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# *Exploring the Relation Between Memory, Gestural Communication, and the Emergence of Language in Infancy: A Longitudinal Study*

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**The relationship between recall memory, visual recognition memory, social communication, and the emergence of language skills was measured in a longitudinal study. Thirty typically developing Swedish children were tested at 6, 9 and 14 months. The result showed that, in combination, visual recognition memory at 6 months, deferred imitation at 9 months and turn-taking skills at 14 months could explain 41% of the variance in the infants' production of communicative gestures as measured by a Swedish variant of the MacArthur Communicative Development Inventories (CDI). In this statistical model, deferred imitation stood out as the strongest predictor. Copyright © 2006 John Wiley & Sons, Ltd.**

*Key words:* imitation; memory; language

## INTRODUCTION

In classic developmental theory deferred imitation (DI) was regarded as a landmark cognitive achievement that emerged during stage 6 of the sensorimotor period, at about 18 months of age, in synchrony with a host of other cognitive and linguistic milestones (Piaget, 1962; Uzgiris & Hunt, 1975). Modern empirical research indicates that infants imitate from memory at an earlier age than previously believed (e.g. Barr, Dowden, & Hayne, 1996; Meltzoff, 1985, 1988a, 1988b, 1995) and stable individual differences in response patterns have been observed in longitudinal studies spanning from 9 to 14 months (e.g. Heimann & Meltzoff, 1996). DI is regarded as a sign of the young child's ability to form internal

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representations and is also assumed to capture early memory processing skills (Piaget, 1962).

If previous assumptions that DI taps memory and representational capacities are true, then the documentation that DI appears earlier should prompt us to systematically reassess how a whole suite of early skills emerge. The relation between DI and other early emerging cognitive processes is still an uncharted territory. In this study, we examine whether DI co-varies with other cognitive and communicative milestones in infancy such as visual recognition memory (VRM), joint attention (JA) and turn-taking skills. Furthermore, we also investigate if these measures assessed in the first year of life predict non-verbal communication skills and vocal comprehension at 14 months. There are good theoretical reasons for examining the relation among the four developmental milestones, as described below.

### *Early Memory Processes*

#### *Deferred Imitation*

DI has emerged as a widely-used paradigm for measuring non-verbal recall memory (Barr & Hayne, 2000; Meltzoff, 1985, 1988a,b, 2002; Rovee-Collier, Hayne, & Columbo, 2001). The inferences that can be drawn from the behaviour depend heavily on the test paradigm used to elicit it. In what Meltzoff (1995) called the 'observation-only design' the child is briefly exposed to an action on an object but is not allowed to handle the object during the observation. A lengthy delay is imposed (usually between 10 minutes and 24 hours), and the object then re-presented, and observers note whether or not the child imitates the action seen earlier. Successful DI in this case indicates that the response is based on the stored representation of the action the participant saw earlier, and is therefore assumed to capture recall memory processes (Meltzoff, 1995). Representation of the visual presentation is inferred because the infant was blocked from immediate imitation and habit-formation; successful imitation cannot rely on the repetition of a previously practiced behaviour in the presence of the test object, because the infant was not allowed motor involvement with the toy at Time 1. The evidence to date indicates that DI, even under these strict conditions, is a skill that is within the child's capabilities by 9 months (Collie & Hayne, 1999; Heimann & Meltzoff, 1996; Meltzoff, 1988b; Meltzoff & Moore, 2001). At that age a child is able to remember actions with several different objects after a relatively brief exposure (<20 s per action). There are reports that DI of actions with objects can be demonstrated at 6 months of age (Barr *et al.*, 1996; Barr, Vieira, & Rovee-Collier, 2001; Heimann & Nilheim, 2004) but it seems that these young infants need longer exposure and more presentations compared to the 9-month-olds and also that they remember fewer actions. Thus, for the purposes of the current study, we felt that 9 months was a better age to choose, because we wanted to measure a range of gestures using the object-based DI test paradigm and isolate stable individual differences (see Learmonth, Lamberth, & Rovee-Collier, 2004, for a fuller discussion of 6-month-olds' capacity).

#### *Visual Recognition Memory*

Visual attention and visual memory are both important information processing abilities in young infants (Fagan & Detterman, 1992). Typically, a child shows preference for new information (a novel stimulus) in comparison with familiar information. Thus novelty preference provides one way of measuring the child's VRM since the individual has to remember the familiar target in order to show a preference for the novel one (Colombo, 1993). The infant's ability to rapidly process new information has proven to be robust (Rose, Feldman, & Jankowski, 2004) and a significant predictor of later IQ (Bornstein & Sigman, 1986; McCall & Carriger, 1993; Smith, Fagan, & Ulvund, 2002; Slater, 1995) and language development (Bornstein & Sigman, 1986; Thompson, Fagan, & Fulker, 1991). VRM in early infancy (6–12 months) appears to be an especially good predictor of receptive language skills. Thompson *et al*. (1991) measured VRM in infancy and language when the participants were three years old. They found that VRM was a predictor of receptive language even when controlling for general IQ. These results suggest that the attentional and memory capacities tapped by VRM (as measured by novelty preference) might be tied to later developing communication skills.

### *Early Social and Communicative Skills*

#### *Joint Attention*

JA skills are of crucial importance for early communicative development (Baldwin, 1995; Bruner, 1983). It reflects the child's ability to coordinate attention to objects and events within an interpersonal interaction, taking into account the gaze patterns of other people (Bakeman & Adamson, 1984), and includes several behavioural skills such as gaze, point following, pointing and showing (Brooks & Meltzoff, 2002; Mundy, Hogan, & Doehring, 1996). Emerging forms of JA can be observed from about 7–8 months but it is not until about 12 months of age that the skills are observed with a relatively high frequency. The ability to engage in JA with others has important implications for later language development (Brooks & Meltzoff, 2005; Dunham & Dunham, 1995; Tomasello, 1995), and lack of this capacity seems to be implicated in certain forms of atypical development, e.g. autism (Charman, 2003; Dawson, Meltzoff, Osterling, & Rinaldi, 1998).

Before the child produces words he or she has already developed an understanding of what is involved in conversational turn-taking and how this is played out between two persons interacting (Bruner, 1983; Tomasello & Farrar, 1986). Another important aspect of the link between JA and language is that JA helps the child to connect the novel words that an adult expresses with the referent object (Baldwin, 1995; Morales *et al*., 2000). The adult can label the objects that the child shows an interest in and is motivated to learn about (Bruner, 1983; Dunham & Dunham, 1995; Mundy & Gomes, 1997).

Several findings lend support to the relation between early social communication skills and later language development. For example, Mundy, Kasari, Sigman, and Ruskin (1995) found that the child's ability to *respond* to JA bids (point following) and social interaction skills (eliciting attention or engaging in turn-taking games) was predictive of later receptive language ($r = 0.70$ and 0.56) and somewhat more weakly to expressive language ($r = 0.49$ and 0.55). The predictive relation between *responding* to JA and receptive language has been replicated by other researchers (Morales, Mundy, & Rojas, 1998; Morales *et al*., 2000; Mundy & Gomes, 1998; Ulvund & Smith, 1996). In addition, Ulvund and Smith (1996) found that children's *initiating* of JA bids at 13 months could predict both receptive and expressive language at three years, and Mundy and Gomes (1998) reported a prediction from initiating JA at 16 months to both expressive and receptive language two months later. Finally, a recent study revealed that how children responded to JA bids at 15 months relating to targets invisible to the child (when the tester points behind the child) were predictive of expressive language, tested at two years of age (Delgado *et al.*, 2002).

*Turn-Taking Skills*

Turn-taking skills are also an essential ability emerging early in life (Bruner, 1975). The earliest form of turn-taking is seen in face-to-face interaction between an infant and adult (Trevarthen, 1979). In these situations the two participants are the object of each others' attention but during the second half of the first year of life this ability matures and the infant becomes able to enter into a game-like interaction with an adult participant, where each takes turns in playing with a toy. Turn-taking in this sense can be viewed as a first step towards role-taking, a more mature capacity that evolves during the second year of life as new forms of self- and other-awareness develop (Hobson, 2002). These capacities, i.e. turn-taking and role-taking, signal a major step towards achieving a 'meeting of minds' in Bruner's sense of the term (Bruner, 1996, p. 58). Bruner (1983) argues that early turn-taking is a form of give-and-take-game that provides a setting for structured action and play, which creates predictability and well known themes that help the infant to master language. Turn-taking games 'provide a framework for early to-and-fro communications' (Hobson, 2002, p. 42).

### Research Questions

In summary, the empirical relation between VRM and language and between early social communication and later language has been fruitfully examined whereas the contribution of DI prior to 18 months was too recently discovered to generate such studies on the links to language acquisition. VRM and DI are both used as indices of memory, although a recent study comparing these two measurements as well as the conjugate reinforcement paradigm did not lend support to the hypothesis of a common underlying memory system that could explain both VRM and DI (Gross, Hayne, Herbert, & Sowerby, 2002). Instead, Gross *et al.* suggest that VRM and DI probably tap different memory processes, which makes some intuitive sense because VRM is assumed to be a reliable measure of recognition memory (the infant takes no action) whereas DI is assumed to assess recall memory processes. However, there is still a debate about how well various infant measures capture different memory processes (Bauer, 2004; Courage & Howe, 2004; de Haan & Johnson, 2003; Gross *et al.*, 2002; Howe & Courage, 2004; Howe, Courage, & Edison, 2003; Meltzoff, 1999; Moore & Meltzoff, 2004; Neisser, 2004; Rose *et al.*, 2004; Rovee-Collier *et al.*, 2001; Siegler, 2004).

The goal of this study is to investigate how DI of actions on objects in infants under 1-year of age relates to other early emerging developmental milestones. More specifically we examined the developmental relations among VRM at 6 and 9 months, DI at 9 and 14 months, and JA and turn-taking skills at 14 months. We also asked if these measures predicted or were related to gestural communication skills and vocal comprehension at 14 months. Our predictions were as follows:

1. DI, VRM, JA, and turn-taking skills will all display positive correlations with gestural communication and vocal comprehension at 14 months. We expected this association to be especially strong for VRM measured at 6 months, DI measured at 9 months, and JA and turn-taking skills measured at 14 months.

 

2. DI, VRM, JA, and turn-taking skills tap differential cognitive abilities and are expected to contribute uniquely in predicting verbal as well as non-verbal communicative development.

For theoretical and practical reasons the cognitive and social abilities that were included in the present prediction model should be helpful in understanding the roots and contributors to children's early communication.

## METHOD

### Participants

The participants were 30 infants (17 females) with a mean birth weight of 3755 grams (S.D. = 486.8), a mean Apgar score at five minutes postpartum of 9.8 (S.D. = 0.7) and a mean gestational age of 40.2 weeks (S.D. = 1.4; range 37–43). The first observation was carried out when the participants were approximately 6 months ($M = 26.7$ weeks; S.D. = 1.4), the second observation when they were 9–10 months ($M = 40.7$ weeks; S.D. = 1.3) and the third observation at age 14–15-months ($M = 62.5$ weeks; S.D. = 2.9). All children participated in all three observations but at each age some data were lost due to fussiness, illnesses or procedural errors. More precisely, we lost VRM data for nine children (three at 6 months of age and six at 9 months of age), observations on deferred imitation for one child (9 months), ESCS data for one child (14 months), and information on language and communication for three children (14 months).

### Procedure

*Deferred Imitation*

Both the 9- and 14-months observation implemented a procedure as similar to that previously used by Heimann and Meltzoff (1996) as possible.

9-*month observation*: A set of three specially constructed toys was used. They were replicas of the toys used by Meltzoff (1988b). The first object was an L-shaped wooden construction composed of a wooden rectangle connected by a hinge to a larger rectangular base. The action was to reach out and push the vertical extension over so that it lay flat on top of the base. The second object was a small black box with a black button mounted in a recess. The action demonstrated was pushing the button in order to produce a beeping sound. The third object consisted of a small plastic orange egg, and the action demonstrated was to pick up the egg and shake it.

Each action was demonstrated three times during approximately 20 s. The infants were not allowed to handle the toys during the presentation. After the actions had been presented, a memory delay of 8–10 min was imposed ($M = 8.2$ min; S.D. = 2.7; range: 5.7–17.5). During this delay the Fagan Test of Infant Intelligence was administered.

After the delay, the experimenter engaged in a short warm-up until the infants were judged to be comfortable. Next, the participants were presented the toys one by one in the same order as they had been presented. The children were videotaped to see if they would produce the target acts they had been shown. A response time of 20 s was used.

14-*month observation*: The procedure at 14-months was essentially similar to the one used at 9 months although a different set of toys was used. These three toys corresponded to the set previously found to be appropriate to this age group (Heimann & Meltzoff, 1996; Meltzoff, 1988a). The first object was a pull toy that could be pulled apart and put back together again. It consisted of two 2.5 cm wooden cubes, each with a 7.5 cm length of plastic tubing extending from it. One length of tubing was slightly narrower and fit inside the other. The action demonstrated was to pick up the object by the wooden cubes and pull outward with a very definite motion so that the toy came apart. The second object was a collapsible cup that could be folded up like a telescope by pressing downward on it. The action demonstrated was to show the cup in its unfolded position and then let the child see the experimenter place an open palm on the top surface and press it closed. The third action used two objects: one empty plastic cup and a string of beads. The action demonstrated was for the adult to pick up the beads and slowly lower them into the plastic cup.

The test procedure was similar to that described for the 9 month-old observation but a slightly longer delay was imposed ($M = 12.7$ min; S.D. $= 2.3$; range 9.8–18.5) due to the fact that the Fagan Test of Infant Intelligence takes longer to administer at this age.

*Scoring*: The scoring procedures and operational definitions from Meltzoff (1988a,b) were adopted. The videotape records of the response periods were identical to one another in the sense that all infants had a series of three response periods that were at least 20 s long. The scorers viewed an edited and digitized version of the tape that only included the response periods. The task of the scorer was to make a dichotomous yes/no code as to whether the infant produced the target action with each object. For the L-shaped toy, a 'yes' was recorded if the vertical flap was folded down with a greater arc than 45° toward the baseplate; a 'yes' for the egg was coded if the infant shook the egg, where shake was defined as a quick bi-directional movement in which the trajectory retracted itself; a 'yes' for the black box was recorded if the button was pushed so that a beeping sound could be heard. A 'yes' was coded for the pull toy if the child succeeded in separating the two parts of the toy; a 'yes' for the collapsible cup was recorded if the cup was completely folded; a 'yes' for the beads and cup was coded whenever the string of beads ended up within the cup with no more than a third of the beads hanging over the edge of the cup.

If the target action was produced during the response time, the infant received one point, resulting in a score ranging from 0 to 3 at both ages. Two different research assistants coded all deferred imitation tasks. The Pearson product–moment correlation assessing their agreement was $r = 0.93$ for the 9-month-old data and $r = 0.94$ at 14-month-old data. Cohen's kappa was also calculated and yielded $\kappa = 0.85$ at 9 months and $\kappa = 0.89$ at 14 months.

### *The Fagan Test of Infant Intelligence (FTII)*

The computer edition of the FTII (Fagan & Shepherd, 1987), which is used as a measure of infants' ability to rapidly detect new information, was administered on two different occasions (6 and 9 months). The FTII is a paired-comparison test of visual novelty preference. The participants received 10 novelty problems on each occasion and all the test items involved comparisons of digitalized face images presented on a computer monitor. Each trial consisted of a brief familiarization with one target, then pairing the briefly studied pattern with an image of a new face. Given a familiarization period that is long enough, infants typically devote a greater percentage of total fixations to the novel target. Novelty preferences were measured by differential fixation to the novel over the previously seen facial pattern. At both ages, identical targets were used, but based on past literature, the study and test times were longer at the younger age. The study time was 20 s at 6 months and 12 s at 9 months. The paired-comparison test trial was presented for 10 s at 6 months and 4–6 s at 9 months. Right-left positions of the pictures were switched midway through the test phase in order to control for side preferences.

*The Abridged Early Social Communication Scales (ESCS)*

The ESCS was administered when the participants were 14 months old. This is a 15–20 min structured assessment method designed to measure a variety of non-verbal communication skills in the 8–30 month period (Mundy *et al.*, 1996). The session was videotaped for subsequent scoring. The mean length of administration was 17.3 min (S.D. = 4.4; range: 11.0–27.5). The infant sat on his/her mother's lap and faced the experimenter across a table. A set of toys, including several small wind-ups and hand-operated mechanical toys, a comb, a pair of baby sunglasses, a hat, a ball, a toy telephone, a toy car, a doll, and a picture book, was used as targets. Some of the toys were placed in view of the child but out of its reach. Posters were placed on the walls 90° to the child's left and right, and behind the child. The experimenter presented and activated the toys one at a time. Intermittently, he pointed and looked at a wall poster (trials to the left, right and behind the child were conducted in each set of observations); or he made requests (e.g. 'give it to me'). The experimenter also presented the participants with social games and turn-taking opportunities.

The ESCS measures the participants' behaviour in three major areas: Joint Attention, Requesting and Social Interaction (Mundy *et al.*, 1996). The first and second of these scales involve the coordination of attention relative to objects and events. The third, the Social Interaction scale, assesses skills related to turn-taking and interaction maintenance, but not necessarily coordination of attention to objects and events. For each of the three major areas a child may either initiate a bid for attention or respond to a request from the experimenter, creating a total of six scales: Initiating Joint Attention (IJA), Responding to Joint Attention (RJA), Initiating Object Requesting (IOR), Responding to Requesting (RR), Initiating Social Interaction (ISI), and Responding to Social Interaction (RSI). Based on previous research, the scales of primary interest for this study were Joint Attention (IJA and RJA) and Initiating Social Interaction (ISI; especially turn-taking, which is part of the scale).

*Scoring*: The scoring system, which was used in the current study, is based on frequencies of behaviours and ratio scores (Mundy *et al.*, 1996). ESCS provides an opportunity to calculate a separate ratio score for high-level behaviours on the IJA scale. The items that are scored as low-level behaviours on this scale occur when the child makes eye contact with the tester while he/she at the same time is touching a toy or alternates a look between an active toy and the tester. The behaviours that are scored as high-level take place when the child points to something before the tester points or shows a toy to the tester. These high-level behaviours are developmentally more advanced and thus reveal the communicative intents of a child more easily (Mundy & Gomes, 1998). It has been argued that behaviour on a lower level might be too rudimentary to involve true joint attention (Tomasello, 1995). In the current study, a high-level ratio score was computed for the IJA scale by dividing the frequency of high-level joint attention bids by the total frequency of joint attention bids. Ratio scores (dividing the number of correct responses with the total number of trials) were also calculated for the RJA scale. Behaviours scored include occasions when the child follows the tester's pointing, either to a picture in a book (6 trials) or to a poster on the wall (6 trials). Turn-taking is scored whenever the child initiates a turn-taking sequence with the tester. The child is given two different toys (a car and a ball) and is encouraged (with gestures) to roll the toy to the tester (obtaining a score of 0–2).

The first author, who also scored part of the tapes together with the fourth author, administered the ESCS. In order to further assess scoring reliability, a graduate student assistant who remained unaware of the research questions also scored the tapes. Scoring agreement obtained by rescoring three randomly-chosen tapes (10% of the sample) was as follows: Joint Attention (IJA and RJA) $r = 0.94$ and Social Interaction (ISI and RSI) $r = 0.75$.

*Communicative Development Inventories (SECDI)*

A Swedish version of the MacArthur Communicative Development Inventories (CDI) was used in order to assess the children's communicative skills at 14 months. This Swedish Early Communicative Development Inventories, SECDI (Eriksson & Berglund, 1999), is based on parental reports and consists of two versions. The age-appropriate inventory used in this study comprises 'words and gestures' (SECDI-w&g) and is primarily designed for children 8–16 months of age. The complete inventory consists of five parts, two of which were used in the present study: Vocal comprehension (out of 382 words) and Gestures Produced.

*Statistical Analysis*

Similar statistical effects were investigated using parametric ($t$-tests and ANOVAs) and non-parametric (Mann–Whitney or Kruskal–Wallis) methods. For ease of exposition, only the former tests are reported, because there were very few cases of divergence between them.

## RESULTS

Preliminary analyses revealed that the infants' gender and the mothers' socioeconomic status were not significantly related to the SECDI outcome measures in this sample. These variables were excluded from the subsequent analyses.

The descriptive statistics for the predictor and outcome variables were computed and are presented in Table 1. The mean VRM scores of percent looking at

Table 1. Descriptive statistics for predictors and outcomes

| | *M* | S.D. | Range |
|---|---|---|---|
| *Predictor variables* | | | |
| Visual Recognition Memory 6m (%) | 54.81 | 3.46 | 47.79–60.78 |
| Visual Recognition Memory 9m (%) | 57.04 | 4.31 | 47.82–62.77 |
| Deferred Imitation 9m (correct *R*) | 1.59 | 0.83 | 0–3 |
| Deferred Imitation 14m (correct *R*) | 1.97 | 0.72 | 1–3 |
| IJA Ratio Score 14m | 0.17 | 0.16 | 0.00–0.67 |
| RJA Ratio Score 14m | 0.53 | 0.19 | 0.25–0.86 |
| Number of Initiating turn-taking 14m | 0.45 | 0.69 | 0–2 |
| *Outcome variables* | | | |
| Vocal Comprehension (SECDI) 14m | 119.59 | 77.96 | 8–283 |
| Gestures Produced (SECDI) 14m | 40.07 | 10.51 | 15–61 |

 

the novel targets was 54.8% at 6 months and 57.0% at 9 months which are slightly lower than those usually reported. For example, Fagan and Detterman's (1992) norms for the FTII list a mean novelty preference of about 60%. Nonetheless, the range of VRM scores in the present sample (47.8–60.8%, and 47.8–62.8%) was quite reasonable for correlational analysis. As stated in the method section, ESCS consists of six different scales. Three of them, high-level Initiating Joint Attention, Responding to Joint Attention and Initiating Social Interaction (e.g. turn-taking) were used in this study and the other ESCS measures were excluded.

### Gestures Produced

*Correlations*

In order to examine the hypothesized associations between VRM, DI, and social communication in infancy and the communicative level on SECDI at 14 months of age, a number of pairwise correlation analyses were performed. The results of these analyses, when Gesture Production was the outcome, are listed in Table 2. As expected, VRM at 6 months was positively and significantly related to the production of gestures at 14 months of age ($r = 0.46$, $p < 0.05$). However, VRM at 9 months bore a negative, but not significant, relation to the production of gestures at 14 months ($r = -0.30$, $p > 0.10$).

The association between DI at 9 months and the production of gestures at 14 months was $r = 0.35$, $p = 0.08$, Table 2. The concurrent relation between DI and gestures, both assessed at 14 months of age was also positive, but did not reach statistical significance ($r = 0.24$, $p > 0.10$). Both the ratio score of high-level IJA and the number of times the participants initiated turn-taking (both measured at 14 months) bore a positive and significant concurrent relation to the production of gestures at 14 months ($r = 0.46$, $p < 0.05$, $r = 0.47$, $p < 0.05$, respectively). In contrast, RJA (ratio of correct responding to all bids) did not yield a significant positive correlation with Gesture Production (Table 2).

Table 2. Correlations ($r$) between predictors and SECDI at 14 months

| | $r$ | $p$ | $N$ |
|---|---|---|---|
| | Gestures produced at 14 months | | |
| Visual Recognition Memory (6m) | 0.46 | 0.03 | 24 |
| Visual Recognition Memory (9m) | −0.30 | 0.18 | 22 |
| Deferred Imitation (9m) | 0.35 | 0.08 | 26 |
| Deferred Imitation (14m) | 0.24 | 0.23 | 27 |
| Initiating Joint Attention[a] (14m) | 0.46 | 0.02 | 27 |
| Responding to Joint Attention[a] (14m) | 0.08 | 0.69 | 27 |
| Initiating turn-taking (14m) | 0.47 | 0.01 | 27 |
| | Vocal Comprehension at 14 months | | |
| Visual Recognition Memory (6m) | 0.38 | 0.06 | 24 |
| Visual Recognition Memory (9m) | 0.09 | 0.68 | 22 |
| Deferred Imitation (9m) | 0.29 | 0.15 | 26 |
| Deferred Imitation (14m) | 0.57 | 0.00 | 27 |
| Initiating Joint Attention[a] (14m) | 0.24 | 0.24 | 27 |
| Responding to Joint Attention[a] (14m) | 0.29 | 0.14 | 27 |
| Initiating turn-taking (14m) | 0.14 | 0.49 | 27 |

[a] Ratio scores.

 

*Multiple Regression Models*

Concerning the outcome measures, the number of words the children understood and the total number of gestures that they used was highly related ($r = 0.64$, $p < 0.001$). We turn first to the predictors of Gestures Produced. It was hypothesized that the cognitive and social predictors tap different abilities and therefore make unique contributions to the outcome variable. A regression analysis was conducted to address this issue. The predictors constituting this model should all bear a positive contribution to the outcome variable, and the model should also include one variable at each age level. Following these principles, the regression model included VRM at 6 months, DI at 9 months and turn-taking at 14 months as the independent variables, and Gesture Production as the dependent variable. Correlations between the variables constituting the models are listed in Table 3. In this analysis the multiple correlation coefficient ($r$) and the coefficient of determination ($R^2$) were 0.70 and 0.49, respectively (Table 4). Adjusted for small sample size, $R^2$ was 0.41. This adjusted $R^2$ indicates that approximately 40% of the variance in the criterion variable was attributable to the variance in the combined predictor variables. The multiple $R$ was statistically significant. The probability that $r = 0.70$ would have occurred by chance was less than 0.01 if the null hypothesis were true ($F = 6.14$; $p < 0.01$). In determining the relative importance of the predictor variables, one notices that the second predictor variable, deferred imitation, was a significant contributor to the regression when used in combination with the other two predictor variables ($t = 2.84$, $p < 0.05$). Similarly, the $t$ values for the third predictor variables indicate that turn-taking was a marginally significant contributor ($t = 2,04$, $p < 0.06$), but that VRM was not. When all the variables were included in a stepwise regression analysis, VRM did not make a contribution to the model and was excluded.

A second regression analysis used VRM at 6 months, DI at 9 months in combination with IJA at 14 months. This analysis resulted in $R^2 = 0.47$ (adjusted for small samples $R^2 = 0.38$). Thus, this model explained almost as much of the variance as the first model but was considered less fertile since none of the predictor variables contributed uniquely to the model.

Table 3. Correlations ($r$) among variables constituting the regression model (Gestures Produced at 14 months)

| | 2 | 3 | 4 |
|---|---|---|---|
| 1. Visual Recognition Memory (6m) | 0.48 | 0.29 | 0.42 |
| 2. Deferred Imitation (9m) | | 0.10 | 0.60 |
| 3. Initiating turn-taking (14m) | | | 0.42 |
| 4. Gestures Produced (14m) | | | |

*Note*: $N = 23$.

Table 4. Summary of standard (simultaneous) regression analysis for variables predicting Gestures Produced at 14 months

| Variable | $B$ | S.E. $B$ | $\beta$ | $p$ |
|---|---|---|---|---|
| Visual Recognition Memory (6m) | 0.19 | 0.53 | 0.07 | 0.73 |
| Deferred Imitation (9m) | 5.95 | 2.10 | 0.53 | 0.01 |
| Initiating turn-taking (14m) | 4.54 | 2.23 | 0.35 | 0.06 |

*Note*: $R^2 = 0.49$, adjusted $R^2 = 0.41$ ($p < 0.01$), $N$=23.

 

### *Vocal Comprehension*

*Correlations*

Pearson correlation analyses were also conducted to examine the hypothesized associations between VRM, DI, and social communication to vocal comprehension at 14 months. The results of these analyses are listed in Table 2. As expected, VRM at 6 months was positively related to outcome at 14 months, but the correlation did not reach statistical significance ($r = 0.38$, $p = 0.06$). VRM at 9 months was unrelated to vocal comprehension at 14 months ($r = 0.09$). DI at 9 months was positively related to vocal comprehension at 14 months, but not significantly so ($r = 0.29$, $p > 0.10$). The correlation between DI at 14 months and concurrent vocal comprehension was positive and significant ($r = 0.57$, $p < 0.01$).

As shown in Table 2, the three measures of social communication were all positively related to vocal comprehension, although none of them reached statistical significance.

*Multiple Regression Models*

Following the same principles as in the model above, the regression model when Vocal Comprehension was outcome included VRM at 6 months, DI at 9 months and RJA at 14 months as the independent variables and Vocal Comprehension as the dependent measure. Correlations between these variables are listed in Table 5. In this analysis the multiple correlation coefficient ($r$) and the coefficient of determination ($R^2$) were 0.46 and 0.21, respectively (Table 6). Adjusted for small sample size, $R^2$ was 0.09. The multiple $R$ was not statistically significant. Testing the same model but substituting IJA or turn-taking for RJA did not improve the prediction model ($R^2 = 0.20$ and 0.18, respectively). It was however possible to find a significant model predicting Vocal Comprehension. This was achieved when DI at 9 months was dropped while DI at 14 months was added. Thus, this regression model uses two predictors at 14 months ($R^2 = 0.34$ adjusted for small sample size; $p < 0.01$; see Tables 7 and 8) and the only single significant variable was DI at 14 months. This means that, out of all of the infant

Table 5. Correlations ($r$) among variables constituting the regression model (Vocal Comprehension at 14 months)

| | 2 | 3 | 4 |
|---|---|---|---|
| 1. Visual Recognition Memory (6m) | 0.48 | 0.21 | 0.34 |
| 2. Deferred Imitation (9m) | | 0.15 | 0.38 |
| 3. Responding to Joint Attention (14m) | | | 0.27 |
| 4. Vocal Comprehension (14m) | | | |

*Note*: $N = 23$.

Table 6. Summary of standard (simultaneous) regression analysis for variables predicting Vocal Comprehension at 14 months

| Variable | $B$ | S.E. $B$ | $\beta$ | $p$ |
|---|---|---|---|---|
| Visual Recognition Memory (6m) | 4.02 | 5.38 | 0.18 | 0.46 |
| Deferred Imitation (9m) | 25.28 | 21.97 | 0.27 | 0.26 |
| Responding to Joint Attention (14m) | 84.97 | 93.50 | 0.19 | 0.38 |

*Note*: $R^2 = 0.21$, adjusted $R^2 = 0.09$ ($p < 0.20$), $N = 23$.

 

Table 7. Correlations ($r$) among variables constituting the regression model (Vocal Comprehension at 14 months)

| | 2 | 3 | 4 |
|---|---|---|---|
| 1. Visual Recognition Memory (6m) | 0.43 | 0.24 | 0.38 |
| 2. Deferred Imitation (14m) | | 0.30 | 0.64 |
| 3. Responding to Joint Attention (14m) | | | 0.30 |
| 4. Vocal Comprehension (14m) | | | |

*Note*: $N = 24$.

Table 8. Summary of standard (simultaneous) regression analysis for variables predicting Vocal Comprehension at 14 months

| Variable | $B$ | $SE\ B$ | $\beta$ | $p$ |
|---|---|---|---|---|
| Visual Recognition Memory (6m) | 2.84 | 4.39 | 0.12 | 0.52 |
| Deferred Imitation (14m) | 64.66 | 22.58 | 0.55 | 0.01 |
| Responding to Joint Attention (14m) | 49.76 | 82.01 | 0.11 | 0.53 |

*Note*: $R^2 = 0.43$, adjusted $R^2 = 0.34$ ($p < 0.01$), $N = 24$.

variables, DI measured at 14 months was the only significant predictor of Vocal Comprehension.

## DISCUSSION

Taken together these results suggest that early deferred imitation, visual recognition memory, and social communication skills are related to the emergence of more sophisticated communication skills at 14 months. This was especially true for Gestures Produced as measured by the Swedish version of the MacArthur CDI: All predictor variables (VRM, DI and turn-taking) correlated significantly with this scale. Together they explained more than 40% of the observed variance in Gestures Produced. In contrast, only DI at 14 months had significant input to the prediction of Vocal Comprehension. Perhaps of most interest is the fact that DI at 9 months was the single strongest predictor to Gestures Produced at 14 months while not contributing at all to Vocal Comprehension. Both memory capacity and representational ability could be responsible for the link between DI and later communicative skills. In order to use words or gestures in communication, the child needs to learn them from someone else, store their meaning in memory and use it in a different situation at a different time. These elements are basic parts of the DI procedure, which could be one possible explanation for the relation between them. However, further studies are needed in order to understand why DI relates to gestures when measured before the child's first birthday and to verbal language when observed after.

At 6 months the infants' VRM, as measured by novelty preference, was related to the total number of Gestures Produced at 14 months, and for Vocal Comprehension at 14 months there was a similar trend. This is consistent with previous findings and strengthens the role of the attentional, information processing, and memory skills involved in VRM as a useful early predictor of language. We assumed that VRM at 6 months would have a strong relation with language, since this is the age when novelty for facial patterns is emerging. It was surprising that VRM three months later, at 9 months of age, did not have a significant correlation with the same outcome measure. McCall and Carriger (1993) reviewed the published studies involving VRM and language between 1974 and 1989. They analysed how the predictive relation of habituation and recognition memory to later IQ and language differ according to the participants' age. McCall and Carriger reported that the predicted correlations for later IQ or language were higher at 6 months ($r = 0.46$) than at 9 months ($r = 0.17$). The reason, they argued, might be that the child needs a more cognitively challenging task to tap advanced information processing capacities and that the Fagan-like VRM tasks are more appropriately challenging at 6 months of age. The results from this study are highly consistent with such an argument. This opens the possibility that other measures of recognition memory may be discovered in the future for older infants that have predictive value for language measures.

DI displayed a strong and significant correlation with vocal comprehension when measured concurrently at 14 months. However, a similar correlation between DI at 9 months and later vocal comprehension did not reach significance. At 9 months of age DI, together with VRM and turn-taking, predicted more than 40% of variance in the Communicative Gestures Produced at 14 months. Together these results strongly suggest that DI at young ages have predictive value for later communicative/language development. The regression models evidenced that it was DI that had the strongest predictive validity. The correlation between VRM and gesture production actually disappeared when controlling for DI. The rather high correlation between DI and VRM ($r = 0.48$) suggests that memory processes are an important underlying component of later communicative development.

The three ESCS measures used in this study all displayed positive correlations with the two SECDI scales Gestures Produced and Vocal Comprehension. IJA and turn-taking (from the Initiating Social Interaction scale) were most strongly and significantly related to Gestures Produced as opposed to Vocal Comprehension. Moreover, Responding to Joint Attention was not significantly correlated with either the production of gestures or vocal comprehension.

Thus a stronger association was observed between social behaviours measured on the ESCS and Gesture Produced than between ESCS and Vocal Comprehension. Two of the measures reflect the child's willingness to *initiate* a social communication with another person, whereas one of the ESCS variables measures the willingness to *respond*. It has been suggested that initiating joint attention and responding to joint attention reflect different processes (Morales *et al*., 2000). In the present study, IJA and turn-taking correlated with the production of gestures while RJA had a positive correlation with vocal comprehension. To initiate joint attention is probably a more active behaviour on the part of the child than to respond, and the production of gestures at this age may also constitute a more active form of communication as compared to vocal comprehension. Turn-taking ability was a useful measure in the regression model, predicting Gesture Produced, together with VRM and DI. This measure refers to behaviours that do not necessarily involve attention to an object but rather a face-to-face interaction with another person. The turn-taking measure resembles in part the SECDI gesture scale since this also includes social games and routines. The two social communicative measures—IJA and turn-taking—were not correlated although they both contributed as predictors. It is conceivable that these measures tap different communicative abilities or different aspects of the infant's early communicative competence.

 

As already stated, VRM at 6 months, DI at 9 months and turn-taking skills at 14 months explained a substantial part (over 40%) of Gesture Production outcome at 14 months. Indeed, none of the measures could independently explain more than approximately 25% of the variance in Gesture Produced. Thus, an early sign of visual recognition memory plus an early sign of recall memory combined with a concurrent social communicative ability, have been demonstrated to explain a large part of the variability in communication level as observed at 14 months. Consistent with our initial hypothesis, DI and turn-taking each made a unique contribution to the prediction model. The results demonstrates that different abilities may be important at different periods of time during infancy.

It is of considerable interest to note that DI measured at 9 months stands out as the single strongest predictor of Communicative Gesture Production at 14 months. Until very recently DI was not even considered possible at 9 months of age, and so no one had yet examined correlations between this early cognitive skill and the later emergence of communicative gestures. The present study suggests that measures of DI should be as seriously considered as two more standard measures in infancy, novelty preference and social communication skills, in the attempt to predict or understand communicative and language development. But before any definitive suggestions can be made these results need to be confirmed in replication studies.

In spite of the relatively small sample, this study has provided the first preliminary results to date showing that DI obtained well before the child's first birthday is related to communication skills measured five months later. Combined with an established early memory measure (VRM) and concurrent dyadic competence (turn-taking skills) DI predicted the production of gestures. The results also indicate that among these three predictor variables, DI stood out as the strongest. The current regression model underscores the value of a multifaceted and developmental approach: (a) different abilities are important at different ages and (b) both DI and turn-taking make unique contributions to the prediction. DI taps early recall memory whereas turn-taking reflects a relational/social way of communicating. It has long been a desire of developmental scientists to explain the roots of the communicative-linguistic abilities that flower in the second half year of life. The present results suggest that predicting language outcomes will be enhanced if researchers simultaneously take into account both cognitive *and* social abilities.

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