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The Modified Checklist for Autism in Toddlers: An Initial Study Investigating the Early Detection of Autism and Pervasive Developmental Disorders

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Autism, a severe disorder of development, is difficult to detect in very young children. However, children who receive early intervention have improved long-term prognoses. The Modified Checklist for Autism in Toddlers (M-CHAT), consisting of 23 yes/no items, was used to screen 1,293 children. Of the 58 children given a diagnostic/developmental evaluation, 39 were diagnosed with a disorder on the autism spectrum. Six items pertaining to social relatedness and communication were found to have the best discriminability between children diagnosed with and without autism/PDD. Cutoff scores were created for the best items and the total checklist. Results indicate that the M-CHAT is a promising instrument for the early detection of autism.

KEY WORDS: Autism; modified checklist; toddlers.

INTRODUCTION

Autism and related disabilities are severe disorders of development, affecting between 5 and 30 children in 10,000 (Mays & Gillon, 1993; Rapin, 1997; Siegel, Pliner, Eschler, & Elliot, 1988; Stone, Hoffman, Lewis, & Ousley, 1994). These disorders are disruptive and sometimes devastating to social relationships, communication, and imaginative play (Wing, 1988), and cause a restricted range of activities and interests (Rapin, 1997; Siegel *et al.*, 1988).

Given currently available diagnostic instruments, autism and other pervasive developmental disorders (PDD) are difficult to detect in very young children. This may be due to several factors: presentation of symptoms varies from case to case, social and language deficits and delays may not be identified until the child is given the opportunity for peer interaction in preschool, low incidence leads to a low index of suspicion, and motor milestones are usually unaffected. Furthermore, there is no standard and easily administered screening instrument for young children.

For all these reasons, pediatric evaluations rarely identify autism/PDD before the age of 3 (Gillberg, 1990). However, evidence indicates that there is a large gap between the age of the child at the parents' first concern, the age of the first evaluation, and the age of a definitive diagnosis (Siegel *et al.*, 1988). Parents are typically first concerned between the ages of 15 and 22 months (earlier for children who have comorbid mental retardation), but the child is often not seen by a specialist until 20–27 months (De Giacomo & Fombonne, 1998). In addition, there is often further delay between the first visit to a specialist and a definitive diagnosis (Siegel *et al.*, 1988). However, evidence shows that this delay in diagnosis causes additional distress to parents, as well as wasting valuable intervention time, indicating that professionals in the field of autism need instruments to aid in the detection of autism/PDD in very young children.

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Current evidence indicates that early intervention and therefore identification is essential. Early educational intervention optimizes long-term prognosis (Lord, 1995; Prizant & Wetherby, 1988; Mays & Gillon, 1993). More specifically, children with autism/PDD who develop language and symbolic play before the age of 5 have better prognoses (Mays & Gillon, 1993). Early intervention may enable children to reach important milestones; research has shown that children who receive early intervention are more likely to develop communication skills and fewer out-of-control behaviors (Siegel *et al.*, 1988). Interventions with children with autism/PDD may show diminishing returns as the children get older (Mars, Dowrick, & Mauk, 1996). Clearly, time is of the essence in the early detection of autistic features. The necessity of early screening and diagnosis, as well as the current state of the field, has been comprehensively reviewed by Filipek *et al.* (1999).

Researchers have variously suggested that the primary deficit in autism is accounted for by deficits in language (Tager-Flusburg, 1993), arousal modulation and sensory responsiveness (Dawson & Lewy, 1989; Kinsbourne, 1987), theory of mind (Baron-Cohen, Leslie, & Frith, 1985), motor functions (Teitlebaum, Teitlebaum, Nye, Fryman, & Maurer, 1998), social/emotional development (Fein, Pennington, Markowitz, Braverman, & Waterhouse, 1986; Hobson, 1998; Waterhouse, Fein, & Modhal, 1996), and other functions. The checklist designed for this study, the Modified Checklist for Autism in Toddlers (M-CHAT), includes items for these functions or their precursors, for example, sensory abnormalities (undersensitive to noise), motor abnormalities (unusual finger movements, climbing), social interchange (eye contact, smiling in response to parent's smile), early joint attention/theory of mind (bringing objects to show parents, pointing to indicate interest, following adult's point), early language and communication (pointing to request, understanding "no," indicating own wishes). Analysis of which items most frequently indicate autistic features at this early point in development may lend support to the centrality or primacy of specific impairments in the development of autism/PDD.

One difficulty in studying the "primary" deficit is that the presentation of autism/PDD changes depending on the child's age. Children younger than the age of 3 rarely display perseveration, preoccupations, or resistance to change (Dahlgren & Gillberg, 1989; Rapin, 1996; Tanguay, Robertson, & Derrick, 1998); these children may not have the cognitive ability necessary to play repetitively (Lord, 1995). However, preschool children with autism/PDD often show unusual sensory responses, including the repeated interest in certain stimuli (e.g., a spinning top, the clanging of a dropped spoon). In middle childhood and adolescence, the fascination with repetitive sensory and motor toys drops off, and is often replaced with an obsessive fascination with extremely narrow topics or activities, and the child may learn a great deal in one restricted area, without the ability to broaden the topic (Volkmar & Lord, 1998).

Lord (1995) found that at age 2, failures in showing things to others and responding to name alone correctly predicted autism at age 3 with 83% accuracy. Charman *et al.* (1998) contrasted signs of autism in infancy with signs found between 3 and 4 years of age in order to determine whether the features of autism characteristic of preschool children were apparent at 20 months. They particularly focused on behaviors reflecting empathy, pretend play, joint attention, and imitation. They found that evidence of gaze shifting, awareness of distress in others, imitation, and sharing of positive experiences (affect sharing is a part of joint attention) was greatly reduced among autistic children compared to children with PDD and other nonautistic developmental delays.

Characteristics of a Screening Device

Pediatric screening is often the only evaluation children receive until they begin preschool or even kindergarten. Therefore, pediatricians must be sensitive to developmental concerns. A screening device that alerts physicians to possible cases of autism/PDD and related disorders at 18 months would therefore be invaluable.

Given the pressures of the typical pediatrician's office, such an instrument must be objective, easy to administer, and brief. Furthermore, physicians cannot always reliably identify a developmental delay based on a child's behavior in one session in the doctor's office (Rapin, 1996); particularly for very young children, a potentially serious communication and social delay may be confused with shyness in a typically developing youngster and behavior in the doctor's office may not represent the child's typical behavior. This makes parent report essential to any screening instrument.

The M-CHAT, created for the current study, has been designed to meet these requirements for a screening device (see the Appendix).

Existing Measures

There are several tools available to evaluate autistic symptoms, but none has yet been found to be appropriate to detect signs of autism/PDD in unselected populations of very young children. These instruments include the Autism Behavior Checklist (Krug, Arick,

& Almond, 1980), the E-2 form of the Diagnostic Checklist for Behavior-Disturbed Children (Rimland, 1964), the Behavior Rating Instrument for Autistic and Atypical Children (Ruttenberg, Dratman, Fraknoi, & Wenar, 1966), the Behaviour Observation Scale for Autism (Freeman, Ritvo, Guthrie, Schroth, & Ball, 1978), the Childhood Autism Rating Scale (Schopler, Reichler, DeVellis, & Daly, 1980), the Autism Diagnostic Interview-Revised (Lord, Rutter, & LeCouteur, 1994), the Autism Diagnostic Observation Schedule-Generic (Lord, Rutter, & DiLavore, 1997), the Screening Test for Autism in Two-Year-Olds (Stone & Ousley, 1997) and the Infant Behavioural Summarized Evaluation (Adrien *et al.*, 1992). Each has its advantages. Most of these are appropriate for older children, particularly those for whom developmental concerns have already been identified.

All of the existing instruments have one or more of the following problems *as a screening device*: their administration is too long and cumbersome; they are designed for school-age children and may not be valid for younger children; some do not take into account parent report, but rather rely on a sample of behavior observed in the office; some rely on abnormalities in behavior that rarely appear before the age of 3 (e.g., idiosyncrasies of speech, resistance to change); many of the measures available have not been standardized; they need to be administered by a specialist in developmental disabilities or autism; and they require setting up structured interactions, which is not possible in the pediatrician's office. Most important, they are used with children already identified as having autistic features or other developmental concerns, rather than being administered to all children. Therefore, none of the previously mentioned instruments is appropriate for screening a large number of very young children. What is needed is a brief screen that is easy to administer and score and that will alert physicians to the need for further evaluation in children with the early signs of autism/PDD.

Researchers have begun to develop other screening and early diagnosis instruments; some of these have not yet appeared in the literature but their current status is described in the comprehensive review of Filipek *et al.* (1999).

The Current Instrument

The M-CHAT is a simple screen that can be given to all children during pediatric visits. It does not rely on the physician's observation of the child, but on parents' report of current skills and behaviors. The format is extremely simple (parents fill out the checklist in the waiting room) and does not require the physician's administration. The M-CHAT can also be given to parents of children who have already been referred for early intervention services. The Connecticut early intervention (EI) system does not screen specifically for autism/PDD, and children usually receive minimal services before a diagnosis is made; this diagnosis must be made by a psychologist or physician outside the EI system.

The M-CHAT is an extension of The Checklist for Autism in Toddlers (CHAT; Baron-Cohen, Allen, & Gillberg, 1992). The format and the first nine items are directly taken from the CHAT, with the authors' permission.

The CHAT was developed and validated in Great Britain. The CHAT is used to help identify the early signs of autism at 18 months by assessing the child's attainment of developmental milestones. Items include report of such behaviors as taking an interest in other children, pointing, and pretend play. The CHAT consists of nine items asked of the parents by the physician, and five items for which the home health visitor observes the child in the home. The American health care system has no analogous role to British home health visitors; in addition, Rapin (1996) reported that developmental delays could be missed in a one-session behavior observation. Therefore, the modified checklist consists only of parent report of current behavior.

A follow-up study by Baron-Cohen *et al.* (1996) pinpointed three items on the CHAT as key items indicating early signs of autism: protodeclarative pointing (pointing at an object of interest), gaze monitoring, and pretend play. Baron-Cohen *et al.* (1996) screened 16,000 children with the CHAT and 12 of those children met the criteria for the autism risk group. Of the 12 children considered to be at risk for autism, 10 received a diagnosis of autism, and 2 received a diagnosis of developmental delay. All diagnoses were confirmed at 3.5 years, showing the stability of the earlier diagnoses. It should be noted that Baron-Cohen *et al.* (1996) were looking for children who met strict criteria for Autistic Disorder, rather than the broader population of children with autistic features who need intervention services and who are the target of the current screening.

A long-term follow-up study (Baird *et al.*, 2000) used intensive methods to identify the total number of children with autism or PDD in the previously screened population at age 7. They found 50 cases of autism and 44 cases of PDD. They classified children from the 18-month screening as having high risk for autism (failing all five key items on the CHAT involving protodeclarative pointing, gaze monitoring, and pretend play in two successive screenings) or medium risk for autism (failing the two protodeclarative pointing items in two successive screenings). Of the 50 cases of autism, 10 were identified at 18 months using the high-risk cutoff and 19 were identified using the medium-risk cutoff. Of the total 94 cases on the PDD spectrum, 11 were identified using the high-risk cutoff, and 33 were identified using the medium risk cutoff. These identification rates resulted in sensitivity rates of 11.7% (high risk–PDD spectrum), 20% (high risk–autism), 35.1% (medium risk–PDD spectrum), and 38% (medium risk–autism). Specificity was high for all of these conditions (above 97.5%).

No research has yet been done with the CHAT in the United States. In a review of autism assessment tools, Vostanis, Smith, Chung, and Corbett (1994) called the CHAT "the most promising work in this area [assessment of autism], although it requires further evaluation." The current work is designed to evaluate the nine parent-response items from the CHAT, in addition to 21 new items. These 21 items (see Method) were designed to (a) broaden the checklist symptoms to identify a greater range of children with PDDs and (b) to compensate for the elimination of the home health visitor's observations, Part B of the original CHAT. The revised checklist has been named the Modified Checklist for Autism in Toddlers (M-CHAT). The M-CHAT is expected to have improved sensitivity compared to the CHAT for several reasons: (a) the age of screening is 24 months instead of 18 in order to catch children who regress between 18 and 24 months, (b) the M-CHAT has a lower threshold for follow-up, and (c) the use of a structured telephone interview as an intermediate screening step keeps the specificity relatively high without compromising sensitivity.

The current study determines (a) how predictive each item is for autism/PDD, and (b) how many items are failed by children who have autism/PDD. This analysis leads to a final recommendation of how many items failed should lead to an evaluation. In addition, (c) discriminant function analysis determines whether the total checklist score or any subset of items are sufficient to predict autism/PDD with reasonable accuracy, and (d) how the total score compares with the original CHAT (Baron-Cohen *et al.*, 1992, 1996).

METHOD

Participants

Participants consisted of children screened during well-baby checkups with their pediatrician or family practice doctor at 18 or 24 months (570 male, 531 female; 21 unknown (parents did not identify the child's sex and the name was nongendered) and children screened through early intervention service providers at any age between 18 and 30 months (123 male, 46 female, 2 unknown; mean age 26 months) (Table I). None of the children referred from early intervention sites had been diagnosed previously with a DSM-IV disorder (American Psychiatric Association [APA], 1994). They were receiving minimal services (e.g., 1 hour of speech therapy every week). Analyses were conducted on the entire sample, although some analyses eliminated a small number of participants as a result of missing data.

Physicians were invited to participate in the study through several mass mailings sent throughout Connecticut. In addition, a few physicians from outside Connecticut agreed to participate after hearing about the project directly from one of the investigators. Currently, 98 physicians' offices are involved in ongoing data collection, and additional sites are continually being enrolled.

Connecticut's statewide early intervention program, Birth-to-Three has invited their offices throughout the state to participate in the study.

Children were excluded if they had a combination of (a) total lack of expressive language or any functional communication system and (b) motor deficits so severe as to preclude obtaining meaningful responses on developmental/cognitive testing. Based on these criteria, one nonspeaking child with severe cerebral palsy was excluded from the study.

Instruments

The M-CHAT (see the Appendix) incorporates the nine parent-report items from Baron-Cohen *et al.*'s (1992) CHAT. For additional items, the investigators

Table I. Demographic Information

	18-month screen (nonselected pop.) (*n* = 1,122)	Early intervention screen (high-risk sample) (*n* = 171)
Male	570	123
Female	531	46
Sex unknown	21	2
Age range (in months)	18–25	18–30
No. of Spanish checklists	8	0

generated a list of symptoms thought to be present in very young children with autism. Items were created based on hypotheses in the literature, clinical instruments used to evaluate older children, and their own clinical experience. Some items were generated based on findings from home videos of children later found to have autism (Adrien *et al.*, 1991, 1992; Baranek, 1999; Osterling & Dawson, 1994). The investigators did not change the original wording of the first nine items (taken from the CHAT), but for the remaining items, responses were balanced so that some responses indicating development within normal limits are answered by "yes" and others by "no."

Initially, the M-CHAT consisted of 30 items. Following preliminary analyses of the first 600 participants, 8 items were discarded because they were not as discriminating as other items or because many parents misunderstood them. Items were retained which (a) were sensitive and specific as determined by the discriminant function analysis, (b) were directly related to key symptoms of autism, or (c) formed a set of "buffer" items to which virtually all parents would be able to respond positively (e.g. "Does your child walk?"). Most of the items representing atypical sensory responsiveness were eliminated (e.g., Does your child rock back and forth?, Does your child seem undersensitive to noise?). One new item was added: Several investigators (Bacon, Fein, Morris, Waterhouse, & Allen, 1998; Sigman, Arbelle, & Dissanayake, 1995) have found that social referencing deficits (i.e., failure to look at caregiver's face in frightening or new situations) are extremely characteristic of both high- and low-functioning children with autism; therefore, a new item on social referencing has been added.

Initially, participants received a follow-up call after failing 5 of the 30 items on the checklist. If a child failed 3–5 items, one of the senior clinicians (D.F. or M.B.) examined the checklist in order to flag for telephone follow-up any child where the failed items were of concern. Parents were also called regardless of their checklist score if the child's pediatrician or early intervention provider indicated concern. After the first 600 participants were recruited, preliminary analyses led to revisions of both the checklist itself and the cutoff criteria. A subset of eight items was determined to be critical based on preliminary analyses of the first 600 participants. The cutoff criteria was set to two of the critical items or any three items.

Once a child failed the M-CHAT, the family was called, and responses were confirmed over the phone. If the child's score was still above the cutoff, the family was invited to participate in a free developmental evaluation. No families declined to participate. One family with a low checklist score agreed to participate but then stopped returning phone calls.

The developmental evaluation included the following measures: the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984), the Bayley Scales of Infant Development, Second Edition (Bayley, 1993), the Communication and Symbolic Behavior Scale (CSBS; Wetherby & Prizant, 1993), the Childhood Autism Rating Scale (CARS; Schopler *et al.*, 1980), and a semistructured interview based on DSM-IV criteria for Autistic Disorder (APA, 1994), a full history of the child was also taken during an interview with the parents.

The Vineland Adaptive Behavior Scales is a widely used parent interview scale that assesses communication, socialization, self-help, and motor competence. The Bayley Scales of Infant Development is a test administered to the child that assesses mental and psychomotor development. The CSBS consists of four parts. First, the evaluator offers a child eight "communicative temptations:" toys for which the child must ask for help in order to play with them (e.g., a bottle of bubbles closed tightly). Next, the evaluator engages the child in symbolic play using two different sets of toys. Third, the evaluator assesses verbal comprehension (e.g., "Where's your nose?"), and last, engages the child in combinatorial play (e.g., stacking blocks, nesting cups). For this study, the CSBS was not scored; rather, it was used qualitatively, to evoke communicative attempts and play from the child. The CARS, a frequently used measure of autistic behavior and diagnosis, consists of 15 subscales for rating aspects of autistic behavior; children are rated on each subscale based on the clinician's observation of how the child responds to structured and unstructured activities. Lord (1995) suggested a cutoff of 32 for very young children (the standard cutoff is 30); however, based on clinical judgment, five participants were diagnosed with autism/PDD with CARS scores below 32. The follow-up study will investigate whether Lord's finding is confirmed, when these five participants are seen again between the ages of 3.5 and 4 years.

Procedure

Physicians who agreed to participate gave a consent form and an M-CHAT to the parents of every child who came into the office for an 18 or 24 month checkup. Initially children were screened at 18 months. However, following preliminary analyses of the first 600 participants, the age of screening was raised to 24 months for several reasons: Pediatricians were more willing to screen at 24 months, children are not usually referred to an early intervention center before age 2, and most important, children who show regressions are most likely to do so between the ages of 15 and 24 months, indicating that children screened at 24 months are not likely to regress after the checklist is completed.

Early intervention providers screened children using the M-CHAT as they were referred for early intervention services. Therefore, these children were considered to be at risk for a developmental disorder, but none had received any specific diagnoses and none had received more than several weeks of minimal intervention services.

Parents' participation was voluntary. They were told that they had no obligation to participate, and that their participation could be withdrawn at any time during the study. Parents were assured that the data would be coded using subject numbers and that no results would be published with any identifying information. Checklists were sent back to the investigators for scoring in stamped and addressed envelopes provided by the investigators. Pediatricians and early intervention providers were also given the opportunity of flagging the checklists of any children about whom they were particularly concerned for telephone follow-up by the investigators.

The use of the M-CHAT with an unselected pediatric population constitutes a Level I screen. Although the M-CHAT was primarily designed to act as a Level I screen, the sample of children already referred for early intervention (considered a high-risk sample) constitutes a Level II screen. This was done concurrently with the unselected population in order to obtain a large sample of children diagnosed with autism/PDD. In addition, the high-risk sample consisted of children receiving minimal intervention (usually 1 hour each week), and none had yet received diagnoses on the autism spectrum.

Any child who failed two or more of the eight items determined to be the critical (the best discriminators from a discriminant function analysis performed during preliminary analyses of the first 600 participants) or any three items was considered at risk. The physician or early intervention provider's office was contacted, and permission was requested to invite the family in for a complete developmental evaluation. Fifty-eight evaluations were completed. The evaluation was performed either in the Psychological Services Clinic at the University of Connecticut (n = 34), in the child's home (n = 14), or in the early intervention office (n = 10). The amount of time that elapsed between screening and assessment ranged from less than 1 month to 7 months, with a mean of 2.12 months between the time of screening and the time of evaluation. Only 7 children waited longer than 3 months for an evaluation. Delays occurred with these participants for a variety of reasons: The checklist was not returned to the investigators immediately, the investigators had difficulty reaching the families by phone for follow-up, and at times there were scheduling conflicts necessitating a delay before evaluation.

Evaluations were performed by a team of investigators, consisting of one licensed clinical psychologist, one graduate student clinician participating in the evaluation, and one student videotaping the session. One person on the team collected history and parent measures, while the second person on the team collected the child measures. Since all children presented with some degree of risk, having failed the M-CHAT, it was felt that truly blind assessment was not possible.

Following the evaluation, children were diagnosed as (a) on the autism spectrum (n = 39), or (b) having developmental delays, usually either language delay or mental retardation, but not a disorder on the PDD spectrum (n = 19). No children were found to be developing typically. Appropriate recommendations were provided for the parents.

RESULTS

Reliability

Reliability was determined using Cronbach's alpha for the 22-item checklist as well as for the subset of 6 items found to be the best discriminators of children diagnosed with autism spectrum disorders (see Discriminant Function Analysis). Internal reliability was found to be adequate for both the entire checklist and for the critical items ($\alpha = .85$ and $\alpha = .83$, respectively). When the social referencing item was included, reliability remained high ($\alpha = .85$), even though the sample was much smaller, since only 480 participants completed the social referencing item.

Descriptive Statistics

Children were divided into four groups: (a) children who did not require any follow up (n = 1,161), (b) children who required telephone follow up, but did not require an evaluation (n = 74), (c) children who were evaluated and found to have language or global delays, but not autism or PDD (n = 19), and (d) children who were evaluated and diagnosed with autism or PDD (n = 39). No children who were evaluated were found to have entirely typical development.

Table II shows the percentage of items failed by each group. Of the children evaluated and found to have language or global delays, 4 were from the unselected pediatrician screen and 15 were from early intervention. Of the children who received a diagnosis of autism/PDD, 3 were from the unselected pediatrician screen and 36 were from early intervention. In all tables, the No Follow-up sample sizes vary slightly because of missing data.

Table II. Percentage of Children in Each Group Who **Failed** Each Item

Item	No follow-up (n = 1,144)	Ok on phone follow-up (n = 74)	Evaluated nonautistic (n = 19)	Evaluated autistic/PDD (n = 39)
1	0.7	5.4	10.5	2.6
2	0.1	6.8	31.6	59.0
3	0.2	0	15.8	5.1
4	0.3	2.7	15.8	25.6
5	0.9	20.3	31.6	51.3
6	1.0	14.9	42.1	71.8
7	0.4	17.6	31.6	82.1
8	1.7	10.8	21.1	41.0
9	0.2	4.1	31.6	53.8
10	1.3	8.1	15.8	35.9
11	17.9	40.5	57.9	41.0
12	0	5.4	5.3	20.5
13	2.1	18.9	42.1	59.0
14	0.3	5.4	15.8	64.1
15	0.1	16.2	42.1	74.4
16	0.3	2.7	0	0
17	1.0	9.5	31.6	51.3
18	4.4	27.0	26.3	38.5
19	7.1	35.1	57.9	76.9
20	2.0	18.9	21.1	53.8
21	0.3	17.6	15.8	51.3
22	8.2	37.8	57.9	61.5
23[a]	2.0	12.2	15.8	17.9

[a] Item 23 had a smaller sample, because it was added later. Sample for Item 23 are No Follow-up (n = 402), Phone (n = 54), Evaluated Nonautistic (n = 8), Evaluated Autistic (n = 16).

Once the children were categorized, several different scores were compared: (a) total score based on all 23 items (M-CHAT 23), (b) the score based on the CHAT's original nine items (CHAT 9), and (c) a statistically derived score from a discriminant function analysis consisting of the 6 most discriminating items (DFA 6; as, for example, in Siegel *et al.*, 1988; see below). See Table III for a comparison of groups on these summary scores.

Children who were not followed up failed an average of 0.5 items of the 23 items on the checklist, children who passed a telephone screen failed 3.4 items, children who were evaluated and found to be nonautistic failed 6.4 items, and children with autism/PDD failed an average of 10.3 items.

Analysis of Variance

One-way analysis of variance indicated that there was a significant difference between groups based on all three summary scores. Tukey's post-hoc tests indicated that all differences between groups were significant on every measure (Table III).

Item Analysis

Chi-square analyses indicated that all items were significantly different between the children diagnosed as autistic compared to all other participants, except Items 1 ("Does your child enjoy being swung, bounced on your knee, etc.?") and 16 ("Does your child walk?").

Discriminant Function Analysis

A discriminant function analysis (DFA) was performed using the 22 original M-CHAT items (excluding the social referencing item) in order to determine the ability to classify children as either autistic/PDD or nonautistic. Due to the small sample in this initial study, it was not possible to include the false positive children

Table III. Comparison of Groups on Summary Scores[a]

	No follow-up done	Phone screen	Evaluated nonautistic	Evaluated autistic	ANOVA		
					F	df	p
M-CHAT 23	0.53 (0.71)	3.38 (2.33)	6.37 (2.79)	10.32 (4.11)	1121.85	3, 1268	<.001
DFA 6	0.03 (0.18)	0.74 (0.99)	2.00 (1.31)	4.13 (1.53)	1220.20	3, 1269	<.001
CHAT 9	0.05 (0.24)	0.82 (1.17)	2.32 (1.57)	3.92 (1.95)	802.58	3, 1267	<.001

[a] Post-hoc Tukey's tests indicated that all differences were highly significant (p < .001). Mean differences ranged from 2.85–9.86 for M-CHAT 23, 0.71–4.10 for DFA 6, and 0.77–3.87 for CHAT 9.

who were evaluated and found to be nonautistic as a separate group (n = 19). The DFA was therefore conducted dividing the total sample into two groups: the children who were not autistic (n = 1,196; 58 children who had missing responses were excluded from the DFA) and the children diagnosed as autistic/PDD (n = 38, 1 child who had missing responses was excluded from the DFA).

Table IV lists the standardized canonical discriminant function coefficients for each item, along with the percentage of autistic and nonautistic children who failed each item. The items with the highest weights (in descending order) are 7, 14, 2, 9, 15, and 13. These are the items designated as DFA 6 in the following discussion of optimal scoring.

The discriminant function analysis correctly classified 33 out of 38 children with autism/PDD, and only misclassified 8 of the 1,196 nonautistic children (false positives), indicating that the M-CHAT is successful at indicating children who require further follow-up. Of the nonautistic children misclassified as autistic, 5 were children who received evaluations and received diagnoses other than autism/PDD, and 3 were children who received phone follow-up. The 5 children with autism/PDD who were misclassified as nonautistic were children whose parents initially underreported symptoms, and the child's early intervention provider or pediatrician flagged the checklist for further investigation (n = 3), or children with checklist scores not very far above the cutoff (n = 2).

Table IV. Standardized Canonical Discriminant Function Coefficients and Percentage Failing Each Item

Item	Function 1	Failed item: % of nonautistic (n = 1,229)	Failed item: % of autistic (n = 38)
7	.480	1.9	82.1
14	.341	0.9	64.1
2	.279	1.0	59.0
9	.225	0.9	53.8
15	.167	1.7	74.4
13	.118	3.7	59.0
12	.088	0.4	20.5
3	−.087	0.4	5.1
5	−.078	2.5	51.3
10	.074	1.9	35.9
1	−.071	1.1	2.6
19	.069	9.5	76.9
18	.056	6.1	38.5
6	−.056	2.4	71.8
8	.055	2.6	41.0
20	.044	3.3	53.8
21	.042	1.5	51.3
17	.039	1.9	51.3
4	.026	0.7	25.6
22	−.009	10.8	61.5
16	.005	0.5	0
11	.003	19.9	41.0
23	—[a]	2.8	17.9

[a] Item 23 was excluded from DFA because not all participants received the item; for nonautistic subjects n = 464, for autistic subjects n = 16.

A larger sample will allow the investigators to determine a second algorithm that would differentiate the children who were found on evaluation to be nonautistic but developmentally impaired from the children who were diagnosed with autism/PDD. Furthermore, most of the children diagnosed as having autism/PDD came from early intervention referrals and only 3 from unselected pediatric referrals (as would be expected from the sample to date of approximately 1,000 children and an estimated base rate of 1 in 300 of an unselected sample). Therefore, it was not possible to determine whether the items that characterize autism/PDD in an unselected sample are different from the items that characterize autism/PDD in a sample identified as having a language delay or nonspecific developmental issue of concern. Since the content of the items found by the DFA are entirely consistent with prior literature, this is unlikely but will be a focus of analysis in future studies.

Sensitivity, Specificity, and Predictive Power

Calculation of absolute sensitivity and specificity cannot be determined until follow-up of the entire initial sample, which has begun, is complete. However, the discriminant function analysis gives values for sensitivity and specificity consisting of the statistical significance of the DFA classification based on current diagnoses. These values are reported here, in addition to positive predictive power, which can be determined at this time. Based on the DFA classification, the M-CHAT has a sensitivity of .87, specificity of .99, positive predictive power of .80, and negative predictive power of .99.

However, another way to discuss the psychometric properties of the test is by examining sensitivity, specificity, and predictive power for both the M-CHAT 23 and the 6 best items as indicated by the DFA. The M-CHAT 23 score and the 6-item score were determined to have cutoff scores that maximized sensitivity without a large false positive rate.

Given a conservative cutoff score of any three items out of the entire checklist, 67 false positives are referred for phone follow-up and/or evaluation, and 38 out of 39 children with autism/PDD are flagged (Table V). This yields sensitivity of .97, specificity of .95, positive predictive power (PPP) of .36, and negative predictive power (NPP) of .99. However, if the phone call is considered part of the screening process (since the children who pass the phone interview are not offered an evaluation), a cutoff of three on either the original screen or phone interview yields 18 false positives, causing the sensitivity to remain at .97, specificity to rise to .99, PPP to rise to .68, and NPP to remain at .99.

When looking at the 6-item score (Table VI), a cutoff of two leads to 21 false positives (if the children called are considered false positives) and 10 false positives (if the children called are considered part of the screen). The former case would lead to sensitivity of .95, specificity of .98, PPP .64, and NPP of .99. The latter would yield sensitivity of .95, specificity of .99, PPP of .79, and NPP of .99.

Calculation of sensitivity for this initial study presumes that all children with autism/PDD would fail at least two critical or three total items on the checklist and would therefore be caught by phone interview or evaluation, or that their checklist would be flagged by the pediatrician or early intervention provider as having concerns related to autism, as happened in several cases. Children not netted by the screen or flagged by their health provider would therefore not be ascertained in the initial study, and therefore true sensitivity may be lower, but ascertaining misses is a major focus of the ongoing project.

Table V. Number of Items Failed Out of M-CHAT 23 Items

Item	No follow-up done (*n* = 1,140)	OK on phone interview (*n* = 74)	Evaluated nonautistic (*n* = 19)	Evaluated autistic (*n* = 39)
0	669	4		
1	354	6		
2	108	15	1	1
3	6	24	2	2
4	3	11	3	
5		4	2	2
6		6	2	3
7			1	4
8		2	5	2
9			1	1
10			1	1
11				5
12		1		4
13			1	6
14		1		2
15				2
16				2
17				1
18				1

Table VI. Number of Items Failed Out of Six Best Discriminating Items (DFA 6)

	No follow-up done (*n* = 1,141)	Phone screen (*n* = 74)	Evaluated nonautistic (*n* = 19)	Evaluated autistic (*n* = 39)
0	1,104	41	1	
1	37	22	8	2
2		7	5	7
3		1	2	6
4		3	2	8
5			1	9
6				7

Comparison of M-CHAT to Original CHAT

A discriminant function analysis was run using the original nine items from the CHAT. Of 1,233 nonautistic participants, 27 were misclassified as having autism/PDD (5 children who were not followed, 14 who received phone follow-up, and 8 who were evaluated and found to be nonautistic). Four children were misclassified as nonautistic when the clinical diagnosis was autism/PDD. A cutoff score of two items failed (Table VII) would lead to sensitivity of .87, specificity of .98, PPP of .63 and NPP of .99.

Clinical Data

Analysis of variance showed that the children who received diagnoses on the autism spectrum (*n* = 39)

Table VII. Number of Items Failed Out of the Original CHAT Items (CHAT 9)

Item	No follow-up done (*n* = 1,140)	Phone screen (*n* = 74)	Evaluated nonautistic (*n* = 19)	Evaluated autistic (*n* = 39)
0	1,080	41	2	1
1	57	15	5	4
2	3	13	4	6
3		2	3	5
4		1	3	6
5		2	2	8
6				5
7				4
8				
9				

Table VIII. Clinical Data for Children Evaluated

Scale[a]	Evaluated autistic *M* age = 27.6 months (n = 39)	Evaluated nonautistic *M* age = 26.7 months (n = 19)	F	df	p
Bayley MDI[b]					
M	53.46	70.53	12.08	1, 54	.002
SD	12.99	23.88			
VABS-Comm.					
M	64.46	75.79	19.96	1, 54	.001
SD	5.93	13.11			
VABS-DL					
M	68.03	75.37	7.63	1, 54	.009
SD	6.22	13.74			
VABS-Soc.					
M	67.24	78.26	16.53	1, 54	.001
SD	8.09	12.07			
VABS-Motor					
M	82.05	84.58	0.56	1, 54	.457
SD	10.27	14.72			
CARS					
M	35.43	22.84	91.20	1, 50	.001
SD	4.61	4.11			

[a] Bayley MDI = Bayley Scales of Infant Development, Mental Development Index; VABS-Comm. = Vineland Adaptive Behavior Scales, Communication Domain, Standard score; VABS-DL. = Vineland Adaptive Behavior Scales, Daily Living Domain, Standard score; VABS-Soc. = Vineland Adaptive Behavior Scales, Socialization Domain, Standard score; VABS-Motor = Vineland Adaptive Behavior Scales, Motor Domain, Standard score; CARS = Childhood Autism Rating Scale.
[b] When the Bayley MDI was found to be "below 50," a score of 49 was assigned.

were significantly more impaired on all measures used in the developmental evaluation except for the Vineland Adaptive Behavior Scales Motor Domain (Table VIII) than the children who were evaluated and found not to have diagnoses on the autism spectrum (n = 19).

DISCUSSION

The purpose of the current study was to validate the M-CHAT, a 23-item parent-report checklist, examining children's developmental milestones. The M-CHAT was found to be reliable, as was the subset of six most discriminating items. The children who were diagnosed with autism/PDD failed more items than all other children, and were significantly different on each item except enjoying being swung/bounced and walking. Analysis of variance and post-hoc Tukey's tests confirmed that all groups were significantly different from one another on all summary variables (i.e., M-CHAT 23, DFA 6, and CHAT 9), supporting the use of the M-CHAT as a screen for the early signs of autism.

The M-CHAT was able to accurately detect children at risk for autism/PDD. A discriminant function analysis correctly classified 33 of 38 autistic/PDD children and 1,188 of 1,196 children who did not have autism/PDD. The group of children who were misclassified as having probable autism/PDD when they did not consisted of 5 children who had received follow-up evaluations and non-PDD diagnoses and 3 children who had received phone follow-up but did not require evaluations, suggesting that the parents of the latter children had overreported symptoms. The children with autism/PDD who were misclassified as not having autism/PDD consisted of 3 children whose parents underreported symptoms but were flagged by early intervention providers or pediatricians for follow-up, and 2 children with relatively low checklist scores.

The nonautistic group included both normally developing children and those children who were evaluated and found to have other global delays that were not on the autism spectrum (e.g., language delays or mental retardation). The sample size was not sufficient to attempt to discriminate the children with these global delays from the children on the autism spectrum, but future research will address this question.

The DFA yielded canonical discriminant function coefficients for each item. Based on these weights, a set of optimal items was created. This set of items was composed of those items having the highest canonical discriminant function coefficients, DFA 6. This statistically derived subset of items was used to determine optimal cutoff scores on the checklist. An optimal cutoff score is defined as a score that will identify almost all children with autism/PDD, with the identification of minimal false positives. It is expected that some children who do not receive diagnoses on the autism spectrum will be identified by the checklist as needing further evaluation; it is necessary to have these false positives in order to maximize sensitivity to autism/PDD. Cutoff scores based on DFA 6 were as successful as cutoff scores using all 23 items, indicating that a smaller subset of items can successfully identify those children requiring additional assessment. In order to miss as few children as possible, a cutoff of two critical items (DFA 6) or any three total items is suggested as sufficient to warrant follow-up. These cutoffs lead to sensitivity of .87–.97, specificity of .95–.99, positive predictive power of .36–.80, and negative predictive power of .99 depending on which score is used and whether the children who received telephone follow-up are considered to be false positives or part of the sample screened but not evaluated. Based on the discriminant function analyses, the M-CHAT is slightly better than the CHAT at detecting autism/PDD without compromising the false positive rate.

It is useful to examine the individual items that serve to discriminate the children with autism/PDD from the other children in the sample. The content of the DFA 6 items may shed light on those signs of autism/PDD that are apparent in very young children. Furthermore, the symptoms that indicate the earliest signs of autism/PDD may support one or more of the current theories of the underlying disorder in autism/PDD. The six items that had the largest canonical discriminant function coefficients pertained to *joint attention* (protodeclarative pointing, following a point, and bringing objects to show parent), *social relatedness* (interest in other children and imitation), and *communication* (responding to name). These items as a group discriminated the children on the autism spectrum from the other children in the sample, indicating that failure of these behaviors to develop may be among the earliest signs of autism or PDD. It is also interesting to note that the most potent predictors of autism/PDD in these very young children are generally negative symptoms—failure of normal behavioral systems to mature—rather than positive signs (such as finger twiddling), which may appear later. It should be pointed out that several items not in the DFA 6 (such as protoimperative point; see Table IV for the percentage of children failing these items) are good discriminators; they apparently did not add unique variance to the discrimination after the best six items were accounted for.

The M-CHAT continues to be studied. A large-scale validation study is under way in parts of Connecticut, Massachusetts, Rhode Island, and northeastern New York. It is expected that several thousand children will be screened, yielding a large enough group to examine separately children referred for evaluation but found not to have autism/PDD. This study will be used to validate the M-CHAT, and confirm the subset of items best used to discriminate those children who warrant further evaluation from children developing typically. Follow-up of the initial sample at age 3–4 is also under way; this will allow better estimates of true sensitivity. It is predicted that the 23-item M-CHAT will have better sensitivity than the 9-item section of the CHAT because the age of screening is 24 months instead of 18 in order to catch children who regress between 18 and 24 months, the M-CHAT has a lower threshold for follow-up, and the use of the telephone interview as an intermediate step keeps the specificity relatively high without compromising sensitivity.

An effective checklist may greatly improve the ability of pediatricians and family practitioners to detect autistic features in very young children. As effective as a screening checklist can be, the authors caution physicians against screening solely based on parent report. Some parents are poor observers or judges of their child's behavior, particularly if they have limited exposure to other young children, and others may have difficulty answering written questions; therefore, a physician who has concerns about a child's development should refer the child for a diagnostic evaluation even without a checklist score above the cutoff.

It should also be remembered that the M-CHAT is solely for the purpose of initial screening and is not a diagnostic instrument. Children who fail the screening need comprehensive evaluations to establish developmental profiles and diagnoses and to make appropriate recommendations for intervention services.

Administering such a checklist as standard practice in 18–24 month checkups will improve the early detection of autism/PDD and facilitate an early start on effective therapies. The early discovery of autism/PDD with the M-CHAT may increase the success rate of these therapies. This may lead to an increase both in the number of children who can be integrated into regular education programs and in the experience of educational success and long-term adjustment for these children.

Psychologists have begun to document children with a history of autism/PDD who have excellent outcomes (Lovaas, 1987). Although this outcome cannot be expected for all children with autism/PDD who receive aggressive early intervention, the converse may be true: All dramatically improved children with autism/PDD may have received aggressive early intervention.

Furthermore, for those children who cannot be said to be recovered, their outcomes will nevertheless be more positive with early services. The alleviation of child and family suffering that will accompany a positive outcome is immeasurable. In terms of public policy, the financial and personal resources that public schools will save on children with autism/PDD who are recovered or substantially improved are immense. The minimal cost of using the checklist, as well as the temporary adverse effects on parents with false positives, is greatly outweighed by the benefit of early detection of autism and subsequent early intervention.[3]

One limitation of this study is that the unselected pediatric population is analyzed with the high-risk early intervention population. At this time, sample sizes are not sufficient to analyze the two samples independently. A larger sample is being collected; this will allow for separate analyses of the two populations. A second limitation is that true sensitivity and specificity cannot be determined. However, a follow-up study is under way, and longitudinal data will allow the researchers to determine sensitivity and specificity of the M-CHAT.

APPENDIX

M-CHAT

Please fill out the following about how your child **usually** is. Please try to answer every question. If the behavior is rare (e.g., you've seen it once or twice), please answer as if the child does not do it.

1. Does your child enjoy being swung, bounced on your knee, etc? Yes No
2. Does your child take an interest in other children? Yes No
3. Does your child like climbing on things, such as up stairs? Yes No
4. Does your child enjoy playing peek-a-boo/hide-and-seek? Yes No
5. Does your child ever pretend, for example, to talk on the phone or take care of dolls, or pretend other things? Yes No
6. Does your child ever use his/her index finger to point, to ask for something? Yes No
7. Does your child ever use his/her index finger to point, to indicate interest in something? Yes No
8. Can your child play properly with small toys (e.g., cars or bricks) without just mouthing, fiddling, or dropping them? Yes No
9. Does your child ever bring objects over to you (parent) to show you something? Yes No
10. Does your child look you in the eye for more than a second or two? Yes No
11. Does your child ever seem oversensitive to noise? (e.g., plugging ears) Yes No
12. Does your child smile in response to your face or your smile? Yes No
13. Does your child imitate you? (e.g., you make a face-will your child imitate it?) Yes No
14. Does your child respond to his/her name when you call? Yes No
15. If you point at a toy across the room, does your child look at it? Yes No
16. Does your child walk? Yes No
17. Does your child look at things you are looking at? Yes No
18. Does your child make unusual finger movements near his/her face? Yes No
19. Does your child try to attract your attention to his/her own activity? Yes No
20. Have you ever wondered if your child is deaf? Yes No
21. Does your child understand what people say? Yes No
22. Does your child sometimes stare at nothing or wander with no purpose? Yes No
23. Does your child look at your face to check your reaction when faced with something unfamiliar? Yes No

[3] Please contact the corresponding author for more information on receiving copies of the English or Spanish M-CHAT.

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