

## A Cognitive Approach to the Development of Early Language

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A controversial issue in the field of language development is whether language emergence and growth is dependent solely on processes specifically tied to language or could also depend on basic cognitive processes that affect all aspects of cognitive competence (domain-general processes). The present article examines this issue using a large battery of infant information-processing measures of memory, representational competence, processing speed, and attention, many of which have been shown to predict general cognition in a cohort of full-terms and preterms. Results showed that various aspects of infant memory and representational competence (a) related to language at both 12 and 36 months, (b) predicted similarly for the two groups, and (c) predicted 36-month language, independently of birth status, 12-month language, and the 12-month Bayley Mental Development Index. Additionally, the results established predictive validity for the MacArthur 12-month language measure. These findings support a domain-general view of language.

Young children learn language at an incredible pace. Infants show a bias for listening to speech from birth (Vouloumanos & Werker, 2007), match phonetic information in the face and voice by 4.5 months (Kuhl & Meltzoff, 1982; Patterson & Werker, 2003), and use transitional probabilities to segment the speech stream by 8 months (Saffran, Aslin, & Newport, 1996). The first signs of word comprehension appear soon after, around 9 months, with the spontaneous production of words starting around 12–13 months (Fenson et al., 1994). Although word growth is initially slow, there is a spurt around 16–18 months, and by 3 years, children typically have a vocabulary of hundreds of words.

It is a challenge to understand how infants master language so quickly. Although it has long been clear that language learning depends on social interactions (Mundy, Seibert, Hogan, & Fagan, 1983), as well as phonological and lexical coding, more recently, it has been suggested that language also depends on domain-general cognitive processes (Bloom, 1993; Hollich, Hirsh-Pasek, & Golinkoff, 2000). In this view, rather than being a completely modular system involving processes and rules specific to language alone (Pinker, 1994), language is seen as drawing on

a set of processes shared with other realms of cognition (Bates, 1994; Fernald, Perfors, & Marchman, 2006; Hollich et al., 2000). Although the literature with school-aged children and adults has begun to provide evidence of the contribution of processes such as attention, learning, and memory to language skills (Baddeley, Gathercole, & Papagno, 1998; Cowan, Nugent, Elliot, Ponomarev, & Sauls, 1999), there is scant information on the role of these processes in the emergence of language.

Meanwhile, work on infant cognition has begun to show that information processing abilities can be isolated in the 1st year of life and that they are linked to later general cognitive outcomes. For example, using measures from a battery of infant tasks assessing performance in four specific areas—memory, processing speed, attention, and representational competence—Rose and her colleagues identified basic abilities in the 1st year of life that are structurally distinct (Rose, Feldman, & Jankowski, 2004, 2005b), sensitive to deficits associated with preterm birth, a risk factor for later cognitive deficits (Rose, Feldman, & Jankowski, 2001a, 2002, 2005a), and related to later mental ability (Rose, Feldman, Jankowski, & Van Rossem, 2005, 2008). Moreover, they were able to model the pathways by which the infant cognitive abilities

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influenced each other and subsequent mental development (Rose et al., 2005, 2008).

If the domain-general theory holds, it would be expected that the same information processing measures would also contribute to the emergence and development of language. Below we provide a brief overview of the measures in each area and their relevance to language.

### *Memory*

Memory is vital for accruing all forms of knowledge, including language. While there are multiple memory systems with diverse time courses and diverse neurological substrates (Nelson, 1995), our battery included four types of visual memory (all dependent on the medial temporal lobe): immediate visual recognition memory, delayed recognition, short-term memory, and recall.

Infants who have better memory can be viewed as more adept at encoding, storing, consolidating, and retrieving representations of objects and events. These skills are fundamental to language development. Infants with better recognition and recall memory are likely to produce memory traces that are highly discriminable and persistent and, as a consequence, more readily available to be linked to their verbal referents. By contrast, infants with limitations in recognition and recall are likely to need more repetitions of these linkages to reach the same level of proficiency, resulting in slower rates of vocabulary growth. Similarly, infants with better short-term memory will be able to hold more information in mind and thus have an advantage in segmenting the auditory stream into meaningful units (words and phrases).

Studies concerned with the relation of infant memory to language have focused almost exclusively on visual recognition memory, and this type of memory has been shown to correlate with assessments of language proficiency from toddlerhood to adulthood. In particular, better visual recognition memory is related to better comprehension and gestural communication in toddlers (Heimann et al., 2006), better receptive and expressive language in the preschool years (Fagan & McGrath, 1981; Rose, Feldman, Wallace, & Cohen, 1991; Thompson, Fagan, & Fulker, 1991) and the school years (Fagan & Detterman, 1992; Rose & Feldman, 1995; Rose, Feldman, & Wallace, 1992), and better comprehension in adults (Fagan, Holland, & Wheeler, 2007). Additionally, impaired visual recognition memory has been found in infants with a family history of specific language impairment (Choudbury, Leppanen, Leevers, & Benasich, 2007).

Studies examining the relation of other forms of infant memory to early language are rare. Only one study we know of examined the relation of infant recall to language proficiency. That study found that recall memory, assessed at 9 months, was related to gestural communication (but not comprehension) at 14 months (Heimann et al., 2006). Although studies with older children have consistently found that both short-term and working memory are also related to language (Cowan et al., 1999; Gathercole & Pickering, 2000; Gathercole, Willis, Emslie, & Baddeley, 1992), to our knowledge, there are no infant studies in this area.

### *Processing Speed*

Processing speed is often considered to be the central limiting factor accounting for performance differences on a wide variety of cognitive tasks in childhood and adolescence (Hale, 1990; Kail, 1991). Faster processing speed can influence language development directly, by allowing operations to be performed more rapidly, and indirectly, by increasing the functional capacity of working memory. It is reasonable to assume that limitations in processing speed would make it difficult to keep up with the audio stream and thus interfere with building up lexical and grammatical representations essential for language development (Leonard et al., 2007).

Two types of speed were included in our infant battery: psychomotor speed and encoding speed. Psychomotor speed, which captures the ocular speed or reaction time (RT) of orienting to predictable and unpredictable events, was assessed using the visual expectation paradigm (VEXp; Canfield, Smith, Breznyak, & Snow, 1997; Haith, Hazan, & Goodman, 1988; Reznick, Chawarska, & Betts, 2000; Rose, Feldman, Jankowski, & Caro, 2002; Wentworth & Haith, 1992). Encoding speed, which captures the rapidity of assimilating information about a target, was assessed using the "continuous familiarization" task (Rose, Feldman, & Jankowski, 2002; Rose, Feldman, Jankowski, & Caro, 2002; Rose, Futterweit, & Jankowski, 1999).

Although it has been known for some time that rapid auditory processing is impaired in school-aged children with specific language impairments (Miller, Kail, & Leonard, 2001; Tallal, Stark, & Mellitis, 1985) and in infants with a family history of language impairment (Choudbury et al., 2007), little is known about the role of processing speed in infants' acquisition of language (but see Fernald et al., 2006).

### *Attention*

Attention is multifaceted and often characterized as including the ability to engage, maintain,

disengage, and shift focus (Mirsky, 1996; Posner & Petersen, 1990; Posner & Raichle, 1994). Infants with better attention are likely to acquire language more quickly because they would be better able to follow others' gazes, engage in bouts of joint attention, and track the referents of others' communications. These attentional skills in a social context might lead to larger receptive and productive vocabularies.

Two interrelated aspects, having to do with the way infants distribute or deploy attention, were included in the present battery: look duration and shift rate. Short looks and more frequent shifts of gaze are thought to reflect more rapid encoding and/or greater facility at disengaging attention (Colombo, 1993; Colombo, Mitchell, Coldren, & Freeseaman, 1991; Freeseaman, Colombo, & Coldren, 1993; Frick, Colombo, & Saxon, 1999; Jacobson, Jacobson, Sokol, Martier, & Ager, 1993). Higher shift rates are believed to reflect, additionally, a more active comparison of targets (Rose, Feldman, McCarton, & Wolfson, 1988; Rose et al., 2001a; Ruff, 1975). Both change dramatically over the 1st year of life with look durations becoming shorter and shift rates becoming faster (Colombo, Mitchell, O'Brien, & Horowitz, 1987; Colombo, Shaddy, Richman, Maikranz, & Blaga, 2004; Frick et al., 1999; Rose et al., 2001a).

Two recent studies have examined the relation of infant attention to language and their results have been contradictory. One found better language to be associated with decreasing look durations (Colombo et al., 2004; Colombo et al., in press), while the other found better language to be associated with longer look durations (Arterberry, Midgett, Putnick, & Bornstein, 2007).

### *Representational Competence*

We have used the term "representational competence" to refer to the ability to extract commonalities from experiences and represent them abstractly or symbolically. Representational and symbolic abilities have long been considered necessary for language development, where arbitrary relations must be established between words and their referents.

Our infant battery included four tasks thought to assess representational ability: tactual–visual cross-modal transfer, where information about shape is extracted from one modality and applied to another (Rose & Feldman, 1995; Rose, Feldman, Futterweit, & Jankowski, 1997; Rose, Feldman, & Wallace, 1988); anticipation of future events (from the VExP task), which necessitates abstracting a rule governing changes in location from a fast-paced sequence of pictures (Canfield et al., 1997; Rose, Feldman, Jan-

kowski, & Caro, 2002); object permanence, which involves keeping in mind the existence and location of a hidden object (Piaget, 1950); and symbolic play, which requires using one object to represent another in pretense (e.g., "drinking" from a block of wood, where the block represents a "cup"; Damast, Tamis-LeMonda, & Bornstein, 1996; Tamis-LeMonda & Bornstein, 1990). All have in common the abstract representation of things (or locations) that are not immediately available to the senses.

There is a considerable amount of work relating symbolic play (Fein, 1981; McCune-Nicolich, 1981; Tamis-LeMonda & Bornstein, 1990; Tamis-LeMonda, Damast, & Bornstein, 1994; Ungerer & Sigman, 1984) and object permanence (Corrigan, 1978; Tomasello & Farrar, 1984) to language proficiency. However, less is known about the relation of the other two aspects of infant representational competence to language. Anticipations have not been studied at all in this regard, and, aside from two reports from a single cohort (Rose & Feldman, 1995; Rose et al., 1992), little work has been done with respect to tactual–visual cross-modal transfer. A possible mechanism explaining the connection between tactual–visual transfer and language is offered by the recent discovery of cortical multisensory neurons, which respond to sight, sound, and touch (Wallace, Carriere, Perrault, Vaughan, & Stein, 2006; Wallace, Ramachandran, & Stein, 2006), which suggests that the ability to transfer information across modalities may be independent of the specific modalities involved.

### *Present Study*

The present study addresses a theoretically important issue about the development of language—namely, whether those processes that foster its growth are domain general in character. Few previous studies have addressed this issue in infancy and those that have done so have looked at only one or very few infant abilities at a time. Additionally, most have related infant abilities either to contemporaneous language or to later language but not to both. The present study, by contrast, uses an extensive battery of infant abilities, including some not previously studied in relation to language, and examines both concurrent and predictive relations. The battery was developed in the course of a longitudinal study of cognitive development from infancy to 3 years (Rose et al., 2004, 2005b). It has been shown to provide a differentiated and theoretically meaningful view of infant's cognitive abilities and to predict general cognitive ability at ages 2 and 3 (Rose et al., 2005, 2007). By following children longitudinally, we will be

able to assess the role of these domain-general processes not only in the emergence of language but also in its subsequent development.

Another unique aspect of the present study is that the longitudinally followed cohort includes groups that differ with respect to biological risk—namely, preterms and full-term controls (group matched on age, gender, and socioeconomic status [SES]). Several studies have found language deficits in preterm or low-birthweight children in the preschool period, primarily in receptive language and, to a lesser extent, expressive language (Caravale, Tozzi, Albino, & Vicari, 2005; Scottish Low Birthweight Study Group, 1992). However, relatively few studies have examined the language capabilities of preterms at the earliest stages of language development (Briscoe, Gathercole, & Marlow, 2001), and to our knowledge, none have examined the cognitive underpinnings of early language in preterms.

An ancillary contribution of the present study will be to provide hitherto unavailable data on the predictive validity of the short form of the MacArthur Communicative Developmental Inventory (CDI/ Words and Gestures), a parent-report instrument designed for 8- to 18-month-olds (Fenson et al., 2000). Although there is considerable evidence for concurrent and predictive validity for the CDI/ Words and Sentences, designed for older children, evidence for the predictive validity of the CDI/ Words and Gestures is lacking. Predictive work with this latter version has not been done, in part, because its concurrent validity was called into question when a negative association was found between maternal education and the vocabulary scores reported for 1-year-olds (Feldman et al., 2000). Negative relations are not the norm, and were unexpected, because language development is often delayed in children from families with less education; moreover, negative relations have not been found between CDI scores and maternal education at older ages (Pan, Rowe, Spier, & Tamis-Lemonda, 2004). The current study offers the opportunity to reexamine the relation of the Words and Gestures version of the CDI to maternal education and to examine its predictive validity.

Overall then, the present work, part of a longitudinal, prospective study of preterms and full-terms, uses an extensive battery of infant information processing measures from 12 months to examine whether and how early language might be affected by memory, representational competence, processing speed, and attention in infancy and whether relations between these cognitive abilities and language are similar for preterms and full-terms. In addition, we will determine

whether these infant information processing abilities have any unique role in later language outcome (over and above that of concurrent language). These results will be relevant to the role of domain-general processes in the emergence and growth of language.

## Method

### *Participants*

The original sample for this prospective, longitudinal study included 59 preterm infants and 144 full-term controls born between February 1995 and July 1997. The present report included those infants ( $N = 182$ ; 56 preterms and 126 full-terms) who had data on tasks of information processing at 12 months.

Preterm infants were recruited from consecutive births admitted to the neonatal intensive care units of two hospitals affiliated with Albert Einstein College of Medicine. Criteria for study intake were singleton birth, birthweight  $< 1,750$  g, and the absence of any obvious congenital, physical, or neurological abnormalities. Term infants were recruited from consecutive births from the same hospitals; criteria for study intake were birthweight  $> 2,500$  g, gestational age of 38–42 weeks, 5-min Apgar scores of 9 or 10, and uneventful pre- and perinatal circumstances (Rose et al., 2001a).

Of the 56 preterms seen at 12 months, 50 returned at 36 months (89.3%); of the 126 full-terms seen at 12 months, 110 returned at 36 months (87.3%). Subject loss was principally due to mothers returning to work after maternity leave and the attendant scheduling difficulties.

Visits of the preterm infants were targeted to “corrected age,” calculated from expected date of birth, with the result that preterms were, on average, 10.4 weeks older in postnatal age than the full-term infants.

### *Sample Characteristics*

At 12 months (as at intake), the two groups for the longitudinal study were similar in gender, birth order, ethnicity, parental education, and SES, with 52.7% male, 36.0% firstborn, and 87.6% either Black or Hispanic. Maternal education averaged 13.2 years ( $SD = 2.2$ ), and SES, as assessed by the Hollingshead (1975) Four-Factor Index of Social Status, averaged 32.3 ( $SD = 13.9$ ). English was the only or the primary language spoken in the home for 89.8% of the sample. The remainder was solely (3.2%) or

primarily (7.0%) Spanish speaking. For further details on medical and background characteristics, see Rose et al. (2001a).

#### Procedure

The measures considered here include those assessing different types of memory (immediate and delayed recognition, recall, and working memory), representational competence (cross-modal transfer, object permanence, symbolic play, and anticipations), processing speed (psychomotor RT and encoding speed), attention (look duration and shift rates) at 12 months, developmental outcome at 12 months (Bayley performance), and several aspects of language and early communication at 12 and 36 months.

#### Information Processing (12 Months)

##### Memory

*Visual recognition memory.* Recognition memory was assessed with two visual paired-comparison (VPC) tasks. In both, infants were familiarized with a stimulus and then tested for recognition by pairing the familiar with a novel target. Recognition memory is typically inferred from differential attention to the two test stimuli and is measured by the *novelty score*, the percentage of looking time devoted to the novel target.

One task, the “Rose,” developed in our lab, comprised five face problems (10-s familiarization) and four pattern problems (3-s familiarization). The test periods lasted for 10 s (Rose et al., 2001a). The other task, the Fagan Test of Infant Intelligence (Fagan & Sheperd, 1989), comprised of 10 face problems, had a similar, though somewhat more varied, format. Composites for each test were created by averaging individual novelty scores.

Moderate test–retest reliabilities have been reported for composites such as these over periods of 1 week,  $r_s = .40$  and  $.51$  (Colombo, Mitchell, & Horowitz, 1988; Rose & Feldman, 1987; Rose, Feldman, & Wallace, 1988).

*Short-term memory capacity.* This aspect of memory was assessed with a span task, which consisted of 10 problems, arranged in spans of 1, 2, 3, and 4. For a span of 1, the procedure was similar to that described above for the VPC procedure. For the remaining spans, the infant was familiarized to two or more objects in succession and then immediately given a series of test trials in which each successive familiar object was paired with a new one.

Spans were presented in ascending order. The stimuli were colorful, attractive, three-dimensional objects. On familiarization trials, an object was displayed until the infant accumulated 3 s of looking time. On test, paired stimuli were presented for 10 s (for further details, see Rose, Feldman, & Jankowski, 2001b). *Span length* was measured by the highest number of items “recognized” (defined by a novelty score  $\geq 55\%$ ) from any of the four spans.

Reliability estimates are not available for this measure, although short-term stability over a 2-month period (5–7 months) was  $r = .28$ .

*Delayed recognition.* To assess delayed recognition, infants were initially habituated to three objects in succession, using a modified infant-controlled procedure (Diamond, 1990), and then, after a 1-s delay, given a series of test trials in which each habituated object was successively paired with a new one for 10 s. This habituation–test procedure was repeated twice more, with delays of 3 and 5 min. The stimuli were colorful, attractive, three-dimensional objects (similar to those used in the span task). The *overall novelty score*, computed by averaging novelty scores for each of the nine problems (three problems at each of the three delays of 1, 3, and 5 min), was used here.

There are no reliability data for this measure.

*Recall memory.* Recall memory was assessed with the elicited imitation task (adapted from Bauer, 2002). Here, the examiner modeled each of three event sequences—make a noisemaker, make a rattle (e.g., place small block on paddle, cover block, shake paddle to create rattle sound), and ring a gong—three times in succession; after a 15-min delay, the infant was given the props for each sequence, in turn, to reproduce the sequences (for further details, see Rose et al., 2005a). Recall memory, measured by the *percentage of target actions reproduced* for each event sequence, was averaged over sequences.

Reliability estimates are not available for this measure.

##### Representational Competence

*Cross-modal transfer.* Cross-modal transfer was assessed with a task of tactual–visual transfer, which involves extracting information about shape from one modality and applying it to another (Rose & Feldman, 1995; Rose, Feldman, & Wallace, 1988; Rose et al., 1997). In this task, which comprised 11 problems, three-dimensional forms were presented for familiarization in the tactile mode (20 s). On test, the previously felt object and a new one were presented visually for 20 s (Rose, Gottfried, and Bridger, 1978).

Cross-modal transfer was measured by the *novelty score*, the percentage of looking time devoted to the novel target in the visual test phase. A composite was created by averaging over problems.

Although reliability data are unavailable for this measure, modest stability over periods of 1 month (6–7 and 7–8 months) has been found,  $r_s = .25$  and  $.41$  (unpublished data).

*Anticipations.* The ability to anticipate forthcoming events was measured by the VExP task. Here, infants had to abstract the rule governing changes in location from a fast-paced sequence of pictures (Canfield et al., 1997; Rose, Feldman, Jankowski, & Caro, 2002). In this task, there were 60 trials in which computer-generated images were presented in a predictable right–right–left (RRL) spatiotemporal sequence. Stimulus durations were 500 ms; interstimulus intervals were 720 ms (for further details, see Rose, Feldman, Jankowski, & Caro, 2002). Saccades to the upcoming stimulus were considered to be anticipatory, and thus to reflect rule-based expectations, if they were initiated before the stimulus could be perceived, that is, before onset or within 200 ms of onset, the minimal time thought to be required to initiate a saccade (Haith et al., 1988). Performance was assessed by the *percentage of anticipatory saccades*.

Test–retest reliability has been reported as  $r = .34$  for 3-month-olds tested on two occasions 2–8 days apart; internal consistency (split half) reliability was  $r_s = .51$  and  $.52$  within sessions (Haith & McCarty, 1990).

*Object permanence.* Object permanence, which involves keeping in mind the location of an object, even though the object is hidden from view (Piaget, 1950), was assessed with the Einstein Scale of Object Permanence (Corman & Escalona, 1969). Here, the infant's ability to retrieve hidden objects after successive hidings is coded into stages: *Stage 3*—recovers an object that has been partially but not fully hidden, *Stage 4*—recovers a completely hidden object but errs on succeeding trials when the location of the object is changed, *Stage 5*—correctly retrieves a hidden object but only if its displacement had been visible, and *Stage 6*—correctly retrieves objects even after invisible displacements. The infant's score is the *highest level achieved*.

Green's index of consistency was 1.00, indicating that this scale meets Guttman's criterion for a true scale (Corman & Escalona, 1969), and infants are consistent between 75% and 92% of the time across sessions in whether they performed a particular action (Uzgiris & Hunt, 1975).

*Symbolic play.* Symbolic play was elicited by modeling increasingly higher complex sequences of pre-tense actions (adapted from those found in free play; see Belsky & Most, 1981; Damast et al., 1996; Tamis-

LeMonda & Bornstein, 1990) and encouraging the infant to imitate each. The sequences included self- and other-directed actions (child drinks from a toy cup and feeds the doll from a cup), sequencing (child stirs the cup with a spoon and then feeds the doll with the spoon), object substitution (child stirs on block with spoon and then drinks from the block), and vicarious action for others (child feeds the doll and makes eating sounds for the doll). There were 18 levels, with four opportunities to succeed at each; testing terminated when 2 levels were failed in succession. Performance was measured by the *highest level achieved*.

Interrater reliability obtained on this task in our lab was  $r = .97$ . Test–retest reliability is not yet available.

### Speed

*Psychomotor speed (RT).* This aspect of processing speed was assessed with RT measures from the VExP task (Haith et al., 1988) described earlier. In addition to the 60 series trials, where the images were presented in a predictable RRL sequence, the task included 10 baseline trials, where the right or left placement was random. All latencies > 200 ms after stimulus onset were scored as RTs (Haith et al., 1988). Performance was indicated by *mean RT* on baseline trials and *mean RT* on series trials.

Test–retest reliability has been reported as  $r = .48$  for the median RT in 3-month-olds tested on two occasions 2–8 days apart (Haith & McCarty, 1990).

*Encoding speed.* This aspect of speed was assessed with the continuous familiarization task, in which infants view a series of paired photographs, one of which changes across trials. Testing continues until infants show a consistent preference for the new one, defined as four of five consecutive trials having a novelty score > 55% but < 100% (thus ensuring some looking to each target in the criterion run), or for the maximum of 36 trials. Encoding speed is measured by *trials to criterion*, the trial on which the criterion was met, or 36 if it was not met (for further details, see Rose, Feldman, & Jankowski, 2002).

Test–retest reliability over a 2-week interval, obtained for a sample of 5-, 7-, and 9-month-olds, was  $r = .27$ , partialled for age (unpublished data).

### Attention

*Look duration.* One measure of attention was look duration, defined as the mean length of look (in seconds). Six measures of look duration were drawn from four tasks in the battery: two from the Rose VPC task (familiarization and test), two from the Fagan

VPC task (familiarization and test), one from the cross-modal task (test), and one from the continuous familiarization task (all trials). In each case, *mean look durations* were obtained by averaging over all problems in a task (or all trials for continuous familiarization). A composite was formed by standardizing all scores and then averaging them (for further details, see Rose et al., 2005b).

Although test-retest reliability is not available for these measures, for the scores in the present study, internal consistency coefficients (another method of estimating reliability) were high:  $\alpha = .76$ .

*Shift rate.* A second measure of attention, shift rate, was defined as the number of shifts of gaze between paired targets per second. Four measures of *shift rate* were drawn from three tasks: two from the Rose VPC task (familiarization and test), one from the cross-modal task (test), and one from the continuous familiarization task (all trials), averaged over problems within each task and then averaged across tasks to form an overall composite.

The internal consistency coefficient was high for scores in the present study:  $\alpha = .70$ .

#### *Developmental Level (12 Months)*

Developmental level was assessed at 12 months with the Bayley Scales of Infant Development (Bayley, 1993), which yields a Mental Development Index (MDI) that has a mean of 100 and a standard deviation of 15.

Rater reliability is checked periodically in our lab and is uniformly greater than  $r = .97$ .

#### *Language (12 and 36 Months)*

The short form of the CDI/Words and Gestures (Fenson et al., 2000) was used to assess emerging language at 12 months. Parents completed the 89-word vocabulary checklist of the CDI/Words and Gestures (designed for 8- to 18-month-olds). For each word, they indicated which their child understood (comprehension) or understood and said (production). They also selected, from a list of 12 communicative gestures (included in a preliminary version of this instrument), those actions the child understood and produced.

Although the CDI was designed to be self-explanatory, the examiner went through the protocol orally with each parent. In preliminary work, we discovered that many parents misinterpreted the word "understand," leading them to credit their child with understanding a word if the child had any familiarity with it. One mother initially stated that her child understood the word "lion" because he had seen lions at the zoo. However, she readily acknowledged that he did not

know the word "lion" referred to a creature rather than some other object, such as a tree. Such misunderstandings were common in this population but were readily countered when the instructions were elaborated to make clear that understanding involved knowledge of the one-to-one correspondence between word and object (or word and action).

At 36 months, language was assessed with the Peabody Picture Vocabulary Test (PPVT Revised – Form L; Dunn & Dunn, 1981) and an age-appropriate modification of the Educational Testing Service (ETS) test of verbal fluency (Singer, Corley, Guiffreda, & Plomin, 1984). These measures of comprehension and expressive language were chosen because we had used them for an 11-year follow-up in a previous study and found them to relate to some of the same infant measures used here (Rose & Feldman, 1995). The PPVT, a widely used test of receptive language and comprehension, is a standardized assessment that has a mean of 100 and a standard deviation of 15. Verbal fluency, a measure of expressive language, was evaluated with a task of category fluency. In this task, the child was asked to name as many things as he or she could think of in three different categories: (a) things to eat, (b) all the animals you know, and (c) things that make noise. Thirty seconds were allowed for responses to each part; timing began with the first response. The child's score was the total number of items correctly listed, summed over all three 30-second response periods.

For those infants who were from households that were solely or predominately Spanish speaking, the language tasks were administered in Spanish by an examiner who was fluent in Spanish. (All analyses were repeated and restricted to the 89.8% subsample having English as their sole or primary language. There were no appreciable differences from those reported below.)

## **Results**

### *Descriptive Statistics*

Descriptive statistics for the full-term and preterm groups are presented in Table 1. The majority of the 1-year information processing variables showed significant differences favoring the full-terms, who had better recognition and recall, higher levels of symbolic play and object permanence, shorter look durations, more frequent shifts of gaze, and faster processing speeds. The full-terms also had higher MDIs. On language measures, full-terms outperformed preterms in using gestures at 12 months and in performance on the PPVT at 36 months; there

were no significant differences on the other language measures.

#### *Correlations of 12-Month Information Processing With Language*

Correlations between information processing measures and language measures are presented in Table 2, partialled for birth status. Initially, these correlations were obtained separately for the pre-terms and full-terms and compared across groups, using tests of difference for independent correlations. Only 4 correlations of the 75 (5 language measures  $\times$  [14 infant measures + MDI]) met the criterion for a significant difference at the .05 level, about the same number that would have been expected by chance. Consequently, data were collapsed across birth status, as shown in Table 2, and in all further analyses. Birth status was partialled to avoid inflation of the correlations due to mean differences.

In general, better 12-month memory was significantly associated with better language at both 12 and 36 months. With the exception of short-term capacity, all the 12-month memory tasks were related significantly (or nearly so) to one or more aspects of language at each age. Of the various types of memory assessed at 12 months, delayed recall was most consistently related to language, having significant correlations (ranging from .20 to .28) with all the language measures but fluency.

Similarly, better representational competence at 12 months was generally related to better language; with the exception of visual anticipations, most of the 12-month measures for this aspect of infant cognition were significantly associated with one or more aspects of both contemporaneous and later language. Two of these measures—cross-modal transfer and object permanence—had significant correlations with both measures of 3-year language; they also had fairly consistent correlations with contemporaneous language measures.

By contrast, none of the measures of processing speed or attention related to language at either age.

#### *Correlations Among Language Measures*

As shown in Table 3, for the most part, correlations among all language measures, both within and across age, were fairly substantial. It is noteworthy that parent-report measures of comprehension and production at 12 months correlated moderately well with standardized or lab-based measures of these same two constructs (PPVT and verbal fluency) obtained 2 years later ( $r = .29-.49$ ). The measure of gestural

communication from the 12-month CDI was also related to later language but less strongly.

#### *Regressions*

Hierarchical regressions predicting 36-month outcomes were done to establish the variance predicted by (a) infant information processing measures beyond that of birth status, (b) infant language beyond birth status, and (c) individual information processing measures beyond all other measures (birth status and infant language combined). The regressions included only the seven information processing measures that related significantly to at least one of the 36-month language measures.

The results are shown in Tables 4 and 5, where the change in  $R^2$  indicates the increase in variance predicted by adding successive sets of variables and the cumulative  $R^2$ s indicates the total amount of variance predicted. Several statistics are provided from the final equation: the squared semipartial correlation coefficient,  $sr^2$ , which indicates the independent contribution to outcome of each individual predictor when all are simultaneously included in the regression equation; the standardized partial regression coefficients,  $\beta$ , which indicates the change in standard deviation units in the outcome variable associated with a 1 *SD* increment in the predictor, all else being held constant; and the  $t$  value with its significance level associated with both the  $sr^2$  and the  $\beta$ .

#### *Regressions Predicting Comprehension (PPVT) at 36 Months*

*Predicting from infant information processing.* The first model in Table 4 shows that, over and above birth status, about 31% of the variance in the PPVT was predicted by the 12-month battery of information processing measures. Three variables are uniquely predictive independently of all others, namely, recognition memory (as assessed in the Rose task), recall, and cross-modal transfer. The total amount of variance predicted by birth status and the infant information processing measures was 34%.

*Predicting from infant language.* The second model in Table 4 shows that the three 12-month parent-report measures of language from the CDI accounted for 26% of the variance in PPVT, over and above birth status. Two of the language measures, comprehension and production, were uniquely predictive. The total amount of variance predicted by birth status and the three 12-month measures of language was 29%.

*Predicting from both infant language and infant information processing.* The third model in Table 4



Table 1  
Descriptive Statistics

	Full-terms			Preterms			<i>t</i>
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	
12-month measures							
Information processing							
Memory							
Visual recognition: Rose VPC (% novelty)	126	58.68	5.24	56	57.06	5.75	1.87 <sup>†</sup>
Visual recognition: Fagan VPC (% novelty)	128	60.29	5.12	54	58.30	6.79	2.16*
Short-term capacity (span length)	126	2.54	0.83	56	2.48	0.81	0.44
Delayed recognition (% novelty)	126	54.61	6.26	54	54.52	6.15	0.09
Recall—elicited imitation (% correct)	121	42.17	19.64	55	33.69	17.50	2.75**
Representational competence							
Cross-modal (% novelty)	118	48.32	4.27	52	48.40	4.86	0.11
Symbolic play (highest level)	113	7.45	2.49	53	6.32	2.73	2.64**
Anticipations—VExP (%)	113	25.13	14.79	51	26.95	16.25	0.71
Object permanence (highest level)	113	4.31	0.60	51	4.10	0.46	2.24*
Attention							
Mean look duration composite <sup>a</sup>	129	-0.14	0.59	56	0.31	0.72	4.45**
Shift rate composite <sup>a</sup>	129	0.14	0.71	56	-0.30	0.67	3.95**
Speed							
Encoding speed (trials to criterion)	117	10.00	6.21	55	12.89	9.71	2.36*
Reaction time baseline—VExP (ms)	101	293.59	45.09	43	291.58	34.65	0.26
Reaction time postbaseline—VExP (ms)	113	294.93	31.43	51	289.06	29.39	1.13
Language—CDI							
Vocabulary comprehension	124	25.44	15.18	54	23.61	14.41	0.75
Vocabulary production	124	4.17	5.03	54	3.67	4.93	0.62
Gestures produced	124	7.94	2.12	54	7.17	2.39	2.16**
Mental development							
Bayley MDI	126	97.56	9.75	56	90.09	10.57	4.65***
36-month measures							
PPVT	95	87.76	14.88	42	82.05	17.39	1.97*
Verbal fluency	98	3.74	4.26	43	4.26	3.48	0.85

Note. VPC = visual paired-comparison; VExP = visual expectation paradigm; CDI = MacArthur Communicative Developmental Inventory; MDI = Mental Development Index; PPVT = Peabody Picture Vocabulary Test.

<sup>a</sup>An average of variables standardized to a mean of 0.

<sup>†</sup> $p \leq .10$ . \* $p \leq .05$ . \*\* $p \leq .01$ . \*\*\* $p \leq .001$ .

shows that, even with birth status and infant language controlled, the 12-month information processing measures independently contribute about 15% to PPVT. Moreover, the same three information processing measures continue to contribute uniquely to prediction, namely, recognition memory (Rose task), recall, and cross-modal transfer. The total amount of variance predicted by birth status and 12-month measures of information processing and language combined was 44%.

#### Regressions Predicting Expression (Verbal Fluency) at 36 Months

*Predicting from infant information processing.* The first model in Table 5 shows that, over and above

birth status, about 17% of the variance in verbal fluency was predicted by the 12-month battery of information processing measures. Here, only one variable was individually predictive independently of all others, namely, cross-modal transfer. The total amount of variance predicted by birth status and the infant information processing measures was 18%.

*Predicting from infant language.* The second model in Table 5 shows that the three 12-month parent-report measures of language from the CDI accounted for 12% of the variance in verbal fluency above and beyond birth status. Of these three CDI measures, comprehension and production were both uniquely predictive. The total amount of variance predicted by birth status and the three 12-month language measures was 13%.

Table 2  
Correlations of 12-Month Infant Information Processing and Developmental Level With Language at 12 and 36 Months

12-month measures	12-month language			36-month language	
	CDI/Words and Gestures			PPVT	Fluency
	Comprehension	Production	Gestures		
<b>Memory</b>					
Recognition—Rose	.11	.03	.04	.24**	.18*
Recognition—Fagan	.21**	.05	.20**	.15 <sup>†</sup>	.22*
Short-term capacity	.01	.04	.15 <sup>†</sup>	-.04	.05
Delayed recognition	.13 <sup>†</sup>	.12	.21**	.20*	.10
Delayed recall	.24***	.24***	.21**	.28***	.11
<b>Representational competence</b>					
Cross-modal	.17*	.23**	.09	.41***	.30***
Symbolic play	.30***	.12	.30***	.12	.22*
Anticipations	.04	.06	-.02	-.11	-.05
Object permanence	.33***	.24**	.14 <sup>†</sup>	.30***	.22*
<b>Attention</b>					
Mean look duration composite	-.05	.02	-.05	.00	.00
Shift rate composite	.12	.09	.05	.09	.05
<b>Speed</b>					
Encoding speed	-.08	-.01	-.06	.03	-.06
Reaction time baseline	-.06	.03	-.08	-.08	-.03
Reaction time postbaseline	-.10	-.03	-.06	-.11	-.07
<b>Developmental level</b>					
Bayley MDI	.32***	.32***	.33***	.29***	.27**

Note. Partial correlations controlling for birth status; pairwise,  $n = 118-174$ . CDI = MacArthur Communicative Developmental Inventory; PPVT = Peabody Picture Vocabulary Test; MDI = Mental Development Index.  
<sup>†</sup> $p \leq .10$ . \* $p \leq .05$ . \*\* $p \leq .01$ . \*\*\* $p \leq .001$ .

Predicting from both infant language and infant information processing. The third model in Table 5 shows that even with birth status and the three infant language measures controlled, the 12-month information processing measures independently contribute about 10% to verbal fluency. Again, only cross-modal transfer contributed uniquely to prediction. The total amount of variance predicted by birth status

and 12-month measures of information processing and language combined was 23%.

Ancillary Analyses

Controlling for 12-month MDI. The hierarchical regressions of Tables 4 and 5 (Model 3) were repeated, including an additional control measure to represent

Table 3  
Correlations Among Language Measures

	12 months			36 months	
	Comprehension	Production	Gestures	PPVT	Fluency
<b>12-month CDI</b>					
Comprehension	—	.42***	.41***	.49***	.29***
Production		—	.35***	.40***	.31***
Gestures			—	.28**	.15 <sup>†</sup>
<b>36-month language</b>					
Comprehension (PPVT)				—	.44***
Expression (verbal fluency)					—

Note. Partial correlations controlling for birth status; pairwise,  $n = 99-170$ . CDI = MacArthur Communicative Developmental Inventory; PPVT = Peabody Picture Vocabulary Test.  
<sup>†</sup> $p \leq .10$ . \* $p \leq .05$ . \*\* $p \leq .01$ . \*\*\* $p \leq .001$ .

Table 4

Regression Models Predicting Comprehension (Peabody Picture Vocabulary Test) at 36 Months From Birth Status and 12-Month Measures of Information Processing and Language

Set/measure	$\Delta R^2$	Cumulative $R^2$	Final equation		
			$sr^2$	$\beta$	$t$
Model 1: Birth status + infant information processing					
Control	.028*	.028*			
Birth status			.007	.090	1.16
Infant information processing	.308***	.336***			
Recognition—Rose			.060	.260	3.39**
Recognition—Fagan			.001	-.011	-0.15
Delayed recognition			.005	.071	0.95
Recall			.047	.259	3.02**
Cross-modal			.116	.364	4.73***
Symbolic play			.006	-.094	-1.11
Object permanence			.009	.108	1.33
Model 2: Birth status + infant language					
Control	.028*	.028*			
Birth status			.011	.112	1.48
Infant language	.262***	.290***			
Comprehension			.095	.361	4.22***
Production			.039	.226	2.69**
Gesture			.001	.026	0.30
Model 3: Birth status + infant language + infant information processing					
Control	.028*	.028*			
Birth status			.008	.094	4.29
Infant language	.262***	.290***			
Comprehension			.050	.281	3.33***
Production			.010	.121	1.52
Gesture			.001	.043	0.53
Infant information processing	.147***	.436***			
Recognition—Rose			.044	.227	3.14**
Recognition—Fagan			.003	-.059	-0.81
Delayed recognition			.003	.053	0.75
Recall			.018	.167	2.02*
Cross-modal			.070	.292	3.95***
Symbolic play			.014	-.145	-1.79
Object permanence			.004	.068	0.89

\* $p \leq .05$ . \*\* $p \leq .01$ . \*\*\* $p \leq .001$ .

overall developmental status, namely, 12-month MDI. Even with this additional control, the set of information processing measures continued to contribute independently to the prediction of 36-month PPVT (14% of the variance,  $p < .001$ ) and verbal fluency (8%,  $p = .067$ ). Moreover, in both cases, the same 12-month information processing measures remained significant in the final equation: for PPVT, recognition memory—Rose ( $\beta = .23$ ,  $p < .01$ ), recall ( $\beta = .17$ ,  $p = .05$ ), and cross-modal transfer ( $\beta = .29$ ,  $p < .01$ ) and for

verbal fluency, cross-modal transfer ( $\beta = .20$ ,  $p < .05$ ). MDI had no significant independent effect in either equation.

### Discussion

The present study examined whether basic cognitive processes that are not specific to language, but rather domain general, play a role in the emergence and

Table 5  
*Regression Models Predicting Expression (Verbal Fluency) at 36 Months From Birth Status and 12-Month Measures of Information Processing and Language*

Set/measure	$\Delta R^2$	Cumulative $R^2$	Final equation		
			$sr^2$	$\beta$	$t$
Model 1: Birth status + infant information processing					
Control	.005	.005			
Birth status			.118	-.142	-1.71
Infant information processing	.173***	.178***			
Recognition—Rose			.021	.153	1.84
Recognition—Fagan			.008	.094	1.10
Delayed recognition			.002	.043	0.52
Recall			.001	.004	0.04
Cross-modal			.055	.248	2.98**
Symbolic play			.019	.162	1.75
Object permanence			.005	.075	0.86
Model 2: Birth status + infant language					
Control	.005	.005			
Birth status			.007	-.083	-1.01
Infant language	.120***	.125***			
Comprehension			.030	.202	2.16*
Production			.038	.224	2.44*
Gesture			.001	-.030	-0.33
Model 3: Birth status + infant language + infant information processing					
Control	.005	.005			
Birth status			.027	-.121	-1.46
Infant language	.120***	.125***			
Comprehension			.010	.125	1.29
Production			.025	.186	2.04*
Gesture			.003	-.067	-0.72
Infant information processing	.100*	.225***			
Recognition—Rose			.027	.120	1.46
Recognition—Fagan			.004	.070	0.84
Delayed recognition			.001	.036	0.44
Recall			.003	-.063	-0.67
Cross-modal			.036	.205	2.46*
Symbolic play			.021	.175	1.88
Object permanence			.001	.042	0.49

\* $p \leq .05$ . \*\* $p \leq .01$ . \*\*\* $p \leq .001$ .

development of language ability. To do this, four aspects of infant information processing were assessed at 12 months—memory, representational competence, processing speed, and attention—and related to language, concurrently and predictively. Language was assessed at 12 months with a parent-report measure, the short form of the CDI/ Words and Gestures, and at 36 months with the PPVT and verbal fluency. Although some of the infant measures have been used in previous research exam-

ining the cognitive antecedents of language, studies of this type are somewhat limited, and none have examined measures from multiple cognitive areas at once, a strategy that enables evaluation of the relative importance of each.

There were five main findings. First, several measures of infant information processing from two of the domains—memory and representational competence—were related to language, both concurrently and predictively. Second, although preterms had

lower scores than full-terms on a number of measures, the relations between information processing and language proficiency was similar for both groups. Third, the 12-month information processing measures predicted language at 36 months independently of birth status, 12-month language, and 12-month Bayley MDI. Fourth, three of the infant information processing measures (recognition memory, recall, and cross-modal transfer) predicted later language independently of one another. Fifth, this study provided the first evidence of the predictive validity of the short form of the CDI/Words and Gestures.

The memory measures that were related to language included recognition (both immediate and delayed) and recall. All related modestly, with correlations generally in the .30s. These findings corroborate previous work that has linked infant recognition memory to comprehension through adulthood. They show that this form of memory is also predictive of expressive language and reveal, for the first time, that infant recall memory has strong and consistent relations with later language extending at least to 3 years. Surprisingly, our measure of short-term memory did not relate to language, despite the extensive literature supporting such a relation in older children (Baddeley et al., 1998; Gathercole et al., 1992).

As noted earlier, infants who have better memory are more likely to have memory traces that are highly discriminable and persistent, increasing the probability that words would be semantically linked to them. It is not immediately clear, however, why recognition and recall tended to impact language independently. One possible reason might be the differences in the level of perceptual support involved. It is easier to evoke a representation where the object is present to serve as a cue than in recall where the object is absent. A second possible reason is that the recall task involves a social component that is absent in recognition tasks. In the recall task, the infants need to imitate action sequences demonstrated by the experimenter; success depends upon the infants' having a desire to imitate the actions of others.

Because language would seem to be more dependent on auditory than visual memory, it might seem surprising that visual measures would be related to language. However, a recent study of recognition memory found parallel effects in the visual and auditory modalities for the number of items to be remembered, retention interval, and serial position (Visser, Kaplan, Kahana, & Sekuler, 2007). These findings suggest that recognition memory abilities may be general rather than modality specific.

Three measures of representational competence were related to language: tactual–visual cross-modal transfer,

symbolic play, and object permanence. As was the case for memory, relations were modest, again generally in the .30s. These measures involve the ability to abstract and manipulate fairly complex representations—matching tactual impressions to visual ones, performing actions in pretend scenarios, and understanding that objects hidden from view still exist. They all share with language the abstract mental representation of objects absent any immediate visual support.

Our findings for symbolic play complement an extensive body of work showing its relation to language (Fein, 1981; McCune-Nicolich, 1981; Tamis-LeMonda & Bornstein, 1990; Tamis-LeMonda, Shannon, Cabrera, & Lamb, 2004). Advances in symbolic play, using one object to represent another, could pave the way for advances in linguistic representations, using words to represent objects. Similarly, infants who are able to understand that objects continue to exist even when out of sight, as evidenced by their advances in the object permanence scale, are more likely to use words to refer to objects that are absent. The findings of relations between infant tactual–visual cross-modal performance and language ability are in line with earlier results from our lab (Rose et al., 1992, 1995). These results have recently been confirmed by findings from two large samples of preschoolers, where performance on a similar cross-modal task was found to be related to concurrent measures of phonological awareness and language comprehension (Giannopulu, Cusin, Escolano, & Dellatolas, 2008). As noted earlier, the ability to transfer information across modalities may be independent of the specific modalities involved, a possibility supported by the recent finding of cortical multisensory neurons, which respond to sight, sound, and touch (Wallace, Carriere, et al., 2006; Wallace, Ramachandran, et al., 2006).

Measures from the other two domains, processing speed and attention, were not related to either measure of language. Although the literature relating measures from either domain to language is, as noted earlier, sparse, the present results are in accord with the only two studies previously conducted. A study by Fernald et al. (2006) used one of the same measures used here, namely, RT from the VEXp task and, like the present study, found that it did not relate to language. Similarly, Colombo et al. (2004) used one of the same measures of attention used here, namely, mean look duration; like the present study, they found that mean look duration per se did not correlate with language. However, both authors did find associations between language and speed or attention using measures of age-related change. Colombo et al. (2004), for example, found that infants who showed

an age-appropriate decline in mean look duration from the earlier to the later part of the 1st year had better scores on a language factor in the 2nd year. And Fernald et al. found that word recognition speed at 25 months was related to the rate of vocabulary growth over the 2nd year of life. Moreover, additional measures of these two elementary cognitive abilities may also prove fruitful in future research, such as measures of temporal processing speed (Tallal et al., 1985) or measures of focused or joint attention (Ruff & Lawson, 1990).

The present study is the first, to our knowledge, to examine the predictive value of the short form of the CDI/Words and Gestures, designed for 8- to 16-month-olds (Fenson et al., 2000). In the present study, 12-month measures of comprehension and production from this inventory correlated significantly with 36-month performance on the PPVT and a test of verbal fluency ( $r_s = .29-.49$ ), thus showing predictive validity over a 2-year delay. These findings support those obtained with the toddler form of the CDI (Feldman et al., 2005; Pan et al., 2004; Reese & Read, 2000). Predictive validity for the infant form of this parent-report instrument had been in question for two reasons. First, the original versions of the CDI were standardized on a middle- and upper-class sample, and it was not clear they would be applicable to a largely minority and/or racially and economically diverse sample (like the present one). Second, Feldman et al. (2000) found a negative association between maternal educational level and parent report, suggesting that mothers with less education overreport their children's language abilities in the 1st year. However, in the present study, correlations between maternal education and infants' language were positive, as one would expect ( $r = .20, p = .01$ ;  $r = .22, p < .01$ ; and  $r = .11, p > .10$ , with comprehension, production, and gestures, respectively). Thus, the previous finding of an inverse relation between social class and parent report does not appear to be robust. Moreover, as noted earlier (see the Procedure section), preliminary work in our lab had suggested that overreporting at 1 year is often due to adults' equating infant "understanding" with a general familiarity with the word or action rather than with the infant's ability to recognize the word as a label for a particular object or action. Once this misunderstanding was addressed, overreporting did not appear to be a major problem.

Finally, it should be noted that, with respect to language, the effects of birth status were mixed. Preterms were reported to use fewer gestures at 12 months and were found to have lower PPVT scores at 36 months, but on other measures, there were no

group differences. This mixed picture is consistent with the literature. In any event, the relations between measures within and across age were similar for both groups.

In sum, the findings from the present study suggest that basic, visually based, cognitive processes in infancy contribute to the development of early language and its growth from 1 to 3 years. These results support the theoretical notion that the cognitive bases of language are not solely proprietary but instead may be of a domain-general nature.

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