

Infant Visual Expectation in Relation to Feature Learning

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Five-month-old infants were administered a modified version of Haith, Hazan, and Goodman's (1988) visual expectation paradigm. Infants were presented with 60 trials of a left-left-right or right-right-left alternating sequence of moving graphic stimuli. An immobile and unchanging visual feature (i.e., a V or a ∇) appeared at random locations on each of the graphics. Infants then received a series of six test trials in which a novel pair of identical moving stimuli was simultaneously presented to the left and right of visual center. The "familiar" feature (e.g., V) appeared on one member of the pair and the "novel" feature (e.g., ∇) appeared on the other member of the pair. Results indicated that infants who engaged in more anticipatory looking during the 60 familiarization trials attended more to the graphic containing the novel feature during test trials. Results suggest that 5-month-old infants who are better at learning spatiotemporal patterns are also better at learning the contents of brief and changing graphic displays. It is suggested that the relation between anticipatory looking and novelty preference is explained by cognitive as well as attention-regulatory factors.

novelty preference anticipation infancy learning attention
 expectation formation reaction time

Research on infant visual attention might be categorized into two general classes of investigations. On the one hand are studies that focus on the infant's visual behaviors during stimulus presentations. So, for example, in habituation and novelty preference paradigms, researchers assess how much time infants take to encode or process a stimulus and whether they rebound in attention to a novel picture after viewing a standard picture (e.g., Bornstein, 1985; Bornstein & Tamis-LeMonda, 1994; Colombo, Mitchell, O'Brien, & Horowitz, 1987; Rose, Feldman, & Wallace, 1992; Rose & Wallace, 1985; Sigman, Cohen, Beckwith, & Parmelee, 1986; Tamis-LeMonda & Bornstein, 1989, 1993).

In a second class of visual attention studies, focus has been on the infant's preparatory behaviors prior to or between visual events. For example, over successive visual presentations, infants have been shown to "expect" future events when presented with regular spatiotem-

poral patterns as indicated by anticipatory looks to the correct location prior to picture onsets (e.g., Haith, Hazan, & Goodman, 1988). Researchers have referred to these and similar orienting behaviors as "response preparation," "anticipation" or "expectancies" (Canfield & Haith, 1991; Capaldi & Verry, 1981; Haith et al., 1988; Hull, 1943; Schmidt, 1968), "prospective memory" (Rovee-Collier & Hayne, 1987; Sherrington, 1906; Wasserman, 1986), and "vigilance" (Ruff, Capozzoli, Dubiner, & Parrinello, 1990).

For some time, investigations of visual expectation were conducted independently of paradigms that focused on the encoding of stimulus information and preference for novel stimuli, despite the fact that similar underlying processes (e.g., learning) were often attributed to the infant's behaviors during both assessments. Recently, investigators have begun to explore interrelations between expectancy formation and novelty preference as well as the relative predictive validity of the two paradigms for measures of later intellectual functioning (e.g., Benson, Cherny, Haith, & Fulker, 1993; Jacobson et al., 1992). These research inquiries have identified moderate covariation between measures obtained from the visual expectation paradigm and those obtained from novelty preference tasks, lending empirical support to the speculation that performance on the two paradigms reflects common underlying processes.

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This study builds on this integrative approach to infant visual attention by investigating the relation between anticipatory looking and novelty preference as assessed in a single paradigm. To date, no studies have examined whether or not infants who participate in visual expectation paradigms are encoding information about the content of the visual displays that are rapidly presented to them (cf. Wentworth & Haith, 1992). Are infants learning content as well as spatiotemporal information during such tasks? Do those infants who more readily form visual expectancies (i.e., show more anticipatory looking) demonstrate better learning of the content of visual displays? The examination of anticipatory looking and novelty preference in a single assessment targets learning at two levels—that is, the infant must learn about where and when pictures will appear as well as what features of those pictures remain constant over trials—hence, such a paradigm might permit investigation of more cognitively complex problem-solving abilities in infants.

To this end, a visual expectation-novelty preference paradigm was developed as a possible window onto individual differences in learning at these dual levels. Infants were exposed to a constant spatiotemporal sequence (i.e., left-left-right or right-right-left) in which changing and moving stimuli each contained an unchanging and immobile visual feature. During a subsequent test phase, infants were presented with a series of trials in which the familiar feature was paired with a novel feature, and infants' differential attention to the novel feature was examined.

It was hypothesized that infants who are better at forming expectations would be better at learning the constant feature that was presented during these spatiotemporally regular trials. This speculation was guided by two rationales. First, expectation formation and novelty preference are thought to each reflect underlying processes of representation and learning, that is, the learning of spatiotemporal patterns and stimulus content, respectively. Accordingly, infants who are quicker or more efficient learners ought to more quickly form expectations and be better at encoding the details of a repeatedly presented feature. Empirical support for a cognitive interpretation of novelty preference has been reviewed by Bornstein and Sigman (1986) and more recently elaborated by McCall

and Carriger (1993) and Colombo (1993). Similarly, a cognitive interpretation has been ascribed to infants' behavior during expectancy paradigms (e.g., Haith et al., 1988) and has been empirically supported by age differences in anticipations (e.g., older infants show more anticipatory head-turns; Haith et al., 1988) as well as by recent studies documenting concurrent and/or predictive correlations between expectancy formation and performance on other visual attention paradigms or standardized assessments (Benson et al., 1993; Jacobson et al., 1992).

The second reason infant expectation formation might relate to novelty preference is based on an ethological model. According to many researchers, expectancies are thought to be adaptive, reflecting the efficient regulation of attention so that the infant is prepared for incoming information (e.g., Haith et al., 1988). Accordingly, infants who are better at processes that serve to regulate attention, as reflected in anticipatory looking, should more efficiently encode information. Information processing theorists have long recognized that individual differences on intelligence tests are best explained by metacognitive processes such as attention regulation as well as more basic processes such as information encoding (e.g., Sternberg, 1985). Studies that have documented the significant role of expectation for learning and memory (Friedman, 1979; Goodman, 1980; Haith et al., 1988; Minsky, 1975; Schank & Abelson, 1977) lend additional support to the hypothesis that more anticipatory looking might lead to more efficient learning of stimulus features by infants.

METHOD

Subjects

Subjects were 24 5-month-old infants who were administered a modified visual expectation paradigm. All subjects were recruited from private pediatric and obstetric groups in New York City as well as New York University Hospital. Subjects were all term at birth and had not had any prenatal or postnatal complications. Subjects were from middle-class households (Hollingshead = 59).

One subject did not complete the expectation paradigm due to fussiness. Three additional subjects attended to fewer than 50% of the stimulus presentations (15%, 31%, and 46%, respectively). Thus, the reported analyses are based on a final sample of 20 infants (13 males, 7 females). Examination of outlier information derived from boxplots (Tukey, 1977) indicated that all measures were normally distributed and that there were neither univariate nor bivariate outliers.

Experimental Arrangement

Infants were seated on their mother's lap approximately 150 cm from a graphics monitor (65 cm × 48 cm) which was embedded in a white panel that extended from ceiling to floor. A Macintosh IIcx computer (located in an adjacent control room) controlled the presentation of geometric stimuli onto the graphics monitor.

A Panasonic AG-190 camera equipped with a zoom lens was embedded in the white panel 14 cm above the monitor and was angled down at the infant's eyes so that a video-recorded image of infant eye movements could be obtained. A second camera, located on the wall above and behind the infant, video recorded the monitor display. The signals from the two cameras, that is, the infant's eyes and monitor display, fed into an American Dynamics 1479 Digisplit split-screen box, so that both images appeared side-by-side on the videotape. This single video signal and ongoing frame count and time from a Panasonic VW-CG1P time-date generator were recorded onto videocassettes. During subsequent scoring, experimenters viewed the split-screen signal and were able to note the onsets of graphics and shifts in infant looking with respect to one another to the nearest 0.03 s. The rest of the infant area was enclosed by white curtains.

During the experiment, the video signal was displayed on two monitors, one to the experimenter in the adjacent control room and one to the mother. The signal to the mother permitted her to adjust her infant's position so that the infant's eyes would remain centered on the screen throughout the session.

Procedure

Figure 1 illustrates the procedures for stimulus presentations. All stimuli were pictures of simple abstract geometric patterns in various colors, including red, blue, yellow, green, purple, black and white; during all presentations, the contents of these pictures moved so as to optimize infant attention. Each of the pictures differed in shape, color, and type of movement. Pictures shrank and then exploded, went through various oscillations, flashed different colors, or had component parts move in relation to other parts (e.g., a pair of circles moved within the perimeter of a larger square). In the context of these movements, the center position of pictures on the display monitor did not change.

Once infants were properly positioned, a series of eight colorful pictures were irregularly (i.e., randomly) presented to the left and right of visual center. These initial trials provided baseline reaction-time data for individual infants not yet influenced by the learning of spatiotemporal information. Graphics were 25 cm × 27 cm. The midpoint of each graphic was 6.8° to the left and right of visual center. The total graphic spanned a visual angle of 9.4°. In instances in which the graphic shrank and then exploded, the visual angle of the graphic decreased from 9.4° to 4° to 6° and then increased to 9.4° again by the end of the exposure period.

After these baseline trials, infants were shown 60 pictures presented in a left-left-right or right-right-left alternating sequence for a period of 700 ms per graphic and an inter-stimulus interval of 700 ms. Each of these graphics shared a single common feature (e.g., V). The feature measured a constant 7.2 cm × 8.9 cm, spanning an average visual angle of 2.7° across trials. This constant feature did not move or change size within a trial in order to create a figure-ground image that would engender notice of the feature in infants.

Otherwise, background graphics moved during the entire exposure in order to maintain infants' attention. For different graphics, the visual feature appeared at different locations on the graphic; however, differences in the visual angle of the feature always ranged between 2.66° and 2.74°.

Following the 60 trials, six test trials were administered to the infant, in which a novel graphic was simultaneously presented to the left and right of the infant's visual center for a period of 10 s per trial. The center points of each graphic were 6.8° to the left and right of visual center. Inner borders were separated by a distance of 10.8 cm and a visual angle of 4.1°; outer border borders were separated by a distance of 60.8 cm and a visual angle of 23°. One graphic in the pair contained the familiar visual feature (e.g., V), and the other graphic contained a novel feature (e.g., the ∇). For each test trial, the background graphic display changed; the familiar and novel features were presented on alternating sides across the six trials. Six test trials assured that even if infants continued looking in the same pattern with which they were familiarized (e.g., left-left-right or right-right-left), they would view the novel feature and familiar feature an equal number of times (i.e., three times). Thus, novelty preference scores could not be confounded with the familiarization pattern to which the infant had been assigned. There was then a posttest in which there were eight irregular presentations as in baseline trials.

Scoring

During subsequent scoring, coders played back the video signal containing the image of the infant's eyes, the graphics display, and frame count in a frame-by-frame mode using a Panasonic AG-7350 SVHS commercial industry video recorder. Stimulus onsets and offsets and all infant eye shifts were coded to the nearest frame (Haith et al., 1988). During initial stages of coding, four different adults were run on the paradigm and were instructed to look at all presented stimuli and to provide verbal information as to the location of their fixation (e.g., "I'm on the left graphic now"). This enabled coders to gauge infant eye shifts with respect to adult eye shifts. Moreover, these adults were asked to provide "false trials," that is, they would look too far left or too far right in order to identify the approximate locations of looks that were off the monitor or graphic.

Scoring proceeded through three phases. First, coders noted whether or not infants attended to each of the pictures. A criterion was established in which infants had to attend to 50% of the pictures in the familiarization phase in order to be included in analyses (criteria followed those established in laboratories using visual expectation paradigms (M.M. Haith, personal communication, Fall, 1993). Twenty of the 23 infants who completed the paradigm achieved the criterion of 50%. Second, the onsets of all eye shifts were coded by two experimenters for baseline trials and anticipation trials. During the familiarization phase, each look to the correct picture location was classified into one of three categories:

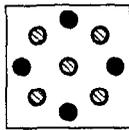
1. Reactive Shifts—defined as those that occurred > 200 ms after picture onset.
2. Anticipatory Shifts—defined as those that occurred to the correct location prior to picture onset or ≤ 200 ms after picture onset.
3. Correct Fixations—maintaining attention to the same side at which a stimulus has recently appeared and will

appear again (e.g., continuing to look at the left field after the first left exposure in a left-left-right sequence).

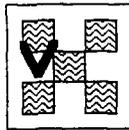
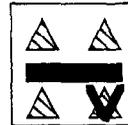
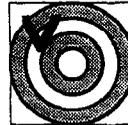
Haith et al. (1988) noted that adult visual reaction times average between 200 and 400 ms; thus, they suggested that eye shifts occurring within 200 ms are within reasonable bounds of anticipatory looks for infants, because movements within this time frame must have been initiated prior to the stimulus onset. In this study, we examined the reaction-time distributions for individual infants in order to garner further support for the 200-ms criterion. To do this, we calculated the number eye shifts to stimuli that fell within each possible 100-ms window. So, for example, we calculated the number of eye shifts falling between -150 ms and

-50 ms, -50 ms and 50 ms, 50 ms and 150 ms, and so forth, for all possible negative and positive latencies. The largest proportion of these (i.e., 23%) fell between 250 and 350 ms, suggesting that shifts occurring within 200 ms might in fact reflect anticipatory looking.

In addition to these looking categories, coders noted eye shifts and fixations to incorrect sides (e.g., the infant shifts gaze to the left, but the subsequent stimulus does not appear there). These additional categories served as checks in analyses to assure that results were not an epiphenomenon of frequent but random eye shifts or freezing fixation on a particular location on the graphics monitor. Incorrect eye shifts and fixations comprised only 4% of all looks on average and did not relate to anticipatory looking, reaction



Familiarization Phase: 60 graphics in regular pattern (e.g., RRL) -- 700 msec



Test Phase: 6 paired-comparison graphics -- 10s each



Post Test Phase: 8 graphics randomly presented to left and right -- 700 msec each

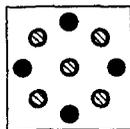


Figure 1. Procedures for Expectation-Novelty Preference Paradigm

times, or novelty preference scores; thus, they are not included in further analyses.

Third, the onset and offset of all eye shifts were coded for each of the six test trials, so that total looking time at the graphic with the familiar feature and total looking at the graphic with the novel feature could be obtained for each trial separately as well as across the six test trials.

Coders agreed on whether or not infants looked at the graphic 99% of the time; they agreed on looking category (i.e., reactive shift, anticipatory shift, or correct fixation) 95% of the time and on the timing of look onsets and shifts 86% of the time (based on a criterion in which > 100 ms difference was considered a disagreement). Coders of the test phase were unaware of the results from the baseline and anticipation phases. That is, if Coder A coded the anticipation phase for a given infant, Coder B coded that infant's test phase.

Data Reduction

Average baseline reaction time was calculated across the eight trials for those trials during which the infant showed a reactive shift to graphic onsets. From the 60 anticipation trials, frequencies were obtained for the three looking categories defined previously: the number of reactive shifts, the number of anticipatory shifts, and the number of correct fixations. A total anticipation score was then calculated by summing anticipatory shifts and correct fixations. In addition, the longest sequence of anticipatory looks to the correct side (which could include correct fixations), average reaction time for reactive shifts, and a composite reaction time score (based on the average latency across all reactive and anticipatory eye shifts) were calculated.¹ From the test phase data, a novelty preference score was calculated by summing the time infants attended to the picture with the novel feature divided by the total time spent looking at the novel and familiar features for each trial separately as well as across trials.

RESULTS

Infants varied substantially on all measures. Descriptive statistics for baseline and anticipation phase reaction times, looking categories during the anticipation phase, and novelty preference scores from the test phase are presented in Table 1. As indicated by the descriptive data on novelty preference during the test phase, infants did not spend significantly more time attending to the novel versus familiar feature (time looking to novel was 51% and time attending to familiar was 49% across trials). Thus, as a group, infants did not appear to be

learning the constant feature during the expectation task.

In the first stage of correlational analyses, we examined average reaction time during the eight baseline trials in relation to looking during the anticipation phase and novelty preference during the test phase. There was a moderate relation between baseline reaction time and reaction time of reactive shifts during the anticipation phase, $r = .46, p < .05$. However, baseline reaction time did not relate to the composite reaction-time score, $r = .04$. It may be that reaction-time estimates that include anticipatory eye shifts are reflecting different processes than those that index *responses* to graphic onsets. Faster baseline reaction time was marginally associated with novelty preference during the test phase, $r = -.36, p < .10$, but was not related to the total anticipation score, $r = -.19$. These data accord with those of Jacobson et al. (1992) in which baseline reaction time in the visual expectation paradigm related moderately to infants' performance on cross-modal transfer and novelty preference tasks but related only weakly to anticipation, $r = -.19$.

The second set of analyses examined relations between looking during the anticipation phase and novelty preference during the test phase (see Table 2). First, those infants with faster composite reaction-time scores showed greater novelty preference in the test phase, although reactive shifts demonstrated a weak and nonsignificant relation to novelty preference. As hypothesized, those infants with more anticipatory looks tended to look more at the novel stimulus but not the familiar stimulus in the test phase (see Table 2). Specifically, more anticipatory shifts, a greater number of correct stays, and the total anticipation score were associated with higher novelty preference in the test phase.² There was a weak tendency for more reactive shifts to relate inversely to novelty preference, as might be expected.

Not shown is the fact that the relation between anticipatory looking and novelty preference was consistent across all six test trials.

¹ Only *shifts* in attention were used in the reaction-time calculations in order to be consistent with the baseline reaction-time measure as well as operational definitions of reaction time in the extant adult and infancy literature. That is, fixations on the correct side, although thought to indicate an expectancy of the upcoming event (and hence, included in the total anticipation score), were not considered to provide ecologically valid latency data.

² Relations between anticipatory shifts and novelty preference were examined using different criteria cutoffs for looking latencies, specifically, with cutoffs at < 300 ms, < 100 ms, and < 0 ms. Zero-order relations did not change dramatically as a function of these different criteria, $r = .42$ for a 0-ms cutoff, $r = .36$ for a 100-ms cutoff, $r = .28$ for a 300-ms cutoff.

TABLE 1
Descriptive Statistics

	<i>M</i>	<i>SD</i>	Range
Baseline 8 trials			
Average Reaction Time	.54	.13	.30–.70
Anticipation Phase			
Average Reaction Time (anticipatory shifts and reactive shifts)	.28	.15	.00–.55
Average Reaction Time (reactive shifts only)	.50	.10	.35–.70
<i>N</i> Reactive Shifts	23.9	7.8	11.0–43.0
<i>N</i> Anticipatory Shifts	13.4	6.5	5.0–27.0
<i>N</i> Correct Fixations	11.0	6.0	0.0–19.0
Total Anticipation Score	24.4	8.6	5.0–42.0
Maximum Segment Correct	3.3	1.8	1.0–8.0
Test Phase			
Novelty Preference	.51	.18	.18–.88

That is, during every trial, infants with greater anticipatory looking looked less at the graphic with the familiar visual feature and looked more at the graphic with the novel feature.

To further illustrate these findings, infants were divided into two groups based on their anticipation data. A median split was conducted based on infants' total anticipation scores. Novelty preference scores of the "high" anticipators versus "low" anticipators were then compared to chance looking. For infants classified as high anticipators, novelty preference averaged 62%, $t(8) = 2.43, p < .05$. Infants classified as low anticipators had novelty preference scores that did not differ from chance (42%), $t(10) = 1.55$. Thus, in contrast to the finding for the entire group of infants in which novelty

preference scores did not differ from chance, infants who learned the spatiotemporal information did demonstrate novelty preference.

Hierarchical Regressions

In the final analyses, we examined unique relations between three significant predictors of novelty preference—baseline reaction time, the composite reaction time score during anticipation, and total anticipatory looking. Specifically, we asked whether each of the three predictors would continue to predict novelty preference after controlling for the contributions of the other two measures. Together, the three predictors accounted for a significant 39% of the variance in novelty preference, $F(3, 16) = 3.37, p < .05$. However, this was due to the strong contribution of the total anticipation score. That is, anticipatory looking continued to predict novelty preference after controlling for the two reaction-time measures, R^2 change = 16%, $p < .05, F(3, 16) = 4.20, p < .05$. In contrast, baseline reaction time contributed a non-significant 7% additional variance to novelty preference, and reaction time during anticipation accounted for virtually no additional variance in novelty preference after controlling for baseline reaction time and the total anticipation score. These data suggest that the relations that were identified between reaction times and novelty preference were mediated by infants' anticipatory looking.

DISCUSSION

In this investigation, 5-month-old infants were tested on a modified version of the Haith et al. (1988) visual expectation paradigm, in which

TABLE 2
Relations Between Looking
During Anticipation Phase and Novelty
Preference During the Test Phase

	Test Phase: Novelty Preference <i>r</i>
Anticipation Phase	
Average Reaction Time (anticipatory and reactive shifts)	-.40**
Average Reaction Time (reactive shifts only)	-.20
<i>N</i> Reactions	-.20
<i>N</i> Anticipatory Shifts	.30*
<i>N</i> Correct Stays	.53**
Total Anticipation Score	.59***
Maximum Segment Correct	.22

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

the simultaneous formation of expectancies and the learning of a visual feature were examined. As hypothesized, infants who showed more anticipatory looking during the anticipation phase subsequently attended more to graphics containing a novel visual feature during the test phase. This relation upheld after controlling for reaction times during baseline and anticipation trials, both of which were significant predictors of novelty preference at the zero-order level.

Two alternative explanations might be ascribed to these data. As noted, it is possible that the formation of anticipations and attending to novel features of the environment both reflect a common underlying construct of representation formation. Thus, although the processes of anticipatory looking and novelty preference might be differentiated at one level (e.g., preparatory set/planning vs. encoding/memory), they are each central to and indicative of learning. That is, infants who are quicker learners might be better at extracting information about the spatiotemporal aspects of visual arrays as well as better at learning about the visual features that are a constant part of such rapidly changing environments. This interpretation accords with findings by Jacobson et al. (1992), in which baseline reaction time from the visual expectation paradigm was associated with infants' performance on other perceptuo-cognitive tasks, as well as with work by Colombo (1993), in which faster habituators were found to be "faster processors" rather than just "feature processors."

Alternatively, it may be that infants who are better at metacomponent processes such as the regulation of attention are better at forming expectations which in turn facilitates the task of learning. That is, infants who are better prepared for upcoming events might acquire feature information more readily as a function of this preparatory set. Such an interpretation has been ascribed to individual differences in habituation and novelty preference, albeit less frequently than cognitive or representational interpretations. For example, Sigman (1988) suggested that infants who are better able to regulate attention might be those who habituate faster and subsequently learn faster in early childhood. Similarly, work by Ruff et al. (1990) on vigilance in infants suggests that efficient performance in any attention task requires a more or less constant level of alertness and preparedness to respond throughout interstimulus intervals.

Finally, a series of studies by Tamis-LeMonda and Bornstein (1989, 1993; Bornstein & Tamis-LeMonda, 1994) indicates that attention measures in infancy, notably habituation and novelty preference, relate to multiple aspects of cognition in infancy and toddlerhood, including infant activity, flexible language, symbolic play, and attention span. They suggested that visual attention measures are best conceptualized as reflecting multiple underlying processes that encompass both representational and attentional competencies. Investigations by Jacobson et al. (1992) also accord with this notion. Based on a principal-components analysis of measures of infants' visual expectation performance, recognition memory, and cross-modal transfer, they suggested that performance on such tasks was indicative of basic cognitive processes such as information processing speed as well as a combination of memory and attention. More recent investigations in this area ought to elucidate the various processes which together and in interaction explain infant performance on such tasks.

In sum, research on infant attention has often been methodologically bifurcated. That is, researchers have investigated what infants do in preparation or in expectation of a visual stimulus or what infants do during inspection of a stimulus. This study integrates these dual approaches by focusing on infants' performance on two problems: the learning of spatiotemporal information as well as the learning of feature information. We suggest that the association we identified between these two abilities is explained by both basic and meta-cognitive components, and further inquiries in this area ought to consider multiple determinants and outcomes of infant visual attention measures.

REFERENCES

- Benson, J.B., Cherny, S.S., Haith, M.M., & Fulker, D.W. (1993). Rapid assessment of infant predictors of adult IQ: Midtwin-midparent analyses. *Developmental Psychology*, 29, 434-447.
- Bornstein, M.H. (1985). How infant and mother jointly contribute to developing cognitive competence in the child. *Proceedings of the National Academy of Sciences (USA)*, 82, 7470-7473.
- Bornstein, M.H., & Sigman, M.D. (1986). Continuity in mental development from infancy. *Child Development*, 57, 251-274.
- Bornstein, M.H., & Tamis-LeMonda, C.S. (1994). Antecedents of information-processing skills in infants: Habituation, novelty responsiveness, and cross-modal transfer. *Infant Behavior and Development*, 17, 371-380.

- Canfield, R.L., & Haith, M.M. (1991). Young infants' expectations for symmetric and asymmetric stimulus sequences. *Developmental Psychology, 27*, 198-208.
- Capaldi, E.J., & Verry, D.R. (1981). Serial order anticipation learning in rats: Memory for multiple hedonic events and their order. *Animal Learning and Behavior, 9*(4), 441-453.
- Colombo, J. (1993). *Infant cognition: Predicting later intellectual functioning*. Sage: Newbury Park.
- Colombo, J., Mitchell, D.W., O'Brien, M., & Horowitz, F.D. (1987). The stability of visual habituation during the first year of life. *Child Development, 58*, 474-487.
- Friedman, A. (1979). Framing pictures: The role of default knowledge in automatized encoding and memory for gist. *Journal of Experimental Psychology: General, 108*, 316-355.
- Goodman, G.S. (1980). Picture memory: How the action schema affects retention. *Cognitive Psychology, 12*, 473-495.
- Haith, M.M., Hazan, C., & Goodman, G.S. (1988). Expectation and anticipation of dynamic visual events by 3.5-month-old babies. *Child Development, 59*, 467-479.
- Hull, C.L. (1943). *Principles of behavior*. New York: Appleton-Century-Crofts.
- Jacobson, S.W., Jacobson, J.L., O'Neill, J.M., Padgett, R.J., Frankowski, J.J., & Bihun, J.T. (1992). Visual expectation and dimensions of infant information processing. *Child Development, 63*, 711-724.
- McCall, R.B., & Carriger, M.S. (1993). A meta-analysis of infant habituation and recognition memory performance as predictors of later IQ. *Child Development, 64*, 57-79.
- Minsky, M.A. (1975). A framework for representing knowledge. In P.H. Winston (Ed.), *The psychology of computer vision*. New York: McGraw-Hill.
- Mowrer, (1938). Preparatory set (expectancy)—A determinant in motivation and learning. *Psychological Review, 45*, 62-91.
- Rose, S.A., Feldman, J., & Wallace, I. (1992). Infant information processing in relation to six-year cognitive outcomes. *Child Development, 63*, 1126-1141.
- Rose, S.A., & Wallace, I. (1985). Visual recognition memory: A predictor of later cognitive functioning in preterms. *Child Development, 56*, 885-891.
- Rovee-Collier, C., & Hayne, H. (1987). Reactivation of infant memory: Implications for cognitive development. In L. Lipsitt & C. Rovee-Collier (Eds.), *Advances in child behavior and development*. New York: Academic.
- Ruff, H.A., Capozzoli, M., Dubiner, K., & Parrinello, R. (1990). A measure of vigilance in infancy. *Infant Behavior and Development, 13*, 1-20.
- Shank, R.C., & Abelson, R.P. (1977). *Scripts, plans, goals and understanding*. Hillsdale, NJ: Erlbaum.
- Schmidt, R.A. (1968). Anticipation and timing in human motor performance. *Psychological Bulletin, 70*, 631-646.
- Sherrington, C.S. (1906). *The integrative action of the nervous system*. New Haven, CT: Yale University Press.
- Sigman, M.D. (1988). Infant attention: What processes are measured? *European Bulletin of Cognitive Psychology, 8*(5), 512-516.
- Sigman, M.D., Cohen, S.E., Beckwith, L., & Parmelee, A.H. (1986). Infant attention in relation to intellectual abilities in childhood. *Developmental Psychology, 22*, 431-437.
- Sternberg, R.J. (1985). *Beyond IQ: A triarchic theory of human intelligence*. Cambridge: Cambridge University Press.
- Tamis-LeMonda, C.S., & Bornstein, M.H. (1989). Habituation and maternal encouragement of attention in infancy as predictors of toddler language, play, and representational competence. *Child Development, 60*, 738-751.
- Tamis-LeMonda, C.S., & Bornstein, M.H. (1993). Antecedents of exploratory competence at one year. *Infant Behavior and Development, 16*, 423-439.
- Tukey, J.W. (1977). *Exploratory data analysis*. Menlo Park, CA: Addison-Wesley.
- Wasserman, E.A. (1986). Prospection and retrospection as processes of animal short-term memory. In D.F. Rilling & M.R. Denny (Eds.), *Theories of animal memory*. Hillsdale, NJ: LEA.
- Wentworth, N., & Haith, M.M. (1992). Event-specific expectations of 2- and 3-month-old infants. *Developmental Psychology, 28*, 842-850.