Chapter 7

Changing patterns of infant behavior and mother-infant interaction

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ABSTRACT

This chapter presents the results of a sub-study of intra- and inter-individual variability in behavior, based on the data of the four normally developing infants who were followed for 15 months. General differences between the infants were investigated, and the variability and stability in macroscopic patterns of associations between behaviors were studied. Specifically, the relationship between infant behaviors (crying, fretting/fussing and smiling) and mother-infant body contact (divided into three subcategories) were determined, together with the changes they underwent over time. A considerable number of associations was found between the behaviors, and most of them changed importantly as the infant developed. Individual differences in the nature of the associations and in the changes they underwent over time predominated, but in a limited number of cases, the infants shared the same developmental trajectories of behavioral associations. The results show how the use of intensive time series designs can be advantageous in clarifying issues of long-term variability and stability in human behavior. They also support the notion that changing patterns of behavior are a normal feature of early development.

INTRODUCTION

Variability and stability

Individual human beings typically possess an ample array of behaviors which they display variably according to circumstances and internal states. Each of us shows, to a greater or lesser degree, behavioral plasticity in the face of external and internal stimuli. This variability has important adaptive value; moreover, it is essential for dealing with the complex environmental demands that are made on a daily basis on humans. However, as we develop from infancy into adulthood and our behavioral repertoire increases, we tend to show more and more systematic selection of certain behaviors rather than others; adults have achieved a level of stability of response to stimuli, which in psychology is referred to as 'personality'. Although a person's personality characteristics will predispose him or her to act in certain ways, it does not mean that one of the essential characteristic of humans, namely our behavioral flexibility and plasticity, has disappeared. Adults, and with more reason developing youngsters, are capable of showing variable behavior in similar situations, of adapting their behavior to different environmental demands, and of changing their behavior over time as a response to the changing characteristics of the environment to which they are attuned.

However, variability and plasticity are but one side of the coin. Meaningful, adaptive behavior also requires a sufficient level of stability, of patterns that are relatively invariant across contexts, yet adaptive to varying features of those contexts. This is especially so when the context is social, in interactions between subjects. We shall employ the term "behavioral pattern" to refer to relatively stable, adaptive connections between various forms and frequencies of specific behaviors. An example of such a behavioral pattern would be an infant's crying, to which the mother reacts by soothing the infant through body contact. The fact that this sequence of behaviors forms a pattern does not imply that it occurs every time a certain contextual condition occurs, nor that it occurs with similar intensity or frequency, nor that all components of the pattern must be present. Without variability, such patterns would not be adaptive. On the other hand, without a certain level of stability, behavior would not be adaptive either, since in that case it would amount to mere random fluctuation or blind responses to whatever coincident events occur. Behavioral patterns are not only flexible under short-term conditions (contexts). They are also adaptive to long-term changes. For instance, it is likely that as the infant grows older the conditions that release the crying-and-comforting pattern change qualitatively and quantitatively, and that the association between crying and comforting in the form of body contact greatly diminishes.

The mother-infant system provides a good example of the flexibility (short-term variability), plasticity (long-term variability) and stability (characteristic patterning) of human behavior. Whereas the mother is an adult who can be assumed to have acquired relatively stable personality characteristics which have been shown to affect her interactions with the infant (Kaeller & Roe, 1990), the infant possesses relatively unstable temperamental characteristics (Crockenberg & Smith, 1982; Isabella, Ward & Belsky, 1985; Peters-Martin & Wachs, 1984; Worobey & Blajda, 1989) which help shape his display of behaviors. At the same time, the infant is developing rapidly and is constantly confronted with new -or newly perceived- stimuli. Changes in the infant will in turn mean different demands on the mother, and in such a rapidly developing system it does not seem too farfetched to assume that important demands will be made on the mother's behavioral plasticity. While a natural goal for the mother will be to obtain homeostasis (i.e. stable patterns) in her relationship with the infant, the infant's quick pace of development will possibly greatly diminish the chances of attaining long-lasting and unchanging periods of homeostasis, especially during the first year of life. The consequence would be that temporary periods of stability follow each other, with each period showing different patterns of maternal and infantile behavior. In this way we are assuming that the mother-infant system shows plasticity, i.e. the capacity of displaying changes in patterns of behavior over time, notwithstanding the constraints imposed by the mother's personality characteristics and the infant's temperamental tendencies.

Although this view of early infant behavior and mother-infant interactions is appealing in its dynamic nature and its probable explanatory value for both the stabilities and instabilities found by many researchers in mother and infant behavior, it has received little attention up till now. Developmentalists often appear to focus almost solely on stable features of behavior and to dismiss variability of behavior as the result of undesirable extrinsic factors instead of viewing it as an intrinsic characteristic of the system. However, as Bornstein and Tamis-LeMonda (1990) affirm, stability need not be synonymous with sensitivity or appropriateness, as it might equally be adaptive developmentally for one activity to display consistency over time but for another to change. The fact that results of studies on diverse aspects of early development repeatedly show the presence of instability or variability in behavior, especially in the first year of life, supports this view. Examples of studies which have found evidence of intra-individual variability in infant behavior are those on temperamental characteristics (Crockenberg & Smith, 1982; Isabella et al., 1985; Peters-Martin & Wachs, 1984; Worobey & Blajda, 1989), on behavior related to emotions (St James-Roberts & Wolke, 1988; Worobey, 1986; Bornstein & Tamis-LeMonda, 1990; Fish, Stifter & Belsky, 1991; Belsky, Gilstrap & Rovine, 1984), on visual behavior (Canfield, Wilken, Schmerl & Smith, 1995; Wachs, Morrow & Slabach, 1990), on play behavior (Tamis-LeMonda & Bornstein, 1991) and on sleeping and waking patterns (Dittrichova, Paul, Tautermannova & Vondracek, 1992). Furthermore, a number of studies has found evidence for day-to-day and week-to-week behavioral variability in infants, and have interpreted it as a normal component of infantile development. These are studies on motor and mental development (Freedland & Bertenthal, 1994; McCall, Eichorn & Hogarty, 1977), on crying (Rebelsky & Black, 1972; Barr, 1990; St James-Roberts & Halil, 1991) and on crying, fretting/fussing, smiling and time spent in body contact with the mother (Chapters 5 and 6, this thesis).

The above mentioned studies report variability in infant behavior, but we are also interested in the (in)stability shown by the mother in her interactions with the infant. Studies of mothers of older children and adolescents have found evidence of stability in parental practices and attitudes over time (e.g. Hock & Lindamood, 1981; McNally, Eisenberg & Harris, 1991), although parents naturally adjust to different ages and situations in interactions (Rogoff, Ellis & Gardner 1984). However, studies of mothers of young infants show both stability *and* change in maternal behavior. Note that the data used in the examples that follow originates mostly from maternal questionnaires or from microscopic analyses of mother-infant interactions of short duration, which are often limited to very specific contexts such as a play situation. For example, both modest stability and instability of maternal behavior were found with respect to different aspects of promptness of response to infant crying across the first 9 months (Hubbard & van Ijzendoorn, 1991), while no stability was found in maternal responsiveness between the first and last quarter of the first year (Crockenberg & McCluskey, 1986) and in sensitive responsivity and rejection between 1 and 9 months (Isabella, 1993). Moderate stability in responsiveness was found between 3 and 9 (Fish & Crockenberg, 1981) and 5 and 10 months of age (Stifter & Braungart, 1992). St James-Roberts, Conroy, and Wilsher (1997) found substantial changes rather than stabilities in maternal behavior between the infants' ages of six weeks and five months. They interpreted these changes as a response to a decline in infant crying over this age period. Schölmerich, Fracasso, Lamb, and Broberg (1995) found stability in only three of eight maternal behaviors between 7 and 10 months of age of the infant. Tamis-LeMonda and Bornstein (1991) observed mother-infant play behavior at 13 and 20 months of age, and found that although mothers change their overall level of play between these ages, they maintain their relative status in play sophistication. Also, Fish & Stifter (1995) report modest stability in maternal sensitivity and intrusiveness in play behavior at the infant's ages of 5 and 10 months. Finally, Belsky et al. (1984) found stability of diverse caregiver behaviors between 3 and 9 months, but not between 1 and 3, and 1 and 9 months. These authors attribute the changes to the large fluctuations in the infant's behavioral states in the first months, which can cause him/her to behave very differently from day to day and week to week, thus obliging the parents to respond to these changes and display instability. It is important to add here that this small overview consists almost exclusively of studies which have relied on 2, 3 or 4 assessment points and not on more frequent measurements of behavior, the only exception being Hubbard & van Ijzendoorn whose research design consisted of 12 assessments distributed over the first 9 months of life.

Associations between behaviors

From the above it is clear that both infants and mothers show considerable variability and change in specific behaviors over time. However, given the fact that the behavior within the mother-infant system is one of interaction, both directed at and dependent on that of the other partner, it is important to know how the *patterns of behaviors* develop over time. More specifically, taking into account the variability found in both individual maternal and infant behavior, is it still possible to find patterns of relationships between different behaviors? And also, how stable are these patterns over time? I.e., do they, as we proposed in the beginning of this chapter, change as the infant develops?

There are few studies which have investigated changes in mother-infant patterns of interaction, and those that have have focused on the micro-analysis of exchanges between mother and infant. Furthermore, the studies described below consist of analyses of 2 or 3 home observations lasting from 45 minutes to approximately 2 hours. Kindermann (1993) found changes in the interaction patterns of mothers and infants as the infants grew more competent in specific developmental tasks. He observed dyads with infants of 9, 12 and 21 months of age, and concluded that mothers follow their infant's development by adjusting their socializing interactions to the children's growing competence. Schaefer (1989) made observations of mother-infant dyads at 4 and 12 months of age, and found that while the dimension of positive mother-infant interaction was stable over the two observations, that of punitiveness and irritability was not. Schölmerich et al. (1995) found composite measures of mother-infant interaction to be moderately stable between the ages of 7 and 10 months; and while Findji, Pêcheux and Ruel (1993) found stability of dyadic activities between observations performed at 5 and 8 months of age, Bornstein & Tamis-LeMonda (1990) found stability for some maternal activities together with instability of infant behaviors between the ages of 2 and 5 months.

That mother-infant interaction when the infant is very young, differs from interaction when the infant is around a year of age should not be surprising. For example, infants in their first 3 months of age show increased crying of a reflexive nature which would primarily be due to poor state regulation and irritability (St James-Roberts et al., 1997). This fits in with the idea that altricial species (e.g., primates, rats, dogs) in contrast to precocial species (e.g., sheep, cattle, guinea pigs) have a prolongation of immature developmental stages which allows the infant to maintain an "open" homeostatic system, whose regulation is partially delegated to phenomena within the relationship with its mother (Hofer, 1987). Thus, particularly in the first months of life, the mother plays an essential role in the regulation of the internal state of the infant and the communication between mother and infant is determined by the mutual attempts to reach homeostasis in the infant. Later on, as the infant becomes more adept and independent in his/her state regulation, other aspects of mother-infant communication (i.e. social, cognitive, etc.) will gain in relative importance. Such an interpretation would explain the differences between early and later developmental stages in the nature of a behavior such as crying, and in the mother-infant interaction.

It therefore seems plausible that change is inherent to normal infant behavior and normal mother-infant interaction, and not, as has been suggested, a characteristic of a sub-population such as especially irritable babies (Crockenberg & McCluskey, 1986). Other studies have supported the notion that change is a part of normal development. For example, Kindermann's (1993) findings in the study described above are consistent with the notion of normal developmental adjustments. The author discusses the need to include time in the study of socialization processes, because the fact that the mother adjusts to her developing child's changing demands might mean that a certain pattern of maternal behaviors could be more adaptive at one age of the child than at another. Change, and not stability, would be extended and natural in early mother-infant interactions. Bornstein (1989) states that caretakers will interact with their children in a different balance of patterns during different developmental periods. He found that aspects of the interaction between the two varied over time in their prevalence as well as in their predictive validity for developmental outcome. And he describes development as a dynamic in which prior experiences as well as maturation intrinsic to the child changes the effectiveness of different modes of interaction, which in turn changes the nature of the caretaker-child interaction. Here again, the accent is on change as a normal part of development. *Not* being able to adapt behaviorally to changes in the developing infant could even have deleterious effects on the child. Bee, Barnard, Eyres, Gray, Hammond, Spietz, Snyder, and Clark (1982) found evidence consistent with the hypothesis that one of the features of low-education families that increases the infant's risk of poor intellectual performance in later childhood is the decreased ability of the caregivers to adapt to the child's changing demands.

Goals of the study

In cases in which uniform behavior is expected in infants, a groups design is the adequate assessment technique because it filters out chance variability. However, if substantial differences are expected between infants, but at the same time clear behavioral patterns are expected over a certain period of time within each mother-infant pair, then it is important to determine whether the pattern is stable during the period studied or whether it is due to chance. If one were to do this by comparing one observation of an interaction pattern at, for instance, the age of two months, with one observation made at five months, it would be very difficult to distinguish the difference between stable characteristics and coincidental, contextual variability for each of the observations separately. That is, in view of the contextual dependency and flexibility of behavior, it is possible that the observed similarities and differences across the three-month interval are based on mere coincidental aspects of the behaviors at issue. A few assessments will not be enough to clarify the issue. Moreover, a mother-infant behavioral pattern that is stable but that changes its nature in the long-term, could easily be confused with instability or chance variability when assessed on a few occasions separated by important time lapses.

What is needed are longitudinal time series studies that monitor the behavioral patterns sufficiently frequently to distinguish locally stable from locally variable properties on the one hand, from long-term variability (plasticity) on the other. However, there are no studies that have followed patterns of relationships between different mother and infant behaviors longitudinally, and investigated possible general, macroscopic shifts and changes over time. And as we have seen, by relying on 2 or 3 assessment points, the studies mentioned before are especially vulnerable to limited diversity in mother-infant interactions and to situational factors. They are also vulnerable to the mother presenting ‘unnatural’ behavior due to the unusual situation of being observed (Findji et al., 1993).

In this chapter we will attempt to contribute to the knowledge of variability, stability and change in mother-infant interactions, by using an intensive (weekly) longitudinal design to investigate patterns between infantile behaviors related to emotions (crying, fretting/fussing and smiling) and different types of body contact with the mother. The behaviors mentioned are very likely to change in function and form over age. For example, as we have seen crying is initially largely reflexive in nature, but it becomes increasingly a complex social signal as the infant develops and begins to combine it with visual regards and gestures (Gustafson & Green, 1991; St James-Roberts et al., 1997). On the other hand, smiling is a behavior that is initially (almost) non-existent, gains in frequency and importance over the months (Belsky et al., 1984), and finally comes to play an increasingly sophisticated and complex role in social interactions. Therefore, because these behaviors change over age, and mother-infant interaction has been shown to be influenced by each partner’s contributions to the relationship (Tamis-LeMonda & Bornstein, 1991; Fish & Stifter, 1995; Brinker, Baxter & Butler, 1994; Acebo & Thoman, 1995), a logical consequence would be for the patterns of association between them to also change.

The main goal of the research reported in this article was to study both variability and stability between and within mother-infant dyads. First of all, we wished to establish whether or not, for any given moment in time, (relatively) stable macroscopic patterns in emotion-related behaviors in mother-infant dyads existed. If such patterns could be found, we wanted to know whether they were stable across the whole time interval covered by our observations (approximately fifteen months). If they were not, we wanted to know how they changed. More specifically, did new patterns or associations between the behaviors involved emerge as the mother-infant system developed? Furthermore, because the questions of stability, flexibility (short-term variability) and plasticity (long-term variability) relate primarily to processes that occur within dyads, we also wished to know whether the patterns and changes found applied to all infants or whether they were characteristic of specific dyads and therefore showed considerable between-dyad differences.

METHOD

Subjects

The subjects were four Caucasian mother-infant pairs from two-parent middle-class families. The mothers were recruited through midwives, pre-natal gym classes, a local newspaper and letters sent through the Green Cross (state agency that provides help at home for mothers with new-borns). All the mothers had completed secondary school at least and one had a college degree. They were selected on the basis of the following criteria: a) they were married, financially secure, and had an extended support system (family and friends nearby); b) during the research period they did not intend to work outside the home and would be the primary caretakers; c) the pregnancies had been uneventful and had resulted in deliveries without major complications (three vaginal and one Caesarean); d) the infants, two males (E and F) and two females (J and S), were healthy, full-term firstborns; e) the infants had adequate Apgar scores (8 and 9 at 1 min. and 9 and 10 at 5 min.), and they showed no abnormalities during the neurological examination that was performed by a physician 7 days later.

In order to determine whether the infants were developing normally, they were tested with the Bayley Scales of Infant Development (BOS 2-30) around the age of 15 months. The resulting Mental/Motor scores for the 4 infants were: 117/45, 114/47, 115/57, 115/49 which indicate developmental ages between 14 and 16 months, with the exception of the motor score of 57 which indicates a developmental age of 22 months.

Materials

The ethological home observations were not videotaped, but were carried out by typing in behavior codes on a laptop computer while observing the mother and infant. The software package used for registering the observed behaviors was The Observer 3.0 (Noldus, 1991). The one-minute periods of the interval sampling were identified by a clip-on timer and were communicated to the observer through an inconspicuous ear-phone. Thus, the observer possessed a relatively high degree of freedom of movement and was able to follow the mother and her infant around the house.

Procedure

Weekly data collection

The four mother-infant pairs were visited weekly by the first author, who carried out all of the observations. The first observation took place in the second to fourth week of life of the infants; the last observation took place 61 to 64 weeks later. Observations were missed only during the weeks the families went on vacation and one week when the observer was ill. Each mother had her "own" observation day and it was very rarely necessary to reschedule the weekly visit for another day of the week. The observations began around 9.00 in the morning and continued until 3 hours of data collection had been completed. If the child fell asleep, the observation was stopped until the child awakened.

The mothers were told that the goal of the project was to determine regressions and transitions in infant development, as these were the main objects of investigation (see Chapters 2-4). They were also instructed to ignore the observer as much as possible and to go about their everyday household routine. During the observations, the observer's interactions with the infants were limited to smiling back when they smiled at her and fending them gently off when, at an older age, they tried to touch the keyboard of the computer. In practice, the infants largely ignored the observer.

Ethogram

The following behaviors were observed:

Vocalizations. *Crying:* weeping. Often accompanied by intense facial coloring and production of tears. *Fretting/fussing:* protesting, whimpering, whining. Vocalizations of an audible negative affect which suggest complaint, irritation, frustration, worry, distress, annoyance, tiredness, etc. Vocalizations which were not clearly interpreted as having a negative affect were not scored.

Facial expressions. Smiling: corners of the mouth are fully drawn up. Mouth may be open or closed. Unclear smiles (“half smiles”) were not scored.

Contact/distance. Ventral: the infant’s weight was supported by the mother, it was facing the mother and their ventral sides were touching. *Lap:* the infant’s weight was supported by the mother, and there was contact between them (though no ventral contact). The infant may be facing the mother or have its back toward her. It may be standing or sitting, or could be held in the air or on a hip. *Contact:* the infant stood/sat/lay on its own, but its body was in contact with the mother’s. It included physical contact even if there was something between the mother and the baby's skin. For example: pull or tug at clothes, arrange clothes, wipe baby's mouth, tickle the baby with something (like a teddy bear), etc. *Total contact:* the sum of the categories described above; i.e. the total time spent in body contact.

Contact/distance and *crying* were scored by continuous coding of events.

Fretting/fussing and *smiling* were recorded by means of interval coding. The observer categorized each 60 sec. interval of the observation according to the occurrence or non-occurrence of these behaviors. The decision to use interval sampling was based on the low reliability scores which were obtained when sampling these behaviors continuously.

Reliability

The observer received an intensive training by a senior observer during live home observations. Training was continued until the inter-observer reliability scores were satisfactory. The mean percentage agreements for the body contact categories was 91.1% and for crying 90.8%, and Cohen's kappa for smiling-fretting was .88 (these last two behaviors were combined in a single reliability analysis because each one-minute period was categorized in different ways by combining smiling/no smiling/bad visibility with fretting/no fretting).

To rule out the possibility of observer drift or decay, videos were made of two mother-infant pairs after 7 months of the observation period had elapsed. Fragments containing active mother-infant interaction were used to calculate intra-observer reliability by scoring each fragment twice, with an interval of a month between both occasions. The mean percentage agreements for the body contact categories was 89.3% and for crying 86.6% and the kappa for smiling-fretting was .71, levels which indicate little observer drift.

Analysis

Illnesses

The infants did not suffer from serious illnesses during the study period and were consequently observed every week notwithstanding minor illnesses. The observations during which, according to the mother (and confirmed by the observer), the infant's behavior was clearly affected by fever, the flu, diarrhoea, etc., were the observations pertaining to weeks 30, 32 and 53 for infant E, weeks 20 and 56 for infant J, week 65 for infant F and weeks 44, 47 and 59 for infant S. Because these minor ailments involved a small number of observations and did not systematically affect the studied behaviors (only ‘body contact’ for week 44 of infant S was an outlier, i.e. had a Cook’s distance ≥.70), the observations were included in the analyses.

Missing data

Linear interpolation was used to fill in the gaps due to missing observations (5.2% of the observations).

Detrending of the data

Most of the graphs of the observed behaviors showed important non-linear trends in the data, for instance exponential decreases (see graphs in Chapters 2 and 5). This made the study of the relationships between the behavioral variables unreliable as indicators of *local* correspondence between those variables. Most of the variance explained by, for instance, a regression model, will be based on the general trends in the data, for instance a general decrease in crying and a general increase in smiling. What we wanted to know, however, is whether, given a specific temporary or "local" level of crying at the age of, for instance, two months, more or less crying is correlated with more or less comforting behavior in the form of bodily contact. We also wanted to know, for instance, whether a comparable deviation from the average level of crying at the age of twelve months, was accompanied by a comparable deviation from the average level of body contact at that age. If this were the case, the nature of the relationship between crying and body contact would have remained stable, irrespective of whether crying and body contact showed similar or different developmental trends across the ten month interval.

In order to be able to study the (dis)similarities between behavioral patterns across age we needed to detrend the data, that is, we had to subtract the general trend from the actually observed data in order to arrive at data sets which have a constant average across time. The data were detrended by calculating the residuals, that is, the differences between the observed values and the value of the best fitting polynomial regression function. The polynomial estimates the best fitting curve for a sequence of observations. If O_t is the value of an observed variable at time t, its corresponding polynomial value P_t equals:

$$P_t = a + b\,t + c\,t^2 + d\,t^3 + e\,t^4 + \ldots$$

A polynomial curve of the second degree (i.e. one with 2 as its highest exponent) was chosen because such a curve eliminates linear and eventually also quadratic trends, while conserving the interesting local fluctuations. The residuals for the total data series were then calculated. These residuals were then used for all the multiple regression analyses presented in this chapter.

Statistical analyses

In order to determine the **general differences** between the four mother-infant pairs, the following method was applied. Each infant's undetrended data series were regressed against two variables: 'time' and 'time squared', both centered by subtracting the mean of the series. In this way, each behavioral variable was described by the following function:

$$y = a_0 + a_1{*}\text{centered time} + a_2{*}\text{centered time}^2 + e$$

where a_0, a_1 and a_2 are the regression parameters and e is a residual error term. The a_0's obtained are the means of the data series and can be used, together with their standard errors (SE's), to compare the data of the different infants. The overall differences between the infants were thus investigated using the following formula, which has a Chi-square distribution with 3 degrees of freedom:

$$\chi^2 = \Sigma\,(a_{0i} - \bar{a})^2 / SE_i^2 \qquad \text{where } \bar{a} = (\Sigma\, a_{0i}/SE_i^2\,)\,/\,(\Sigma\, 1/SE_i^2\,) \text{ and } i = 1 \text{ to } 4 \text{ (infants)}$$

The differences between each individual pair of infants were then studied by using the following formula, which is a 'z' value with a normal distribution N(0,1):

$$z = (a_{01} - a_{02}) / \text{SQRT}\,(SE_{01}^{\,2} + SE_{02}^{\,2})$$

where, as an example, the differences between infants 1 and 2 are investigated.

Second, multiple regression analyses were used to study the **associations between the observed behaviors**, and the changes they underwent over time. Because the data consisted of residuals with mean equal to 0, the constant was excluded from the equation and the multiple regressions were calculated through the origin. The regression for the association between two variables was therefore:

$$(1) \qquad y = \beta{*}x + e$$

In order to investigate whether these associations changed with time, β was modeled as a function of 'time' and 'time^2', where time was the observation week and thus varied from 1 to 61, 63 or 64, according to the length of each infant's observation period:

$$(2) \qquad \beta = \beta_0 + \beta_1{*}\text{time} + \beta_2\,{*}\text{time}^2 + e$$

In this way the regression was:

(3) $y = \beta_0 * x + \beta_1 * x * time + \beta_2 * x * time^2 + e$

Significant results of this overall dynamic or time-dependent regression indicate that variable ‘y’ has a significant association to variable ‘x’ and that this association varies linearly and/or quadratically over time. *How* the association varies can be observed by plotting the ‘β’ of regression (2). The ‘β’ plots of the different infants can thus be compared in order to see if the associations between the variables vary in the same way over the observation period of 15 months.

It is important however, to test the hypothesis that significant multiple regressions which include the variables with linear and quadratic time (3), actually yield more information (i.e. explain more variance) than the simple regressions between the two variables studied (1). To this end, variance gains tests were conducted (Tatsuoka, 1988, p. 50). Significant results indicated that important gains in explained variance could be obtained by including (in the regression) the linear and quadratic changes over time in the association between the two variables.

A meta analysis was employed (Glass, McGaw & Smith, 1981) based on the p-values observed for the four infants, to test the hypothesis that significant associations exist between the behavioral variables, and that these associations change over time for the population from which the four infants were selected. The meta analytic procedure used is called 'the chi-square method' (Glass et al., 1981, p. 99), and it combines the p-values of the four infants into one overall p-value (see Chapter 5). In cases in which individual infants have p-values <.005 it is important to rule out the possibility that significance is based solely on that one infant. In those cases, p-values <.005 were replaced by .01. In this way the possibility that significant results were based on one infant could be largely ruled out. If the results were not altered greatly by this replacement, the original p-values were used in the analysis.

Finally, moving regressions of pairs of observed variables were performed on 20-week series in order to examine in more detail how well one variable predicts another at different points in time. Thus, a standard linear regression model of the form

$$y_{t\,(1\text{-}20)} = \beta_{0\,(1\text{-}20)} + \beta_{1\,(1\text{-}20)}\, xt$$

was fitted on a moving series consisting of 20 weeks, where the subscript 1-20 refers to the fact that the parameters were estimated for the data set comprising the observations from week 1 to week 20. For an observation set consisting of 63 weeks, for example, we obtained 44 parameter sets, namely

$$\beta_{0\,(1\text{-}20)}, \beta_{0\,(2\text{-}21)}, \beta_{0\,(3\text{-}22)}, \ldots \beta_{0\,(54\text{-}63)}$$
$$\beta_{1\,(1\text{-}20)}, \beta_{1\,(2\text{-}21)}, \beta_{1\,(3\text{-}22)}, \ldots \beta_{1\,(54\text{-}63)}$$

By plotting the series of β_1 parameters we obtain an indication of the relationship (and the eventual change in that relationship) between the independent variable x (e.g. crying) and the dependent variable y (e.g. smiling).

Both regression methods, the overall dynamic linear (possibly quadratic) regression method described above and the method of moving regression intervals, have their particular advantages and disadvantages. The overall method is simple and conforms to the standard regression technique. It allows us to estimate the relative importance of the contributing factors, that is, the independent behavioral variable, the linear change in the contribution of that variable across age and the quadratic change in the contribution of that variable. The disadvantage is that, given the form of regression equation (2), the nature of the changes in the way the independent variable contributes to the dependent variable is confined to either linear or quadratic polynomials, which is only a meager subset of the set of all possible, meaningful patterns of change. Finally, however, a regression analysis based on 63 data points (the average number of observations per child) is significant at .05 level if it explains slightly more than 10% of the variance of the data, whereas a regression analysis based on 20 data points requires 20% or more explained variance in order to reach a similar significance level. The advantage of the second, moving regressions method, is that it can specify all possible ways in which the contribution of the independent variable changes. Its major disadvantage is that it is based on overlapping series of observations (the moving 20-week series) and thus does not allow for a standard testing of significance. For instance, assume that the series of 44 regression analyses contains three analyses that are significant beyond the .05 level, and thus explain more than 20% of the variance of the corresponding data. What is the probability that this result is based on chance alone? In order to answer this question, we ran a simulation consisting of 1000 random permutations of our data sets. We computed the series of 44 parameter sets a thousand times, using the original, permuted data. That is, we "explained" a series of data (e.g. the data on crying) on the basis of randomly permuted independent data (e.g. a random permutation of the data on smiling). We then calculated the frequencies with which such permuted series show 0, 1, 2, … significant regressions at the .05 level. It turned out that, with such permuted series, there is a 95% chance that the number of significant regression analyses is smaller than or equal to 10. Thus, only the series in which 11 or more series proved significant were considered valid.

In summary, the overall dynamic regression analysis and the moving windows method were employed as complementary methods that hopefully provided converging evidence. In view of its computational and analytic simplicity, we decided to employ the overall dynamic regression method as our primary method of statistical analysis.

Adequacy of ‘β’ plots. A sample of the series of 42-45 β’s obtained through the moving regressions were plotted and fitted with quadratic curves. These curves were used to check that the ‘β’ plots obtained from the overall dynamic regression method (2) were accurate representations of how the β varied over time. If the associations between the variables mostly varied non-linearly, then the ‘β’ plots would not be adequate due to their obligatory linear and quadratic nature. Because this test was post-hoc, a sample consisting of half of the overall dynamic regressions which showed gains in variance in the meta analysis (i.e. where the p values were <.20) was used. Therefore, because the data of the four infants for 14 multiple regressions were used, a total of 56 series of β’s obtained through the moving regressions were plotted, fitted with quadratic curves, and compared to the curves of the ‘β’ plots.

The results indicated that in 79% of the cases, the two curves strongly resembled each other. In the remaining 21% of the cases, the curves were clearly different. In 7% of the cases, the multiple regression resulting in the ‘β’ plot was significant at the 5% level. In these cases, although the association between the two variables varies significantly over time in a quadratic manner, the moving regressions deliver a different quadratic trajectory over time. An example is shown in Figure 1. The two methods ‘disagree’ in the trajectory followed by the association between the two variables. In the remaining 14% of the cases studied, the multiple regression resulting in the 'β' plot was not significant at the 5% level. An example of these cases is displayed in Figure 2. Here we can assume that the linear quadratic nature of the 'β' plot is not adequate for describing the changes in the associations between the two variables over time. However, this does not mean that these associations do not change over time. It only means that the changes cannot be described linearly or by means of the linear quadratic formats, as in most of the cases. As can be seen in Figure 2, the association between the variables apparently does change over time, but not in a manner which can be captured by a simple linear function. Had a different or more complicated function (a polynomial of a higher order, for example) been used in this case, the overall dynamic regression of the changes in the association between the variables over time would have possibly been significant at the 5% level.

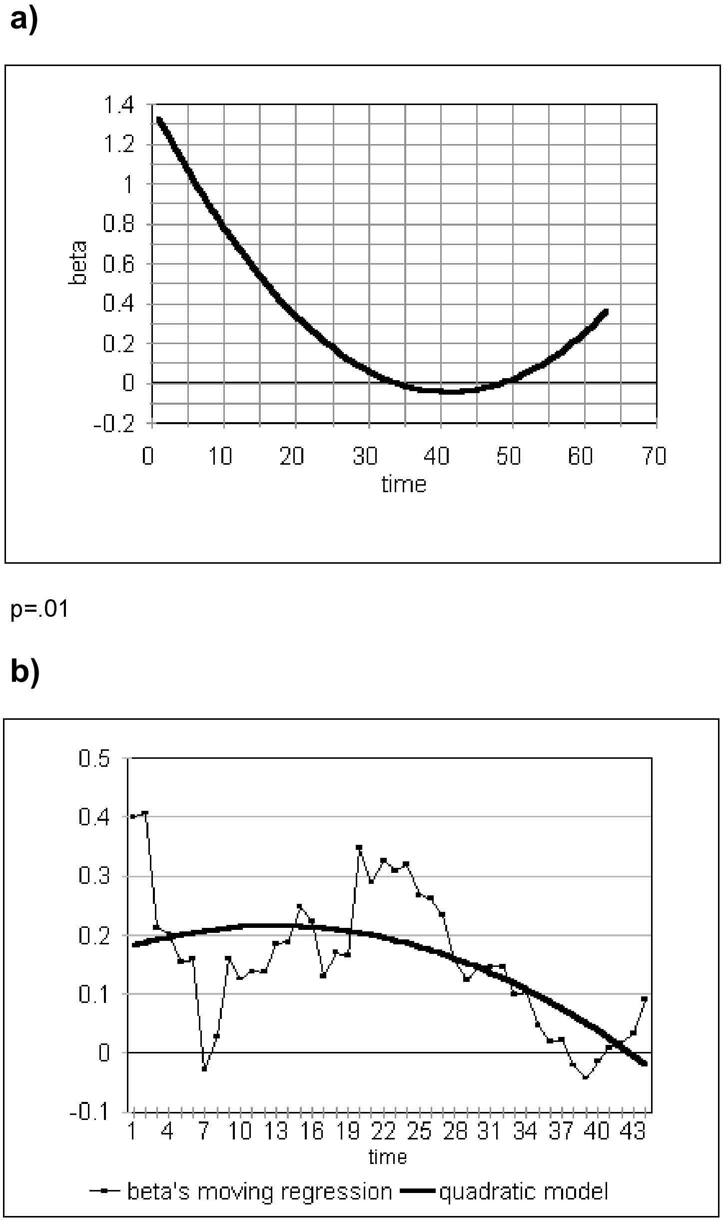
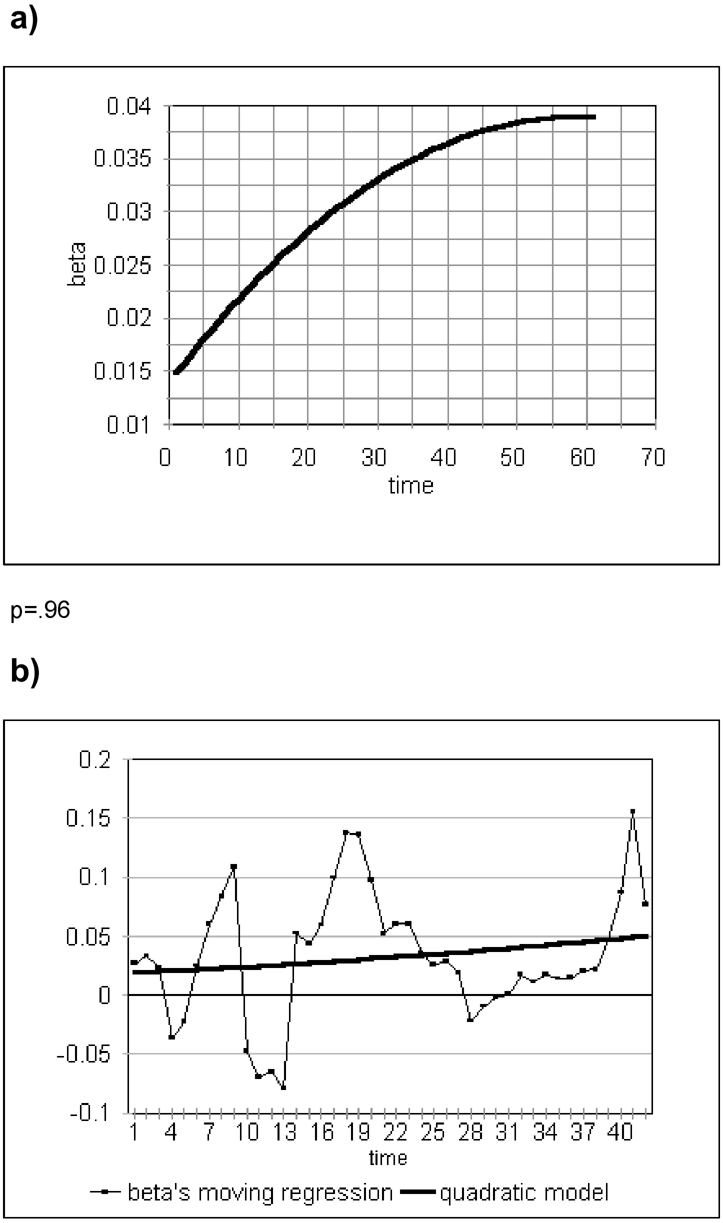


Figure 1. Non-matching ‘β’ plot (a) and moving regressions’ quadratic curve (b), in which the overall dynamic regression resulting in the ‘β’ plot was significant at the 5% level. Dependent variable: total contact; independent variable: fretting/fussing; infant: S.



p=.96

Figure 2. Non-matching ‘β’ plot (a) and moving regressions’ quadratic curve (b), in which the overall dynamic regression resulting in the ‘β’ plot was *not* significant at the 5% level. Dependent variable: crying (duration); independent variable: total contact; infant: J.

As a conclusion, because the great majority of the sample analyzed showed the 'β' plots to be an adequate representation of the changes between variables over time, we are confident that our use of this overall dynamic regression function is justified. Moreover, the 14% of the cases in which the curves were different and the dynamic multiple regressions were not significant made our analysis more conservative: possible cases of true changes over time were missed due to the function chosen. It is important to add the cautious note that due to the 7% of the cases in which both methods 'disagreed' in the trajectory followed by the association between the two variables, detailed interpretations of the 'β' plots should be left out. However, the goal of this article is not to study individual and very specific changes between behaviors, but to determine whether or not changes occur over time. As we have just seen, the methods used appear to be adequate for this end.

Types of 'β' plots. In order to gain more insight in the developmental pathways followed by the associations between behaviors, the 'β' plots obtained from the overall dynamic regression method (2) were divided into 8 exclusive categories according to the prototypical trajectory followed by the curve. The categories were not chosen on theoretical grounds, but on the basis of qualitative characteristics which were considered important in developmental processes; thus, they were based on the positive or negative nature of the β coefficient and on the shape of the curve:

β coefficient:	linear/quadratic:	U-shaped:
+ to - / - to +	1	2
+ to 0 / - to 0	3	4
0 to + / 0 to -	5	6
all + / all -	7	8

The rules followed to classify each of the studied curves were:

1) to distinguish a U-formed from a quadratic curve, the shortest arm must be at least longer than half the longest arm.

2) for categories 1 and 2, when the curve changes sign at least half the absolute maximum value must be reached; if not, it is considered to be 0 instead of the new sign and categories 3, 4, 5 or 6 are appropriate.

3) for categories 7 and 8, the lowest absolute value has to be greater or equal to 1/5th of the highest absolute value; if it is smaller, then it is considered to be 0 and categories 3, 4, 5 or 6 are appropriate.

4) for the U-shaped curve, the distinctions between curves 2, 4 and 6 are based on the trajectory of the longest arm.

RESULTS

General differences and similarities between the infants in the studied behaviors

For each infant there were 61-64 weekly data points for body contact categories, negative vocalizations and smiling. Each data point covered a period of 3 hours of direct observation, and the whole series covered a period of 15 months of the infant's development. Therefore, the observational data give a fairly good picture of each infant's characteristics, and of the dynamics of each mother-infant pair. Before going into the more detailed study of the relationships between the behaviors and the changes these underwent over time, the general differences and similarities in the behavioral measures studied were investigated. The means and standard errors obtained through the overall dynamic or time-dependent regressions (see *Statistical Analyses*) for each behavior are presented in Table 1.

Significant differences were found between the infants in the total time spent in physical contact with the mother (Chi-square= 43.92, p=.000). Specifically, infants S and E spent more time in body contact than both infants F and J.

Furthermore, the three individual categories of body contact showed differences between the subjects. The amount of time spent in "ventral" contact with the mother was significantly different for all the infants (Chi-square= 35.02, p=.000), and these differences were specifically due to infant J spending significantly less time in this category of body contact than the other 3 infants. The time spent in "contact" also showed differences between the infants (Chi-square= 66.56, p=.000). In this case infant E spent significantly more time in this category than infant J, while infant F spent significantly less time in "contact" than the other 3 infants. The time spent in "lap" also differed significantly, although less strongly, between the infants (Chi-square= 8.10, p=.04), specifically due to infant E spending more time in 'lap' than F and J.

Table 1Individual means and standard errors of the studied behaviors (a0 stands for the mean and SE for the standard error of the mean, see *Statistical Analysis).*

infant	total contact		contact		lap		ventral	
	a0	SE a0	a0	SE a0	a0	SE a0	a0	SE a0
E	37.30	1.05	16.46	0.53	16.32	0.87	4.50	0.50
F	29.05	1.11	10.88	0.47	13.40	0.85	4.77	0.46
J	29.61	1.21	13.35	0.83	13.84	0.91	2.37	0.34
S	36.51	1.36	14.90	0.66	15.96	1.05	5.59	0.54

infant	crying dur.		crying freq.		fretting/fussing		smiling	
	a0	SE a0	a0	SE a0	a0	SE a0	a0	SE a0
E	4.05	0.50	8.91	0.89	29.41	0.94	26.50	0.90
F	2.68	0.31	6.94	0.88	16.51	0.72	38.42	1.03
J	3.71	0.53	11.54	1.22	21.05	0.86	30.22	1.05
S	1.96	0.26	6.78	0.80	19.50	0.88	30.38	1.15

In short, these results all point in the general direction of infants E and S spending more time in physical contact with their mothers than infants F and J.

As to negative vocalizations, the greatest differences in the behavioral observations were found in fretting/fussing (Chi-square= 121.66, p=.000), with E fretting the most, followed by J, then by S and finally by F. The differences between the infants were all significant except for the difference between S and J. Significant general differences were also found between all the infants for frequency of crying (Chi-square= 13.23, p=.00) and for duration of crying (Chi-square= 18.88, p=.000). In the case of frequency, the difference was due specifically to infant J crying more frequently than infants S and F, while in the case of duration, it was due to infant E spending more time crying than infants S and F, and J crying more than S.

As a conclusion, we can generalize by saying that infants E and J showed more negative vocalizations than infants S and F.

It is important to add here that the four infants studied showed normal levels of crying; i.e. none of them were persistent criers. In the first three months of life, for example, they cried an average of 5.75 minutes/hour (E: 5.59; J: 8.71; S: 3.10; F: 5.60), which fits in nicely with the results obtained by other researchers (Bell & Ainsworth, 1972: 7.7 min/hour; Hubbard & van Ijzendoorn, 1991: 6.5 min/hour; St James-Roberts & Halil, 1991: 5 min/hour).

Table 2Meta analyses of the regressions between each two pairs of variables.

		independent							
		tot.cont.	cry-d	cry-f	fretting	smiling	ventral	lap	contact
	tot.cont.		*** 0-22-0-15	** 5-6-3-10	** 3-2-4-9	* 2-7-0-4			
	cry-d				*** 25-10-6-21	*** 18-4-3-2	*** 23-12-11-18	*** 4-12-1-15	
	cry-f				*** 41-14-33-26	* 8-3-5-1	*** 28-7-24-6	** 1-5-1-13	
dependent	fretting					* 10-0-2-4	*** 18-0-5-13		
	smiling						++ 3-0-8-1		(***) 0-24-1-1
	ventral							++ 1-1-12-1	
	lap								
	contact								

Note: ***: p<.001; **: p<.01; *: p<.05; ++: p<.10; (***) this significance is due to only one infant with p<.005, when this p is replaced by .01, the meta analysis is no longer significant; the numbers are the percentage of explained variance for the individual infants, in the order E-F-J-S.

Finally, significant differences were also found in the amount of smiling which the infants displayed (Chi-square= 77.72, p=.000) during the observations; these differences were due to infant F smiling significantly more than the other 3 infants, and infants J and S smiling more than infant E.

Associations between the studied behaviors

The results of the meta analyses of the regressions between each two pairs of variables can be seen in Table 2. The table presents the general significances and the individual percentages of explained variance (which vary between 0 and 41%). For the significant meta analyses, the direction of the associations for the individual infants with ‘p’ values <=.20 are as follows. Not surprisingly, crying (duration and frequency) were positively related to fretting/fussing, and negatively related to smiling. Also, fretting/fussing was negatively related to smiling in two infants (E and S).

The associations between body contact categories and negative vocalizations showed more individual differences. The strongest associations were between ‘ventral’ contact and crying (duration and frequency). These were positive for infants E, J and S, and negative for infant F. ‘Ventral’ was also positively related to fretting/fussing in infants E, J and S. ‘Lap’ was positively related to duration of crying in infant S, and negatively in infants E and F. Frequency of crying was positively related to ‘lap’ in infant S and negatively in infant F. Furthermore, infant S showed a positive association between ‘lap’ and fretting/fussing (p=.03), but as she was the only one, the meta analysis was not significant.

‘Total contact’ was positively related to frequency of crying in infants E, J and S, and negatively in infant F, and was positively related to duration of crying in infant S and negatively in infant F. ‘Total contact’ was also positively related to fretting/fussing in infants E, J and S.

‘Smiling’ was positively related to ‘total contact’ in infants E and F, and negatively in infant S. It was also strongly positively related to ‘contact’ in infant F (p<.000), although this meta analysis was only significant due to this particular infant. ‘Smiling’ also showed one meta analysis with a p value <.10. In this case, it was negatively related to ‘ventral’ in infants E (p<.18) and J (p<.02).

The different types of body contact were not related for these infants. There was only one tendency to significance in the meta analyses, and this was for the association between ‘ventral’ and ‘lap’ which had a p value <.10. In this case, the behaviors were positively related for infant J (p<.005).

In conclusion, it is possible to say that, in this group of infants, crying and fretting/fussing were strongly related, and smiling was negatively related to the negative vocalizations. Total body contact, and specifically ‘ventral’ contact, were positively related to negative vocalizations in infants E, J and S, but negatively related in infant F. The association of ‘lap’ with negative vocalizations was of a more idiosyncratic nature, i.e. it depended on the individual infant, while ‘contact’ showed no association whatsoever with negative vocalizations for any of the infants. The associations between smiling and body contact were also idiosyncratic, and the associations between the different types of body contact were virtually non-existent for these infants. Therefore, the results suggest that there were stable patterns between behaviors across the entire age range. Some of these patterns were shared by all four infants, while others were typical of individual infants.

Changes in the associations between behaviors

Table 3 presents the results of the meta analyses of the dynamic multiple regressions (between each dependent variable and the independent variable, the independent variable * time, and the independent variable * time^2). The significant results are shown, together with the significant results of the comparison of this time-dependent multiple regression with that of the simple regression, and with the individual gains in explained variance. The first significances therefore indicate that there are changes in the association between the two behaviors over time, while the second significances indicate whether important gains in explained variance were actually obtained by including the two time-dependent variables in the regression.

In general, a comparison of Tables 2 and 3 shows that the significant associations between the variables are not altered greatly by adding the time-dependent variables. Also, in most cases, significant gains in explained variance are obtained with the dynamic multiple regression: twenty-eight (out of 48) meta analyses of multiple regressions had p values <=.20, 23 had p values <=.10 and 18 had p values <=.05. There are however a few associations which show up only when time is included. The most significant was that the time spent in ‘contact’ predicted the time spent in ‘lap’. Furthermore, weaker associations (based mostly on the values of 2 infants) were found indicating that the amount of fretting predicted the time spent in ‘lap’, and that ‘lap’ predicted smiling.

Also, there were two cases in which, while the meta analyses were not significant, there was a significant association between two variables in the time-dependent multiple regression, and at the same time also a gain in explained variance for an individual infant. These were the time spent in ‘lap’ as a predictor for the time spent in ‘contact’ for infant E (p value for the multiple regression =.04 and for the 9% gain in explained variance =.05), and fretting as a predictor for smiling, also for infant E (p value for the multiple regression =.01 and for the 7% gain in explained variance =.08).

Table 3Meta analyses of the multiple regressions including time. In each box, the upper significance is for the time-dependent multiple regression and the lower significance is for the advantage of including time in the regression.

		independent							
		tot.cont.	cry-d	cry-f	fretting	smiling	ventral	lap	contact
dependent	tot.cont.		*** * 8-9-2-6	**	** * 3-8-7-7	+			
	cry-d	*** *** 7-23-0-10			*** ** 7-6-1-11	*** *** 5-9-8-31	*** ** 5-8-1-15	*** ** 7-18-0-6	
	cry-f	** + 1-9-1-6			*** *** 11-9-14-9	*** *** 6-2-16-35	*** ++ 1-6-3-9	** + 3-9-1-4	
	fretting	* + 1-6-8-3	*** * 2-7-8-6	*** ++ 4-8-1-3		* + 8-3-6-2	*** ** 4-1-20-4		
	smiling		*** * 8-2-5-7	* ++ 6-4-4-7	++		* * 5-1-6-13	++ * 3-14-0-7	(*)
	ventral		*** ++ 1-4-2-12	*** ++ 2-4-3-11	*** *** 15-0-3-15	* * 3-1-10-10		++	
	lap		*** * 11-7-1-3	*	* (*)++ 0-18-5-4		+		** ** 12-3-11-11
	contact							+	

Note: ***: p<.001; **: p<.01; *: p<.05; ++: p<.10; +: p<.20; (*) this significance is due to only one infant with p<.005, when this p is replaced by .01, the meta analysis is no longer significant, although in one case the p value remains <.10 (see table); the numbers are the individual infants' percentual gains in explained variance, in the order E-F-J-S, when time is included in the regression.

The results presented above thus indicate that most of the associations between the variables studied varied over the 15-month study period and that these variations were significant, i.e. adding the time dimension significantly increased the percentage explained variance.

Our next step was to compare the 'β' plots (see *Statistical Analyses*) of the different infants in order to see whether the associations between the variables varied in the same way for all four subjects. The 'β' plots of all the associations which showed gains in explained variance when the time variables were included in the regression (i.e. with p values <.20 for the meta analysis), were compared between the infants. There were very few associations which varied in the same way over time for all four infants. Those that did all consisted of behaviors of which the infant was the sole author. These were fretting and smiling as predictors of duration of crying, and fretting as predictor of frequency of crying. Also, in the case of fretting as a predictor of 'ventral' contact, three infants showed the same trends, while the fourth, whose individual multiple regression with the three variables was the only one with p>.20, did not. The common trends were the following: a positive association which decreased in importance in time was found for fretting as a predictor of duration and frequency of crying (Figure 3a shows the curves for duration of crying); a negative association which decreased in importance in time was found for smiling as a predictor of duration of crying (Figure 3b); and a positive association which decreased in importance over time was found for fretting as a predictor of 'ventral' contact. All these shared associations were mainly of a linear nature, with each infant exhibiting different degrees of a slight quadratic trend in the curve.

All the other associations studied showed differences in trends over time between the four infants. These differences were due to the sign of the β, or to its linear and/or quadratic trajectory, and were often substantial. In order to illustrate how variable the associations between the behaviors can be and how differently they can vary over time in individual mother-infant pairs, we shall show a selection of three multiple regressions.

Figure 4a shows the curves for total time spent in body contact as a predictor of duration of crying. In this case all of the infants showed fairly linear trends. The association between the two behaviors was clearly different for infant S and infants E, F and J (although this last infant's individual regression showed no tendency towards a significant linear association between the variables).

Figure 4b consists of the curves for the time spent in 'contact' as a predictor of the time spent in 'lap'. The association between the two behaviors was negative at the beginning for all four infants. However, while infants S and J thereafter followed a fairly linear trajectory, infants E and F followed a strongly quadratic trajectory (although infant F's individual regression was not significant).

Finally, Figure 5 presents the curves for the duration of crying as a predictor of the time spent in 'lap' contact. The graphs show striking dissimilarities between the four infants, although infant J's individual regression was not significant. While infant E showed an almost perfect linear trend in his curve, infants S and F showed quadratic elements, but different trajectories, in their curves.

What types of change formats can be found in the analyses? The associations which showed gains in explained variance in the meta analysis (i.e. with p values <.20) when the time-dependent variables were included in the regression were used for the analysis of ‘β’ plots. From these, the 86 curves in which the individual infants had p values <.20 were inspected in order to determine their form. Two major groups of curves were distinguished: those that were linear or quadratic (n=66) and those that were U-shaped (in which the associations at the beginning and at the end

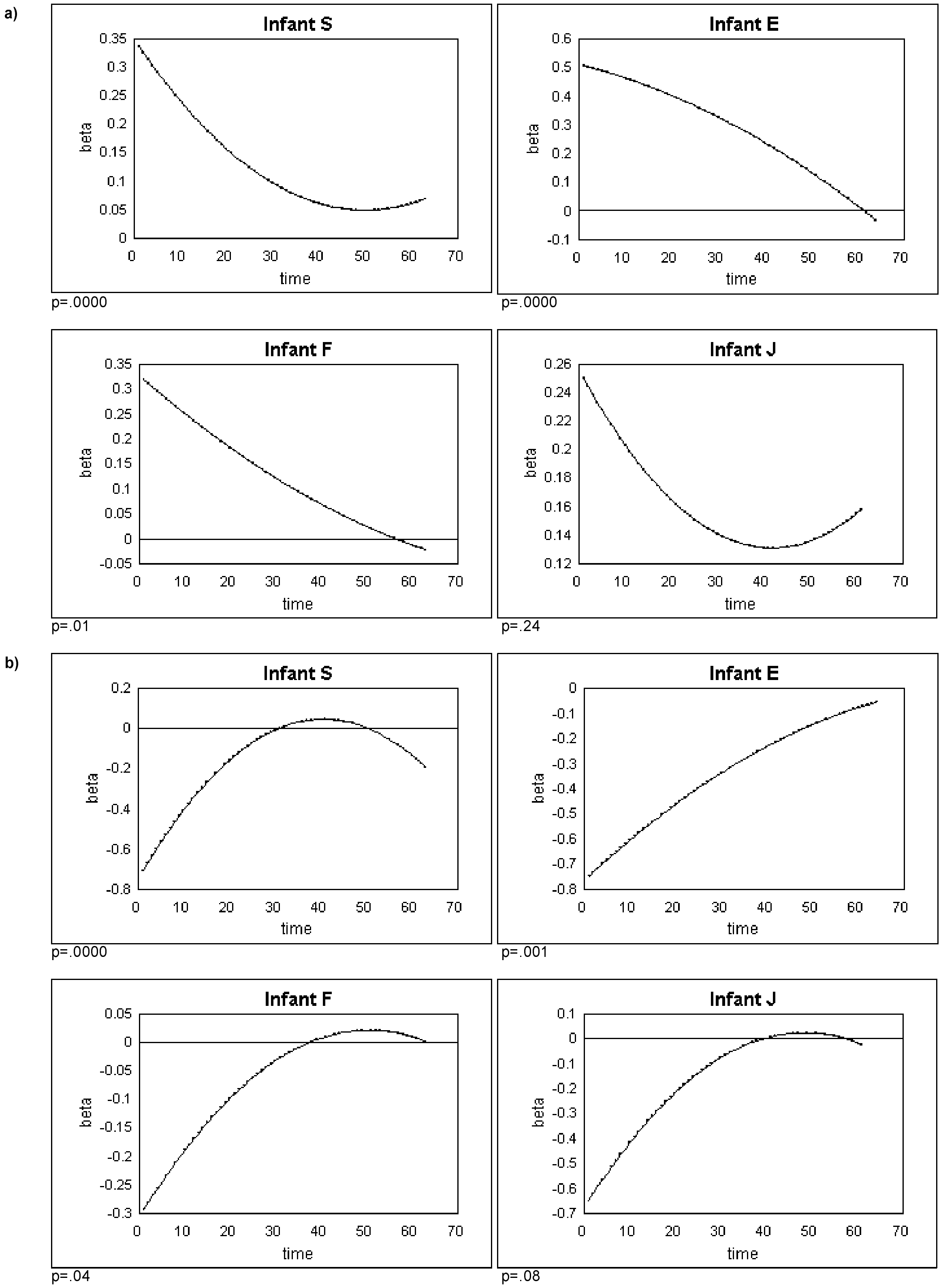


Figure 3. 'β' plots showing common trends for the four infants, p-value for the time-dependent multiple regression is presented under each graph; **a)** dependent variable: duration of crying; independent variable: fretting/fussing; **b)** dependent variable: duration of crying; independent variable: smiling.

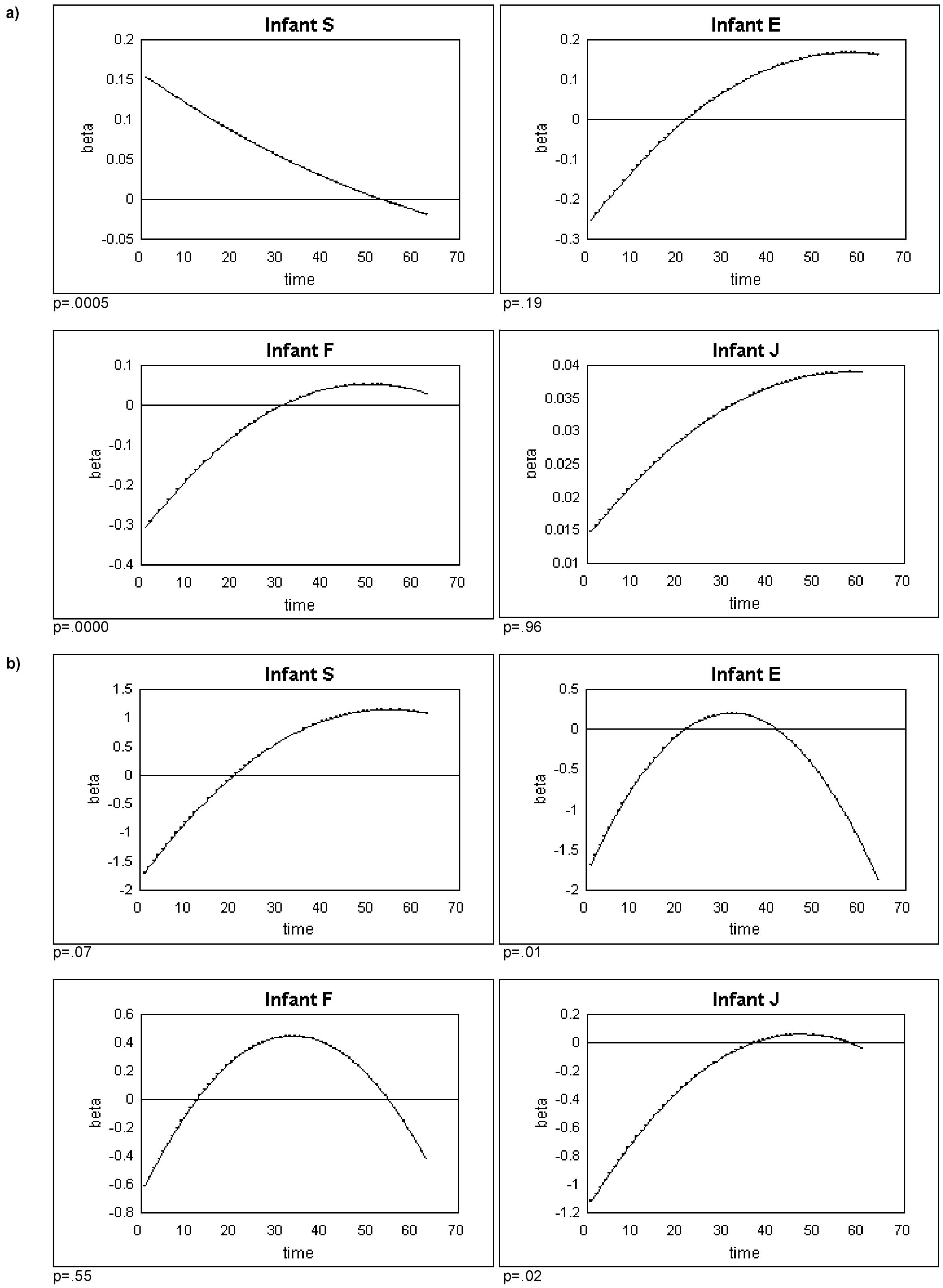


Figure 4. 'β' plots showing different trends for the infants, p-value for the time-dependent multiple regression is presented under each graph; **a)** dependent variable: duration of crying; independent variable: total body contact; **b)** dependent variable: lap; independent variable: contact.

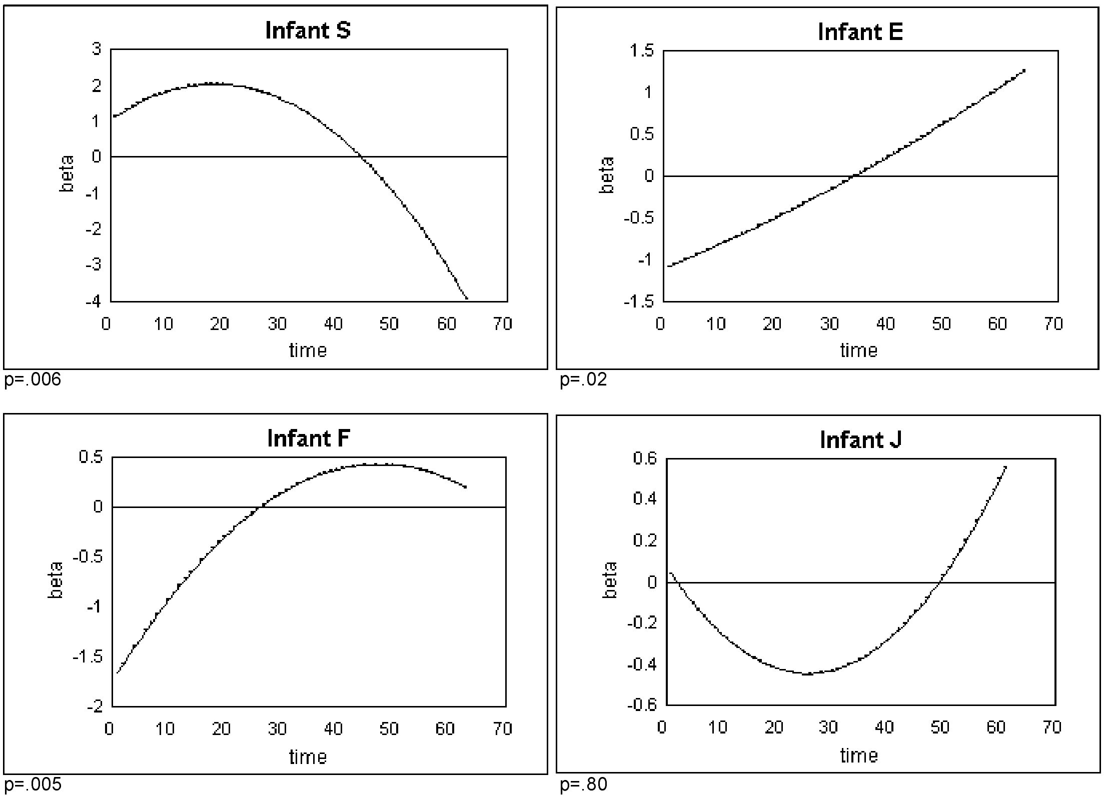


Figure 5. ‘β’ plots showing different trends for the infants, p-value for the time-dependent multiple regression is presented under each graph; dependent variable: lap; independent variable: duration of crying.

tend to be the same; n=20). Within these groups, four types of trajectories were found (see Table 4). The first group consisted of curves in which the nature of the relationship (+ or - association) clearly changed over the observation period (for ex., Figure 5, infants S and E). In the second group, the relationship changed from strongly negative to approximately zero (for ex., Figure 4b, infants E and J) or from strongly positive to approximately zero (for ex., Figure 3a). This was characteristic of the weakening or disappearance of an initial relationship (which could be either positive or negative), although in the case of the U-shaped curves, the pattern reappeared later. The third type was the opposite of the second: the relationship strengthened or appeared over time, going from approximately zero to strongly positive or negative. Again, in the case of the U-shaped curves the pattern later returned to approximately zero. Finally, the fourth type consisted of relationships which remained the same (+ or -) throughout the observation period. Note however that these patterns are quadratic approximations of more complicated and variable patterns of association, which can be obtained, among others, with the moving regression method.

Given that the form of the change in the relationships differed between infants (or, more correctly, mother-infant dyads) and between behaviors, we can ask if the differences are mere idiosyncrasies or coincidences, or whether there exists a systematic connection between the types of behaviors which were related and the way the relationships changed over time. In general, while around half the ‘β’ plots showed associations which decreased in importance over time, the other half displayed associations which stayed approximately the same, increased in importance over time, or changed dramatically in nature (+ to -, or vice versa). However, the data do not suggest that the type of 'β' plots shown depended on the individuals: each infant showed a variety of curve types, depending on the infant, 5-7 of the 8 possible types. On the other hand, there did appear to be a few systematic connections between the dependent variable and the type of curve. For example, in the 17 curves where duration of crying was the dependent variable, 71% were of the second type, in which a weakening or disappearance of the initial relationship occurred. This was the same for the curves where ventral contact was the dependent variable: 77% of the 13 curves were of the second type. Contrarily, when smiling was the dependent variable, the third curve type was more common: 75% of the 12 curves showed associations which strengthened or emerged over time.

Table 4 Occurrence of different types of beta plots.

Trajectory	Curve type		Total
	linear/quadratic	U-shaped	
+ to - / - to +	17	5	22
+ to 0 / - to 0	31	7	38
0 to + / 0 to -	11	6	17
all + / all -	7	2	9

In short, most of the associations between the infants' behaviors were found to change over time, with a few changes being shared by all four infants and the others being idiosyncratic to each mother-infant pair. The trajectories followed by the associations between behaviors could be divided into discrete categories of types of curves. These types were not equally represented and appeared to depend more on the behavior in question than on the particular infant.

Moving regressions of 20-week series

Moving 20-week regressions were performed for each infant for all the associations which showed gains in explained variance in the meta analysis (i.e. with p values <.20) when the time variables were included in the regression. In this way a total of 112 moving regressions were performed. Table 5 shows the number of significant series which were obtained for each of the moving regressions, together with the significance of the overall dynamic regressions. From the table it is possible to see that 64 were significant at the 5% level. Of the 112 moving regression analyses, 39 had more than 10 significances at the 5% level (which as has been seen in *Statistical Analysis*, is the number of significances above which the results are unlikely to have been obtained by chance[7]). Of these 39 analyses, 34 belonged to the 64 significant individual dynamic regressions.

Table 5 Number of significant 20-week series in the moving regressions analyses. The results are presented for the 28 multiple regressions which in the meta analysis showed $p<.20$ for the advantage of including time in the regression.

		E		J		S		F	
dep.var.	indep.var.	#R2	p (m.r.)	#R2	p (m.r.)	#R2	p (m.r.)	#R2	p (m.r.)
cryD	tot.cont.	0	0.19	0	0.96	8	0.0005	7	0.0000
	fretting	31	0.0000	13	0.24	16	0.0000	30	0.01
	smiling	32	0.001	11	0.08	7	0.0000	1	0.04
	ventral	35	0.0002	17	0.06	7	0.0000	0	0.003
	lap	2	0.07	0	0.82	19	0.003	11	0.0001
lap	contact	1	0.01	1	0.02	9	0.07	3	0.55
	cryD	2	0.02	0	0.80	19	0.006	11	0.005
	fretting	0	0.98	0	0.38	5	0.06	1	0.007
smiling	ventral	9	0.16	5	0.03	0	0.03	0	0.94
	cryF	19	0.03	10	0.14	7	0.17	3	0.24
	cryD	32	0.0004	11	0.19	7	0.11	1	0.32
	lap	4	0.16	0	0.97	14	0.13	4	0.03
tot.cont.	cryD	0	0.15	0	0.80	8	0.003	7	0.0000
	fretting	1	0.25	10	0.07	0	0.01	4	0.09
cryF	tot.cont.	2	0.31	1	0.46	8	0.01	9	0.02
	fretting	41	0.0000	25	0.0000	26	0.0000	33	0.001
	smiling	19	0.03	10	0.003	7	0.0000	3	0.41
	ventral	37	0.0001	32	0.0003	0	0.02	2	0.03
	lap	2	0.48	0	0.79	15	0.01	7	0.02
fretting	tot.cont.	1	0.48	10	0.06	0	0.04	4	0.15
	cryD	31	0.0002	13	0.03	16	0.0002	32	0.01
	cryF	41	0.0000	25	0.0000	26	0.0001	33	0.002
	smiling	20	0.01	0	0.18	4	0.29	2	0.65
	ventral	23	0.001	0	0.29	3	0.01	0	0.91
ventral	cryD	36	0.001	17	0.04	7	0.0001	0	0.01
	cryF	37	0.0001	32	0.0003	0	0.01	2	0.08
	fretting	23	0.0000	0	0.20	3	0.0002	0	0.97
	smiling	9	0.31	5	0.01	0	0.08	0	0.94

Note: '#R2': number of significant R2's in the moving regressions analyses; 'p (m.r.)': p-value of the overall dynamic multiple regression; shadowed boxes: more than 10 significant 20-week series; E, J, S, F: infants.

In conclusion, it is possible to say that a significant overall dynamic regression produced 'significant' results in the moving regression analysis of 20-week series in only half of the cases. Therefore, when one variable was a good predictor of another and their

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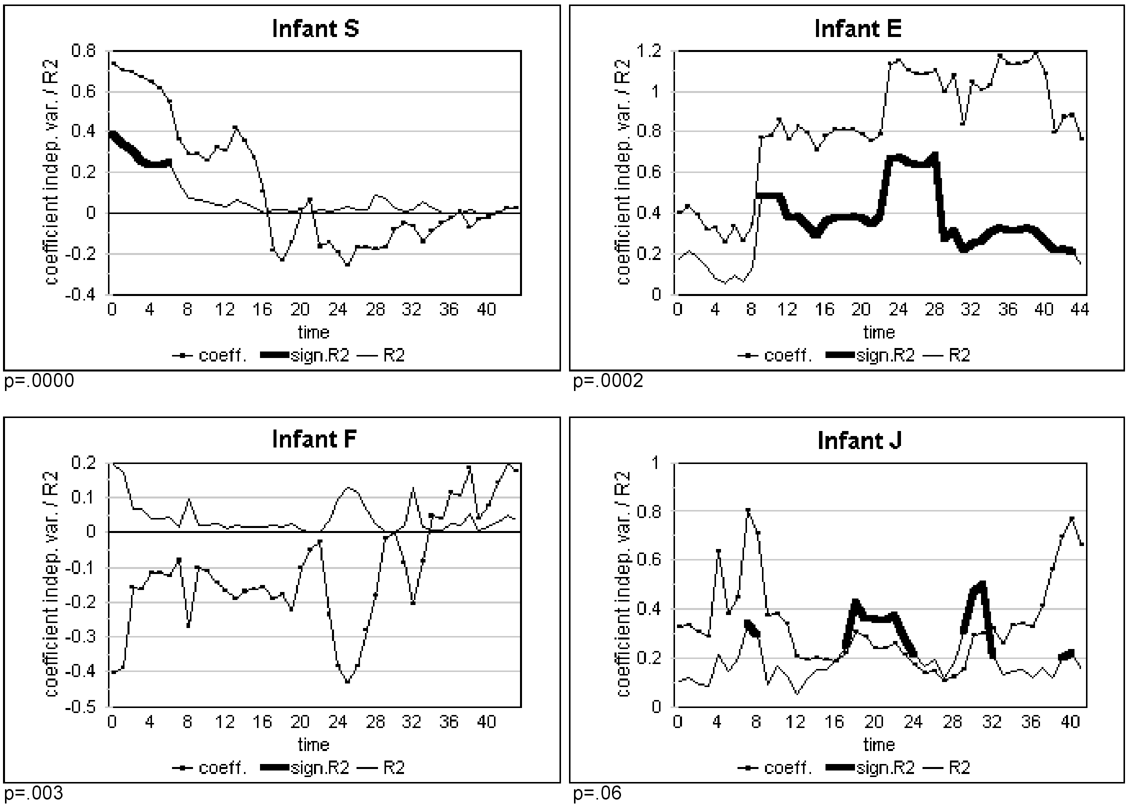
[7] Recall, however, that in the case of a 20-week moving window significance means that more than 20% of the variance is explained, in contrast with the analysis based on 61-64 weeks, in which slightly more than 10% explained variance sufficed to reach significance.

association varied over time, the moving regression analysis provided more information about the most important periods in the association between the variables in only half the cases. In the other cases it was necessary to assume that, although the variables were associated and their associations varied over time, they did not show such strongly associated 20-week periods, or, if they did, because they possessed series of 7-10 significances in the moving regressions (as was the case here in 20 out of the 112 moving regressions) they could not be distinguished from random results when the confidence level was set above 95%.

Both cases in which more than 10 significances were found in the moving regressions, as those in which 7-10 significances were found, often displayed the significances in series of successive weeks located at the beginning, end or in the middle of the observation period. This means that there were delimited periods of at least 6-7 months in which one behavior successfully predicted another, and that these periods were often preceded or followed by periods in which they did not.

It is also interesting to notice that there are individual differences in the results. Infant S had the largest number of significances in the dynamic multiple regressions (21), followed by infant E (17), infant F (16) and infant J (10). However, only 8 of infant S's moving regressions analyses had more than 10 significances, compared with 6 for infant F, 10 for infant J and 15 for infant E. The mean number of significant 20-week series per moving regression was also different for each infant: 17 for infant E, 8 for infants J and S, and 7 for



p=.0000

p=.0002

p=.003

p=.06

Figure 6. Moving regressions of 20-week series. The curves are of the independent variable's coefficient for each regression and of the R square for each regression (significant R squares in a thicker trace, and p values for the time-dependent multiple regression under each graph).

infant F. Figure 6 illustrates how the same association between behaviors, in this case ventral contact as a predictor of duration of crying, can show interesting individual differences both in the number of significant 20-week series, and in their position in the time series. As can be seen in the figure, the dynamic multiple regression was significant for three infants and almost significant for the fourth. However, while infant E had a total of 35 significant 20-weeks series starting at observation week 9, infant J had 17 in a more scattered pattern, infant S had 7 at the beginning of the observation period and infant F had no significant 20-week series.

It is clear that the results of the moving regressions provide additional information about how the associations between two behaviors vary over time. The method is not limited by linear or quadratic trends, and shows the changes that occur with a moving 20-week window. Thus, the moving regressions identify the periods in the infant's development in which the associations between the two variables are strongest, or, on the contrary, they show that it is not possible to pinpoint any specific period of time in which the association is strongest. The patterns shown by each infant and mother-infant pair will in turn depend, among other things, on their general tendency to stability in behavior, together with their tendency to showing linear and non-linear changes herein.

DISCUSSION

Methodological aspects of time series research

The strength of the findings presented in this chapter lies in the fact that, because detrended data were used instead of raw data, the similarities and differences between the mother-infant pairs give us information about patterns and interactions between behaviors which goes much further than describing general developmental trends over age. Studies of developmental changes in infancy mostly rely on raw data, and are therefore limited to describing general differences between behaviors in the developmental trends that they follow (for ex.: St James-Roberts & Plewis, 1996). As a consequence, stability or patterning that occurs across shorter time stretches (e.g. 10 to 20 weeks) is lost because it is overshadowed by the general longtime trends. Further, the percentages of explained variance found in the multiple regression analyses were relatively high taking into account that the residuals and not the raw data were used in the analysis. That such strong associations were found between behaviors, a few of which were common to all the infants studied, is even more relevant when we take into account the fact that the associations were found notwithstanding natural day-to-day and week-to-week variabilities in behaviors of the type studied (Rebelsky & Black, 1972; Barr, 1990; St James-Roberts & Halil, 1991; St James-Roberts & Plewis, 1996; Chapters 5 and 6, this thesis).

The time series design used in this study proved to be an important tool in determining long-term changes in associations between mother and infant behaviors. It was valuable in showing how, despite the flexibility in human behavior (short-term variability), temporary periods of stability (characteristic patterning) can succeed each other, therefore supporting the notion of plasticity in behavior (long-term variability).

Variability, stability, flexibility and plasticity

The main goal of this study was to determine whether both variability and stability in the associations between behaviors could be found for different mother-infant dyads and within one-and-the-same mother-infant dyad. For each separate mother-infant pair, *stability* was found in that several patterns between emotion-related behaviors could be identified. Although these patterns indicate that (relatively) stable associations existed between the studied variables, the associations accounted for percentages of explained variance that were sometimes as high as 41%, but often around 10%. This suggests *flexibility* in the behaviors and their associations. It probably indicates that factors such as day-to-day and week-to-week variability in behavior, due for example to contextual characteristics and to the nature of infant development, also account for an important part of the unexplained variance in the associations (St James-Roberts & Plewis, 1996; Chapters 5 and 6, this thesis). Finally, the *plasticity* of the associations between the behaviors was evident in that most of them showed significant changes in patterns over time. These changes involved the strength or the nature of the association, with in many cases, several major changes in the nature of the association occurring throughout the 15-month period.

With respect to the variability between dyads, the analyses carried out in this intensive study show that even when mother-infant pairs are drawn from a normal and narrowly defined population, they display important general differences in amounts of infant crying, fretting/fussing and smiling, and in the amount and types of body contact between mother and infant. Despite these differences, several similarities were found in the associations between the behaviors studied, in the tendency for the associations to change over time and in the way the patterns changed over time. This fact makes the results all the more remarkable. However, we must not forget that both the associations between the behaviors and the way in which they changed over time were often highly variable and idiosyncratic to each mother-infant pair. An interesting point is that the similarities in associations between behaviors and in how these associations changed over time were limited to behaviors in which the infant was the sole author, namely the negative vocalizations and smiling. All associations which included body contact, where the mother was the most important determining factor, showed much more variability both in the association *per se* and in how it changed over time. This finding appears to indicate that, while infants possess generalities in development which go beyond their natural differences in temperament, mothers, with their more established personalities and beliefs, show fewer generalities in their interactions with their infants.

However, we should note here that when referring to generalities, we are referring to the macroscopic level: to general associations between the time spent in different behaviors over a 3-hour observation period. Such associations between behaviors say nothing about how the behaviors are organized over shorter time intervals. For example, a strong positive association between crying and the time spent in body contact provides no information about the ‘microscopic’ interactions between the two behaviors, such as the delay in the mother’s response to crying. Therefore, our suggestion that mothers might show fewer macroscopic generalities in their behaviors than their infants, does not imply that they would also show fewer generalities at a microscopic level of interaction.

Further, most earlier studies were designed differently from the present one, consisting of relatively few assessments of microscopic interactions between mother and infant.

Nonetheless, these studies also often report changes over time, for example the study by Crockenberg & McCluskey (1986) which found differences in maternal responsiveness at 3 and 12 months of age. This could imply that changes at the general, macroscopic level are related to changes in the microscopic patterns of the mother-infant interaction. Further research is needed to investigate this hypothesis thoroughly.

Another interesting result was that the types of trajectories followed by the associations between behaviors were not found in equal numbers and, when one left the specific positive or negative nature of the association aside, appeared to depend more on the behavior in question than on the particular infant. Recall that in the regression analyses, when one behavior (independent variable) was a good predictor of another (dependent variable), it accounted for a considerable percentage of the variance of the dependent variable. The trajectories of the associations in which duration of crying and ventral contact were the predicted behaviors were mostly of the type in which a weakening or disappearance of the initial relationship occurred, while those in which smiling was predicted, were mostly curves showing associations which strengthened or appeared over time. This finding is probably related to the simple fact that the first two behaviors play their most important role in the beginning of life, while smiling is a behavior that gains in frequency and complexity as the infant develops.

The use of moving regressions on 20-week data series showed that in half the cases in which the meta analysis of the overall dynamic regression was significant (or approached significance), periods could be delimited in which one variable predicted another. Individual differences were found with respect to the occurrence and length of these periods: while in some cases no 20-week period could be distinguished, in others, as many as 41 20-week periods could be determined. These findings indicate that in many cases clearly delimited periods with relative stability in the associations between two behaviors could be found. And they also support earlier research results in which stability of behavior was found over shorter periods of time (for ex., Crockenberg & McCluskey, 1986; Green, Gustafson, and West, 1980; Findji et al., 1993; Schölmerich et al., 1995).

An important point that should not be forgotten is that by studying the associations between pairs of behavioral variables, we left aside more complex interactions between groups of variables. This approach overly simplifies reality and precludes potentially significant influences and effects between groups of behaviors (Bornstein, 1989). Although the study of such complex associations was beyond the scope of this chapter, we did perform explorative moving multiple regressions of 20-week series in which one behavior was predicted by three others. The results showed associations and changes over time that often accounted for important percentages of the variance. The interactions between groups of variables should constitute interesting and at the same time possibly essential study material for further research on the subject of changing associations in behaviors.

In sum, while several changes and their trajectories apparently depended more on the variables in question than on the infants, most of them were highly variable and idiosyncratic to each mother-infant dyad. Which, if any, delimited 20-week periods showed the strongest association between the variables was also highly dependent on the particular mother-infant pair. Finally, as mentioned earlier, the infants participating in the study showed normal development and were not especially irritable babies. Nonetheless, they all showed (to a greater or lesser degree) macroscopic changes in the associations between the observed behaviors. These results therefore lend support to the position that change is a part of normal development, which, as we saw in the introduction, has been supported by Kindermann (1993), Bornstein (1989) and others.

CONCLUSION

Methodologically, this chapter has made a contribution to general knowledge of the use of intensive time series research designs in studies of maternal and infant behavior and interaction. Further, it has shown the advantages of the method in clarifying issues of variability and stability in human behavior over longer periods of time.

The chapter has presented evidence for associations between infant behavior (crying, fretting/fussing and smiling) and mother-infant body contact (divided into three subcategories), and the changes in these associations over time. Its results support the notion that changing patterns of behavior are a normal, natural characteristic of early development. Besides providing evidence for this concept, it goes one step further by describing similarities and differences between mother-infant dyads, with respect to the associations and changes in behavior. Because of the macroscopic nature of the associations studied, and the many individual differences or idiosyncrasies found, it is impossible to generalize about more microscopic or detailed issues. For example, although the data point in the direction of differences in both infant behavior and mother-infant interaction styles, and of differences in when and how often changes occur in these behaviors and interactions, further research will be needed in order to test more specific hypotheses. By limiting the number of variables and increasing the number of subjects, hypotheses about the types of associations and changes therein, the factors influencing them, and the developmental outcomes produced, can be investigated. Together with research which has already been published on the subject, the findings presented in this chapter should serve as a starting point for the building of theories and the testing of hypotheses on the meaning and consequences of patterns and changes.

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