INFANT BEHAVIOR AND DEVELOPMENT 20 (2), 1997, pp. 133–140 ISSN 0163-6383

Why Does Infant Attention Predict Adolescent Intelligence?

MARIAN SIGMAN
University of California, Los Angeles

SARALE E. COHEN
LEILA BECKWITH
University of California at Los Angeles

Ninety-three 18-year-olds were tested with measures thought to tap information processing, sustained attention, executive function, and intelligence. The visual fixation patterns and home rearing conditions of these adolescents, born preterm, had been observed in early infancy. Infant fixation durations were negatively associated with information processing, executive function, and intelligence scores but did not predict ability to sustain attention. Continuity between infant attention and adolescent intelligence was moderated by qualities of the home environment so that "short-looking infants" whose caregivers vocalized a great deal had mean intelligence quotients that were 20 points higher than "long-looking infants" with less vocal caregivers. The results suggest that at least some of the continuity between infant attention and adolescent intelligence stems from infant capacities to process information efficiently and to inhibit prepotent responses and that this continuity is affected by caregiver responsiveness.

infant attention intelligence maternal vocalizations

Numerous studies have demonstrated that infant attention predicts later intelligence (Bornstein & Sigman, 1986; Fagan & Singer, 1983; McCall & Carriger, 1993). Research investigations have moved from a concern with identifying relations between infant attention and childhood intelligence to a focus on explaining this continuity. Based on the assumption that some similar process must be tapped by both infant attention and childhood intelligence measures, one aim of current research is to identify this underlying process.

Three different characterizations of the shared underlying process have been proposed. One theory suggests that the process reflected in both effective attention by infants and intelligent behavior by children is speed or efficiency of information processing (Bornstein, 1985, 1989; Colombo, 1995). Infants who habituate rapidly, show short durations of attention to repeated or unchanging stimuli, or strong preference for novel stimuli are thought to be infants who either use efficient scanning strategies or form memory traces quickly. Children who can solve the kinds of language and perceptual problems that are tested on intelligence tests are known to have mastered these skills partly because of their strengths in encoding and retrieving information (Ceci, 1990; Dreary, 1995; Vernon, 1987).

A second theory suggests that the underlying process shared by the infant and childhood measures is the ability to inhibit responses to uninformative and familiar stimulation (McCall, 1994). Both infants who attend briefly and intelligent children are considered to be able to detect repetitive or irrelevant information and to turn their attention away from it towards more informative stimuli. The third theory, proposed by Berg and Sternberg (1985), is that an important characteristic is comfort with or a taste for novelty. Infants who have experienced a greater variety of stimulating conditions (within certain limits), may be better able to incorporate novel information into solutions than infants who have had more restricted novel experiences. Ease with novel stimuli may lead the child into more varied learning experiences, thereby improving his or her capacity to solve cognitive problems.

Research investigations of infant attention have provided support for the first hypothesis in

Direct all correspondence to: Marian Sigman, University of California, Los Angeles, Neuropsychiatric Insititute, Room 68-237, 760 Westwood Plaza, Los Angeles, California 90024-1759. E-mail: msigman@ucla.edu

that "long-looking" and "short-looking" infants differ in both the speed and nature of their processing. For example, Freeseman and her colleagues (Freeseman, Colombo, & Coldren, 1993) have demonstrated that "short-looking" infants needed only about 10 s of familiarization time to demonstrate preference for a novel stimulus while "long-looking" infants needed 40 s to process the same stimulus. In these studies, "short-looking" infants began by attending to global features and moved to local features as exposure duration was increased, a pattern also employed by adults. In contrast, "long-looking" infants focused on local elements at familiarization times just beyond those required for discrimination of global features (Colombo, Freeseman, Coldren, & Frick, 1995). Furthermore, "long-looking" infants have been reported to inspect parts of stimuli for prolonged periods while "short-looking" infants engaged in more extensive scanning (Bronson, 1991).

Information processing has also been identified as important in longitudinal studies of preterm infants using multiple outcome measures to provide divergent validation. Rose and Feldman (1995) administered a battery of measures to 11–12 year old children whose preference for novelty and cross-modal transfer had been studied at 7 and 12 months of age. Speed of perceptual processing, as measured by the Colorado Perceptual Speed Test and an Educational Testing Service measure called Finding A's, was the adolescent ability most consistently correlated with visual recognition memory tested in infancy with the preference for novelty paradigm.

Divergent validation was also used in our study of children born preterm after follow up assessments at 5 and 8 years of age had shown that children who were "long-lookers" in early infancy scored lower on intelligence tests than children who had been "short-lookers" in infancy. At 12 years, the children from English-speaking families were tested with a measure of information detection (the Span of Apprehension), sustained attention and inhibition of incorrect responses (the Continuous Performance Test), and ease in handling novel information (verbal analogies test: Marr & Sternberg, 1986) as well as standard tests of intelligence. The results showed that the infant measures were correlated with number of correct responses on one matrix of the Span of Apprehension but not the Continuous Performance Task or the novel relevant items of the verbal analogies task (Sigman, Cohen, Beckwith, Asarnow, & Parmelee, 1991). Thus, the results seem to support the first theory that infant fixation duration taps speeded information processing but not the third theory that infant fixation duration reflects facility with novel information.

The findings with respect to inhibition were more ambiguous. Two measures of inhibition were employed, only one of which was associated with infant fixation duration. The Continuous Performance Test was designed to include a task in which the target and nontarget stimuli were reversed after 400 trials. The child had to inhibit responding to the previously correct stimulus and begin responding to the previously incorrect stimulus. Infant fixation duration did not predict score on the reversal phase of the Continuous Performance Test. The other task that required inhibition was the verbal analogies test (Marr & Sternberg, 1986). Subjects had to incorporate novel relevant information into their responses and refrain from attending to irrelevant information. As mentioned above, infant fixation duration was not associated with score on incorporating relevant novel information into the verbal analogies solution, even when the adolescent was told that the information was relevant. However, when the cue was irrelevant and had to be ignored, verbal analogies score was associated with infant fixation duration. Thus, the child's capacity to inhibit responses on tasks requiring logical thinking was predicted by the infant's responses to the unchanging visual target.

The second issue addressed in the 12-year follow-up was whether the rearing environment mediated or moderated the relation between infant attention and childhood intelligence. Many theories of intelligence (e.g., Fagan, 1992) propose that both characteristics of the individual and rearing environments shape individual differences in intellectual capacities and studies of risk infants have supported these theories (Smith, Ulvund, & Lindemann, 1994). In order to address this question, a measure of the caregiving environment, the frequency with which the mother talked to the infant during a home visit 1 month following the attention assessment, was used in analyses. Infant attention and maternal vocalizations were unrelated but both were independently associated with the children's intelligence at 12 years. The effects of the variables were additive in that the interaction was not significant so that both the infant's style of attending and the caregiver's style of interacting contributed to later intelligence.

To extend these findings, the sample was retested at age 18 with similar measures as had been used at age 12 years. It seemed important to reexamine these results to determine whether the link between early attention and later information detection was sustained over time. In addition, the sample was expanded to include 18-year-olds from all backgrounds not just the children from English-speaking backgrounds as had been done at age 12 years. Because there had been no association between infant fixation duration and either ability to incorporate novel information into a solution or simple inhibition of response, these tasks were not readministered to the subjects. Instead, the subjects were administered a measure of executive function, the Tower of Hanoi, which is thought to require both the capacity to inhibit prepotent responses and strategic planning ability (Borys, Spitz, & Dorans, 1982; Hayes, Gifford, & Ruckstuhl, 1996; Welsh & Pennington, 1988). This task was substituted for the verbal analogies test used at 12 years in order to assess inhibition in a nonverbal context.

Based on the previous findings, the following hypotheses were proposed:

(1) Infant fixation duration will be negatively correlated with 18-year intelligence; (2) Infant fixation duration will be negatively correlated with 18-year scores on the Span of Apprehension and the Tower of Hanoi, and these relations will be independent of intelligence; (3) Infant fixation duration will not predict 18-year score on the Continuous Performance Task; and (4) Infant fixation duration and maternal level of vocalization will contribute independently to the prediction of 18-year intelligence.

METHOD

Participants

The sample was composed of 93 adolescents who had been tested with the infant attention measure and, at least, one of the outcome assessments. Infants in the sample had a mean birthweight of 1895.5 gms. (SD = 470.54), mean gestational age at birth of 33 weeks (SD = 3.2), and a mean Hollingshead index of 36.3 (SD = 15.9). The majority of subjects were Caucasian with 27 adolescents from families who were predominantly Spanish speaking during their infancy. The sample was not different in terms of birthweight, gestational age at birth, infant attention, or maternal vocalizations from the 33 children who were also followed from birth to two years but were not seen at 18 years of age. However, subjects who returned for testing at 18 years were from families with higher SES background on the Hollingshead index than those who were not tested at age 18 years, t (124) = 2.57, $p < .01$.

Procedure

Infant Fixation Duration

The infant's attention to a single 2 × 2 checkerboard was observed for 60 seconds and recorded in half-second intervals when the infant reached expected date of birth (Sigman, Kopp, Parmelee, & Jeffrey, 1973). In order to minimize the variations due to differences in state, all infants were first tested with a 10-min neurological assessment and then fed a small amount of milk. The interrater correlation in duration of fixation to the stimulus was r (13) = .92, $p < .001$.

Maternal Vocalization Rate

Assessments of the rearing environment were derived from naturalistic home observations made when the infants were 1, 8, and 24 months of age, with age corrected for the length of prematurity (Beckwith & Cohen, 1984). For the purposes of this study, only the 1-month observation was used in order to keep both the infant and home assessment within the same time period. At 1 month, the infants were observed for an average of 73 min of awake time. The observer used a precoded check list, and every 15 s recorded the presence of a set of infant behaviors, caregiver behaviors, and events defined as contingent or reciprocal interactions between caregiver and child. Observer reliabilities were assessed during 30-min observations of 10 dyads by computing correlation coefficients for the total frequency of a specific behavior each observer had recorded in an observation. The coefficients ranged from .80 to .98 with the majority > .90.

Certain interactive events were selected a priori as indicators of attentive/responsive caregiving and were used in a total score at each age. At 1 month, these were maternal positive attentiveness to the infant, caregiver talks, mutual visual regard, maternal contingency to distress, and the infant held upright. For the purposes of this article, only the percentage of time that the caregiver engaged in talking was considered because this was the only 1-month variable associated with intelligence at 5 and 8 years of age (Beckwith & Cohen, 1984). Vocalization time at 1-month was significantly predictive of vocalization time when the infants were 8 and 24 months corrected age, $r(90) = .62$, $p < .001$, and with total caregiving scores at 8 and 24 months of age, r(89) = .44, $p < .001$ and r(80) = .44, $p < .001$, respectively. Mothers who vocalized more came from more advantaged families in that there was a significant association between maternal vocalization time and score on the Hollingshead Index, r(90) = .40, $p < .001$.

Adolescent Intelligence

Intelligence was tested at age 18 years with the WAIS-R (Satz mogel version). The mean IQ of the sample was 101.99 with a *SD* of 15.47 and a range from 71 to 134.

The Span of Apprehension

The Span of Apprehension was used because it is thought to measure the individual's capacity to detect information that is exposed very briefly (Bartfai, Pedersen, Asarnow, & Schalling, 1991). A series of matrices of capital letters was tachistoscopically flashed on a computer screen for 50 ms. Each matrix contained a random array of letters, including either a "T" or an "F," but not both. The subject's task was to determine whether the predesignated target letter was present on each trial. Sets varied in the number of items displayed, including 3, 5, and 10 items. There were 16 matrices randomly presented over 96 trials for each task. The dependent measure was the percentage of trials on which the child was correct. Since there was little variability in scores for sets containing less than 10 items, only scores on the 10-item set were used in analyses.

The Continuous Performance Task

The Continuous Performance Task seems to assess the capacity to sustain attention to a monotonous task over repeated trials in contrast to the Span of Apprehension which measures the accuracy of information detection with very brief presentations of complex stimuli (Neuchterlein, 1983). This measure was included to assess whether infant attention predicted general childhood attention capacities rather than specific information processing abilities. The subject was required to monitor a screen while a long sequence of rapidly presented random target stimuli was displayed. The paradigm involved the brief (50 ms.), rapid (every 1.0 s) presentation of randomly generated digits from 0–9 on the center of a viewing screen. The subjects's task was to attend and press a button when, and only when, a particular target digit appeared. The task was continued for 480 trials and the number of correct responses (hit rate) was calculated.

The Tower of Hanoi

The Tower of Hanoi is a task on which the subject has to reproduce a pattern in as few moves as possible. This task is used frequently by neuropsychologists to assess executive function, which is thought to include inhibition, planning, and mental representation of tasks and goals (Eslinger, 1996). Two identical pegboards with three vertical pegs and four rings of different sizes and colors are set up and one is placed in front of the experimenter and one is placed in front of the subject. The subject has to transform his or her configuration to a configuration identical to that of the experimenter.

The rings on the experimenter's pegboard are arranged on the experimenter's right hand peg to form a tower, with the largest ring on the bottom and the smallest ring on the top. The arrangement of rings presented to the subject differs for each problem. Only one ring can be moved at a time and a larger ring cannot be placed on a smaller ring. The subject has six trials to solve a problem and two consecutive successes are needed for correct solution. Inhibition is required on some of the more difficult problems because the subject needs to move some of the rings initially in the opposite direction from that required ultimately for the solution of the problem. Performance was scored on each problem so that a score of 6 was assigned if the subject succeeded on the first two trials, a score of 5 was assigned if the subject succeeded on the second and third trial, and so forth down to zero. Six different problems were administered to each subject. Subjects were told that this was a measure of how well they could plan or think ahead.

RESULTS

Preliminary analyses were conducted to determine the extent to which abilities assessed on the Span of Apprehension and the Continuous Performance Task were stable across the six years. Results showed that scores on the two matrices of the Span of Apprehension were correlated with the 18 year score on the 10-item matrix, r(76) = .40, $p < .0003$, r(76) = .36, $p < .0001$ but there was no significant stability across age in scores on the Continuous Performance Task. Moreover, in contrast to 12 years when scores on the Span of Apprehension and Continous Performance Task were correlated, there was no significant association between these scores at 18 years of age.

Correlations were computed between infant fixation duration and scores on the measures administered to the adolescents with probability values based on one-tailed tests. As hypothesized, there was a negative association between fixation duration in infancy and score on the intelligence test, r(91) = -.36, $p < .0002$, and Span of Apprehension, r(85) = -.26, $p < .007$ administered at 18 years of age. The infant attention measure was not associated with hit rate on the Continuous Performance task. Thus, infant attention seems to be predictive of information detection and not of sustained attention at 18 years of age.

More intelligent 18-year-olds had higher scores on both the Span of Apprehension, r(87) = .23, $p < .015$ and the Continuous Performance Task, r(85) = .25, $p < .01$. The association between infant fixation duration and score on the Span of Apprehension was independent of intelligence; the correlation between the infant and adolescent scores remained significant even with adolescent intelligence covaried, r(80) = -.20, $p < .04$. Similarly, the correlation between infant attention and adolescent intelligence remained significant when score on the Span of Apprehension was covaried, r(80) = -.31, $p < .005$.

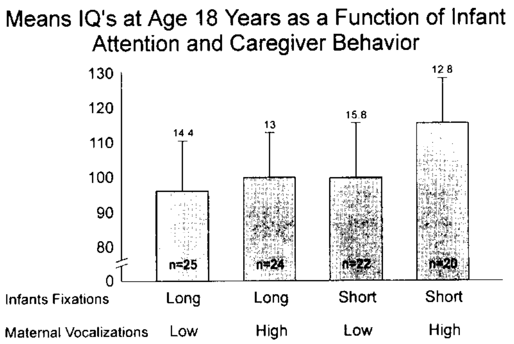

Figure 1. Mean IQs at age 18 years as a function of infant attention and caregiver behavior.

The Tower of Hanoi was administered to assess the adolescents' capacities for inhibition of prepotent responses and strategic planning in the context of a nonverbal task. Score on the Tower of Hanoi was strongly correlated with IQ, $r(89) = .54$, $p < .001$, but not with score on the Span of Apprehension. Infant fixation duration was negatively associated with score on the Tower of Hanoi, $r(91) = -.32$, $p < .002$, but the correlation was not significant when adolescent intelligence was covaried. However, the association between fixation duration and intelligence remained significant even when score on the Tower of Hanoi was covaried, $r(88) = -.25$, $p < .02$. In a hierarchical multiple regression, infant fixation duration continued to contribute to the variance in adolescent IQ even after scores on the Span of Apprehension and Tower of Hanoi had been entered, $R^2 = .03$, $F(1, 89) = 3.86$, $p < .053$.

In order to determine whether adolescent intelligence was jointly predicted by infant attention and caregiver vocalizations, two hierarchical multiple regressions were calculated, one with infant fixation duration entered first and the other with rate of caregiver variable entered first. In both cases, the multiple regressions were significant and both variables contributed significantly to the regression, overall $R^2 = .22$. When the interaction term was added to these multiple hierarchical regressions, the interaction term added a small but significant amount, $R^2 = .04$, to the regression, $F(1, 89) = 3.88$, $p < .05$.

In addition, the sample was divided on both measures using a median split and a 2 × 2 ANOVA was conducted using IQ as the dependent measure. Significant main effects of both factors was modified by a significant interaction between the two, $F(1, 87) = 4.11$, $p < .05$. The caregiving environment clearly moderated the extent of prediction from infant attention to adolescent intelligence (see Figure 1). Tests of simple main effects revealed that difference in intelligence as a function of infant attention only occurred for the children from homes where caregivers vocalized more to them, $F(1, 87) = 13.58$, $p < .001$, and not for the children from less stimulating homes. Similarly, the difference in intelligence as a function of maternal vocalizations was only significant for the children who showed brief fixation durations, $F(1, 87) = 13.13$, $p < .001$.

DISCUSSION

A major aim of this investigation was to use divergent measures in adolescence to define the processes assessed in infancy. The accomplishment of this aim depends on the extent to which adolescent measures can be found that tap specific processes. However, the identification of the processes involved in most tasks is imprecise, particularly because most tasks measure more than one cognitive process. Moreover, multifaceted tasks are of inherent interest since successful adaptation usually requires the integration of various capacities. Given these considerations, the answers that can be given to the question in the title of this paper are necessarily tentative.

Results from the current study replicate what was found previously with a smaller part of this sample, at a younger age, and with somewhat different measures. Infant attention was predictive of adolescent tasks thought to tap information processing ability but not of adolescent measures designed to test the capacity to sustain attention. Thus, the findings at age 12 years were not just chance associations. The association between infant fixation duration and adolescent information detection appears to be fairly specific in that the infant measure does not predict all forms of controlled attention.

The capacity for efficient information detection is clearly not the only form of processing that is shared by the infant attention and childhood intelligence measures. Intelligence continues to be correlated with infant attention even when score on the Span of Apprehension is controlled. The evidence that capacity for inhibition is a shared process cannot be ruled out. At both 12 and 18 years, infant attention was predictive of scores on measures thought to tap the capacity to inhibit prepotent responses in tasks requiring analogical and strategic thinking. The evidence that the association does not persist if intelligence is covaried does not disprove the inhibition hypothesis since intelligence very likely requires some capacities for inhibition of responses.

At the same time, the relation between infant fixation duration and inhibition only seems to hold for tasks that are intellectually challenging. Infant attention did not predict the simple ability to inhibit responses to a previously correct stimulus and shift to a different stimulus at 12 years of age. Regulating attention to attractive targets may be a challenging task for the very young infant, comparable in degree of cognitive difficulty to a verbal analogies task at age 12 years and the Tower of Hanoi at age 18 years.

Long-term continuity has been identified most frequently in studies of preterm infants. About 20 years ago, we showed that preterm infants tested at term looked longer at a single stimulus than full-term infants, that preterm infants tested at four months corrected age showed less preference for novel stimuli when fixed familiarizations time were used, and that preterm infants tested at eight months corrected age explored a familiar object rather than novel objects for longer periods than full-term infants (Sigman, 1976; Sigman, Kopp, Littman, & Parmelee, 1977; Sigman & Parmelee, 1974). In addition, Rose (1980, 1983) demonstrated that preterm infants as a group required longer familiarizations times than full-term infants in order to show preference for novel stimuli. These results suggest that there are more infants who process information slowly within preterm groups than within full-term groups. Followup studies of children born preterm demonstrate that, as a group, they have more learning problems than is true for children born full-term (for reviews, see Friedman & Sigman, 1992). Thus, continuity may be established best by studies of preterm infants because there are a greater number of children who are slow at processing information than is true within full-term groups. Indeed, preterm birth may constitute a risk factor for later cognitive development partly because it is associated with slower processing. Whether early birth causes this outcome, both are markers of some neurological deviance, or both stem from some associated event is completely unknown. However, infant attention measures may be particularly useful predictive tools in samples born preterm.

Early infant characteristics are clearly not the only predictors of later intelligence as shown by the differences in adolescent intelligence as a function of characteristics of the rearing environment. The spread in IQ is about half a standard deviation (98 vs. 106) when either the infants' fixation duration or the caregivers' vocalization rate is used to divide the sample into two parts. When both factors are taken into account, the spread in IQ between the lowest and highest groups becomes nearly 20 points, a very large effect indeed. Thus, the continuity in child abilities seems to be moderated by the environment.

Two explanations for the importance of caregiver vocalization rate seem likely. First, caregiver vocalization rate was a marker in this study for a home rearing environment that continued to be more responsive over the course of the next 2 year's of the child's life. Evidence for this is the association between the rate of maternal vocalizations and the quality of the home environment when the infants were 8 and 24 months of age. In addition, caregiver vocalizations may be particularly important for infants in the early months of life. The mother's voice seems to become familiar to the fetus and is preferred over the stranger's voice soon after birth (DeCasper & Fifer, 1980). Thus, it is possible that verbalizations to neonates may have direct advantageous effects on the infants' capacities to organize themselves and respond to the environment.

The effects of variations in the environment on intelligence were only noted among the infants who showed shorter durations of attention. These infants may be more generally mature or specifically able so that they are able to take advantage of their environments, perhaps partly because of the superior abilities reflected in the infant measure. It was also true that infant abilities only differentiated the adolescent groups if the infants had been reared by mothers who vocalized more to them. Thus, infant fixation patterns did not predict later intelligence except for children reared in environments that provided potential advantages.

The evidence from this study shows that characteristics of both the infant and the rearing environment contribute to the individual's long-term intellectual competence (Cohen, 1995). The extent to which these characteristics reflect genetic proclivities or environmental influences is unknown. The attention patterns of infants in this study could have been shaped by genetic factors, fetal experiences or post-birth experiences in the hospital nursery or home, since all infants had been alive for at least one month when they were tested. Similarly, rearing conditions are likely to reflect genetic and nongenetic factors. While the study, then, cannot differentiate on this basis, the results do show that, early in life, the infant and home environment already have characteristics important for future development.

The fact that brief looking times were advantageous in early infancy to unchanging stimuli does not mean that brief fixations are advantageous at all ages and to all stimuli. Optimal attention times vary depending on the characteristics of the child, stimulus, and milieu. This is an important consideration for studies that use infant attention measures as outcomes of various environmental and nutritional interventions.

The issue of continuity has potential practical significance in identifying and intervening with infants at risk of later cognitive dysfunctions. The specification of "looking time" in infancy as a descriptor of information processing is an important first step. While only a small part of the variance in adolescent intelligence is predicted, the fact that a measure that tests preterm infants with the first few months of life is able to predict intelligence 18 years later is remarkable. Moreover, this measure was designed 25 years ago before much was known about infant cognition so it should be possible currently to design much more sensitive predictors. A necessary first step is to determine the extent to which infant looking time is related to speed of processing, efficiency of scanning, and inhibitory ability. The identification of the contributors to infant attention durations should have important implications for the design of assessment measures and possible early interventions.

AUTHORS' NOTE

We are grateful to Arthur H. Parmelee, who initiated and led the Infant Studies Project and to the many other individuals who contributed to the project over the last 25 years. Robert Asarnow very generously shared his knowledge and some of his neuropsychological measures with us. The project was conceived by the late Theodore Tjossem and has been supported by the National Institute of Child Health and Human Development since its inception. The current follow-up was funded by Grant HD27352 (S.E. Cohen, P.I.).

REFERENCES

Bartfai, A., Pedersen, N.L., Asarnow, R.F., & Schalling, D. (1991). Genetic factors for the Span of Apprehension: A study of normal twins. *Psychiatry Research, 38*, 115–124.

Beckwith, L., & Cohen, S.E. (1984). Home environment and cognitive competence in preterm children in the first five years. In A.W. Gottfried (Ed.), *Home environment and early mental development* (pp. 235–273). New York: Academic.

Berg, C.A., & Sternberg, R.J. (1985). Response to novelty: Continuity vs. discontinuity in the developmental course of intelligence. In H.W. Reese (Ed.), *Advances in child development and behavior* (Vol. 19, pp. 1–47). Orlando, FL: Academic.

Bornstein, M.H. (1985). How infant and mother jointly contribute to developing cognitive competence in the child. *Proceedings of the National Academy of Science, 82*, 7470–7473.

Bornstein, M.H. (1989). Sensitive periods in development: Structural characteristics and causal interpretations. *Psychological Bulletin, 50*, 130–133.

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

Borys, S.V., Spitz, H.H., & Dorans, B.A. (1982). Tower of Hanoi performance of retarded young adults and norretarded children as a function of solution length and goal state. *Journal of Experimental Child Psychology, 33*, 87–110.

Bronson, G.W. (1991). Infant differences in rate of visual encoding. *Child Development, 62*, 44–54.

Ceci, S.J. (1990). *On intelligence...more or less: A bioecological treatise on intellectual development*. Englewood Cliffs, NJ: Prentice Hall.

Cohen, S.E. (1995). Biosocial factors in early infancy as predictors of competence in adolescents who were born prematurely. *Journal of Development and Behavioral Pediatrics, 16*, 36–41.

Colombo, J. (1995). On the neural mechanisms underlying developmental and individual differences in visual fixation in infancy: Two hypotheses. *Developmental Review, 15*, 97–135.

Colombo, J., Freeseman, L.J., Coldren, J.T., & Frick, J.E. (1995). Individual differences in infant fixation duration: Dominance of global versus local stimulus properties. *Cognitive Development, 10*, 271–285.

DeCasper, A.J., & Fifer, W.P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*, 1174–1176.

Dreary, I.J. (1995). Auditory inspection time and intelligence: What is the causal direction? *Developmental Psychology, 31*, 237–250.

Eslinger, P.J. (1996). Conceptualizing, describing, and measuring components of executive function: A summary. In G.R. Lyon & N.A. Krasnegor (Eds.), *Attention, memory, and executive function*, (pp. 367–395), Baltimore, MD: Paul Brookes.

Fagan, J.F. (1992). Intelligence: A theoretical viewpoint. *Current Directions in Psychological Science, 1*, 82–86.

Fagan, J.F., & Singer, L.T. (1983). Infant recognition memory as a measure of intelligence. In L.P. Lipsitt (Ed.), *Advances in infancy research* (Vol. 2, pp. 31–78). Norwood, NJ: Ablex.

Freeseman, L.J., Colombo, J., & Coldren, J.T. (1993). Individual differences in infant visual attention: Discrimination and generalization of global and local stimulus properties. *Child Development, 64*, 1191–1203.

Friedman, S., & Sigman, M.D. (Eds.). (1992). *The psychological development of low birthweight children*. Norwood, NJ: Ablex.

Hayes, S.C., Gifford, E.V., & Ruckstuhl, L.E. (1996). Relational frame theory and executive function; a behavioral approach. In G.R. Lyon & N.A. Krasnegor (Eds.), *Attention, memory, and executive function*, (pp. 279–305), Baltimore, MD: Paul Brookes.

Marr, D., & Sternberg, R.J. (1986). Analogical reasoning with nonentrenched concepts: Effects of conceptual novelty on gifted and nongifted students. *Cognitive Development, 1*, 53–72.

McCall, R.B. (1994). What process mediates predictions of childhood IQ from infant habituation and recognition memory? Speculations on the roles of inhibition and rate of information processing. *Intelligence, 18*, 107–125.

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

Neuchterlein, K.H. (1983). Signal detection in vigilence tasks and behavioral attributes among offspring of schizophrenic mothers and among hyperactive children. *Journal of Abnormal Psychology, 92*, 4–28.

Rose, S.A. (1980). Enhancing visual recognition memory in preterm infants. *Developmental Psychology, 16*, 89–92.

Rose, S.A. (1983). Differential rates of visual information processing in full-term and preterm infants. *Child Development, 54*, 1189–1198.

Rose, S.A., & Feldman, J.F. (1995). Prediction of IQ and specific cognitive abilities at 11 years from infancy measures. *Developmental Psychology, 31*, 685–696.

Sigman, M. (1976). Early development of preterm and full-term infants: Exploratory behavior in eight-month-olds. *Child Development, 47*, 606–612.

Sigman, M., Cohen, S.E., Beckwith, L., Asarnow, R., & Parmelee, A.H. (1991). Continuity in cognitive abilities from infancy to 12 years of age. *Cognitive Development, 6*, 47–57.

Sigman, M., Kopp, C.B., Littman, B., & Parmelee, A.H. (1977). Infant visual attentiveness in relation to birth condition. *Developmental Psychology, 13*, 431–437.

Sigman, M., Kopp, C.B., Parmelee, A.H., & Jeffrey, W.E. (1973). Visual attention and neurological organization in neonates. *Child Development, 44*, 461–466.

Sigman, M., & Parmelee, A.H. (1974). Visual preferences of four-month-old preterm and full-term infants. *Child Development, 45*, 959–965.

Smith, L., Ulvund, S.E., & Lindemann, R. (1994). Very low birth weight infants (<1501 g) at double risk. *Journal of Developmental & Behavioral Pediatrics, 15*, 7–13.

Vernon, P.A. (1987). *Speed of information processing and intelligence*. Norwood, NJ: Ablex.

Welsh, M.C., & Pennington, B.F. (1988). Assessing frontal lobe functioning in children: Views from developmental psychology. *Developmental Neuropsychology, 4*, 199–230.

23 February 1996;
Revised 13 August 1996 ■