PAPER

Development of approach and inhibition in the first year: parallel findings from motor behavior, temperament ratings and directional cardiac response

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Abstract

A group of 139 infants was observed at 6 and 12 months. Approach and inhibition were measured via latencies to touch low- and high-intensity objects, directional cardiac response to low- and high-intensity sounds and maternal ratings of positive and fearful emotionality. Inhibition showed considerable increases in all three domains from 6 to 12 months. Also reflecting increases in inhibitory processes, correlations between individual infants’ responses to low- and high-intensity sounds were significantly smaller at 12 than at 6 months. Limited cross-domain validity was obtained linking large cardiac decelerations, low latencies to reach for toys and high ratings of positive emotionality. These findings are consistent with previous reports documenting relatively greater gains in inhibition than approach during the second half of the first year. Modest cross-domain consistency indicates separate mechanisms may moderate approach and inhibition in the three different realms.

Introduction

In 1962, Kagan and Moss (1962) found fearfulness, measured during the first 3 years of life, to be predictive of similar psychological characteristics assessed in early adulthood. Since then, multiple studies have documented the stability of individual differences in children’s willingness to engage themselves with novel or intense persons and objects throughout childhood (e.g. Asendorpf, 1990; Garcia-Coll, Kagan & Reznick, 1984). In addition, behavioral inhibition has been examined as a moderator of parental socialization (Kochanska, 1995, 1997), as a hindrance to successful peer interactions (Rubin, 1982), and has recently been implicated as a precursor to internalizing difficulties in adolescence (Biederman, Rosenbaum, Chaloff & Kagan, 1995).

The majority of research on inhibition considers only children in the second year and beyond. The few inquiries that have utilized infants younger than 6 months (e.g. Calkins, Fox & Marshall, 1996; Kagan & Snidman, 1991) have focused on activity level and negative affect to novel or intense events as early precursors to fearfulness. This emphasis on reactivity is based on the supposition that individual differences in inhibition are due to differing thresholds for sympathetic nervous system activation, expressed as negative reactivity in early infancy and later as fearfulness and withdrawal. Although common physiological processes presumably link early reactivity to later inhibition, fear reactions to strangers and true inhibition of behavior do not emerge until the third quarter of the first year (Schaeffer, 1966; Schaeffer, Greenwood & Parry, 1972).

In addition to concentrating primarily on children older than 1 year, the majority of work on behavioral inhibition has assumed that approach and inhibition reside on two ends of a single continuum. Evidence from other sources, however, suggests that it may be more appropriate to view the two constructs as separate entities. Recent neurological theories of motivation based on research from a wide variety of sources typically posit two basic systems controlling approach and inhibition. For example, Gray’s behavioral approach system (Gray, 1982), Depue’s behavioral facilitation system (Depue & Iacono, 1989) and the expectancy-foraging system discussed by Panksepp (1982) describe structures leading to approach in response to cues or to motivate exploratory activity. Conversely, Cloninger’s (1987) harm avoidance dimension and the behavioral inhibition systems of Gray...
and Depue refer to systems which halt appetitive approach to stimuli which signal punishment or nonreward. Similarly, Kinsbourne (1978) asserted that approach was controlled, in large part, by activity in the left hemisphere of the brain, whereas the inhibition of approach was primarily under the influence of the right hemisphere.

Rothbart (1988) has investigated the existence of separate systems underlying behavioral approach and inhibition by focusing on differential rates of development of the two underlying mechanisms. She points out the fact that reflexive approach responses exist even in the newborn child but that the inhibition of approach undergoes rapid development between 6 and 9 months (see also Schaffer et al., 1972). Whereas the two processes become closely intertwined and difficult to separate through behavioral observation after this point, the differential developmental rates of approach and inhibition provide a unique window of time to observe behavioral approach without the confounding influence of inhibition. To study this phenomenon, Rothbart developed a procedure involving the presentation of two sets of toys, a highly arousing set and a less arousing set. At 6 months of age, speed of reaching towards both sets of toys is believed to index approach tendencies. Near the end of the first year, however, reaching toward the intense toys is additionally influenced by behavioral inhibition. Supporting this contention, Rothbart (1988) found average latencies to approach low-intensity toys did not increase from 6.5 to 10 months, whereas latencies to reach for high-intensity toys (indexing approach moderated by inhibition) were longer at later ages.

Approach and inhibition have also been conceptualized as being manifest through positive and negative emotions. Fox and Davidson (1984, 1988; Davidson & Fox, 1982) augmented Kinsbourne’s (1978) assertion regarding neural control of motor behavior by focusing on relations between positive and negative emotions and activity from the two hemispheres. Utilizing EEGs of infants in a variety of emotion-eliciting situations, these researchers found approach-related emotions to be associated with activation in the left hemisphere, with withdrawal reactions identified with relatively stronger right hemisphere activity. Thus, positive emotionality and motor approach both appear to be regulated by the left hemisphere, whereas inhibition, actualized both as cessation of approach and through negative emotionality, may be controlled primarily by the right hemisphere.

Factor analysis of personality inventories in children and adults have also linked approach and inhibition tendencies to specific emotions. For instance, ‘Big Five’ models of adult personality (e.g. Digman, 1990; Goldberg, 1990) contain factors that can be characterized as Neuroticism/Negative Emotionality and Extroversion/Positive Emotionality (Rothbart, Derryberry & Posner, 1994). Recent work (e.g. Digman, 1994; Havill, Allen, Haberson & Kohnstamm, 1994) has documented substantial similarity between five-factor structures of temperament and personality in infants and older children with these adult dimensions. Rothbart et al. (1994) argue that the higher-order factors of Positive Affect and Fear found in infant models correspond with the motivational dispositions of approach and behavioral inhibition/avoidance, respectively.

Consistent with the assertion that approach motivation appears very early in development, whereas inhibition does not emerge until later, are observations regarding the appearance of emotion expressions. By 3 months, joyful expressions emerge (Lewis, 1993) and the infant is able to exhibit interest in unexpected events (Brooks & Lewis, 1976). Sometime during the third quarter of the first year, however, unexpected and novel events such as the approach of a stranger are likely to elicit expressions of fear rather than interest (Schaeffer, 1966). Whereas the early appearance of interest and joy and the onset of fear between 6 and 9 months have been well documented, few researchers have explicitly conceptualized psychophysiological components of approach and inhibition. The cardiac orienting and defensive responses potentially represent such physiological indices. Pavlov (1927) is credited with being the first scientist to develop the notion of orienting and defensive reflexes as instrumental processes in organizing behavior in response to an unexpected event (Sokolov & Cacioppo, 1997). The orienting reflex (OR), he proposed, served as a ‘what-is-it’ reaction that focused receptor organs in an effort to understand the source of a discrepant stimulus. In contrast, the defensive reflex (DR) led to postural shifts away from the stimulus. Parallelizing the rationale of Schnierla (1959) regarding motoric approach and withdrawal, Sokolov (1963) reasoned that an OR is elicited by stimuli that are low or moderate in intensity, whereas a DR occurs in response to high-intensity stimuli. Concurrent with the theorizing of Sokolov, the Lacey’s (Lacey, 1959; Lacey, Kagan, Lacey & Moss, 1963) suggested that heart rate decelerations could facilitate sensory intake and that cardiac acceleration was associated with rejection of sensory input. In what has been referred to as ‘one of the most influential deductions in psychophysiology’ (Sokolov & Cacioppo, 1997), Graham and Clifton (1966) united the theories of Sokolov and the Lacey’s by proposing that orienting and defensive responses could easily be measured via directional changes in heart rate in reaction to unconditioned stimuli, suggesting that cardiac acceleration was characteristic of a defensive response, whereas cardiac deceleration was a component of the orienting response.
These differential responses according to stimulus intensity, however, may not be present at birth, but may develop over the first year. In a study of infant response to variations in sound intensity, 4-month-old infants did not react with cardiac accelerations (defensive responses) to 85 dB tones, but actually responded with larger decelerations (orienting responses) to 85 dB tones of white noise than to tones of 60 or 75 dB (Finlay & Iviniskis, 1987). By 10 months, infants do demonstrate heart rate acceleration in response to 90 dB stimuli (Berg, Jackson & Graham, 1975), but continue to consistently exhibit deceleratory responses to 75 dB tones. In the current study, it was expected that similar findings would be obtained, in that infants would show accelerations or attenuated decelerations to the 80 dB tone at 12 months, but not at 6 months.

In sum, the underlying goal of this study was to examine the development of the approach and inhibition systems over the second half of the first year, utilizing data from three distinct arenas. In an attempt to replicate the work of Rothbart (1988), in the area of motor activity, approach and inhibition were operationalized as latencies to reach for toys that were either high or low in intensity. In the emotion domain, frequency of approach- and inhibition-related emotions were assessed via parent reports. Finally, in the psychophysiological realm, approach and inhibition were characterized as cardiac orienting and defensive responses in response to auditory stimuli of varying intensities.

The development of approach and inhibition between 6 and 12 months was addressed via three sets of analysis. First, it was predicted that development in all three areas would exhibit patterns of greater relative development in inhibition-related processes than in approach-related tendencies. As the approach system was not expected to undergo dramatic changes from 6 to 12 months, measures of approach (i.e. behavioral and physiological responses to low-intensity sounds and objects, positive emotionality) should not change substantially over this time. In contrast, due to the substantial development of the inhibition system, measures of inhibition (i.e. responses to high-intensity sounds and objects, fear expressions) were expected to show considerable differences from the earlier to the later age.

The development of the inhibition system during the second half of the first year can also be explored using the degree of correspondence among individual infants’ responses to stimuli of varying intensity. At 6 months, latency to reach for both high- and low-intensity toys should be primarily under the control of the approach system, thus latencies to reach for the two sets of toys should be correlated. Similarly, cardiac responses to sounds of varying intensities should be related to one another at this age. At 12 months, responses to high-intensity, but not low-intensity stimuli, should be additionally influenced by the activity of the inhibition system and it was predicted that relations between responses to the low- and high-intensity stimuli would be lower at 12 than at 6 months.

A final set of analyses examined the convergence of measures of approach and inhibition across the three domains. If the influence of the approach and inhibition systems is pervasive across the motor, emotional and physiological realms, individual differences in these areas should be consistent with one another. It was predicted that infants high in motor approach (e.g. those with short latencies to reach for toys) would exhibit strong cardiac orienting responses and would be rated by their mothers as high in smiling and laughter and low in reactivity to novelty. Infants who appeared high in motor inhibition (e.g. those who reach slowly for the high-intensity toys) were expected to show defensive cardiac responses to high-intensity sounds and to be rated high in fear by their mothers.

Methods

Sample

The sample utilized in this study was recruited as part of a longitudinal study following infants and their families from 2 weeks to 23 months of age. Families were contacted through a local community hospital and an area Women, Infants, and Children (WIC) program. Criterion for inclusion in the study was full-term pregnancy (gestational age ranged from 36.5 to 42 weeks with a mean of 39.8 weeks) and ability to speak and read English. The 150 families (78 female infants) recruited were primarily Caucasian, with 5 African/African-American, 2 African, 3 Asian and 1 Native American family. Maternal and paternal age averaged 29.7 (range 16 to 43) and 31.8 (range 19 to 46), respectively. Mother’s education level averaged 15.6 years (range 10 to 26 years) and father’s education level averaged 16.3 years (range 10 to 28 years).

Six families removed themselves from the study prior to the 6 month visit and an additional five families left the study before the 12 month visit. The typical reason for leaving the study was relocation. A considerable amount of data were also lost for specific procedures. For all reported analyses, only subjects with complete sets of usable data for each measure were utilized. Of the 139 families who participated at both time points, questionnaire data were missing for two families at 6 months and five families at 12 months, leaving 132 complete sets of questionnaire data. At 6 months, five cardiac response
recordings were lost due to excessive movement artifact, one cardiac recording was lost due to equipment failure, and one family missed their laboratory session. At 12 months, ten cardiac recordings were lost due to movement artifact. One child had missing cardiac data at both points, leaving 123 complete sets of cardiac data available for analysis. Toy presentation data were lost for two primary reasons. On 14 occasions at 6 months and on three occasions at 12 months, a problem occurred during the placement of the tray containing the toys (for example, the child tipped over the tray before making contact with a toy or the toys were placed beyond the child's reach). In addition, data for nine 6-month-olds and 14 12-month-olds were lost due to audiovisual difficulties. Three children had missing toy presentation data at both visits and 99 complete sets of toy presentation data were available for analysis.

To determine whether missing data were systematically related to approach and inhibition tendencies, a series of t-tests were performed. Subjects with complete data sets for a given domain were compared to subjects with missing data on that domain, with scores on the other measures as dependent variables. Only two of these comparisons were statistically significant. Children with missing cardiac data had shorter average latencies to reach for high-intensity toys at 12 months, t(unequal variances; df = 35.41) = 3.16, p < 0.01, and were rated lower in fear by their mothers at 6 months, t(140) = 2.07, p < 0.05.

Procedures and measures

Infants and their mothers visited the laboratory at 6 and 12 months. The laboratory protocols were identical at the two ages. Mothers and their infants were first brought into the laboratory by the lead experimenter, where the visit was described to the mother and the child was given a short ‘warm-up’ period on the mother’s lap. Two measures of cardiac activity, baseline ECG and cardiac response to white noise tones, were then taken, followed by a series of procedures designed to provoke positive and negative emotional responses from the infant. These included a peek-a-boo game, free play, a toy presentation and a gentle arm restraint. All procedures were videotaped. Finally, parents were asked to complete several questionnaires, including one assessing infant temperament. The proposed investigation utilized data from the cardiac response and the toy presentation episodes, described below.

Toy presentation

The toy presentation procedure was adapted from a protocol developed by Rothbart (1988) to assess approach and inhibition. While seated in a high chair with the mother slightly behind the child and to his/her left, the infant was presented a tray containing a low-intensity set of toys (plate, block, box) for 30 seconds. This set was then removed and a high-intensity set of toys (flashing red light, electronic beeper and wind-up dinosaur) was presented for 30 seconds. Latency to touch a toy (in seconds) was coded from videotape by coders trained to 94% reliability. If a child failed to touch a toy, they were assigned a latency score equal to the duration of the presentation (i.e. 30 seconds).

Cardiac response to auditory stimuli

To record heart period, three disposable electrodes were placed in a triangular pattern, with two electrodes at the top of the chest and a third electrode near the sternum to serve as a ground. The child was seated in a high chair or in mother’s lap if the child refused to sit in the high chair. Two meters in front of the child, a small speaker sat on a table, 75 cm above the ground. The cardiac response episode took place following acquisition of 10 minutes of baseline ECG recording. To keep the child's attention focused toward the sound source, the mother sat immediately beside the speaker, on the child’s left-hand side. The assistant and cardiac recording equipment were placed directly behind the child, out of view. The auditory stimuli used to elicit changes in heart period consisted of three 5-second tones of narrow band noise (bandwidth of 866 to 1155 Hz, rise and fall times of 25 ms), separated by 25-second inter-stimulus intervals. The first tone was 60 (+/−1) dB, the second was 70 (+/−1) dB and the third was 80 (+/−1) dB. The sounds were generated and gated from a Beltone 2000 clinical audiometer and the output was rooted to a Sanyo RD5350 tape deck.

The ECG record was collected online, using a Grass preamplifier (Model P15), passed through an analog/digital converter and saved using a data acquisition computer program (Labtech Notebook, 1993). The digital representation of the ECG records were then visually inspected offline to eliminate sections contaminated by significant movement artifact. Portions of the data containing movement artifact were manually edited, using the values of surrounding data points to estimate the heart periods disrupted by artifact. Average heart period (in milliseconds) during the 5 seconds immediately preceding the onset of the noise was subtracted from the average heart period in the 5 seconds following the onset of tones to arrive at an index of cardiac response to the three tones at each age. Thus, negative scores indexed cardiac acceleration in response to the tone and positive scores indexed cardiac deceleration. Although several infants exhibited acceleratory reactions to the tones, the average
change to all three tones at both ages was in a deceleratory direction.

Maternal ratings of temperament

At both ages, mothers filled out the Infant Behavior Questionnaire (IBQ; Rothbart, 1981). This instrument assesses the frequency of temperament-related behaviors displayed over a 1-week period, expressed on a 7-point scale. Six dimensions of temperament were derived from this measure: Smiling and Laughter, Distress to Novelty (Fear), Soothability, Activity Level, Duration of Orienting and Distress to Limitations. In the present sample, the two IBQ scales used in the current study, Fear and Smiling and Laughter, had alpha coefficients ranging from 0.71 to 0.85.

Results

Developmental patterns of approach and inhibition

To appraise the different developmental trajectories for approach and inhibition from 6 to 12 months, latency-to-touch scores were entered into 2 (Sex) × 2 (Age) × 2 (Toy Intensity) repeated measures ANOVAs. An identical 2 × 2 × 2 (Temperament Scale) ANOVA was utilized for mother ratings and a similar 2 × 2 × 3 (Sound Intensity) ANOVA was used with the cardiac response data. Means and standard deviations for all variables, presented separately for males and females, can be found in Table 1. The critical components of these analyses were the Age × Intensity/Scale interactions. It was predicted that the significance and direction of these interactions would reveal greater relative gains in inhibition than approach responses from 6 to 12 months.

Table 1  Means and standard deviations for latencies to touch toys, cardiac responses and IBQ ratings

<table>
<thead>
<tr>
<th>Measure</th>
<th>Females</th>
<th>Males</th>
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<tbody>
<tr>
<td></td>
<td>6 months SD</td>
<td>12 months SD</td>
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<tr>
<td></td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Low Intensity Toy</td>
<td>6.36 9.67</td>
<td>5.15 6.69</td>
</tr>
<tr>
<td>High Intensity Toy</td>
<td>7.80 10.68</td>
<td>9.55 9.10</td>
</tr>
<tr>
<td>Cardiac response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 dB</td>
<td>16.21 32.45</td>
<td>22.98 37.51</td>
</tr>
<tr>
<td>70 dB</td>
<td>22.57 25.48</td>
<td>24.07 29.30</td>
</tr>
<tr>
<td>80 dB</td>
<td>24.23 24.33</td>
<td>15.87 31.61</td>
</tr>
<tr>
<td>IBQ scale score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smile/Laugh</td>
<td>4.97 0.93</td>
<td>5.15 0.79</td>
</tr>
<tr>
<td>Fear</td>
<td>2.38 0.74</td>
<td>3.09 0.64</td>
</tr>
</tbody>
</table>

Toy presentation

Analysis of the latencies to touch the low- and high-intensity toys revealed no significant main effects or interactions for Sex. A significant main effect for Intensity, F(1, 97) = 25.12, p < 0.01, indicated that the average latencies to touch the high-intensity toys were longer than latencies to grasp the low-intensity toys, regardless of age. The main effect for Age was not significant, F(1, 97) = 0.05, n.s., indicating that, when intensity was not considered, there was no change in touch latency from 6 to 12 months. The significant Intensity × Age interaction, F(1, 97) = 4.23, p < 0.05, showed that differences in latency to touch toys of different intensities were moderated by age. Figure 1 graphically represents this interaction.

The interaction was followed up using simple main effect post-hoc tests, as recommended by Roberts and Russo (1999). The main effect for Intensity was significant at both 6 months, F(1, 97) = 5.39, p < 0.05, and at 12 months, F(1, 97) = 21.56, p < 0.01, whereas the main effect for Age was not significant for either low-intensity, F(1, 97) = 0.80, n.s., or high-intensity toys, F(1, 97) = 0.41, n.s.

Cardiac response

Analysis of the directional cardiac response to tones of varying intensity revealed no main effects or interactions for Sex. A significant main effect for Intensity, F(2, 120) = 3.66, p < 0.05, indicated that the average (deceleratory) response was greater for low-intensity tones than for the high-intensity sounds. Main effects for Age were not significant, F(1, 121) = 0.00, n.s., indicating that, when intensity was not considered, there was no change in cardiac response to white noise from 6 to 12 months.

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The significant interaction between Intensity and Age, $F(2, 120) = 3.17$, $p < 0.05$, showed that differences in cardiac response to tones of varying intensity were impacted by development. This interaction is graphically displayed in Figure 2.

Simple main effects for Age were not significant at any level of Intensity, $F_{s}(1, 121) = 1.56$, 0.03 and 2.28 for the 60, 70 and 80 dB tones, respectively. The main effect for Intensity was not significant at 6 months, $F_{s}(2, 244) = 0.63$, n.s., but was significant at 12 months, $F_{s}(2, 244) = 5.91$, $p < 0.05$. Tukey HSD comparisons were used to compare the means at 12 months. Mean deceleratory cardiac responses to the 80 dB tone were significantly smaller than mean responses to either the 60 dB or 70 dB tones ($p < 0.05$; Bonferroni correction applied), whereas responses to the 60 dB and 70 dB tones were not significantly different from one another.

Mother-rated temperament

Main effects for Sex were not significant for mother ratings of Smiling and Laughter or Fear. A significant main effect for Scale, $F(1, 130) = 778.28$, $p < 0.01$, indicated mothers gave higher ratings on the Smiling and Laughter scale than the Fear scale, regardless of age. A significant Age effect indicated mothers gave higher ratings at 12 months than 6 months when the two scales were considered together, $F(1, 130) = 115.08$, $p < 0.01$. These main effects were qualified by a significant interaction between Scale and Age, $F(1, 130) = 24.13$, $p < 0.01$. The Scale $\times$ Sex interaction was also significant, $F(1, 130) = 4.82$, $p < 0.05$.

Figure 3 graphically displays the interaction between Scale and Age. Follow-up tests for this interaction con-
firmed the main effect for Scale at both 6 months, F(1, 130) = 447.64, p < 0.01, and 12 months, F(1, 130) = 313.12, p < 0.01, as well as confirming the main effect for Age in both Smiling and Laughter scores, F(1, 130) = 12.38, p < 0.01, and Fear scores, F(1, 130) = 136.35, p = 0.01.

Analysis of the simple main effects confirmed the main effect for Scale in both boys, F(1, 130) = 446.35, p < 0.01, and girls, F(1, 130) = 335.51, p < 0.01. The significant interaction between Sex and Scale is due to differences in the simple main effects for gender between the two scales. Simple main effects for gender are significant for the Fear scale, F(1, 260) = 4.76, p < 0.05, with mothers giving girls higher Fear ratings than boys. In contrast, there was not a significant main effect for gender on the Smiling and Laughter scale, F(1, 260) = 1.49, n.s.

**Divergence of responses to stimuli according to intensity**

To test correspondence among individual infants’ reactions to stimuli of differing intensity, Pearson correlations were computed between low-intensity and high-intensity stimuli at each age for the toy presentation and cardiac response tasks (see Table 2 for correlations among all dependent variables). It was predicted that motoric and physiological responses to stimuli of different intensities would be highly correlated at 6 months, as these responses were under the control of a single system, approach. At 12 months, however, the inhibition system should exhibit substantial influence upon reactions to high-intensity, but not low-intensity stimuli, resulting in smaller correlations between responses to stimuli at this time. In addition, Fisher’s Z-tests were performed to test whether these correlations between reactions to high- and low-intensity stimuli at the two time points were different.

Regarding the toy-reach latencies, the correlation between low-intensity and high-intensity toys at 6 months was significant, as was the corresponding 12 month correlation. Although the 6 month correlation was higher, it was not significantly different from the 12 month correlation, Z(99) = 1.31, n.s.

Somewhat different results emerged for the cardiac response data. At 6 months, the correlation between cardiac response to the 60 and 80 dB tones was significant, whereas the corresponding 12 month correlation was not. Fisher’s test of comparison revealed the correlations to be significantly different from each other, Z(123) = 2.19, p < 0.05. It is of note that at both 6 and 12 months, responses to the 70 dB tone were significantly correlated with responses to the 80 dB tone. Correlations between the 60 and 70 dB tones, however, followed a pattern similar to those between the 60 and 80 dB sounds, as the 6 month correlation was marginally greater than the correlation obtained at 12 months, Z(123) = 1.88, p = 0.06.

**Relations among measures of approach and inhibition**

Mother-reported temperament and toy presentation

There were no significant relations between toy-reach latency and mother reports of Fear at either age. A
marginally significant correlation at 6 months suggested children with high ratings on Smiling and Laughter tended to reach more quickly to both the high- and low-intensity toys.

Toy-reach latencies and cardiac response

No relations emerged between toy-reach latencies and cardiac response at 6 months. At 12 months, consistent with expectations, a marginal correlation was found suggesting children who reached quickly for the high-intensity toys had large deceleratory responses to the 80 dB tone.

Mother-reported temperament and cardiac response

No significant relations were discerned between cardiac response and mother reports of Fear at either age. Contrary to expectations, at 6 months a significant correlation between Smiling and Laughter and response to the 70 dB tone indicated that children with large deceleratory responses were rated as less positive by their mothers than were other children. At 12 months, however, this relation had been reversed and children with large orienting responses to the 70 dB tone were rated as most positive.

Discussion

The current data conceptually replicate past studies which have documented increases in inhibition processes in the motor and emotional realms during the second half of the first year (e.g. Schaeffer, Greenwood & Parry, 1972; Rothbart, 1988) and extend them by demonstrating developmental parallels in the psychophysiological domain. Between 6 and 12 months, the intensity of a toy exerted greater influence upon children's rate of reaching, stimulus volume had a greater impact upon directional changes in heart rate, and infants were rated by mothers as exhibiting more fearful reactions. In addition, individual differences in cardiac response appeared to be under the control of a single process at 6 months, as responses to low-intensity stimuli were correlated with responses to stimuli of higher intensity. In contrast, at 12 months cardiac reactions appeared to be influenced by both approach and inhibition tendencies, as individual differences were not stable across stimulus intensities.

Although approach and inhibition follow different developmental trajectories, with greater gains by inhibition between 6 and 12 months, examination of latencies to touch high-intensity toys suggests that the tendency to inhibit movement in response to stimulus characteristics is not completely undeveloped at 6 months. Although latencies to make contact with the high-intensity items increased substantially after this time, it is of note that children reached more quickly to the low-intensity toys even at this early age. Two explanations may be offered for these results. First, in addition to differing in propensities to exhibit behavioral inhibition, children may also differ in the rate that their inhibition system matures (Rothbart, 1989). It may be the case that several infants had already begun to restrain their impulsive reaching tendencies prior to the 6 month assessment, whereas by 12 months their peers had ‘caught up’ and a greater number of children inhibited their approach. These findings are consistent with those of Rothbart (1988), who found latencies to grasp high-intensity toys to be longer than latencies to grasp low-intensity toys at 6.5 months. A second interpretation is that, although behavioral inhibition existed in a rudimentary form for all infants at 6 months, the efficiency of their ability to arrest their approach tendencies increased from 6 to 12 months.

Whereas differential developmental trajectories for the approach and inhibition systems were clearly demonstrated, only modest support was obtained for the proposition that general approach and inhibition systems link motoric, emotional and physiological responsivity. Consistent with predictions, infants who exhibited a high degree of approach motivation by reaching quickly for both low- and high-intensity toys at 6 months were rated by their mothers as being more positive than other infants. Thus, at 6 months, individual approach tendencies expressed via positive emotionality and speed to reach for objects were relatively consistent. At 12 months, however, these relations were no longer evident. It is particularly surprising that latency to touch the low-intensity toy at 12 months, which presumably assesses approach tendencies unconfounded by inhibition propensities, was not correlated with smiling and laughter. It may be that more specific, higher-order influences are playing a part in the social behaviors reflecting positive emotion at this age, whereas the more primitive and impulsive act of reaching is still primarily under the jurisdiction of more central structures.

Suggesting inter-measure consistency of inhibition, children who reached slowly for the high-intensity toys at 12 months tended to respond to the 80 dB tone with accelerations, rather than decelerations, in heart rate. Importantly, this congruence is not seen at 6 months, prior to the considerable development in inhibition over the ensuing months. Neither is this relation found in responses to low-intensity stimuli, but instead is restricted to motor and physiological reactions to high-intensity toys and sounds. It appears as if the physiological
mechanism leading some children to respond defensively to loud noises may also lead to increased behavioral inhibition when the infant is confronted with high-intensity and potentially threatening objects.

Particularly surprising was the lack of association between mother ratings on the IBQ Fear scale and other measures of inhibition. This may be due to the fact that latencies to touch and cardiac response index approach motivation, moderated by inhibition, whereas the Fear scale of the IBQ represents a more unadulterated measure of reactivity to unfamiliar events. Another possible explanation for this lack of correspondence may be that negative affect and inhibition of motor approach may not be closely associated at this age, but may become more coordinated at a later time. This argument is consistent with those posited by Rothbart (1988), who failed to find significant relations between IBQ Fear ratings and approach latencies at 6.5 or 10 months, but did find these two dimensions of inhibition to be significantly correlated at 13.5 months.

Associations across type of measurements were typically in the predicted directions, linking high approach motivation displayed in three different ways. These relations, however, must be viewed with some degree of suspicion due to the relatively low correlations and the number of comparisons made. Although approach and inhibition represent a valuable heuristic for describing physiological and behavioral phenomena, the overlap in neural systems controlling approach and inhibition across these disparate realms may be minimal. The three levels may be conceived of as being veiled by different functional layers. The limbic system, and the amygdala in particular, has long been presumed to be the dominant mediator of emotion, sending projections to facial nerves, the autonomic nervous system and areas in the central gray implicated in freezing responses (LeDoux, 1995). It is reasonable to speculate that the few cross-domain associations obtained in this study are due to individual differences in reactivity of the amygdala, whereas the infrequency and low magnitude of these relations may be due to individual differences in those circuits which moderate initial approach and inhibition tendencies in the different realms.

It should be noted that several other studies have failed to demonstrate strong multi-method convergence among measures of emotion. For example, in a recent review, Cacioppo, Klein, Berntson and Hatfield (1993) found heart rate to discriminate happiness from fear in only four of nine studies. Similarly, Rothbart (1988) found no significant relations between IBQ Smiling and Laughter scores and latency to grasp either low- or high-intensity toys and, as noted above, found IBQ Fear scores to be related to latency to grasp only at 13.5 months. Thus, even though the paucity of associations between the different forms of approach and inhibition is somewhat disconcerting, it is not necessarily inconsistent with past research.

Our results showing greater levels of mother-reported fear in girls than boys, particularly at 12 months, are consistent with a number of previous studies documenting sex differences in fear during infancy and early childhood (see reviews by Marks, 1987 and Rothbart, 1989). Sex differences were not found for either the cardiac or motoric measures. Rothbart (1988) reported a sex × age interaction in latency to reach scores, with females approaching at the same rate as males at 6 months, more quickly than males at 10 months, and more slowly at 13.5 months. It may be the case that motoric inhibition develops earlier in boys, peaking before the first birthday, is roughly equal in boys and girls around the first birthday, but then becomes more apparent in girls after 13 months.

Two aspects of our sample limit the generalizability of the current study. First, the sample was drawn from an extremely homogeneous population and slightly different results may have been obtained from a more ethnically and socially diverse sample. Somewhat more problematic is the pattern of subject loss for the cardiac data. Children for whom cardiac recordings were lost may have been less fearful than the remaining subjects, since they reached more quickly for high-intensity toys at 12 months and were rated lower in fear by their mothers at 6 months. It is possible that the lower number of such children may have obscured genuine relations between physiology and other measures, resulting in Type II errors. Of more concern are potential Type I errors. Low levels of fear could have led these children to react to the 80 dB tone at 12 months with a large deceleratory response, eliminating the time by intensity interaction. Similarly, low fear may have resulted in an increased correspondence between physiological reactions to the 60 dB and 80 dB tones at 12 months. Given this caveat, our findings showing an increase in defensive cardiac response between 6 and 12 months should only be considered valid for moderately and highly fearful children until replicated with additional samples including children low in other indices of fear.

The central implication of the current study is that approach and inhibition are best conceptualized as separable motivating forces that exhibit different patterns of development over the first year. The approach system, indicated by positive emotionality, cardiac orienting responses and reflexive motor approach, is well developed by 6 months, whereas the inhibition system, manifest as fearfulness, cardiac acceleration and inhibition of approach, develops considerably during the second half of
the first year. Recent theoretical work (e.g. Cloninger, 1987; Fowles, 1988) has implied different forms of psychological dysfunction to be associated with these two separate systems and developmentalists are urged to consider approach and inhibition independently, in contrast to past work that has assumed a unidimensional model of approach/withdrawal. Furthermore, given the growing corpus of evidence showing dramatic increases in inhibition in the second half of the first year across a variety of realms, it is of theoretical import to identify the mechanisms underlying this developmental phenomenon.

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Approach and inhibition in the first year


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