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Infant recall memory and communication predicts later cognitive development

Karin Strid [a,*], Tomas Tjus [a], Lars Smith [b], Andrew N. Meltzoff [c], Mikael Heimann [d,e]

[a] *Department of Psychology, Göteborg University, Box 500, SE-405 30 Göteborg, Sweden*
[b] *University of Oslo, Oslo, Norway*
[c] *University of Washington, WA, USA*
[d] *Linköping University, Linköping, Sweden*
[e] *University of Bergen, Bergen, Norway*

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Abstract

This longitudinal study investigates the relation between recall memory and communication in infancy and later cognitive development. Twenty-six typically developing Swedish children were tested during infancy for deferred imitation (memory), joint attention (JA), and requesting (nonverbal communication); they also were tested during childhood for language and cognitive competence. Results showed that infants with low performance on both deferred imitation at 9 months and joint attention at 14 months obtained a significantly lower score on a test of cognitive abilities at 4 years of age. This long-term prediction from preverbal infancy to childhood cognition is of interest both to developmental theory and to practice.

Keywords: Recall memory; Deferred imitation; Joint attention; Pre-verbal communication; Cognitive development; Prediction

The present study explores whether early indices of declarative memory and nonverbal communication skills predict performance later in childhood. In a previous study, Heimann et al. (2006) documented a relationship between recall memory at 9 months (deferred imitation), communication skills at 14 months (joint attention (JA)), and gestural communication at 14 months. The current study investigates whether a similar relationship exists between these infant skills and linguistic/cognitive performance measured long after the infancy period—at 4 years of age.

Theories of memory development originally proposed at least two major subsystems (e.g. Schacter & Moscovitch, 1984)—a procedural system available from birth and a declarative system that develops later in childhood. However, new test paradigms, such as deferred imitation, reveal that infants have some sort of nonverbal declarative memory already at 6–9 months, and possibly earlier (Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999; Hayne, Boniface, & Barr, 2000; Heimann & Nilheim, 2004; Meltzoff, 1988, 1995; Meltzoff & Moore, 1998). Such findings question the traditional view on infant memory.

In the deferred imitation procedure developed by Meltzoff (1988), children are briefly exposed to a target action; the object is then removed without letting the participants touch or play with it. This means that in order to be successful in a deferred imitation task, children need to form an internal representation of the adult's act and store that representation

* Corresponding author. Tel.: +46 31 7731685; fax: +46 31 7734628.
E-mail address: Karin.Strid@psy.gu.se (K. Strid).

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in memory. Because the participants are not allowed to handle the object prior to the delay, they cannot rely on a previously executed motor pattern in order to remember the action. After a delay, the object is re-presented and the children have the opportunity to produce the target action without any verbal cues. Tests of deferred imitation under these strict conditions have been proposed to measure preverbal representational ability (Meltzoff & Moore, 1998; Piaget, 1952), recall memory (Bauer, Wiebe, Carver, Waters, & Nelson, 2003; Carver & Bauer, 2001; Courage & Howe, 2004; Courage, Howe, & Squires, 2004; Gross, Hayne, Herbert, & Sowerby, 2001; Meltzoff, 1995), and individual differences (Heimann & Meltzoff, 1996). Additionally, by means of this procedure it has been shown that infants can also access memory of actions presented in one context and imitate those actions in another context (Barnat, Klein, & Meltzoff, 1996; Klein & Meltzoff, 1999; Learmonth, Lamberth, & Rovee-Collier, 2004).

Early nonverbal communication skills are thought to provide a foundation for later language development. Behaviors such as gaze following, reaching and pointing are capacities reflecting both communicative and social development (Baldwin, 1995; Tomasello & Farrar, 1986). Relationships between these infant nonverbal communication skills and later language development have been reported (Brooks & Meltzoff, 2005; Morales et al., 2000; Mundy, Kasari, Sigman, & Ruskin, 1995; Ulvund & Smith, 1996) and deficits in these abilities have been associated with atypical communicative development, such as in autism (Adrien, Rossignol-Deletang, Martineau, & Barthelemy, 2001; Dawson et al., 2004; Toth, Munson, Meltzoff, & Dawson, in press; Mundy, Sigman, & Kasari, 1994).

Joint attention refers to situations where a child and adult mutually focus on an object or event. This pattern of behavior typically develops at about 9-10 months of age. Joint attention is viewed as critical for social (Bakeman & Adamson, 1984; Tomasello & Farrar, 1986), communicative (Baldwin, 1995) and language development (Carpenter, Nagell, & Tomasello, 1998; Morales et al., 2000; Morales, Mundy, & Rojas, 1998; Ulvund & Smith, 1996).

An additional social communicative skill that involves two peoples' joint focus on an object is nonverbal requesting behavior, which children use to obtain a desired object. Object requesting (OR) resembles joint attention abilities but is used to regulate another person's behavior. This skill has also been shown to have specific predictive value for later expressive and receptive language (e.g. Mundy et al., 1995; Mundy, Sigman, Kasari, & Yirmiya, 1988).

Despite a global relationship between joint attention and object requesting, different processes have been suggested for behaviors emitted in *response* to another person's initiation and behaviors *initiated* by the child (Delgado, Mundy, Crowson, Markus, & Schwartz, 2002; Morales et al., 1998; Mundy et al., 1995; Ulvund & Smith, 1996). The suggestion that initiating and responding behaviors rely on differential underlying processes emerge, in part, from results showing that they predict different kinds of later language skills. Behaviors initiated by the child have been associated with expressive language skills (Mundy & Gomes, 1998) and later cognitive competencies (Smith & Ulvund, 2003) while responding to joint attention has been associated with both later expressive and receptive language skills (Morales et al., 1998; Mundy & Gomes, 1998). Moreover, there is some evidence that differential nonverbal communication skills are associated with activity in different brain areas. Initiating joint attention (IJA) has been related to activity in the frontal-cortical system, particularly in the left hemisphere, while responding to joint attention has been related to activity in the parietal lobes (Mundy, 2003; Mundy, Card, & Fox, 2000).

Recently, Heimann et al. (2006) reported a short-term longitudinal study showing that deferred imitation and joint attention both influence the development of language and communication skills in infancy. Deferred imitation at 9 months was the single strongest predictor of nonverbal communication at 14 months, but the predictive power increased substantially when deferred imitation and joint attention were used in combination. The present study is a follow-up of the same group of children at 4 years with two specific aims. The first aim was to investigate whether deferred imitation and nonverbal communication skills in infancy predict cognition and language later in childhood. This is relevant because the previous study was restricted to showing relationships within the infancy period itself (predictions from 9 to 14 months), whereas the current study investigates long-term predictions from early infancy to later childhood, across the 'language boundary' and to an age which itself has been shown to predict cognitive performance to still later ages. Such long-term prediction studies have been done using speed of processing and visual recognition memory paradigms in infancy (e.g. Bornstein & Sigman, 1986; Colombo, Shaddy, Richman, Maikranz, & Blaga, 2004; McCall & Carriger, 1993; Slater, Carrick, Bell, & Roberts, 1999), but to date no studies have involved assessments of infant recall memory. The second aim was to explore whether early recall memory and nonverbal communication skills bear a mutual or a unique relation to later ability and whether predictions to later functioning are stronger when combining measures of both cognition and communication, rather than employing one domain exclusively (as is more common in previous studies of infant–childhood predictions). This was of special interest since Heimann and Meltzoff (1996) had reported that low performance on deferred imitation tests was stable from 9 to 14 months. Thus, we wanted to observe children

who performed low on *both* deferred imitation and also social-communicative measures (joint attention or initiating object requesting (IOR)) during infancy to examine whether such children remained low on cognitive/linguistic tasks in early childhood.

1. Method

1.1. Participants

The participants were 26 typically developing 4-year-old Swedish children (16 girls; $M = 50.4$ months; S.D. = 1.47, range = 48.5–54.0). All of the children had previously been observed at approximately age 9 months ($M = 40.7$ weeks, S.D. = 1.0, range = 39–43) and 14 months ($M = 62.8$ weeks, S.D. = 2.9, range = 59–69).

According to Hollingshead's (1975) Four Factor Index of Social Status, the sample included predominately middle- and upper-class Caucasian families ($M = 43.7$; S.D. = 11.9) with a mean educational level of 5.1 (S.D. = 1.4) for mothers and 4.9 (S.D. = 1.4) for fathers. The parents occupational status was 5.7 (S.D. = 2.4) and 5.6 (S.D. = 2.0), respectively.

1.2. Procedure

The children were observed in a lab setting at the Department of Psychology, Göteborg University in Sweden at all three ages. Two experimenters assessed the children at 9 and 14 months (the last author and an undergraduate student), whereas a different experimenter who remained blind to the outcomes at the specific child level (the first author) assessed the children at 50 months.

1.2.1. Infant recall memory (9 months)

The "observation-only" deferred imitation procedure developed by Meltzoff (1988) was used. In this procedure, the children watch as an experimenter manipulates a toy in a specific way, and after a delay they are offered the object and given the opportunity to produce the action themselves. The participants are not allowed to handle the object during the presentation, ensuring that the action produced by the children is based on a representation of the action seen earlier, and not a motor memory of a habitual or already-executed action (see Meltzoff & Moore, 1998 for a discussion of this "observation only" technique).

The children saw three different objects being manipulated by the experimenter. The first object was two wooden rectangles connected with a hinge and the action was to fold them together. The second object was a black box with a black button on top and the action was to press the button, which produced a beeping sound. The third object was a plastic egg that produced a rattling sound when shaken, and shaking the egg was the target action. After a delay of approximately 10 min the children were allowed to manipulate the objects one at a time. If the target action was produced within 20 s, they received one point for each task (possible scoring from 0 to 3).

Two research assistants coded video-recordings of the task performances. The Pearson correlation assessing their agreement was $r = .93$. Cohen's kappa yielded $\kappa = .85$.

1.2.2. Infant social communication (14 months)

The Early Social Communication Scales (ESCS) (Mundy, Hogan, & Doehring, 1996) was used to measure the children's nonverbal communication at 14 months. The Early Social Communication Scales is a structured play procedure where the experimenter and the child sit at a table playing with different toys.

The situation is designed to encourage social communication behaviors from the child. The first category, joint attention, refers to behaviors indicating that the participants are sharing an experience of an object with the experimenter. Children may initiate this behavior or respond to a bid from the experimenter. The variable labelled as joint attention is created from summing the scores of initiating joint attention and responding to joint attention. Initiating joint attention is coded as a low-level (eye contact or alternated eye contact between a toy and the experimenter) or as a high-level (pointing or showing) behavior. The score used in this study is the ratio of high level to all joint attention bids that is calculated by dividing the frequency of high-level joint attention bids by the total frequency of joint attention bids. Responding to joint attention (RJA) measures children's abilities to follow the experimenters pointing to pictures in a book and to posters on the wall. This score is a ratio score, created by dividing the number of responses with the number of trials.

Table 1
Descriptive statistics for all variables ($N = 26$)

Measures	*M*	S.D.	Range
At 9 months			
Deferred imitation	1.50	.81	0–3
At 14 months			
Joint attention	.71	.26	.29–1.30
Initiating joint attention	.17	.15	.00–.67
Responding to joint attention	.54	.19	.25–.86
Object requesting (*z*-transformed)	.00	1.26	−2.87–2.28
Initiating object requesting	.36	.23	.00–.74
Responding to object requesting	2.19	1.67	0–6
At 50 months			
McCarthy Scales of Children's Abilities			
Total scale	113.81	21.82	73–146
Verbal subscale	43.69	10.14	22–64
Perceptual-performance subscale	34.85	8.08	21–51
Quantitative subscale	16.42	3.92	5–23
Memory subscale	18.88	6.58	3–32
Motor subscale	31.12	8.39	15–47
Peabody Picture Vocabulary Test	47.23	11.23	29–72

The second category, object requesting, was also divided and scored as initiating and responding behaviors. IOR was based on eye contact, reaching, giving and pointing. The first two of these measures are counted as low-level behaviors and the last two as high-level behaviors. The IOR score is also a ratio score, obtained by dividing the high-level bids with the total frequency of bids. Responding to object requesting (ROR) was scored when the child gave a toy to the experimenter subsequent to a request. In order to compute a combined variable, Object Requesting, IOR and ROR were first transformed into *z*-scores and then summarized.

Two researchers scored the tapes, the third and the last author. Scorer agreement was assessed by having a third person who was unaware of the research questions rescore 10% of the tapes. Scoring agreement, as measured by Pearson *r* was respectively, .97 for IJA, .91 for RJA, .94 for IOR and .84 for ROR.

1.2.3. Childhood cognition (50 months)

The children's cognitive ability at 50 months was assessed by using five subscales of the McCarthy Scales of Children's Abilities (McCarthy, 1972): verbal, perceptual-performance, quantitative, memory, and motor. In this study, the total raw score of all tests and the raw score on the different subscales were used.

1.2.4. Childhood language (50 months)

At 50 months the children also received the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997), which measures receptive language skills. All words in the test were first translated into Swedish.

2. Results

Table 1 presents the data from 9 to 14 months together with results at 50 months. Performance on the deferred imitation task is in line with previous results from a different Swedish sample in the same age-group (Heimann & Meltzoff, 1996). Results from the different scales on Early Social Communication Scales are also at appropriate levels (Mundy et al., 1996). The children in this study are assumed to be typically developing and the raw score is used on both the McCarthy Scales of Children's Abilities and the Peabody Picture Vocabulary Test since no normative scores exist for a Swedish population.

Table 2
Correlations between all variables ($N = 26$)

	1	2	3	4	5	6	7	8
1. Deferred imitation	–							
2. Joint attention	.08							
3. Initiating joint attention	.11	.69**						
4. Responding to joint attention	.00	.81**	.13					
5. Object requesting	−.19	.20	.15	.15				
6. Initiating object requesting	.12	.30	.33	.14	.63**			
7. Responding to object requesting	−.37¤	−.05	−.14	.05	.63**	−.21		
8. Peabody	−.08	.15	.12	.11	.46*	.55**	.04	
9. McCarthy, total scale	.35¤	.46*	.37¤	.32	.28	.42*	−.07	.46*
10. Verbal subscale	.25	.41*	.44*	.20	.21	.43*	−.16	.60**
11. Perceptual subscale	.27	.48*	.34¤	.39¤	.29	.39*	−.02	.33
12. Quantitative subscale	.27	.07	−.02	.11	.35¤	.37¤	.07	.35¤
13. Memory subscale	.27	.17	.15	.11	.21	.25	.01	.38¤
14. Motor subscale	.30	.44*	.32	.35¤	.19	.26	−.06	.36

¤ $p < .10$.
* $p < .05$.
** $p < .01$.

2.1. Correlations between infancy and later childhood

The correlation between deferred imitation (DI) at 9 months and the total score on the McCarthy at 50 months was positive but did not reach the conventional level of significance ($r = .35$, $p = .08$). However, visual inspection of the observed correlations suggests stable and similar correlations between DI and *all* McCarthy subscales, and the memory subscale had a higher correlation with DI, than with joint attention and object requesting (Table 2).

Significant positive correlations were found between JA and OR, respectively, and the McCarthy and the Peabody (Table 2). The overall joint attention measure was significantly correlated with the McCarthy total score ($r = .46$, $p < .05$) and also with the score on the verbal, perceptual, and motor subscales. A subset of joint attention, IJA, also had a positive correlation with the verbal subscale ($r = .44$, $p < .05$). OR was positively related to receptive language as measured with the Peabody ($r = .46$, $p < .05$). This relationship seems to depend primarily on IOR since the correlation between OR and receptive language decreased to $r = .18$ ($p = .38$) when partialling out IOR. IOR correlated positively with the total score on the McCarthy and also with the scores on the verbal and perceptual subscales (Table 2).

To examine in a more comprehensive manner the degree to which the infancy measures predicted performance later in childhood, simultaneous multiple regression analysis were conducted. The models included DI and one of the variables on ESCS as predictors and the total score on McCarthy or the total score on the Peabody as the outcome variable. We were unable to find any regression model combining DI and any of the social communication variables that could explain more of the variance than the already presented correlation analysis.

2.2. Individual differences

To further analyze the results, the children were divided in two groups; one with high performance in infancy and the other with low performance, based on DI and JA or DI and IOR, and with McCarthy and Peabody scores as outcome measures.

2.2.1. DI and JA

In the deferred imitation procedure, three objects were manipulated and low DI performance was defined as scoring 0 or 1 ($n = 14$) and high DI performance as scoring 2 or 3 ($n = 12$). The mean score on DI was 1.5, so the two groups

Table 3
Mean (S.D.) on outcome measures at 50 months in different groups based on performance on infant deferred imitation and joint attention

	Group			
	Low[a] ($n = 8$)	Mixed[b] ($n = 5$)	Mixed[c] ($n = 6$)	High[d] ($n = 7$)
McCarthy	95 (19)	119 (25)	126 (15)	121 (17)
Peabody	45 (14)	51 (12)	52 (9)	44 (9)

Note: Low on deferred imitation (DI) = 0–1 and high on DI = 2–3. Low on joint attention (JA) = below mean and high on JA = above mean.
[a] Low on both JA and DI.
[b] Low on JA and high on DI.
[c] High on JA and low on DI.
[d] High on both JA and DI.

were respectively below and above the mean. The group defined as low on JA included those with scores below the mean (<.71; $n = 13$) and those defined as high were the 13 children above the mean. Further, the children were divided according to their combined performance on both tests, thus making it possible to create four groups: low on both DI and JA; high on both, and the two cross-pairings.

2.2.1.1. McCarthy. The mean score on McCarthy in the different groups are presented in Table 3. The children scoring low on *both* the cognitive and social-communication infancy measures (called the 'Low' group) had a mean score on McCarthy of 95; they were statistically compared to all other children (called the 'High' group in Fig. 1). The Low group obtained a significantly lower mean as measured by McCarthy total score ($M = 95$; S.D. = 19) compared to the High group of children ($M = 122$; S.D. = 18), $t(24) = -3.54$, $p < .01$.

2.2.1.2. Peabody. The results on the Peabody for the four groups are presented in Table 3. The analysis yielded no significant result when comparing Low group ($M = 45$; S.D. = 14) with High group ($M = 48$; S.D. = 10) on Peabody, $p = .42$.

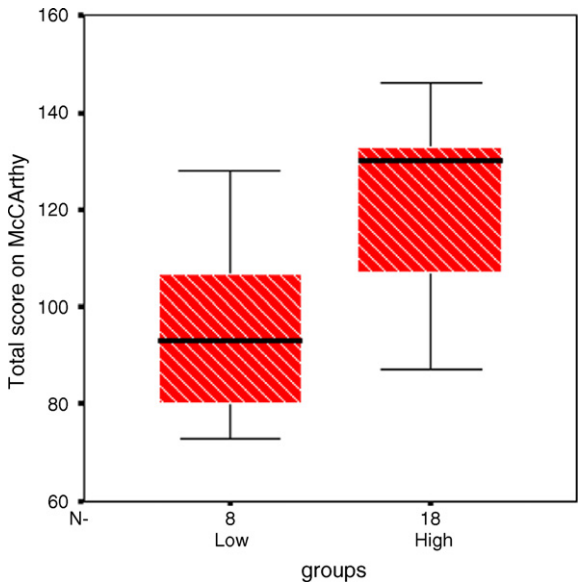

Fig. 1. McCarthy total score at 50 months as a function of two levels of responding in infancy (N = 26). Box plot shows the middle 50% of data for the Low and High groups. The bold lines show the median scores and the whiskers show the extreme points. *Note:* Low = low on deferred imitation (0–1) *and* low on joint attention (below mean). High = high on deferred imitation (2–3) *or* high on joint attention (above mean) *or* high on both variables.

Table 4
Mean (S.D.) on outcome measures at 50 months in different groups based on performance on infant deferred imitation and initiating object requesting

	Group			
	Low[a] ($n = 8$)	Mixed[b] ($n = 6$)	Mixed[c] ($n = 6$)	High[d] ($n = 6$)
McCarthy	104 (25)	117 (19)	114 (20)	123 (21)
Peabody	44 (9)	44 (9)	53 (15)	50 (11)

Note: Low on deferred imitation (DI) = 0–1 and high on DI = 2–3. Low on initiating object requesting (IOR) = below mean and High on IOR = above mean.

[a] Low on both IOR and DI.
[b] Low on IOR and high on DI.
[c] High on IOR and low on DI.
[d] High on both IOR and DI.

2.2.2. *DI and IOR*

The children were also divided according to their combined performance on DI and IOR (low = below mean, high = above mean). This resulted in four groups, i.e. low on both DI and IOR; high on both, and the two cross-pairings. The mean score on McCarthy for the four groups are presented in Table 4. No significant difference was found between the groups, $p = .12$. Nor was there a statistical difference on the Peabody as a function of group, $p = .27$.

3. Discussion

The first aim of the study was to investigate if measures of individual differences obtained in infancy predict later cognitive and language competencies; the results revealed that such a prediction existed. Nonverbal communication and recall memory in infancy displayed moderate positive correlations with cognitive abilities observed at 4 years. The lagged correlations were stronger for nonverbal communication, as compared with recall memory. Diverse nonverbal communicative measures bore significant positive relations with the McCarthy, especially behaviors that were initiated by the child. The only infant measure correlating significantly with language – as measured with the Peabody – at 4 years – was requesting.

The second aim was to investigate if the prediction to childhood cognitive performance was improved if social and cognitive measures in infancy were combined instead of being analyzed separately. The results showed a tendency towards an increased effect for one group of children. By dividing the children into different subgroups, based on their combined performance on deferred imitation and nonverbal communication in infancy, it was possible to identify one subgroup with a significantly lower performance on the McCarthy at 4 years, as compared to the other children. These were the children who scored low on *both* deferred imitation and joint attention in infancy. This group had a lower mean on the McCarthy total score as compared to the rest of the children. This finding suggests that children with a combination of poor recall memory and low nonverbal communication skills in infancy have a poorer prognosis than other children when assessed on a cognitive test administered 3–3.5 years later. The identification of the low performance group as the deviant group is in line with a previous study by Heimann and Meltzoff (1996) reporting that low performing children at 9 months tended to perform low at 14 months as well, on the deferred imitation procedure.

The strongest prediction of outcome was obtained from the two communicative behaviors that were initiated by the child: IJA and IOR. Both behaviors were positively related to general cognitive performance at 4 years and IOR was positively related to the Peabody, while the behaviors measuring infant responding to the bids of others (RJA and ROR) revealed no such significant correlations with the outcome measures. These results are compatible with other studies showing that infants' initiating of nonverbal communicative behavior predicts later cognitive competence (Smith & Ulvund, 2003; Ulvund & Smith, 1996). Studies reporting a connection between responding to joint attention and later language development (Morales et al., 1998) have mostly investigated nonverbal communication at an earlier age (6 months of age instead of 14 months), a difference that could explain the discrepancies between the present results and the results reported elsewhere. Morales et al. (2000) examined infants' responding to joint attention every second or third month between 6 and 24 months. Their results suggested that the 6-month measure of responding to joint attention was the best predictor of language development at 24 and 30 months. However, the link from responding to joint attention at 15 months did not have any predictive validity to the same outcome, which is compatible with

our current results. This suggests that the ability to respond to joint attention may be a more sensitive measure early, perhaps because it is an emerging ability at that time.

It has also been suggested that the initiating and responding aspects of communicative behaviors predict different kinds of language skills, i.e. receptive and expressive language (Mundy & Gomes, 1998; Mundy et al., 1995). Mundy and Gomes (1998) found that initiating joint attention was the best predictor of expressive language, whereas responding to joint attention predicted receptive language. The present study lends support to the former effect, in that both of the initiating behaviors were related to the verbal score on the McCarthy. However, we did not find that responding behavior predicted later receptive language. Instead, the infancy measure that was most clearly related to receptive language in this study was initiating object requesting. Previous research that has included requesting behaviors has also found this connection between initiating object requesting and receptive language (Mundy et al., 1995; Ulvund & Smith, 1996).

By investigating *both* deferred imitation and joint attention in infancy, which has not been done before, it was possible to identify a particular vulnerable subgroup of children who score low on both of these measures. It seems as if conjoint sub-optimal performance in both of these domains around the child's first birthday may capture something problematic that several years later is manifest as reduced cognitive performance. It is important to emphasize, though, that it was enough to score high on only one of the two measures (DI *or* JA) in order to achieve an average score by 4 years. The present results support the usefulness of combining early assessments of both social and cognitive abilities in order to obtain predictions to later childhood. Such a strategy might prove useful for clinical assessments of infants who are at risk and might help identify individuals who could benefit from early intervention programs.

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References

Adrien, J.-L., Rossignol-Deletang, N., Martineau, J., & Barthelemy, C. (2001). Regulation of cognitive activity and early communication development in young autistic, mentally retarded, and young normal children. *Developmental Psychobiology*, *39*, 124–136.

Bakeman, A., & Adamson, L. B. (1984). Coordinating attention to people and objects in mother–infant and peer–infant interaction. *Child Development*, *55*, 1278–1289.

Baldwin, D. A. (1995). Understanding the link between joint attention and language. In C. Moore, & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 131–158). Hillsdale, NJ: Lawrence Erlbaum Associates.

Barnat, S. B., Klein, P. J., & Meltzoff, A. N. (1996). Deferred imitation across changes in context and object: Memory and generalization in 14-month-old infants. *Infant Behavior and Development*, *19*, 241–251.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior and Development*, *19*, 159–170.

Bauer, P. J., Wiebe, S. A., Carver, L. J., Waters, J. M., & Nelson, C. A. (2003). Developments in long-term explicit memory late in the first year of life: Behavioral and electrophysiological indices. *Psychological Science*, *14*(6), 629–635.

Bornstein, M. H., & Sigman, M. D. (1986). Continuity in mental development from infancy. *Child Development*, *57*, 251–274.

Brooks, R., & Meltzoff, A. N. (2005). The development of gaze following and its relation to language. *Developmental Science*, *8*(6), 535–543.

Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, *63*(4).

Carver, L. J., & Bauer, P. J. (2001). The dawning of a past: The emergence of long-term explicit memory in infancy. *Journal of Experimental Psychology: General*, *130*(4), 726–745.

Collie, R., & Hayne, H. (1999). Deferred imitation by 6- and 9-month-old infants: More evidence for declarative memory. *Developmental Psychobiology*, *35*, 83–90.

Colombo, J., Shaddy, D., Richman, W., Maikranz, J. M., & Blaga, O. M. (2004). The developmental course of habituation in infancy and preschool outcome. *Infancy*, *5*(1), 1–38.

Courage, M. L., & Howe, M. L. (2004). Advances in early memory development research: Insights about the dark side of the moon. *Developmental Review*, *24*, 6–32.

Courage, M. L., Howe, M. L., & Squires, S. E. (2004). Individual differences in 3.5-month olds' visual attention: What do they predict at 1 year? *Infant Behavior and Development*, *27*, 19–30.

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., et al. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology*, *40*(2), 271–283.

Delgado, C. E. F., Mundy, P., Crowson, M., Markus, J., & Schwartz, H. (2002). Responding to joint attention and language development: A comparison to target location. *Journal of Speech, Language, and Hearing Research*, *45*, 715–719.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test* (3rd ed.). Circle Pines, MN: American Guidance Service.

Gross, J., Hayne, H., Herbert, J., & Sowerby, P. (2001). Measuring infant memory: Does the ruler matter? *Developmental Psychobiology*, *40*, 183–192.

Hayne, H., Boniface, J., & Barr, R. (2000). The development of declarative memory in human infants: Age-related changes in deferred imitation. *Behavioral Neuroscience*, *114*(1), 77–83.

Heimann, M., & Meltzoff, A. N. (1996). Deferred imitation in 9- and 14-month-old infants: A longitudinal study of a Swedish sample. *British Journal of Developmental Psychology*, *14*, 55–64.

Heimann, M., & Nilheim, K. (2004). 6-months olds and delayed actions: An early sign of an emerging explicit memory? *Cognition Brain and Behavior*, *VIII*(3–4), 249–254.

Heimann, M., Strid, K., Smith, L., Tjus, T., Ulvund, S. E., & Meltzoff, A. N. (2006). Exploring the relation between memory, gestural communication, and the emergence of language in infancy: A longitudinal study. *Infant and Child Development*, *15*, 233–249.

Hollingshead, A. B. (1975). *Four factor index of social status*, New Haven, CT, unpublished manuscript.

Klein, P. J., & Meltzoff, A. N. (1999). Long-term memory, forgetting, and deferred imitation in 12-month-old infants. *Developmental Science*, *2*(1), 102–113.

Learmonth, A. E., Lamberth, R., & Rovee-Collier, C. (2004). Generalization of deferred imitation during the first year of life. *Journal of Experimental Child Psychology*, *88*, 297–318.

McCall, R. B., & Carriger, M. S. (1993). A meta-analysis of infant habituation and recognition memory performance as predictors of later IQ. *Child Development*, *64*, 57–79.

McCarthy, D. (1972). *McCarthy Scales of Children's Abilities*. New York: The Psychological Corporation/Harcourt Brace Jovanovich.

Meltzoff, A. N. (1988). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development*, *59*, 217–225.

Meltzoff, A. N. (1995). What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. *Journal of Experimental Child Psychology*, *59*, 497–515.

Meltzoff, A. N., & Moore, K. M. (1998). Object representation, identity, and the paradox of early permanence: Steps toward a new framework. *Infant Behavior and Development*, *21*(2), 201–235.

Morales, M., Mundy, P., Delgado, C. E. F., Yale, M., Messinger, D., Neal, R., et al. (2000). Responding to joint attention across the 6- through 24-month age period and early language acquisition. *Journal of Applied Developmental Psychology*, *21*(3), 283–298.

Morales, M., Mundy, P., & Rojas, J. (1998). Following the direction of gaze and language development in 6-month-olds. *Infant Behavior and Development*, *21*(2), 373–377.

Mundy, P. (2003). Annotation: The neural basis of social impairments in autism: The role of the dorsal medial-frontal cortex and anterior cingulate system. *Journal of Child Psychology and Psychiatry*, *44*(6), 793–809.

Mundy, P., Card, J., & Fox, N. (2000). EEG correlates of the development of infant joint attention skills. *Developmental Psychobiology*, *36*, 325–338.

Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development*, *21*(3), 469–482.

Mundy, P., Hogan, A. E., & Doehring, P. (1996). *A preliminary manual for the abridged early social communication scales (Escs)*, unpublished manuscript.

Mundy, P., Kasari, C., Sigman, M., & Ruskin, E. (1995). Nonverbal communication and early language acquisition in children with Down syndrome and in normally developing children. *Journal of Speech, Language, and Hearing Research*, *38*(1), 157–167.

Mundy, P., Sigman, M., & Kasari, C. (1994). Joint attention, developmental level, and symtoms presentation in autism. *Development and Psychopathology*, *6*, 389–401.

Mundy, P., Sigman, M., Kasari, C., & Yirmiya, N. (1988). Nonverbal communication skills in Down syndrome children. *Child Development*, *59*, 235–249.

Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.

Schacter, D. L., & Moscovitch, M. (1984). Infants, amnesics, and dissociable memory systems. In M. Moscovitch (Ed.), *Infant memory: Its relation to normal and pathological memory in humans and other animals: Vol. 9*, (pp. 173–216). New York, NY: Plenum Press.

Slater, A., Carrick, R., Bell, C., & Roberts, E. (1999). Can measures of infant information processing predict later intellectual ability? In A. Slater, & D. Muir (Eds.), *The Blackwell reader in development psychology* (pp. 55–64). Malden, MA: Blackwell Publishers.

Smith, L., & Ulvund, S. E. (2003). The role of joint attention in later development among preterm children: Linkages between early and middle childhood. *Social Development*, *12*(2), 222–234.

Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child Development*, *57*, 1454–1463.

Toth, K., Munson, J., Meltzoff, A. N., & Dawson, G. (in press). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. Journal of Autism and Developmental Disorders.

Ulvund, S. E., & Smith, L. (1996). The predictive validity of nonverbal communicative skills in infants with perinatal hazards. *Infant Behavior and Development*, *19*, 441–449.