

Laura P. O'Sullivan

Neil E. Berthier

Department of Psychology
University of Massachusetts Amherst
Amherst, MA 01003
E-mail: berthier@psych.umass.edu

Attention During Looking and Reaching as Assessed by Heart Rate in 7½-Month-Old Infants

ABSTRACT: Attention mediates the acquisition and encoding of information about the world and is central to motor action. Heart rate deceleration and behavioral inhibition are sensitive indices of the attentional process, but it is unknown whether these indices are valid in the context of overt action. The current study investigated the relationship between visual attention, action, and heart rate during reaching in 7.5-month-old infants. We found that infants showed prolonged looking and large heart rate decelerations on reaching and looking trials. We conclude that overt action itself does not prevent the autonomic and behavioral changes that are also seen in attention to simple visual displays and that attention is maintained throughout the act of reaching. © 2003 Wiley Periodicals, Inc. *Dev Psychobiol* 42: 1–9, 2003.

Keywords: infant; heart rate; attention; reaching; looking

Attention has been conceptualized as a process that allows for the acquisition and encoding of information that facilitates adaptation to the world (Cohen, 1972; Sokolov, 1963; Ruff and Rothbart, 1996). In the study of attentional development, most researchers have used overt visual orienting, quieting of motor movements, and deceleration of heart rate to index attention (e.g., Byrne and Smith-Martel, 1987; Richards & Casey, 1992; Clifton, 1978). Heart rate seems to be a particularly good index of the degree or depth of attention. For example, Richards and Casey (1992) showed that the depth of heart rate deceleration predicts the latency of looking to a peripheral distractor and also predicts future looking away from a central visual display. Changes in heart rate can also help discriminate short-latency, automatic responses to a stimulus from longer-latency, voluntary responses that accompany the active processing of information (Cohen, 1972; Sokolov, 1963). The latter phase of voluntary, active

processing of information has been termed sustained (Richards, 1987) or focused attention (Ruff, 1986).

Attention is not only required in simple looking situations but also in situations that require overt actions. Studies of attention in adults show that many complex motor actions require visual attention to the external world as well as visual attention to parts of the body. In this context, Allport (1987, 1989) has argued for attentional *selection-for-action*, the role attention plays in the selection of information that makes action appropriate and efficient. In selection-for-action, attention selects which aspects of the perceptual array are mapped onto the appropriate control parameters for action (Allport, 1989). Other adult researchers have investigated the role attention plays in the execution of a motor response. Execution of non-automatic responses require the on-line monitoring and control of movement (Schneider & Shiffrin, 1977). Such *attention-to-action* has been shown to interfere with verbal tasks in adults (Passingham, 1996).

In considering the relationship of attention to reaching in infants, one would expect that the attentional requirements of reaching would be high in young infants. The prevailing view of reaching in young infants is that infants need to visually attend to a target and to their hand's location and configuration in order to accomplish an effective grasp (Von Hofsten, 1993; Berthier, 1996). This visual attention is required to accomplish a series of

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directional and amplitude corrections during execution (Von Hofsten, 1993; Berthier, 1996; Berthier and Robin, 1998). Like Passingham's (1996) demonstration that attention-to-action interferes with verbal processing in adults, Boudreau and Bushnell (2000) showed in infants that there is a trade-off between motor action and cognition. In two studies, they showed that complex motor acts interfere with cognitive planning and that cognitive planning interferes with motor acts.

Although the need for attention during action seems clear in both adults and infants, it is not clear how the widely used measure of infant attention, heart rate, is related to attention during reaching. On one hand, if attention during action involves similar processes to those of simple visual attention, we would expect that attention during reaching would be accompanied by general behavioral inhibition and heart rate deceleration. On the other hand, reaching involves active stabilization of the trunk and movements of the arm and thus might lead to somatic activation and heart rate acceleration. What then is the relationship of heart rate to movement in attentionally demanding tasks?

First, heart rate deceleration during attention is highly correlated with decreased general body movement. Byrne and coworkers (Byrne and Smith-Martel, 1987; Byrne and Miller, 1988) tested 3- and 6-month-olds in an attentional paradigm and found that heart rate was highly correlated with overall body movement during attention but not during periods of inattention. They also found that the presentation of a stimulus that elicited attention caused a greater increase in cardiac-somatic coupling in the older infants, suggesting an increase in cardiac-somatic coupling with development.

Second, general body movement that occurs during attentional paradigms seems to disrupt or block heart rate deceleration and attentional engagement. Clifton and coworkers (Gregg, Clifton, and Haith, 1976; Morriongiello and Clifton, 1984) found that movement prevented heart rate decreases to an attentional stimulus and Bacher and Robertson (2001) found an inverse relationship between body movement and visual inspection. Furthermore, Robertson, Bacher, and Huntington (2001) showed that body movement rapidly increases just before shifts of visual attention and concluded that these increases in body movement are involved in shifting the infant's visual attention.

The above studies show that general body movement is correlated with a lack of attention and with an increase in heart rate; however, it is not clear if a controlled movement, such as a reach, is likewise correlated with an increase in heart rate. In adult S_1 - S_2 reaction time tasks, heart rate decelerations are observed that are related to the initial ready signal and to preparation of the motor response (Koers, Gaillard, and Mulder, 1997; Lacey and

Lacey, 1974), even when the motor response is metabolically demanding (Chase, Graham, and Graham, 1968). Thus, the adult data suggest that while heart rate might increase in response to general body movement, heart rate might decrease during controlled movements in attentional paradigms.

One study has directly examined the relationship between heart rate changes of infants during reaching. Pomerleau and Malcuit (1980) tested infants from 1.5 to 5.5 months of age in a situation where an object was presented out of reach for 15 s and then presented within reach for 15 s. Pomerleau and Malcuit found heart rate deceleration to the distal presentation of the object in all but the oldest infants, but as the object moved within reach, heart rate accelerated to baseline at all ages. In contrast to Byrne and Smith-Martel (1987) and Byrne and Miller (1988), Pomerleau and Malcuit found low correlations between heart rate and movement. Pomerleau and Malcuit concluded that the heart rate acceleration to proximal presentation of the toy reflected somatic activation as the infants reached for the toy. They also concluded that the lack of deceleration seen in the oldest infants to distal presentation of the toy reflected somatic activation in preparation for the reach as the infant anticipated the toy would be moved within reach.

The Pomerleau and Malcuit (1980) results support the hypothesis that reaching either interferes with heart rate deceleration during attention or that attention during action involves different autonomic processes than during simple observation. However, Pomerleau and Malcuit presented the object distally and proximally in serial steps. It is possible that the return to baseline of heart rate during proximal presentation was not the result of action interfering with heart rate deceleration but instead the result of a substantial attentional disengagement after 15 s of distal regard. Pomerleau and Malcuit also do not present heart rate data synchronized with reaching, so their study did not examine the second-by-second changes in heart rate that occur before, during, and after execution of a reach.

The possibility that reaching and manual examination interfere with heart rate deceleration also has practical implications. Ruff's (1986) definition of focused attention was derived from behavioral scoring, while Richards' (1987) definition of sustained attention was based on heart rate. Lansink and Richards (Lansink and Richards, 1997; Lansink, Mintz, and Richards, 2000) investigated whether these two definitions of attention refer to the same or to separable psychological processes. If they reflect the same processes, Lansink and Richards hypothesized that the classification of behavioral segments using the two definitions should be highly concordant. To test this hypothesis, Lansink and Richards (1997) and Lansink, Mintz, and Richards (2000) tested

infants in a simple toy play situation. While Lansink and colleagues found a general agreement of the two definitions, there was only a 51% concordance between behavioral ratings of focused and heart rate defined sustained attention. The results of Pomerleau and Malcuit (1980) thus raise the possibility that the lack of concordance between the two definitions of attention might be due to the fact that reaching and manual exploration during some bouts of focused attention caused somatic activation and led to increases in heart rate. These increases in heart rate during behavioral segments defined as focused attention then led to classification of those segments as *not* being classified as periods of sustained attention.

The current study seeks to directly investigate the relationship between visual attention, action, and heart rate during reaching in infants. The primary question of interest in the current study was whether controlled action, such as reaching, disrupts heart rate deceleration reflective of attention. Because controlled action requires attention, heart rate deceleration might not be disrupted by the preparation and execution of a reach. On the other hand, the results of Byrne and colleagues (Byrne and Smith-Martel, 1987; Byrne and Miller, 1988), Clifton and colleagues (Gregg, Clifton, and Haith, 1976; Morriongiello and Clifton, 1984), and Pomerleau and Malcuit (1980) showed that movement often disrupts heart rate deceleration and thus suggest that reaching might attenuate or prevent heart rate deceleration reflective of attention. Data on whether reaching and toy examination disrupt heart rate deceleration provided by the current study will also help resolve the problem of scoring discrepancies for sustained and focused attention in behavioral segments of attention.

METHOD^{Q1}

Participants

Participants were identified in State of Massachusetts Birth Records and recruited by exploratory letters and telephone calls to parents. Twenty-five infants participated in this study and were given small gifts for their participation. Data from five infants were not included in the analyses because four of the infants did not provide any usable reaches and because one was reported to have been born prematurely. The remaining twenty ranged in age from 218 to 246 days, with a mean age of 236 days (33.7 weeks; 7.8 months). Seven and a half month olds were used because infants of this age were both reliable in their reaching accuracy and because they did not show gross postural instability, which might lead to artifactual increases in heart rate. This age was also chosen because [Berthier and Robin \(1988\)](#)^{Q2} showed that infants of this age monitor the visual surround and the target object during reaching.

Stimulus and Apparatus

Each infant was presented with reaching trials and looking trials. Each type of trial used a different toy as the object for reaching. Infants were presented with a 12 cm plastic, yellow and red Winnie-the-Pooh toy and a 12 cm plastic, gray and purple Eeyore toy. The exact toy used for reaching and looking trials was counterbalanced across infants.

At the start of each reaching trial, a toy was positioned on a track behind a pair of curtains. The trial started when the toy was moved forward towards the infant by a computer controlled stepper motor. The distance from the starting position of the toy at the beginning of the trial to the stopping position in front of the infant was 80 cm. The toy traveled at a rate of speed of 20 cm/s, reaching the end of the track in 4 s. Upon reaching the stopping position, the toy remained within the infant's reaching space for 10 s before being returned by the stepper motor to the starting position behind the curtains. Coincident with the start of each trial, a 60 W incandescent bulb was illuminated over the apparatus to signal to the infant the start of the trial.

Looking trials followed the same procedure as the reaching trials, with two exceptions. First, the toy that was not presented to the infant during the reaching trials was presented during the looking trials. Second, instead of the toy stopping within the reaching space of the infant, it stopped 40 cm from the infant's end of the apparatus. This stopping position encouraged visual attention to the toy but discouraged reaching movements toward the toy, as it was no longer attainable.

Infant behavior was assessed using two cameras for video analysis and an electrocardiogram (EKG). The first camera, a (Panasonic PV-810), was placed in line with the apparatus to provide a frontal view of the infant. Video from this camera was used to assess the direction of the infant's gaze, orientation to the toy, initiation of the reach, contact with the toy, and general motor activity throughout each trial. Video data from this camera were channeled through a date-time generator (FOR-A) prior to being recorded on a video tape deck (Panasonic AG-1980). The second camera (SONY DCR-VX1000) was placed approximately 4 feet to the right of the infant, providing both a side view of the infant and a view of movement of the toy along the track. Video from this camera was used to assess the time at which the toy emerged from behind the curtains as well as the initiation of reaches which began below the apparatus, and therefore out of view of the first camera.

EKG was conventionally amplified and stored on a computer following 12 bit analog to digital conversion at 100 Hz. The recording of the EKG data was triggered simultaneously and time-locked to video data of the first camera. In addition, a small LED placed within view of the second camera was automatically illuminated with the triggering of the date-timer and allowed for data from the second camera to be synchronized with all other collected data.

Procedure

The infant was seated on a parent's lap, facing the apparatus. Each trial proceeded with the infant and parent being seated slightly off center to the left of the apparatus to encourage right-handed reaching by the infant. We encouraged right-handed

reaching because we monitored the kinematics of reaching with an Optotrak motion analysis system that required the placement of markers on the infant's hand and could only monitor a single hand. Kinematic data were analyzed but are not presented here because they provided no useful information regarding attention and action. The parent was instructed to hold the infant firmly around the hips so as to offer adequate support without hindering the infant's movements and/or reaches. The parent was further instructed not to direct the infant's attention or influence the infant at any point during the trials.

Each infant participated in a minimum of four looking trials and seven reaching trials. The first four trials presented were reaching trials and were intended to familiarize the infant with the apparatus and encourage reaching for the toy. Following these training trials, looking and reaching trials were alternated in blocks of two trials each, with two looking trials beginning the sequence. It was occasionally necessary to reduce the number of looking trials to one per block if an infant showed signs of becoming bored and/or fussy.

Each trial lasted for 25 s, beginning with the triggering of the data gathering systems. Following each successful reach during the reaching trials, the infant was allowed to hold the toy for approximately 10 s to aid in maintaining interest.

Data Analysis

We scored the latency to orient to the toy from the start of each trial, the latency to initiate a reach from the start of each trial, the latency to contact the toy from orientation to the toy, and the latency to look away from the toy. All of the video data were scored by the primary experimenter and one third of the data were also scored by an independent observer. The results were compared to ensure inter-rater reliability. Reliability in scoring a particular event was considered to be achieved if each scorer was within three frames, or 0.09 s, of the other scorer. Reliability was met for all measures with an accuracy rating of 95% or better.

EKGs were acquired using Ag-AgCl electrodes, conventionally amplified, and digitized at 100 Hz. The average inter-beat interval (IBI) of the heart was computed using the temporal distance between peaks of the EKG autocorrelation function. IBIs were computed once every s using a 2-s moving window. Each resulting data file was manually inspected to exclude trials where the IBI showed discontinuities from one sample to the next (less than 5% of trials were excluded). The baseline rate for each trial was computed from the first two-second window of EKG data from that trial and averaged 136.9 bpm. The Huynh-Feldt correction was used and is reported for significant ANOVA effects.

RESULTS

Behavioral Data

Looking Trials. Infants received a total of 141 looking trials ($M = 7.05$ trials/infant). Infants typically showed repeated looks at the toy on each trial ($M = 2.84$ orientations/trial) and first looked at the toy an average of 2.77 s

from the start of the trial. Infants reached for the toy on six of the looking trials but never succeeded in contacting the toy on any trial.

All infants looked at the toy at least once on each of the looking trials. Most infants showed second ($N = 130$) and third ($N = 92$) looks, and a few infants looked to the toy four times on an individual trial ($N = 35$).

Of the four orientations that occurred on the looking trials, paired t -tests showed that first looks ($M = 4.52$ s) were significantly longer than second [$M = 2.60$ s; $t(18) = 3.84$, $p < .001$] and third looks [$M = 2.97$ s; $t(18) = 4.11$, $p < .001$]. The difference in second and third look lengths was not significant [$t(18) = 1.19$, $p < .252$]. The mean look length of the longest look per trial, regardless of when it occurred within the trial, was 5.52 s.

Infants continued to find the toy interesting throughout the session with the first look length for the first three looking trials ($M = 4.42$ s) not differing from the first look length for the last three looking trials of testing [$M = 4.92$ s; $t(15) = 0.72$, $p < .48$].

Reaching Trials: Looking. Owing to the infants' interest in the reaching task, we were able to present a larger number of reaching trials than looking trials. Infants received an average of 12.8 trials each for a total of 256 reaching trials.

Infants always oriented to the toy before reaching, and as with the looking trials, often showed multiple orientations to the toy. The number of orientations per trial, however, was significantly lower on reaching trials ($M = 1.39$) than on looking trials [$M = 2.84$; $t(19) = 13.23$, $p < .001$].

Infants looked to the toy 2.5 s after the start of the trial on average. Infants reached during the first look on 238 of the 256 reaching trials. The mean look length that encompassed the reach was 9.01 s on reaching trials. This length was significantly longer than the mean first look length of 4.52 s on the looking trials [$t(19) = 8.23$, $p < .001$]. This difference in looking times during looking and reaching probably reflects the fact that look lengths on reaching trials included looking while reaching and looking during examination after the infant obtained the toy.

When the average length of the first looks from the initial three testing reaching trials was compared to the average length of the first looks from the final three reaching trials, we found that looks were not shorter for the final reaching trials [$t(19) = 1.91$, $p < .071$].

Reaching Trials: Reaching. Infants attempted 291 reaches and were successful in contacting the toy 272 times on the 256 reaching trials. Each infant averaged a total of 13.6 reaches, with a mean of 1.15 reaches per trial. The average latency to initiate a reach from the start of

each trial was 6.41 s, 2.41 s after the toy stopped within reaching distance. The average reach movement time was 1.15 s.

Behavior during the four reaching training trials presented to each infant at the start of the session was compared to the behavior of the infants on the subsequent reaching testing trials. The look latency from the trial start was found to be significantly longer during the training trials ($M = 3.02$ s) than during the remaining reaching trials [$M = 2.30$ s; $t(19) = 4.05, p < .001$].

Neither the time between look onset and reach initiation [$t(19) = 0.18, p < .86$], nor movement time [$t(19) = 0.96, p < .35$] differed between training and testing. Overall look lengths did differ between the training ($M = 10.07$ s) and testing [$M = 8.47$ s; $t(19) = 2.34, p < .03$].

Heart Rate Data

Electrocardiograms were recorded from all infants on all training and test trials but because of technical difficulties with the recording of the data, we were not able to obtain reliable heart rate measures for all of the trials. Because the repeated measures ANOVA used requires an equal number of contributed trials from each subject, we focused our analysis on a subset of data that met this condition and provided data from most of our infants. In the analyses below, data were used from 18 of our 20 infants.

Figure 1 shows heart rate responses from a representative infant during testing. The data are from the first three consecutive test reaching trials. The figure shows that the infant's heart rate consistently slowed around the time of look onset and remained low during reaching.

We first compared heart rate responses on looking and reaching trials. Figure 2 shows the change in IBIs, aligned for the start of the trial, from the first three looking (left) and first three reaching (right) trials of the test phase of the experiment. The hatched boxes show the range of the central 50% of look and reach latencies. For example, the two boxes for the left-hand panel shows the 25th and 75th percentiles for look onset, and the 25th and 75th percentiles for look offset. Similar boxes are given in the right-hand panel for reach onset and contact. Inspection of this figure suggests that infants showed pronounced decelerations in heart rate near the start of reaching trials that persisted for several seconds. On the looking trials, the deceleration in heart rate returned to baseline around the time the infants looked away from the toy.

ANOVA of these data showed a significant Time main effect [$F(12, 204) = 4.11, p < .01$], indicating that the infants' heart rates varied with the time of recording during the trial. Tests of trial type (looking vs. reaching) and repeated trials were not significant, nor were any of the interaction effects.

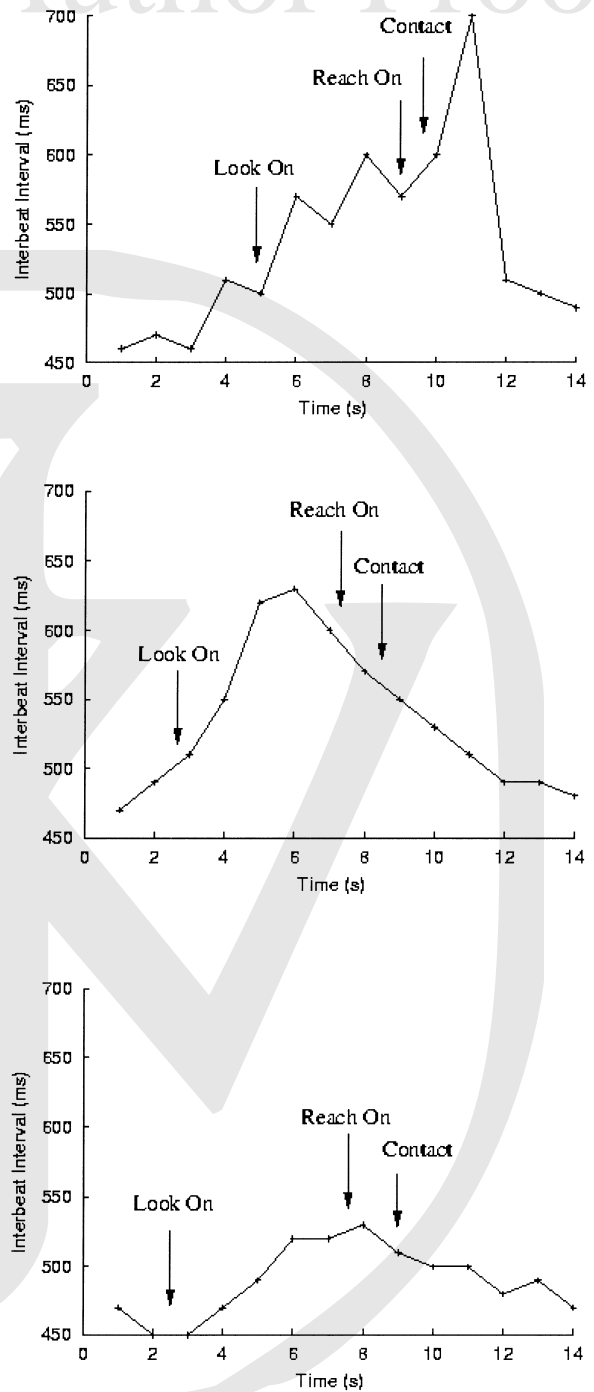


FIGURE 1 Change in IBI for an infant on their first three reaching test trials. Each panel shows the IBI on a second by second basis with the time of look onset, reach onset, and contact indicated by vertical arrows.

While heart rate changes were observed in the above data, significant variability was present. The observed variability could be due to the fact that the infants, while often responding to the appearance of the toy with looks and reaches, also showed considerable variability in their

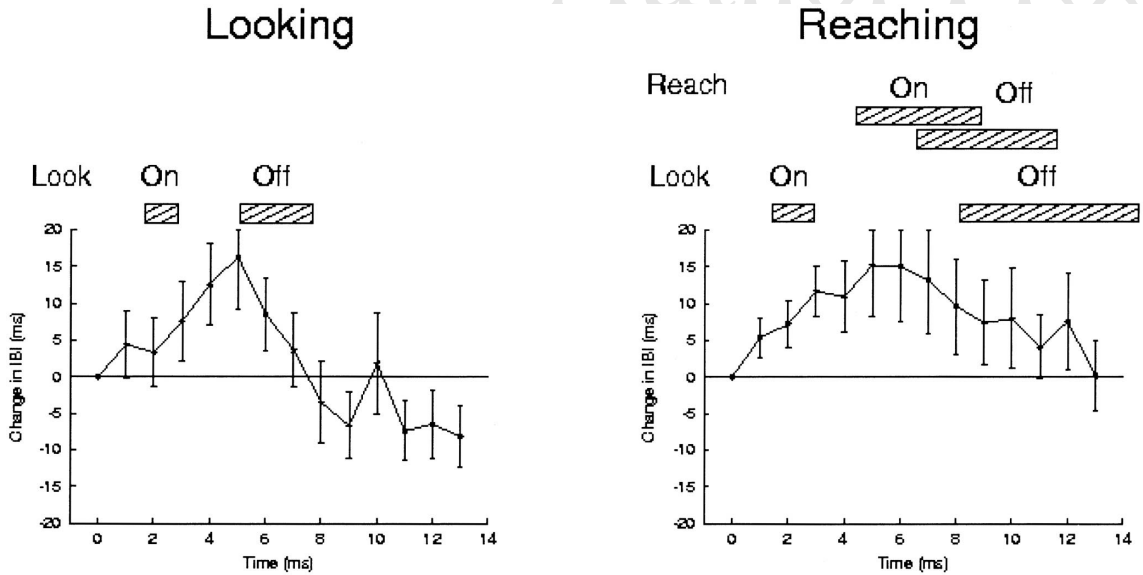


FIGURE 2 Change in IBI for infants on looking (left) and reaching (right) trials. The IBI changes are aligned with the start of the trial and standard errors of the mean are given. Look On refers to time of look onset, Look Away to time of look away, Reach On refers to reach onset, and Reach Off to contact of the hand with the toy. Each hatched block presents the central 50% of the times for each behavior. More precisely, the left edge of each box is the 25th percentile and the right edge the 75th percentile for each behavior.

behavior. If heart rate responses are reflective of increased infant attention correlated with looking and reaching, then synchronization of the heart rate data with the behavior should produce more reliable effects than when the data are synchronized with some relatively arbitrary event such as the start of the trial.

To investigate this possibility, we synchronized the heart rate data with the time of the first look at the toy on the initial three looking and reaching trials of the testing

phase of the experiment. The average IBIs for these two trial types are presented in Figure 3. ANOVA revealed significant Trial Type [$F(1, 17) = 5.39, p < .033$] and Time [$F(10, 170) = 5.63, p < .002$] effects and a marginal Trial Type \times Time effect [$F(10, 170) = 2.39, p < .056$]. This analysis confirms the impression that infants' heart rates respond differently on the two trial types and that the temporal course of the heart rate changes differed by trial type. Inspection of the figure also

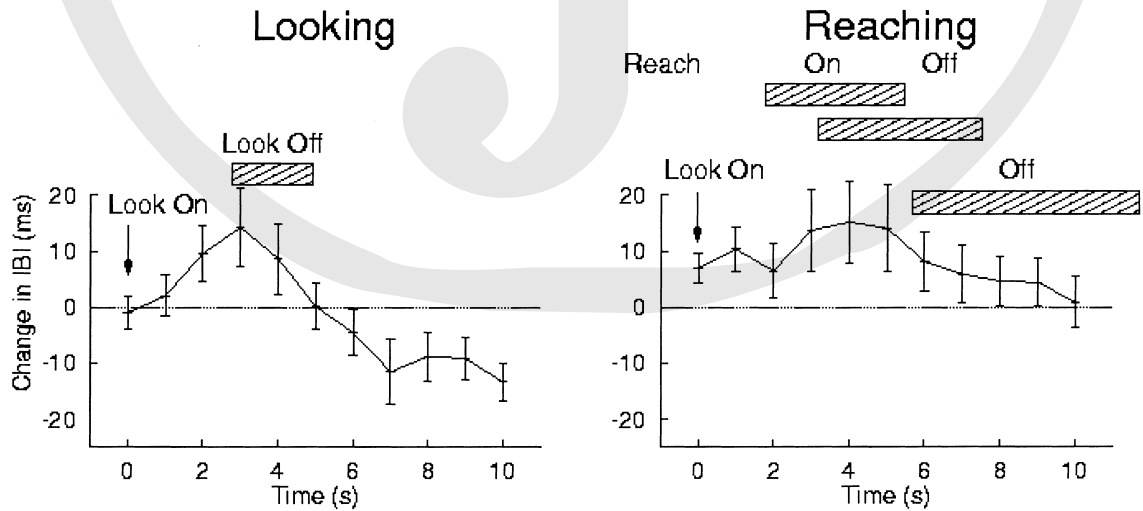


FIGURE 3 Change in IBI for infants on looking (left) and reaching (right) trials. Data are aligned with the onset of looking.

suggests that the heart rate response for the looking trials returned to baseline around the time infants looked away from the toy, but that the heart rate response on reaching trials maintained its deceleration during and after the reach.

To further investigate the degree to which heart rate responses reflected infant attention during reaching, we synchronized the heart rate data from the reaching trials with the onset of the reaches. We first examined heart rate responses during the training trials. As mentioned previously, the training trials consisted of the first four trials presented to each infant and were intended to familiarize the infant with the apparatus and the reaching task. Because we did not obtain usable heart rate data from all four training trials for each infant due to technical difficulties, the analyses for the training trials were based on two trials each from the 18 infants used in the previous analyses.

Figure 4A shows the change in IBIs during the training trials. Examination of this figure reveals that infants' heart rates varied over the time of the trial. In addition, the data show that heart rates decreased prior to the initiation of the reach (time zero) but then quickly accelerated. ANOVA performed on these data confirmed our impressions and disclosed a significant Time main effect [$F(12, 204) = 5.53, p < .001$], indicating that the infants' heart rates varied during the time of the trial. No interaction effects were found to be significant.

Considerable variability was also observed in these data, as indicated by the large error bars. It is possible that this variability is a result of the unfamiliarity of the surroundings and the unknown demands of the task, which may have served to excite the infants. If this were the case,

one would expect that the variability would be reduced as the infants became more familiar with their surroundings and practiced with the reaching task.

In order to examine this possibility, we analyzed data from the testing trials. Because of the greater number of test trials, we were once again able to use three trials from each of the 18 infants for the analyses. The IBIs presented in Figure 4B reveal a change in heart rate over the time course of the trial. In addition, visual comparison of Figure 4A and B suggests that variability was reduced in later trials, as is evidenced by the smaller error bars. Figure 4B also shows that heart rate remained reduced for a greater length of time during the testing trials than was seen during the training trials. This supports our hypothesis that familiarity with the research session may have reduced stress and excitement, resulting in a prolonged and consistent reduction in heart rate. ANOVA of these data confirmed our impression that the IBIs varied across the course of the trial time, with a significant Time effect [$F(12, 204) = 3.25, p < .028$]. None of the interaction effects were significant.

DISCUSSION

Infants found both looking and reaching trials interesting and this interest allowed us to present a large number of trials of each type to the infants. Infants behaved differently on the two trial types, with 6 reaches attempted on the looking trials and 291 reaches attempted on reaching trials. In comparing the two trial types, the reaching trials elicited more involvement than the looking trials. Although the time to visually orient to the toys was

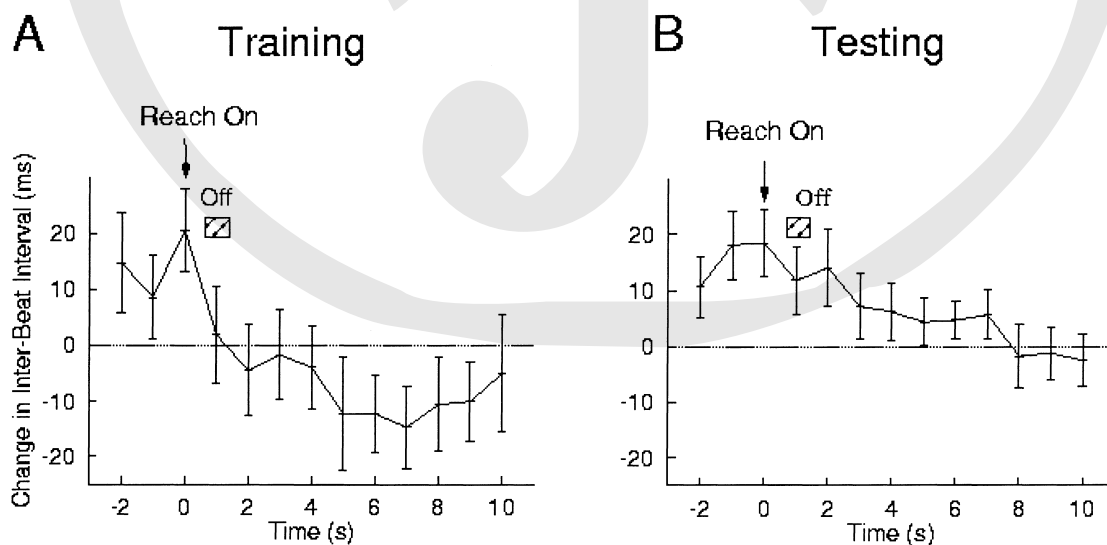


FIGURE 4 Change in IBI for infants on reaching trials. Data are aligned with onset of the reach. Data from training trials are on the left and data from testing trials are on the right.

comparable for both trial types, infants showed longer look durations and fewer look-aways on reaching trials. This more concentrated looking behavior on reaching trials shows that reaching and manual exploration elicited more intense engagement with the task than simple visual exploration.

Heart rate changes paralleled looking behavior. Like orientation latency, the initial heart rate decelerations on the two trial types were comparable. The length of heart rate deceleration varied with trial type with decelerations lasting 4 or 5 s on looking trials and lasting over 6 s on reaching trials. The latter prolongation was likely the result of visual and manual exploration of the toy in the infant's hand.

The finding that heart rate remained low throughout the reach and post-reach manual examination period suggests that manual action did not significantly disrupt vagal activation accompanying attentional engagement. This finding is consistent with the attentional demands of controlled action and with adult studies showing heart rate decelerations with movement preparation in reaction time experiments (Lacey and Lacey, 1974; Koers et al., 1997), and is in contrast to Pomerleau and Malcuit (1980) who found that movement of a toy to within reach caused an acceleration of infant heart rate back to baseline. The discrepancy between the results is likely due to the fact Pomerleau and Malcuit presented the toy out of reach for 15 s and then moved the toy to within reach. The acceleration of heart rate to baseline during reaching in their study could have been due to attentional disengagement with the object. Furthermore, Pomerleau and Malcuit reported heart rate relative to the start of the trial, not reach onset, so that their data do not provide clear information about reach-heart rate relationships.

The hypothesis that the lack of concordance seen between focused and sustained attention during toy play is the result of somatic activation of the heart rate during manual exploration is not supported by our data. At the same time behavioral attention was directed to a toy and a reach executed, the heart rate of our infants remained depressed. Clearly, motor actions such as reaching and manipulation of a toy do not always prevent heart rate decelerations reflective of attention. It therefore seems likely that the reaching and manipulation of toys in Lansink and Richards (1997) and Lansink et al. (2000) did not prevent heart rate decelerations and thus did not prevent characterization of those episodes as sustained attention. This suggests that the lack of concordance of judgments of focused and sustained attention is reflective of some measurement error, the task demands, or that focused and sustained attention are two separable attentional processes.

Lastly, to the extent that heart rate deceleration reflects depth of attention on a second by second basis, our finding

of heart rate deceleration during reaching suggests that attention remains high even during somatic motor action. These attentional demands might reflect visual attention to the target, attention to the current position and configuration of the arm and hand, and might reflect attention to the control of the motor act itself.

NOTES

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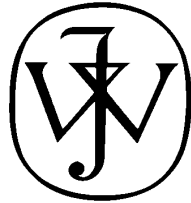
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