer, & Jordan, 1998; Mundy, Sigman, Ungerer, & Sherman, 1987). Leslie (1987) proposed that both pretend play and theory of mind involve the skill of metarepresentation—that is, in pretend play, a child must simultaneously represent a play sequence and knowledge that the play is not real. However, Jarrold (1997; Jarrold, Boucher, & Smith, 1996; Jarrold, Carruthers, Smith, & Boucher, 1994) and

Lillard (1993a, 1993b) have argued to the contrary—that pretend play does not involve theory of mind—and Jarrold et al. (1996) proposed that the problems of children with autism in producing pretend play can be explained in terms of executive (generativity) dysfunction. Evidence from a longitudinal study by Charman et al. (2000) did not provide strong support for pretend play as an independent predictor of theory of mind development in typically developing children, though the authors did conclude that pretend play might be associated with theory of mind as part of a social-communicative system that gradually differentiates in early childhood. If pretend play is a precursor of theory of mind, or at least part of the social-communicative system that in due course gives rise to mind-reading abilities, then it is also of interest to determine its relationship to central coherence, and this is addressed in the present study.

Before outlining the hypotheses of the current investigation, we should note that Jarrold et al. (2000) found that the relationship between central coherence and theory of mind was only demonstrable when they controlled for verbal mental age, which suggests that developmental differences, in age and ability, can mask relationships that are occurring within a given developmental level. Therefore, it is desirable to control for verbal mental age in any correlational or discriminant function analyses when investigating relationships between central coherence and behaviors that tap capabilities fundamental to a theory of mind. An important implication of controlling for verbal mental age, as Jarrold et al. (2000) did, is that verbal ability may discriminate between autism and control groups independently of central coherence or behaviors that tap capabilities fundamental to a theory of mind.

Thus, the current study tested predictions following from two cognitive theories of autism, the linked deficit hypothesis, as espoused by Jarrold et al. (2000), and the independent deficit hypothesis, as espoused by Frith and Happé (1994a). Both the linked and independent deficit views predict that, compared with matched typically developing children, children with autism will perform significantly better on tasks that require only local processing and significantly poorer on tasks that tap capabilities that are fundamental to a theory of mind.

The two theories diverge with respect to their predictions concerning the relationships among central coherence, joint attention, and pretend play. The linked deficit hypothesis leads to the prediction that indices of local processing, for which high scores reflect weak central coherence, will be negatively correlated with joint attention when verbal mental age is controlled, in both the autism group and the control group. We also tested here a similar prediction with respect to pretend play (though it should be stressed that this extension of the linked deficit hypothesis has not been proposed by Jarrold et al., 2000). It also follows from this view that weak central coherence and low verbal mental age should discriminate children with autism from control children but that joint attention (and, according to our extension of the argument, pretend play) should not add significantly to the contribution of these two variables to the discrimination of the two groups.

Alternatively, the independent deficit view (Frith & Happé, 1994a) does not necessarily predict a correlation between central coherence and joint attention or pretend play within each group. However, it does lead to the prediction that, after the contributions of weak central coherence and low verbal mental age are accommodated, poor joint attention or limited pretend play should add significantly to the discrimination of children with autism from control children. This is because joint attention and pretend play purportedly tap capabilities fundamental to a theory of mind, a distinct deficit in children with autism.

Method

Participants

Two groups of children ($n = 21$ per group) participated in the study. Children with autism spectrum disorders (ASD) were recruited either through an autism association providing early intervention services ($n = 16$) or a center catering to exceptional as well as typically developing children ($n = 5$). The 21 control children were also recruited from this center. Among the children with ASD, 19 had received diagnoses of autism, and the remaining 2 had received diagnoses of pervasive developmental disorder not otherwise specified (PDDNOS), according to *DSM–IV* criteria. All the children with ASD received diagnoses from one of four government-funded centers. Diagnosticians from these centers are trained in the use of the Autism Diagnostic Interview and the Autism Diagnostic Observation Schedule and meet regularly to ensure uniform diagnostic practices consistent with *DSM–IV* criteria. Control children were matched to children with ASD on gender, chronological age, and nonverbal ability. Participants ranged in age from 3 years 6 months to 5 years 8 months, with a mean age of 4 years 7 months ($SD = 6.5$ months).

Measures

Verbal and nonverbal ability. Verbal ability was measured using the Peabody Picture Vocabulary Test Form IIIA (PPVT; Dunn & Dunn, 1996). Nonverbal ability was measured by prorating four subscales of the revised edition of the Leiter International Performance Scale (Leiter–R; Roid & Miller, 1997): Matching, Associated Pairs, Forward Memory, and Attention Sustained.

Spontaneous play. Two 5-min spontaneous play trials were recorded on videotape. On the first trial, the researcher placed a set of toys on the table in front of the child and said, “I am going to do some writing now, so here are some toys for you to play with.” As soon as the child reached to play with the toys, a 5-min testing session began. If the child had not started playing after 30 s, the researcher prompted the child by saying “What shall we make the dolls do?” If, after another 30 s, the child did not play with the toys, the researcher repeated the verbal prompt and the 5-min play trial began regardless of the child’s response.

During the play trial, the researcher responded to any interactions initiated by participants with short, pleasant replies but did not initiate interactions. This procedure was repeated in the second trial with different toys. The two sets of toys were (a) a kitchen stove, two teddy bears, a tea set with saucepan, plates, cups, knives, forks, and spoons, and pieces of yellow sponge (for object substitution) and (b) a doctor’s bag, stethoscope, flashlight, thermometer, phone, teddy bear, syringe, and clipboard with pen.

Play was scored later using time-interval analysis (Libby et al., 1998). At every 15-s interval, the play sequence was recorded and rated as either sensorimotor, ordering, functional, pretend play, ambiguous, or no play (based on the work of Baron-Cohen, 1987, and Leslie, 1987). Thus, 20 play sequences were recorded in each 5-min trial, with a total of 40 play sequences for each child across the two play trials. Pretend play was recorded if the child engaged in object substitution (e.g., pretended the sponge was food), attributed properties to an object that it did not have (e.g., attributed heat to the stove top), or referred to absent objects as if they were present (e.g., acted as if there was someone on the other end of the telephone; Leslie, 1987). A pretend play score was derived from the mean number of pretend play sequences a child performed across the two trials out of a maximum of 20.

Play sequences that did not meet criteria for pretend play were rated as sensorimotor, ordering, functional, ambiguous, or no play. *Sensorimotor* behavior included banging, waving, sucking, throwing, rolling, or sniffing objects with no regard to the objects' functions. *Ordering* was recorded when a child imposed a systematic pattern onto objects, such as lining them up or piling them up, but with no regard to their functions. *Functional* play was recorded if the child used the objects as they were intended (e.g., placed the saucepan on the stove). *Ambiguous* behaviors were those that fit two or more categories, and *no play* indicated that a child was not touching any of the toys (Baron-Cohen, 1987).

Joint attention. Three joint attention tasks were administered: blocking, teasing, and active-toy tasks. In the blocking task (based on the work of Phillips et al., 1992), the researcher covered the child's hands while he or she was playing with a toy. A joint attention response was recorded if the child looked at the researcher's eyes within 5 s (children who establish eye contact usually do so instantaneously; Phillips et al., 1992). In the teasing task (also based on the work of Phillips et al., 1992), the researcher offered the child a toy and then withdrew the toy as the child reached for it. A joint attention response was recorded if the child looked at the researcher's eyes within 5 s of withdrawing the toy. At the end of each trial, the toy was given to the child. In the third task, the researcher activated a mechanical toy (a mouse or dog) for 20 s and then stopped it. A joint attention response was recorded if the child looked at the researcher's eyes within 5 s to reactivate the toy. Each task consisted of four trials with 1 point scored each time the child achieved eye contact with the researcher, so a maximum of 12 points could be scored overall.

Central coherence. Two tests of central coherence were administered following the procedure used by Jarrold et al. (2000). The first was the Preschool Embedded Figures Test (Coates, 1972) in which, for each trial, the child had to locate a target figure (a triangle) within a meaningful picture. The child was instructed to find the triangle in each picture and then trace each side with a finger. Twenty-four test items were administered after four practice items. Each trial had a 30-s time limit. Time taken (in seconds) to locate the triangle was recorded. The number of correct responses and the mean reaction time for correct responses were calculated.

The second measure of central coherence was the Pattern Construction subscale of the Differential Ability Scales (Elliot, 1990). The Pattern Construction subscale is equivalent to the block design task referred to in the introduction but has been standardized for preschool children. In accordance with the test manual, an ability score was derived from a combined measure of accuracy and response latency.

General Procedure

Testing took place in a quiet room at the child's regular center. In the first testing session, children completed the Leiter–R and the PPVT. In the second testing session, they completed central coherence, joint attention, and play tasks. Each session lasted around 30 min.

Results

The results are reported in four sections. In the first section, we report preliminary comparisons of the groups on nonverbal ability, chronological age, gender, and verbal ability. The reliability of each measure, including interrater reliability for play tasks, is also reported. In the second section, we report group comparisons on measures of central coherence (embedded figures and pattern construction). In the third section, we report group comparisons on measures that may tap capabilities fundamental to a theory of mind: joint attention and pretend play. Analyses of the latter variables were repeated with verbal mental age entered as the covariate. In the fourth section, we report results from discriminant function analyses regarding the contribution of measures of verbal mental age, central coherence, and joint attention to discrimination of the two groups. Correlations between the predictor variables are also reported. There were missing data for 1 child with ASD on the embedded figures task and for 2 children with ASD on the pattern construction task because of noncompliance with test procedures. The scores on each variable were screened for outliers within each of the two groups. Using the criterion of a score three or more standard deviations from the group mean (as recommended by Tabachnick & Fidell, 1989), we identified no outlier cases. Nevertheless, as a further check, we repeated all analyses after eliminating 5 cases (3 control and 2 ASD) for whom scores were more than two standard deviations from the group mean. None of the significance tests changed in outcome when we did so, so we deemed it appropriate to present the full data.

Group Comparisons on Matching Variables and Verbal Ability

Analyses were conducted to ensure that children were matched on nonverbal ability (based on the four Leiter–R subscales), chronological age, and gender. Two children (1 control and 1 ASD) completed only three of the subscales. For these children, the nonverbal ability score was calculated by prorating the three completed subscales only. Separate independent-samples *t* tests revealed that the two groups did not differ significantly on nonverbal ability, $t(40) = 1.21$, *ns*, or chronological age, $t(40) = 1.68$, *ns*. Nevertheless, because the mean for nonverbal ability was slightly lower for the children with ASD, as a further check, we repeated subsequent analyses while controlling for nonverbal ability. This had no substantial effect on the outcome of results in any of the following analyses. Although there were 3 more boys in the autism group than there were in the control group, this difference was not significant, $\chi^2(1, N = 42) = 1.29$, *ns*. Children with ASD had significantly lower verbal IQ scores derived from the PPVT, $t(40) = 5.23$, $p < .001$, and significantly lower verbal mental ages, $t(40) = 5.38$, $p < .001$, than did control children. Summary statistics for matching variables, verbal IQ, and verbal mental age are presented in Table 1.

Reliability for the joint attention and pretend play scores was assessed with Spearman-Brown split-half reliability coefficients based on odd- and even-numbered trials (Ferguson, 1976). The reliability coefficients for joint attention (.87) and pretend play (.82) fall within the range of values reported in the literature for the embedded figures and pattern construction tests. The Preschool Embedded Figures Test has provided reliability coefficients between .74 and .91 (Coates, 1972), and the Pattern Construction subscale has yielded reliability coefficients between .82 and .90 (Elliot, 1990) for children between 3 and 5 years of age. A second coder, blind to the participants' diagnostic status, rated 20% ($n = 4$ per group) of the play videos. Interrater reliability for the play task was excellent, with Cohen's $\kappa = .92$.

Group Comparisons on Measures of Central Coherence

A series of one-way analyses of variance was conducted on embedded figures and pattern construction task scores. The independent variable was group (autism or control). Children with ASD were significantly faster at responding correctly on the embedded figures task, $F(1, 39) = 18.86$, $p < .01$, whereas there was

Table 1
Summary Statistics for Chronological Age (CA), Nonverbal Ability (Leiter–R), Verbal IQ (VIQ), Verbal Mental Age (VMA), and Gender

Variable	Autism (n = 21) *M*	Autism (n = 21) *SD*	Control (n = 21) *M*	Control (n = 21) *SD*
CA (in months)	54.43	7.67	55.38	5.18
Leiter–R	95.08	24.05	104.60	17.06
VIQ (PPVT)	76.52	15.80	100.90	14.36
VMA (in months)	33.43	12.56	59.14	17.93
Gender (boys:girls)	19:2		16:5	

Note. Leiter–R = revised edition of the Leiter International Performance Scale; PPVT = Peabody Picture Vocabulary Test.

no group difference on the total number of correct embedded figures responses, $F(1, 39) = 0.03$, *ns*. Children with ASD also performed significantly better on the composite measure from the pattern construction task, $F(1, 38) = 5.73$, $p < .05$. Table 2 presents the mean scores on measures of central coherence.

Group Comparisons on Joint Attention and Play

A series of one-way analyses of variance was conducted on joint attention and play measures. On joint attention tasks, group differences were significant on all three tasks used, with control children achieving significantly more eye contact than children with ASD on blocking, $F(1, 40) = 5.08$, $p < .05$, teasing, $F(1, 40) = 2.91$, $p < .05$, and active-toy tasks, $F(1, 40) = 7.12$, $p < .001$. Table 2 presents summary statistics for the number of joint attention behaviors shown by the ASD and control groups in blocking, teasing, and active-toy tasks.

On play tasks, there were no significant group differences for the total number of pretend play acts, $F(1, 40) = 0.04$, *ns*, or the number of novel pretend play acts, $F(1, 40) = 0.13$, *ns*, produced by the ASD and control children. Children with ASD produced significantly more sensorimotor play, $F(1, 40) = 4.58$, $p < .05$, but significantly less functional play, $F(1, 40) = 7.78$, $p < .01$, than did control children. Too few sequences were observed to permit a meaningful analysis of ordering sequences. In particular, only four ordering sequences were produced by just 2 participants (both with autism). Because of the small number of play sequences that were categorized as ambiguous or no play, data for these two categories were aggregated. There was no substantial group dif-

Table 2
Summary Statistics for Central Coherence, Joint Attention, and Number of Sequences per Trial in Each Category of Play

Measure	Autism *n*	Autism *M*	Autism *SD*	Control *n*	Control *M*	Control *SD*
Central coherence						
EF correct responses	20	17.75	3.57	21	18.57	2.91
EF time (in seconds)	20	4.78	2.04	21	7.91	2.54
Pattern construction	19	105.89	20.45	21	92.43	14.94
Joint attention						
Blocking task	21	1.95	1.56	21	3.62	.59
Teasing task	21	2.43	1.43	21	3.62	.67
Active-toy task	21	2.14	1.35	21	2.57	.75
Categories of play						
Pretend	21	5.0	2.8	21	5.0	2.4
Sensorimotor	21	8.0	2.6	21	6.3	2.8
Functional	21	5.7	2.1	21	7.5	2.0
Ordering	21	0.3	0.7	21	0.0	0.0
Ambiguous/no play	21	1.0	1.0	21	1.2	1.3

Note. EF = embedded figures. The maximum possible scores were 24 for EF correct responses, 4 for each of the joint attention variables, and 20 for each of the play variables. Pattern construction scores are standardized scores reflecting a combination of response latency and accuracy.

ference on ambiguous/no play sequences. Mean scores for each category of play are presented in Table 2.

A series of one-way analyses of covariance was performed on the embedded figures, pattern construction, joint attention, and pretend play variables. The independent variable was group (autism or control), and the covariate was verbal mental age. Adjusting for verbal mental age did not meaningfully change the significance of any previously reliable effects. These results indicate that verbal mental age did not mediate differences between groups on measures of central coherence and joint attention, nor did it mask differences on pretend play.

Discriminating the Groups

A hierarchical discriminant function analysis was performed with three variables as predictors of membership in the two groups, autism and control. The predictors were those measures on which significant group differences were found, namely, central coherence, verbal mental age, and joint attention. Pattern construction scores and embedded figures total scores did not add significantly to discrimination of the groups after embedded figures mean response time had been entered into the function. Hence, in the following analysis, central coherence reflects embedded figures mean response time only. Of the original 42 cases, 1 child with autism was dropped from the analysis because of missing data on the embedded figures task.

The discriminant function indicated an association between group and predictor variables, Wilks's lambda $= .36$, $p < .001$. Three predictors—central coherence, verbal mental age, and joint attention—had loadings in excess of .50 on the discriminant function that predicted group membership (.52, .62, and .63, respectively). Hierarchical analyses allowed the order in which predictor variables were entered into the discriminant function to be controlled. Central coherence was entered first, followed by verbal mental age and joint attention. In this order, each predictor contributed significantly to the discrimination between groups, with 85.4% of children classified correctly. In subsequent analyses, the order in which predictor variables were entered into the function was varied. Regardless of whether individual variables were entered into the function at the first, second, or third step, central coherence, verbal mental age, and joint attention measures each contributed significantly to the discrimination between groups at the $p < .01$ level. Table 3 presents the individual contributions of central coherence, verbal mental age, and joint attention to discrimination of the two groups when added last to the function, over and above the contributions made by the other two variables.

Table 3
Contribution of Central Coherence (Embedded Figures Response Time), Verbal Mental Age, and Joint Attention Predictors to Discrimination of Children With ASD From Control Children When Added Last to the Function

Predictor	Rao's *V* test of increased ability to discriminate groups when added last to the function
Central coherence	$\chi^2(3, N = 41) = 19.02$, $p < .001$
Verbal mental age	$\chi^2(3, N = 41) = 29.72$, $p < .001$
Joint attention	$\chi^2(3, N = 41) = 14.16$, $p < .001$

Note. ASD = autism spectrum disorders.

Within-Group Correlations

Pearson correlation coefficients were used to examine the relationship among central coherence, joint attention, pretend play, and verbal ability within the two groups of children. In the following analyses, central coherence reflects embedded figures mean response time only. The reader is reminded that long response times on the embedded figures test reflect a global processing style and that shorter response times are taken to reflect a local processing style (weak central coherence).

Autism group. For children with ASD, none of the correlations of critical theoretical interest reached statistical significance. Correlation coefficients are reported in Table 4. Further analyses were conducted to investigate the possibility that verbal mental age or chronological age was masking significant correlations between other measures. In partial correlation analyses, controlling for verbal mental age and chronological age either singly or in combination had no substantial effect on the statistical significance of the correlation coefficients (see Table 5).

Control group. Outcomes were similar for control children in that none of the Pearson correlation coefficients of critical theoretical interest reached statistical significance (see Table 4). Also, in partial correlation analyses, controlling for verbal mental age and chronological age either singly or in combination had no effect on the significance of correlation coefficients (see Table 5).

Correlations for Aggregated Groups

When data were aggregated across the two groups, the correlation between central coherence and joint attention was significant ($r = .49$, $p < .01$; see Table 4). In partial correlation analyses, the correlation between central coherence and joint attention remained significant even when we controlled for verbal mental age and chronological age in combination. However, such a correlation may still reflect the extent to which the two groups differ on central coherence and joint attention. To check this possibility, we conducted a further partial correlation analysis while controlling for group status, and this analysis did indeed show that the relationship was nonsignificant (see Table 5).

Discussion

The present experiment tested the support for two related but diverging theories about the cognitive bases of autism. The linked deficit view, advanced by Jarrold et al. (2000), holds that weak central coherence may be a primary cognitive deficit in autism, even accounting for theory of mind impairments. The independent deficit view, advanced by Frith and Happé (1994a), holds that children with autism have two distinct deficits, namely, weak central coherence and poor theory of mind. We investigated whether weak central coherence in children with ASD could account for deficits in two behaviors that purportedly tap capabilities fundamental to a theory of mind, joint attention and pretend play.

Central Coherence

As in Jarrold et al.'s (2000) study, the current investigation found that children with ASD performed significantly better than

Table 4
Pearson Correlation Coefficients for Central Coherence (CC), Total Joint Attention (JA), Pretend Play (PP), Verbal Mental Age (VMA), and Chronological Age (CA) for Autism, Control, and Aggregated Groups

Variable	CC	JA	PP	VMA
Autism				
JA	.25	—		
PP	−.12	.16	—	
VMA	−.07	.16	.38	—
CA	.02	.19	−.03	−.35
Control				
JA	.17	—		
PP	−.02	−.04	—	
VMA	−.22	−.06	.38	—
CA	−.29	−.37	.41	.47*
Aggregated groups				
JA	.49**	—		
PP	−.06	.09	—	
VMA	.26	.45**	.28	—
CA	−.09	.10	.13	.34*

* $p < .05$ (two-tailed). ** $p < .01$ (two-tailed).

control children on two tests that require a focus on local detail: embedded figures (Coates, 1972) and pattern construction (Elliot, 1990). This finding supports the hypothesis that children with ASD should process cognitive information in a manner reflecting significantly weaker central coherence than should typically developing children. These results cannot be explained by an additional factor such as poor motivation or general cognitive delay in children with ASD, because these children actually outperformed controls on these tasks. Thus, the present findings are consistent with the argument that weak central coherence is a core cognitive characteristic of autism (Frith, 1989; Frith & Happé, 1994a; Happé, Briskman, & Frith, 2001; Jarrold et al., 2000; Jolliffe & Baron-Cohen, 1997; Pring, Hermelin, & Heavey, 1995; Shah & Frith, 1983, 1993).

Joint Attention and Pretend Play

We compared children with ASD and control children on tasks that have been claimed to tap capabilities fundamental to a theory of mind, namely, joint attention and pretend play. Our findings supported the prediction, compatible with both the linked and independent deficit hypotheses, that children with ASD would demonstrate significant impairments on joint attention measures. However, we failed to obtain support for the prediction that children with ASD would be impaired on measures of pretend play.

Unexpectedly, the results of our study revealed that production of spontaneous pretend play acts was as common in children with ASD as in the control participants. The discrepancy between our findings and those of other studies in the literature (Charman et al., 1997; Lewis & Boucher, 1988; Libby et al., 1998; Mundy et al., 1987) is attributable neither to the reliability of the measures taken from the play task nor to imitation or cooperation with the researcher. It should be emphasized that the definition of pretend play used in this study was strictly limited to symbolic pretend play sequences. More plausible explanations for this result are that children were less inhibited by the test situation (they were tested in their everyday therapy environments) or that toys used in the current study attracted more pretend play. One advantage of the current study was that both groups of children produced a reasonable number of pretend play sequences. Previous findings that pretend play is impaired in children with ASD may reflect floor effects, because studies have reported that many children with ASD produce no pretend play sequences at all (e.g., Baron-Cohen, 1987) and that control children produce very few play sequences (e.g., Charman et al., 1997; Lewis & Boucher, 1988).

Because children with ASD in the current study were able to produce spontaneous pretend play sequences as frequently as control participants and because there is strong evidence of later theory of mind impairments in children with ASD (Baron-Cohen, 1995a, 1995b), it is possible that pretend play does not tap capabilities fundamental to a theory of mind (Jarrold, 1997; Jarrold, Carruthers, et al., 1994). Lillard (1993b) has argued that pretend play does not involve an understanding of mental state. Joint attention and pretend play were poorly correlated both in children with ASD and in control children, which suggests that the two behaviors reflect independent cognitive processes. The interpretation that pretend play does not tap capabilities fundamental to a theory of mind is consistent with the results of Mundy et al. (1987), who found performance on joint attention and pretend play tasks to be poorly correlated in children with ASD, and with several other demonstrations that children with autism can understand pretence (Jarrold, Smith, Boucher, & Harris, 1994; Kavanaugh & Harris, 1994).

Table 5
Partial Correlations of Central Coherence With Total Joint Attention (JA) or Pretend Play (PP), With Verbal Mental Age (VMA), Chronological Age (CA), and Group Status (Autism or Control) Controlled, for the Two Groups Separately and Aggregated

Variable controlled for	Autism JA	Autism PP	Control JA	Control PP	Aggregated groups JA	Aggregated groups PP
VMA	.27	.10	.16	.07	.43**	−.14
CA	.25	−.12	.07	.11	.50**	−.05
VMA + CA	.27	−.09	.08	.14	.43**	−.14
Group status					.19	−.06

** $p < .01$ (two-tailed).

Linked Deficit Hypothesis

Within the ASD and control groups, we failed to replicate, among a younger sample, Jarrold et al.'s (2000) correlations between chronological age and central coherence, and between verbal mental age and central coherence. More significantly, in the current investigation, central coherence was not related either to joint attention or pretend play within the ASD or control groups even when we controlled for chronological age and verbal mental age, which indicates that these tasks tap separate underlying cognitive mechanisms.

Unlike the study by Jarrold et al. (2000), the current investigation incorporated autism and control groups into a primary study, permitting an additional analysis for aggregated groups. Aggregated data revealed a significant relationship between central coherence and joint attention, but this relation disappeared in a partial correlation analysis in which group status was controlled. Hence, it appears that the correlation between central coherence and joint attention within the aggregated data reflects the influence of the important variable of whether an individual has autism or not. There is no evidence from our study of a more pervasive relationship between central coherence and joint attention.

The current study failed to support the prediction, based on the linked deficit hypothesis (Jarrold et al., 2000), that weak central coherence and low verbal ability would discriminate children with ASD from control children with no additional contributions from joint attention or pretend play. Instead, joint attention added significantly and independently to the prediction of group membership after contributions from central coherence and verbal mental age were accommodated, a finding consistent with predictions derived from the independent deficit hypothesis (Frith & Happé, 1994a).

If joint attention taps capabilities that are fundamental to a theory of mind (Baron-Cohen, 1989, 1995b; Baron-Cohen, Leslie, & Frith, 1985), then our investigation provides further evidence for the view that children with ASD have a specific impairment in theory of mind by indicating that a deficit is detectable in a precursor. On the basis of these findings, it seems justified to retain a theory of mind deficit as part of a causal explanation of autism.

Support for the independent deficit hypothesis over the linked deficit hypothesis comes partly from the nonsignificant partial correlations between central coherence and joint attention when verbal mental age and chronological age were controlled. One issue is therefore whether our study had sufficient power to detect critical partial correlations expected under the linked deficit hypothesis. The best estimates of effect sizes expected from this hypothesis come from the study by Jarrold et al. (2000) in which, for children of typical development (Experiment 2) and children with autism (Experiment 3), partial correlations were reported for embedded figures latencies with theory of mind scores, with either verbal mental age alone or verbal mental age in combination with chronological age controlled. The four partial correlations reported by Jarrold et al. ranged from .53 to .71. Effect sizes derived from these partial correlations yield estimates of power ranging from .77 to .99 for the $n = 21$ per group of the present study. (Power was estimated using GPOWER; see Faul & Erdfelder, 1992.[1]) Thus, our study appears to have sufficient power to detect relationships of the magnitude reported by Jarrold et al. (2000). Furthermore, if Jarrold et al.'s (2000) partial correlations are taken as estimates of population values for hypothesis testing, each partial correlation in the present study was significantly lower than the corresponding population value (using Fisher's r to z transformation, smallest $z = 2.16$, $p < .05$; Howell, 1997). Finally, note that the present study provides additional support for the independent deficit hypothesis over the linked deficit hypothesis in that the discriminant function analyses showed significant unique contributions for central coherence and joint attention variables. Therefore, it seems reasonable to interpret the present results as not supporting the linked deficit hypothesis given that power was adequate, that partial correlations were significantly lower than corresponding values reported by Jarrold et al. (2000), and that central coherence and joint attention made independent contributions to the discrimination of the sample of children with autism from the control sample.

One possible explanation for the discrepancy between the current study and the study by Jarrold et al. (2000) is that there is a developmental change in the patterns of relationships among central coherence and mind-reading abilities. A longitudinal study would be required to investigate whether there is a progression from independence at an early age to an association between these variables at a later age.

A second possible explanation is that the theory of mind tasks used by Jarrold et al. (2000) involved additional demands that influenced results. There is evidence suggesting that in standard theory of mind tasks, such as the Sally–Ann false-belief task used by Jarrold et al. (2000), embedded judgments help a person to infer what someone else will think of a situation (Frye, Zelazo, & Burack, 1998). Joint attention measures require less deliberated responses, and the participant is not expected to interpret potentially ambiguous instructions; performance is less likely to involve additional cognitive processes.

Verbal Ability

As expected, verbal ability was impaired in children with ASD. However, the extent to which verbal ability had an impact on the prediction of group membership over and above deficits in weak central coherence and joint attention was surprising. Verbal mental age contributed substantially to the discrimination between autism and control groups even after central coherence and joint attention had been accounted for, and it was poorly correlated with both central coherence and joint attention in each group. The results involving verbal ability do not directly concern the linked-deficit/independent-deficit issue, which pertains specifically to central coherence and theory of mind. It is worth noting that Jarrold et al. (2000) found a relationship between central coherence and theory of mind in children with autism and in typically developing children only when controlling for verbal mental age. This is consistent with verbal ability being somewhat independent of central coherence and theory of mind. Our verbal ability results also have some relevance to Frith and Happé's (1994b; Happé & Frith, 1996) suggestion that language delay may often be due to mental retar-

[1] We are indebted to Edgar Erdfelder for suggesting two ways that GPOWER could be used to estimate power for partial correlations—one based on a t test for partial correlations and the other based on testing a regression weight in multiple regression. The estimates of power reported in the text were consistent across the two methods.

dation or, in other cases, to the failure of communicative understanding. In our study, there were no substantial group differences on nonverbal ability, indicating that low verbal mental age in children with ASD does not reflect general intellectual delay and that deficits in verbal ability were independent from deficits in joint attention, which measures an aspect of communicative understanding. Notably, the task in our study measured receptive vocabulary and therefore reflects only one dimension of language, and the study did not include a control group matched on verbal mental age. Although the sample of children with ASD tested here did indeed have lower verbal mental ages than the control children, not every child with autism had low verbal ability. This leaves open the question of whether low verbal ability has the same status as a primary cognitive deficit in children with ASD as do weak central coherence and poor theory of mind (however, see Bailey, Phillips, & Rutter, 1996, who argue for the need to consider a language deficit hypothesis of autism).

Finally, it should be acknowledged that the present study does not address the executive dysfunction hypothesis, which proposes that children with autism are impaired on tasks that require higher order cognitive processes, such as inhibition (Pennington & Ozonoff, 1996). Executive dysfunction may play an important role in the repetitive behaviors and stereotyped routines commonly engaged in by children with autism (Turner, 1999). Also, several authors have drawn attention to the executive-function and working-memory demands of the traditional theory of mind tasks (Davis & Pratt, 1995; Halford, 1993; Keenan, 2000). Because we used tests of early mind-reading abilities rather than the standard false-belief tasks, we do not have data to address this issue directly. It is certainly possible that executive deficits may interact with theory of mind and central coherence deficits. For example, joint attention requires both disengaging and shifting attention (from an object of interest to a person's eyes), which can be thought of as executive processes.[2]

Conclusions

The results of this investigation provide strong evidence for weak central coherence, poor joint attention, and low verbal ability in a group of 3- to 5-year-old children with ASD matched to control children on age and nonverbal ability. Unique to this study was an investigation into the relationships among central coherence, verbal ability, and behaviors purported to tap capabilities fundamental to a theory of mind: joint attention and pretend play. Measures of central coherence, joint attention, and verbal mental age all contributed significantly and independently to the discrimination of children with ASD from control children. These results are not fully explained by current theories of autism pertaining to a primary cognitive deficit in central coherence (Frith, 1989; Jarrold et al., 2000) or to independent cognitive deficits in central coherence and theory of mind (Frith & Happé, 1994a).

Explaining autism in terms of a primary cognitive deficit in weak central coherence or in terms of coexisting and independent deficits in weak central coherence and poor theory of mind does not adequately account for the complexity and pervasiveness of the disorder. Instead, we suggest that there are at least three independent cognitive deficits in autism: weak central coherence, low verbal ability, and a theory of mind deficit that is preceded by a deficit in joint attention. Future research must address the question of how these deficits influence the core behavioral features of autism and whether these relationships persist or change over time.

[2] We wish to thank the anonymous reviewer who made this suggestion.

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