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Author(s): G. Spangler and K. E. Grossmann
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Biobehavioral Organization in Securely and Insecurely Attached Infants

G. Spangler and K. E. Grossmann

Institute of Psychology, University of Regensburg

Spangler, G., and Grossmann, K. E. *Biobehavioral Organization in Securely and Insecurely Attached Infants.* Child Development, 1993, **64,** 1439–1450. Attachment research has shown the emergence of individual differences in the security of infant-mother attachment during the first year of life as well as their importance for later social-emotional development. A biobehavioral perspective may help settle disagreements about the validity and interpretation of 12-month-old infants' different behavioral patterns of attachment assessed by Ainsworth's Strange Situation. It was shown that, despite less overt distress in insecure-avoidant infants after short separations from the mother, overall cardiac measures indicate arousal patterns similar to the secure infants during separation. However, differences in cardiac response emerged with regard to object versus person orientation during reunion. Additionally, findings of increased cortisol in both insecure-avoidant and disorganized infants support the theoretical interpretation that these infants, in contrast to secure infants, lack an appropriate coping strategy.

Attachment research has shown the extraordinary importance of the quality of infant-mother attachment for the development of social-emotional competence (Main, Kaplan, & Cassidy, 1985; Matas, Arend, & Sroufe, 1978; Suess, Grossmann, & Sroufe, 1992). At the end of the first year of life, the quality of infant-mother attachment can be assessed by Ainsworth's Strange Situation (SS) (Ainsworth & Wittig, 1969), yielding a classification of the infants into securely attached (B), insecure-avoidant (A), and insecure-ambivalent groups (C). Recently, Main and Solomon (1990) described the "disorganized" pattern (D) as an additional insecure attachment status. There is considerable evidence that a secure pattern of attachment is associated with high maternal sensitivity during the first year (Ainsworth, Blehar, Waters, & Wall, 1978; Belsky, Rovine, & Taylor, 1984; Grossmann, Grossmann, Spangler, Suess, & Unzner, 1985). In addition, individual aspects of newborn behavior, such as high orientation (Grossmann et al., 1985), low irritability (Crockenberg, 1981; Egeland & Farber, 1984), or optimal behavioral organization (Waters, Vaughn, & Egeland, 1980), have also been found to be associated with secure attachment classification.

However, despite 2 decades of attachment research using the SS as a prime research instrument, important issues have remained unsolved. Disagreements concern the validity of the classifications and their correct interpretation. First, successful activation of the attachment system by the two separations cannot be demonstrated independently because of the fact that some infants seem to remain outwardly unaffected by the sequences of separations and reunions, as in the A-type infants, who show a low amount of negative emotional behavior and a high amount of exploratory behavior (Grossmann & Grossmann, 1990). Thus, Sagi and Lewkowicz (1987) raised the issue that the SS may not create a similar psychological experience for all infants (see Sagi, van IJzendoorn, & Koren-Karie, 1991).

Second, within attachment theory, the secure attachment pattern has been interpreted as the most adaptive for individual

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development from a phylogenetic point of view. Accordingly, insecure patterns have been seen as less adaptive (Bowlby, 1973, 1980; Sroufe, 1979). However, from a culture-relative point of view, insecure patterns, for example, the behavioral strategy of the insecure-avoidant babies, may under certain cultural conditions be seen as adaptive or even more adaptive than the secure strategy (Hinde & Stevenson-Hinde, 1990). The different attachment patterns have also been conceived as (equivalent) adjustments to varying parenting styles and simply as alternative pathways to maturity (Lamb, Thompson, Gardner, Charnov, & Estes, 1984). Main (1981), in contrast, sees in the avoidant pattern only a "second best strategy" through which the child maintains proximity with the mother; this strategy is suitable for minimizing the risk of being rejected when contact is needed at some psychological cost.

Despite definite phylogenetic assumptions within attachment theory about biological function and preadaptiveness to the maternal care-giving system (Bowlby, 1969), the empirical research has focused on the investigation of psychological and behavioral processes, and at the same time has been "divorced from biology" (Joffe, Vaughn, Barglow, & Benveniste, 1985). However, the inclusion of biological or physiological processes may be necessary for validation of the assessment and the interpretation of different patterns of attachment. For example, changes in cardiac activity can be used as indications for the individual context evaluation. An increase in heart rate (HR) may be part of a defensive response (Graham & Clifton, 1966) or may be seen as an index of the behavioral activation system (Fowles, 1980). According to Ursin, Baade, and Levine (1978), heart activity may be an index of a fast-acting and short-lasting activation to aversive situations, and the heart response is not subject to behavioral coping mechanisms. Heart-rate increases in aversive situations may or may not be accompanied by distress behavior, but may be indicative of emotional arousal or activation, even in the absence of behavioral indications. The separation from the mother during the SS may be considered as an aversive situation for the infant. Thus, if the SS is an adequate procedure for activation of the attachment system in all infants, increases in HR must also be observed during separations in all infants, including the insecure-avoidant ones, who overtly behave as if hardly affected by separations and reunions (Sroufe & Waters, 1977). Specifically, the presence or lack of tonic lowering of HR during exploration may provide helpful information for the interpretation of the extended exploratory behavior in avoidant infants. Thus, changes in cardiac activity may be used as an index for the validity of the SS procedure.

A second physiological system, the adrenocortical system, may also be used for a better understanding of the behavioral patterns observed in the SS. Responses of the behavioral and endocrinological system in coping with stressful situations may be either co-occurring (responses in both systems) or dissociated (response in only one of the systems) (Levine, Wiener, Coe, Bayart, & Hayashi, 1987). For example, the frequency of distress vocalizations in infant squirrel monkeys separated from their mothers was markedly higher during adjacent separation (auditory contact) as compared to total isolation (no sensory contact). In contrast, the totally isolated but calmer infants showed a markedly higher increase in cortisol level as compared to the semi-isolated, overtly distressed monkey infants. Thus, the activation of the adrenocortical system seemed to be most prominent in situations in which behavioral coping responses were not applicable or available. Similarly, tree shrews showed different patterns of physiological reactions depending on specific stress conditions and the availability of coping strategies (von Holst, 1986). In tree shrews subjugated in a territorial fight, two different behavioral patterns could be distinguished. Submissive animals, characterized by extreme withdrawal, apathetic and depressive behavior, and a total absence of active coping strategies, showed a dramatic increase in adrenocortical function. In contrast, subdominant animals, coping actively by continually attempting to avoid possible confrontations with the dominant animal, showed an increase in sympatho-adrenomedullary function associated with a persistent increase in HR, particularly during the night, but no corresponding long-term increase in adrenocortical function. Comparable relations can be assumed for human newborns. Spangler and Scheubeck (1993) reported negative correlations between orientation ability and an increase in cortisol during a Brazelton exam. Gunnar (1991) concluded that adrenocortical reactivity could go along with both behavioral distress and behavioral withdrawal when faced with situations the organism is unprepared to meet.

From the perspective of attachment theory, these findings would suggest an increase in cortisol during the SS in insecurely attached infants as compared to the securely attached ones. Although the traditional insecure patterns (A and C) represent coherent and organized patterns (Main & Solomon, 1990), they cannot be seen as adequate strategies to rapidly establish proximity with the attachment figure. For example, regarding the A pattern as a defense strategy ("displacement behavior"; Ainsworth et al., 1978), which helps to reduce behavioral arousal, it cannot be considered effective if it does not reduce tonic physiological arousal (Ursin et al., 1978, p. 7). In contrast, the behavioral pattern of the D babies indicates definite episodes of behavioral disorganization, that is, the D status denotes a failure to establish an organized or coherent behavioral attachment pattern (Ainsworth & Eichberg, 1991; Main & Hesse, 1990).

Thus, from a narrow attachment perspective, cortisol increases may be expected in the insecurely attached infants who do not have adequate strategies (A, C) or who do not have any coherent strategy at all (D). In contrast, no cortisol response, or at least a smaller increase, would be expected in securely attached infants exhibiting an adequate behavioral strategy by reestablishing contact with their attachment figure. From a wider perspective, assuming that the coherent insecure patterns (A, C) may be functionally adaptive for the given infant-mother pair (Hinde & Stevenson-Hinde, 1990), although at some psychological cost (Main, 1981), low cortisol responses would also be expected in these groups. However, even from this perspective, heightened adrenocortical activity may be expected in the disorganized babies, as they do not have a coherent strategy at their disposal.

Whereas the coping model suggests a relation between cortisol response and the availability of behavioral strategies, an alternate model, the cortisol distress model, would assume associations between behavioral distress and an increase in cortisol (Gunnar, 1986). As there are great differences in distress expressed during the SS between the insecure groups (A vs. C) as well as within the secure group, the traditional attachment subgroups were bifurcated by Belsky and Rovine (1987) into groups with low (A, B1, B2) and high proneness (B3, B4, C) to distress. Within the cortisol distress model, a high cortisol response would be expected for infants with high proneness to distress as compared to the group showing little distress.

The main objectives of this study were twofold: First, we wanted to find indications of an activation of the attachment system in insecure-avoidant babies by comparing their overtly less distressed and more object-oriented behavior with simultaneously assessed HR responses. In particular, we expected an increase in HR in avoidant infants during separation from mother comparable to the securely attached infants. As heart activity responses seem to be fast-acting and short-lasting, and seem not to depend on behavioral coping mechanisms (Ursin et al., 1978), HR increases during separation should occur for all infants independent of their attachment classification. Moreover, regarding the explorative behavior of the avoidant babies as an evasive (defensive) behavior, we expected the absence of HR orienting responses (lowering) with regard to object-oriented behavior in insecure-avoidant babies during reunion. Second, the validity of the interpretation of the attachment patterns should be tested by a comparison of the adrenocortical responses of securely and insecurely attached infants. Comparisons should be conducted between the secure babies (B), the traditional insecure babies with underlying coherent strategies (A, C), and the insecure babies characterized by disorganization (D). From the coping model perspective, higher cortisol responses were expected in insecurely attached infants. At the same time, we have to examine the alternative arousal hypothesis, assuming that increases in cortisol mainly occur for those attachment subgroups exhibiting high behavioral distress.

Method

The sample consisted of 41 healthy German white infants and their mothers (17 girls/24 boys) contacted for the first time at newborn age. The children's families represent a fairly wide range of socioeconomic status, including 49% upper middle class, 24% middle class, and 27% lower class, as assessed by the father's education and occupation as well as by the total family income. In all but one case the mother was the infant's primary caretaker. Four of them were working outside the family in part-time jobs at the end of the first year. For one infant, the father was the primary caretaker throughout the first year, while the mother was doing a full-time job. In this case the father took part in the study (and was treated as a "mother" in this paper).

At the age of 12 months (M = 12.1; SD = .4) the infants were observed during the SS. The SS is a 20-min situation involving a sequence of episodes that progressively activate the attachment system: entrance into an unfamiliar environment, the arrival of a stranger, two brief separations from the mother, and two subsequent reunions with her (Ainsworth, 1985). With regard to the circadian rhythm in cortisol, the data assessment for each subject was planned for the morning. In 83% of the subjects the assessment took place between 8 and 12 A.M., midway between two feedings, that is, about 90 min after the preceding feeding. For several reasons, the morning assessment was not possible in seven cases (individual feeding and sleeping patterns, baby-sitter scheduling for older siblings, etc.).

The quality of infant-mother attachment was analyzed from the videotapes by trained observers. For the traditional ABC classification the training was accomplished using SS videotapes from the Bielefeld longitudinal sample, which were cross-validated by Mary Main (Grossmann, Grossmann, Huber, & Wartner, 1981). Reliability for quality of attachment was 90% (kappa = .87). For the D classification, two different observers were trained with tapes analyzed by an expert judge (Erik Hesse). The observers rated the infants' behavior on the 9-point scale for disorganization. Reliability between the observers for the D status (5 or above) was 82% (kappa = .63).

In addition, specific analyses concerning the infants' negative emotions and looking behavior were conducted in order to assess behavioral measures of infants' arousal and orientation. For every 1-sec interval, the expression of negative emotion and the orientation to mother or objects were assessed. Every occurrence of sad face, fussing, or crying was coded as negative emotion. Four categories were used to describe the infants' orientation: looking to mother, looking to specific objects, object manipulation, and unspecific looking. The criterion for object manipulation was eye-hand coordination. Reliability was 93% (kappa = .90) for negative emotion and 93% (kappa = .84) for orientation behavior.

The cortisol response was assessed from saliva. To collect saliva, the infant's mouth was swabbed with a small sterile cloth. It took about 1 to 3 min to obtain the saliva sample. Saliva samples were collected immediately before the SS, as well as 15 and 30 min after the end of the SS. All saliva samples were frozen until being assayed to −20° C within 24 hours after the collection. To get the infants' saliva out of the cloth, the samples were centrifuged (5,000 rpm). The assessment of cortisol levels was done by radioimmunoassay (RIA). The RIA was performed by the Department of Animal Physiology at the University of Bayreuth (Prof. Dr. D. von Holst). All samples from one individual were analyzed in one assay to minimize the variability of the results. To guarantee validity of analysis, duplicate assays were performed whenever possible. Some samples of the newborns with a volume of less than 0.1 ml were too small for duplicate assay. In these cases, single assays were accomplished. The RIA was highly specific for cortisol. The corticoid antiserum used for analysis significantly cross-reacted with cortisol, 11-deoxycortisol, 11-deoxycorticosterone, corticosterone, and 17-hydroxyprogesterone. However, the proportion of cortisol to the overall corticosteroids is nearly 90% for newborns and about 98% for infants in the first year (Sippell, Dorr, Bidlingmaier, & Knorr, 1980). The sensitivity of the RIA was 21.6 pg per tube. The intra-assay variation was 5.9% for 0.1 ng, 4.1% for 0.2 ng, and 3.8% for 0.5 ng. The inter-assay variation was 9.2% for 0.1 ng, 6.0% for 0.2 ng, and 5.8% for 0.5 ng. The correlation between the assay duplicates was r = 0.94 (for further details, see Fenske, 1987).

The infant's cardiac activity was simultaneously assessed during the SS. Immediately after the collection of the presession saliva, three disposable EKG electrodes were placed, in a triangular pattern, on the infant's chest. Then, during the SS, the infant's heart periods (interbeat intervals) were continuously recorded. The portable recorder was kept in a little jacket on the infant's chest. The equipment was removed after the end of the last saliva sample. The heart periods were controlled for artifacts by computer, using criteria proposed by Foerster (1984). In addition, a visual control was conducted. The heart periods were converted to HR in beats per minute for each 1-sec interval.

The following measures were derived from the behavioral analyses: (1) quality of attachment, (2) duration of negative emotion per episode, and (3) duration of object-orientation per episode (looking to objects and object manipulation, respectively). Change from baseline measures was used to describe physiological responses. The following change scores were used as a measure for the infant cortisol response (Levine & Coe, 1985; Spangler, 1991): delta 15 and delta 30 (the difference between the respective values 15 and 30 min after the SS and the initial value). As there were no differences in time between onset of first separation and the saliva sampling between the attachment groups, $F(2, 36) = .97$, N.S., correction for length of time interval was not necessary. The following measures were defined for the infant's cardiac activity during the SS: (1) change of mean HR (beats per min) from mean HR in episode 2 (baseline) to each of the episodes 3 to 8, (2) difference between mean HR during the child's mother orientation, looking to object, and object manipulation and the mean HR during unspecific looking (baseline).

To assess statistical significance of changes in behavioral and physiological measures, analyses of variance with repeated measures (MANOVAS) were used. To control for heterogeneity of variance, Greenhouse-Geisser corrections for degrees of freedom were used.

Results

Quality of attachment.—Regarding the traditional (forced) ABC classification, the distribution of securely and insecurely attached infants was comparable to previous findings (van IJzendoorn & Kroonenberg, 1988). Thirty out of 41 (73%) infants were classified as securely attached (B). There were 14 B1/B2 and 16 B3/B4. Seven infants were classified as insecure-avoidant (A). One infant was insecure-ambivalent (C); three infants were unclassifiable. In addition, nine infants (7 B, 1 A, 1 not-to-classify) had D scores of 5 and above. The proportion of the D pattern was also comparable to previous findings (Ainsworth & Eichberg, 1991; Main & Hesse, 1990). Thus, including the D status, the analysis of the attachment patterns yielded the following distribution: 56% B, 15% A, 22% D, and 2.5% C. The attachment classification was not related to infant sex and social class.

For technical reasons, the sample sizes for the following analyses were different. Some cortisol values were missing (too little saliva, failure in RIA; 5 B, 2 D), and for some infants there were no valid HR scores (5 B, 3 D). Thus the sample sizes for A, B, and D were 7, 18, and 7, respectively, for the cortisol analyses and 6, 18, and 6, respectively, for the HR analyses.

As there was only one C baby, comparisons between attachment groups were conducted without the C group. Regarding the behavioral and HR responses, a combination of the traditional insecure groups A and C would have been inappropriate both for conceptual and empirical reasons. The behavior and HR scores of the C baby were extremely different from those of the A babies and would have obscured differences between the A group and the other groups. For comparisons regarding the adrenocortical activity, A and C babies were combined. This combination was suitable again for conceptual and empirical reasons. Within the coping model, both the A and the C pattern are inappropriate strategies. Empirically, the cortisol response of the C baby was within the range of the A group.

Behavioral changes during the Strange Situation.—To compare the behavioral changes across the SS episodes of infants with different attachment quality, two-way ANOVAS with one repeated-measures factor (episodes 2 to 8) and one independent factor (attachment: A, D, B) were conducted for negative vocalization and object manipulation. As expected, there were obvious behavioral differences between the attachment groups in negative vocalization and object orientation. For negative vocalization, there was a main effect for attachment, $F(2, 34) = 4.10$, $p \leq .05$, and for episode, $F(3.1, 105.4) = 15.48$, $p \leq .001$, and an interaction between episode and attachment, $F(6.2, 105.4) = 3.22$, $p \leq .01$. A post-hoc ANOVA for simple main effects revealed a change in negative vocalization only for the B babies, $F(3.1, 105.4) = 28.40$, $p \leq .001$, and for the D babies, $F(3.1, 105.4) = 10.70$, $p \leq .001$. Whereas there was a very low occurrence of negative vocalization in avoidant babies over all the episodes, the secure babies and the disorganized ones showed a marked (nearly identical) increase during the second separation (episode 6 and 7; Newman-Keuls, $p \leq .05$; see Fig. 1). For object manipulation, the MANOVA revealed a main effect for attachment, $F(2, 35) = 9.86$, $p \leq .001$, and for episode, $F(5.3, 184.9) = 6.01$, $p \leq .001$, and an interaction between episode and attachment, $F(10.6, 184.9) = 2.61$, $p \leq .01$. A post-hoc ANOVA for simple main effects revealed changes in object manipulation for all groups, $F(5.3, 184.9) = 2.91$, 3.46, and 8.79 for the avoidant, disorganized, and secure infants, respectively; all p's $\leq .015$. However, whereas there was a decrease in object manipulation during the separation episodes in the secure and the disorganized infants (Newman-Keuls, $p \leq .05$, see Fig. 1), an increase could be observed in the avoidant babies with the highest score during the first reunion episode ($p \leq .05$). In the C baby, a high increase of negative vocalization and a marked decrease of object manipulation were observed.

Cardiac changes during the Strange Situation.—The behavioral differences between the attachment groups were not reflected in cardiac activity. Table 1 contains the means and standard deviations of the HR raw values for the different attachment groups. Changes in cardiac activity were assessed as the difference in HR in each of episodes 3 to 8 and the HR in episode 2 (baseline). There was no difference between the attachment groups in HR baseline, F(2,

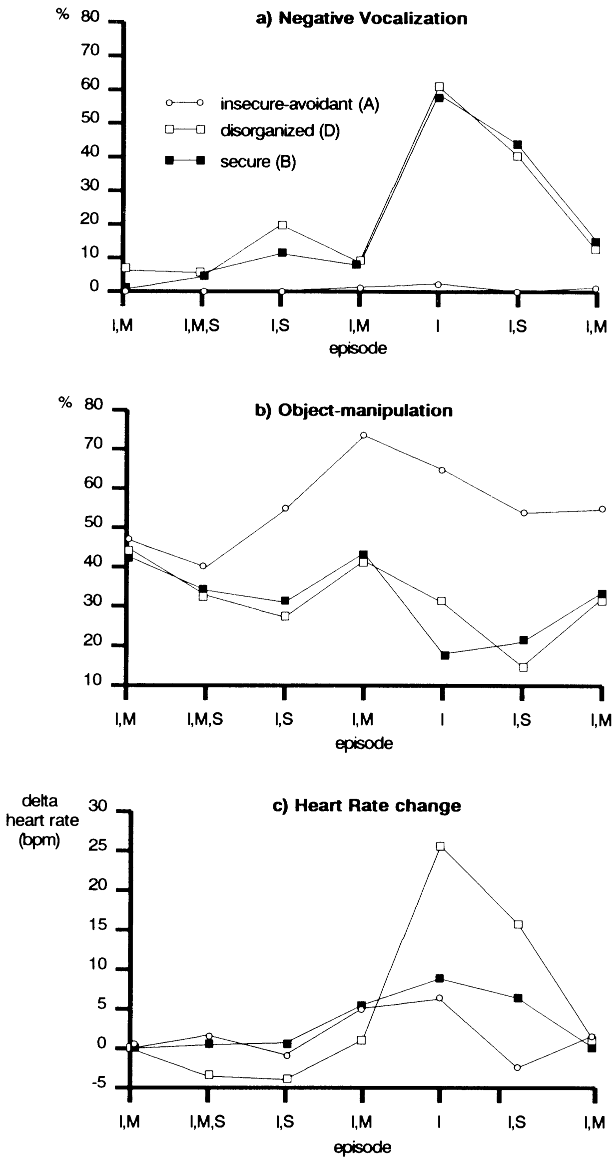

FIG. 1.—Changes in (*a*) negative vocalization, (*b*) object manipulation, and (*c*) heart rate during the Strange Situation episodes for different attachment groups. M = mother, I = infant, S = stranger.

TABLE 1

MEANS (and Standard Deviations) OF CORTISOL AND HEART-RATE VALUES FOR THE DIFFERENT ATTACHMENT GROUPS ASSESSED DURING THE STRANGE SITUATION

	ATTACHMENT GROUPS[a]		
	Insecure-Avoidant (Insecure-Ambivalent)[b]	Disorganized	Secure
Heart rate (bpm):			
Episode 2 (I,M)	142.3 (18.2)	134.2 (6.9)	140.7 (12.0)
Episode 3 (I,M,S)	144.0 (19.0)	130.6 (9.2)	141.2 (10.0)
Episode 4 (I,S)	141.5 (18.7)	130.2 (8.2)	141.5 (19.2)
Episode 5 (I,M)	147.4 (14.9)	135.2 (5.2)	146.3 (10.8)
Episode 6 (I)	148.5 (17.0)	139.8 (22.0)	149.6 (11.8)
Episode 7 (I,S)	139.9 (17.6)	150.0 (22.8)	147.2 (19.6)
Episode 8 (I,M)	144.1 (15.7)	134.9 (8.9)	140.7 (9.9)
Cortisol (ng/dl):			
Before SS	3.63 (1.38)	3.66 (.83)	4.63 (2.75)
15 min after SS	4.36 (2.10)	5.09 (1.73)	4.56 (2.15)
30 min after SS	5.05 (2.66)	5.42 (1.83)	4.21 (2.06)

NOTE.—I = infant, M = mother, S = stranger.

[a] Sample size was 6, 6, and 18 for heart rate and 7, 7, and 18 for cortisol for the insecure-avoidant/ambivalent, disorganized, and secure groups, respectively.

[b] The insecure-ambivalent group was included only for the cortisol values.

28) = .80, N.S. A two-way (episodes 3 to 8 × attachment A, B, and D) MANOVA for change in HR revealed a main effect for episode, $F(2.9, 77.3) = 6.99$, $p \leq .001$, and an interaction between attachment and episode, $F(5.7, 77.3) = 2.41$, $p \leq .05$. No main effect for attachment was found. Newman-Keuls post-hoc tests revealed that the episode effect was due to the HR change in the second separation (episode 6, $p \leq .05$, see Fig. 1). The interaction effect was reflected by the magnitude of HR increase during episode 6. The highest increase occurred for the disorganized infants, which was significantly different from the HR increase of both the B and the A babies (Newman-Keuls, $p \leq .05$), who were not different from one another. However, the 1% confidence interval of the HR increase of both A and B infants in episode 6 did not include zero, indicating a significant HR elevation also for these two groups. In the C baby, an extreme HR increase was observed. Thus, the changes in HR, albeit somewhat different in magnitude, indicate cardiovascular activation for all attachment groups during the SS.

To control for motor artefacts in HR change during the SS due to the child's play or distress behavior, a covariance analysis for infant HR at episode 6 was conducted with attachment as an independent factor and negative vocalization and play manipulation as covariates. A third measure, the child's gross motor behavior, was not different for the various attachment groups (Voelcker, 1991) and thus was omitted from analysis. After controlling for the covariates, the attachment effect remained significant, $F(2, 24) = 3.37$, $p \leq .05$. The means adjusted for the effect of the covariates were 17.6, 22.5, and 6.1 for the A, D, and B infants, respectively. Using Newman-Keuls post-hoc tests, the HR increase proved to be significantly lower in B infants than in D infants ($p \leq .05$). The difference between B and A infants approached significance ($p \leq .10$). Thus, after adjustment for negative vocalization and fine-motor and gross-motor activity, the HR increase seems to be most prominent in insecurely attached infants.

To assess specific HR changes during object and mother orientation, a two-way ANOVA with one repeated measure (orientation: looking to mother, looking to objects, object manipulation) and one independent factor (attachment: A, B, D) controlling for the overall duration of the respective orientation measures was conducted, revealing a significant interaction between orientation and attachment, $F(2.6, 36.2) = 3.31$, $p \leq .05$. Post-hoc ANOVAS for simple main effects yielded significant HR changes within the B group and the D group, $F(1.3, 36.2) = 5.37$ and 4.91, respectively, $p \leq .025$. No differences were found within the A group. Thus, the B and the D babies exhibited the expected HR pattern with low HR during object orientation, in particular during object manipulation, and higher HR when looking to their mother (see Fig. 2). In contrast, an HR orientation response could not be observed in A infants, who behaviorally do not seem to be very concerned about the separation and who show a high frequency of object orientation even during the separation episodes. Moreover, their HR seems to be most elevated during object orientation (see Fig. 2).

Changes in adrenocortical activity during the Strange Situation.—Table 1 contains the means and standard deviations of the cortisol raw values for the different attachment groups. To test the hypothesis about individual differences in the adrenocortical response in securely and insecurely attached infants (cortisol-coping hypothesis), a two-way ANOVA with one repeated measure (delta 15, delta 30) and one independent factor (attachment) was conducted. The insecurely attached infants were divided into two groups: the disorganized infants (D) and the traditionally insecure infants with a coherent but inadequate behavioral pattern (A and C). To control for circadian influences on adrenocortical activity, the time of day of assessment (which was not significantly related to change in cortisol and for which there were no differences between the attachment groups) was included as a covariate in the ANOVA. The ANOVA revealed a significant main effect for attachment, $F(2, 28) = 3.53$, $p \leq .05$. As can be seen in Figure 3, both groups of insecurely attached infants show an increase in cortisol as compared to the securely attached infants, who exhibit a small decrease. Using Newman-Keuls multiple-range tests, the difference between secure and insecure infants was significant for the D babies ($p \leq .05$) and approached significance for the A/C babies ($p \leq .10$). There was no significant difference between the attachment groups in the initial values, $F(2, 29) = .76$, N.S. Regarding the cortisol-distress hypothesis, the high-distress group (B3, B4, C) did not show higher cortisol values as compared to the low-distress group (A, B1, B2) ($p > .75$).

Discussion

The HR patterns of the infants during the SS provide a validation of the SS procedure and the behavioral criteria used for the classification of the quality of attachment. First, HR increases during separation from the mother were observed in all attachment groups, including the insecure-avoidant infants. As the heart response is not subject to behavioral coping mechanisms (Ursin et al., 1978), HR increases were expected for all groups independent of the appropriateness of the behavioral strategy. However, there were differences in the magnitude of the HR response. Whereas the disorganized infants exhibited a particularly high HR elevation, there was a lower but still significant HR increase in both the secure and insecure-avoidant infants.

These findings indicate that even the A babies, though exhibiting low behavioral distress, were nevertheless affected by the SS (Fowles, 1980; Graham & Clifton, 1966; Sroufe & Waters, 1977). Thus, the attachment system in avoidant babies seems to be activated in a way comparable to the secure babies. Moreover, after controlling for behavioral artefacts in HR, the HR increase of the A babies was even higher than in securely attached infants and comparable to the increase of the disorganized infants. The

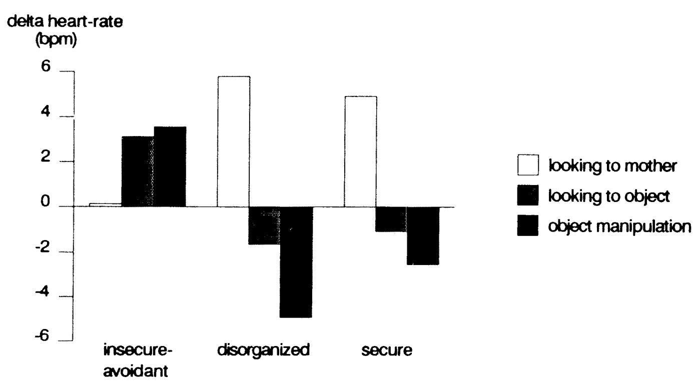

FIG. 2.—Mean heart rate during the infants' orientation to the mother and to objects and during object manipulation for different attachment groups.

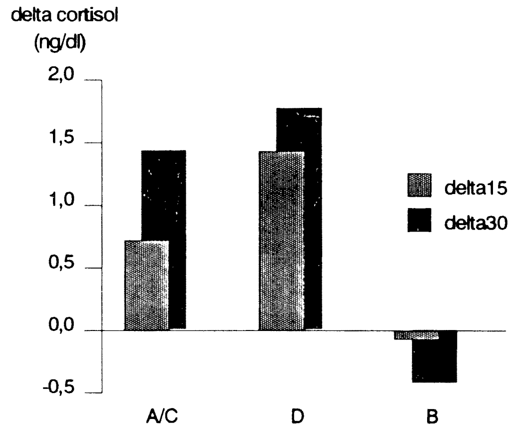

FIG. 3.—Cortisol change during the Strange Situation for secure (B), insecure-avoidant and insecure-ambivalent (A/C), and disorganized infants (D); postassessment 15 min (delta 15) and 30 min (delta 30) after the Strange Situation.

particularly high increase of the disorganized infants warrants further explanation. As pointed out by Main and Hesse (1990), the disorganized baby may be very intensely alarmed by the SS separation to the point that the activation of the attachment behavior cannot be systematically controlled, which may be due to the experience of an unpredictably frightening parent. The high HR during the separation may reflect the high intensity of activation in the disorganized infants.

Second, with respect to the infants' orienting behavior, the HR pattern of both the secure and the disorganized attachment group fits theoretical assumptions about associations between HR and behavior well (Graham & Clifton, 1966). The low HR during object orientation suggests attentive and concentrated play. In contrast, the heightened HR when looking to the mother indicates that visual contact with mother was initiated specifically during episodes of physiological arousal, which, in turn, may be indicative of emotional distress. The missing HR response during object orientation in A babies suggests low-quality play marked by inattentiveness and low involvement. In addition, A babies looked to the mother only during episodes when arousal was not very high, that is, visual contact was established in situations with low emotional stress.

This is in line with previous findings (Grossmann, Grossmann, & Schwan, 1986) demonstrating restricted direct communication with increasing stress in avoidant infants. These findings support on a physiological level the interpretation of the attachment classification: involved exploration (low HR) against the background of a secure infant-mother relationship and contact-seeking after the activation of the attachment system (high HR) in B infants, and, in contrast, contact avoidance and low-level play as an evasive behavioral pattern (high HR) when the attachment system is activated in A babies (Ainsworth et al., 1978). B infants turn toward their mother when their attachment systems are aroused. The mother, therefore, is not "interesting" in the sense of an interesting, novel object. She is, in attachment theory terms, the secure base to which the child returns when aroused, and from which the child starts new bouts of explorations.

Similar findings from case studies were reported by Sroufe and Waters (1977). They observed accelerated HR and the absence of tonic lowering of HR during object orientation in avoidant infants. Furthermore, Donovan and Leavitt (1985) found phasic HR increases at the onset of separation in both securely and insecurely attached infants even though their behavioral responses differed.

The pattern of HR change during specific orienting behavior in the disorganized infants was not different from the pattern of the securely attached infants. This is not surprising, because proximity seeking when distressed, albeit in combination with behavioral inhibition (Main & Hesse, 1990), is a typical aspect of the D pattern, and, moreover, object orientation does not serve as a defensive strategy or displacement behavior in disorganized infants.

The relation between the quality of attachment and the specific responses of the adrenocortical system is in accordance with our hypothesis derived from animal studies (Levine et al., 1987; von Holst, 1986), which assumes that the adrenocortical system would be activated only if adequate behavioral strategies cannot be applied. From the attachment perspective, establishing contact after separation from the mother (i.e., when the attachment system is activated) is the only adequate behavioral strategy for emotional reorganization. In contrast, avoidance or ambivalent behavior to the attachment figure are seen as inappropriate behavioral strategies. Moreover, the D status precludes the presence of any coherent strategy. Thus, from the perspective of the cortisol coping model, the present findings support the interpretation of the behavioral patterns from the perspective of attachment theory. In contrast, the cortisol distress model has not been confirmed. Moreover, cortisol increases were shown by the insecure groups, which include the A babies exhibiting very little behavioral distress during the SS.

The first attempt to assess relations between quality of attachment and adrenocortical activity during the SS was undertaken by Gunnar and co-workers (Gunnar, Mangelsdorf, Larson, & Hertsgaard, 1989), who did not find significant results. However, this may be explained by two methodological issues. First, the attachment analysis of the Gunnar et al. study did not include the D category, for which the adrenocortical response came out most clearly. The inclusion of D babies in the secure group may have obscured potential differences between securely and insecurely attached infants. Second, in the Gunnar et al. study, the postassessment of cortisol was accomplished immediately after the end of the SS. As the adrenocortical system is a slowly reacting system, the time lag may have been too short (Gunnar, 1986). This explanation was supported by our data regarding the traditional insecure group (A and C), in which differences in the cortisol response were, albeit visible, not significant until 30 min after the SS.

The differences between the attachment groups in the adrenocortical response 30 min after the SS also may be related to behavioral differences during the time after the SS. However, as shown in the behavioral analyses, behavioral differences between the attachment groups have vanished already during the last reunion episode. To further clarify this question, the amount of negative vocalization during the time period after the SS was analyzed. However, no significant differences were found between the attachment groups.

In conclusion, the findings provide clear evidence for the validity of the SS procedure in the assessment of individual differences in the quality of attachment. Moreover, they provide external support for the interpretation of the attachment patterns. Finally, biobehavioral associations between attachment system and physiological systems address a number of interesting issues for future research, regarding, for example, basic biological processes underlying the attachment system, the contribution of child factors to the development of individual differences in social-emotional development, and the mutual relations between individual, social, and physiolgical processes.

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