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REPORT

Posture and gaze in early mother–infant communication: synchronization of developmental trajectories

Alan Fogel,[1] Daniel S. Messinger,[2] K. Laurie Dickson[3] and Hui-chin Hsu[4]

1. *Department of Psychology, University of Utah, USA*
2. *Department of Psychology, University of Miami, USA*
3. *Department of Psychology, Northern Arizona University, USA*
4. *Department of Child and Family Development, University of Georgia, USA*

Abstract

Weekly laboratory observations of free play for 13 middle-income mother–infant dyads, from 1 to 6 months of age, were used to study the synchronization of developmental trajectories between infant postural position and gaze direction. Mothers sat in a straight-backed chair while holding infants on their laps and were free to adjust the infant's posture. Postural position was coded as upright (supported sitting or standing on the mother's lap) or other (lying, cradling, or being held close to mother). Gaze was coded as either at mother's face or away. The age of onset of visually guided reaching was also assessed. Results show that there were longer durations of gazing away when the infant was in an upright position. Over the 5 month period of observation, the dyads began with a pattern of non-upright positions accompanied by gaze at mother. Contrary to previous predictions, the developmental shift in the first 6 months from exclusive gazing at mother's face to gazing away from mother was not synchronized with the development of reaching, but rather with changes in the infant's posture to more upright positions. The possible role of postural position in fostering positive emotional communication is discussed.

Adult–infant face-to-face play consists of mutual gazing and smiling to achieve a unique form of positive emotional communication in early life (Brazelton, Koslowski & Main, 1974; Fogel, 1977; Trevarthen, 1977; Tronick, Als, Adamson, Weise & Brazelton, 1978; Kaye & Fogel, 1980; Papousek & Papousek, 1984; Cohn & Tronick, 1987). Face-to-face interaction is the primary form of mother–infant play until around 4 months, after which infants decrease the duration of their undivided attention to mother in order to devote an increasing share of their attention away from the adult's face and toward social play with inanimate objects (Kaye & Fogel, 1980; Super & Harkness, 1982; Cohn & Tronick, 1987; Keller & Gauda, 1987). Although there is no conclusive research, observers have speculated that the onset of visually guided reaching is the main factor accounting for this developmental transition because the developmental decline in attention to the mother's face is usually followed by an increase in attention to objects (Kaye & Fogel, 1980; Cohn & Tronick, 1987).

In addition to the emergence of visually guided reaching during the first 6 months, infants also increase their ability to maintain supported sitting and standing positions with the assistance of an adult. Supported upright positions have been found to be associated with changes in infant gaze direction toward or away from mother. In a cross-sectional experimental study using an adjustable infant seat, Fogel, Dedo and McEwen (1992) observed mother–infant face-to-face play at 3, 4 and 5 months. The infant's position was systematically changed between supine, recline at 45° and sitting upright. Infants gazed the most at their mothers when supine and the least while sitting, suggesting that upright postures for 3- to 5-month-olds are associated with less face-to-face play.

Address for correspondence: Alan Fogel, Department of Psychology, University of Utah, 390 S. 1530 E., Room 502, Salt Lake City, UT 84112-0251, USA; e-mail: alan.fogel@m.cc.utah.edu

A naturalistic approach to the connection between posture and gazing was used in a longitudinal study of mother–infant face-to-face play between 2 and 6 months in which mothers held infants on their laps and were free to change the infant's postural position (Fogel, Nwokah, Hsu, Dedo & Walker, 1993). In this study, the timing of onsets of changes in postural position were examined in relation to the infant's direction of gaze at that moment.[1] Mother's changes of the infant's postural position from upright to supine were more likely when the infant was gazing away from the mother. In a related study of face-to-face play on the mother's lap, postural position adjustments of the infant's body by the mother are most pronounced when the infant gazes away from the mother during face-to-face play (Kaye & Fogel, 1980). Mothers therefore often use a postural position shift to encourage their babies to look more at them.

The Fogel, Dedo and McEwen study also found that infants who could reach gazed less at their mothers than infants who were not able to reach. Postural position has also been experimentally associated with reaching. Infants under 6 months are more likely to reach for objects if they are in upright rather than reclined or supine positions (Savelsbergh & Kamp, 1993).

The literature therefore shows that over the first 6 months there are developmental changes in the following actions: a decrease in gaze at mother during face-to-face play, an increase in upright postural positions, and an increase in visually guided reaching. Nothing is known, however, about the developmental synchronization between these actions. Is the decline in gazing at mother's face (and subsequent gazing elsewhere) related to increases in the infant's ability to reach for and manipulate objects? Or does the decline in gaze at mother occur because infants want to be upright in order to expand their range of visual interest beyond the mother? Or do both reaching and postural position change simultaneously with changes in social attention? One source of evidence to answer this question is to examine the synchronization of developmental trajectories of gazing, posture and reaching within individual mother–infant dyads. We used a multiple case study longitudinal design ($n = 13$) with weekly observations of free play over a 5 month period. The analysis derived power, not from a large number of subjects, but from frequent and repeated observations of each dyad yielding evidence of the within-dyad synchronization of developmental trajectories.

Method

Subjects

Thirteen infants, eight males and five females, were observed weekly during the period from 1 to 6 months of age. The subjects were part of a larger longitudinal study in which the same infants were observed on a weekly or bi-weekly basis until their second birthday. All the infants were born between August 1986 and August 1987, and all passed a hearing test at 6 months of age. They were full-term and healthy at birth; five were first born, three were second born, four were third and one was fourth born. All but four of the mothers worked outside the home. All mothers came from middle-class non-separated two-parent homes in a small mid-western community; one mother was African-American and the others were Caucasian-Americans.

Setting

All of the dyads were videotaped in a 12.5 ft × 12.5 ft carpeted laboratory playroom equipped with three pan–tilt–zoom video cameras mounted on the walls. Each camera was remotely controlled from an observation room located behind a one-way mirror. Camera 1 was focused on the mother's face and the side of the infant. Cameras 2 and 3 were both focused on the infant's face and body. The outputs from the three cameras passed through a special effects generator. Camera 1 and either cameras 2 or 3 (depending on which had the better view of the infant) were mixed into a composite video image onto which a digital time code generator, accurate to a video frame (1/30th of a second), was superimposed. A microphone was hung from the center of the ceiling and passed through an amplifier and then to the audio track of the videotape.

Procedures

Mothers were asked to bring their infants to the laboratory once each week. Attrition and missed weeks were kept to a minimum by regular telephone contacts with the staff, bi-monthly newsletters for the parents, and subject payments of $150 made at the end of every 6 month period. In the data presented here, there were 16.2 observations per dyad (range 9–22). These started at a mean age of 6.5 weeks (range 4–9) and ended at a mean

[1] The videotapes used in the Fogel *et al.* (1993) study are the same ones used in the study presented in this paper. The Fogel *et al.* (1993) study examined the timing of onsets of position changes with respect to gaze direction. In the present study, we examine the co-occurrences of postural position and gaze direction in addition to the developmental trends in their durations.

age of 22.8 weeks (range 22–24). There was an average of three missed weeks for each dyad (range 1–7) during this period. Each observation lasted for 5 min or until the infant became too fussy to proceed. Only 26 out of a total of 210 sessions were less than 5 min. For these 26 sessions, the mean duration was 216 s (range 87–290).

Infants and mothers were observed in two separate conditions for each session. In the first condition, the mother sat in a straight-backed chair without arms and was asked to hold her baby on her lap and 'play and talk to your baby as you would at home'. This instruction was given only on the first visit to the laboratory. Thereafter, the mother was left to develop her own style of interaction with her baby. No toys were provided in this condition which was designed to create opportunities for face-to-face play in which the mother could frequently change the infant's postural position. This is the condition that was used to examine the relationship between gaze direction and postural position.

In a second condition, mother and infant played on a blanket on the floor. In this condition, designed to study mother–infant–object interactions, age-appropriate toys were provided. Although the mother was free to change the infant's postural position in this condition, in practice mothers rarely did this. Instead, they left the infant to lie supine while they presented toys to the infant. For the study presented here, we used the floor condition only in order to get a measure of the age at which the infant became capable of visually guided reaching (see coding procedures, below). This is because more instances of reaching occurred in this condition since objects were available. It did not make sense to assess reaching in the chair condition when no toys were used.

Also, in both the chair and the floor conditions, none of the infants were observed sitting unsupported by the end of the fifth month. Thus, although no independent test was given of sitting, it seems reasonable to conclude that mothers were responsible for the maintenance of the infant's upright postural position during the chair condition throughout the period of observation.

Coding

Coding was done by undergraduate students who were naive to the purpose of the study. Behavior categories were coded continuously in time from the videotape. Each time a defined change was seen, the coder stopped the videotape and recorded the time of the change. The chair condition interactions were coded on two passes through the videotape. On the first pass the infant's gaze direction was coded (GAZE AT mother's face, GAZE AWAY from mother's face, or eyes CLOSED). On a second pass, the infant's postural position as held by the mother was coded (UPRIGHT includes sitting or standing on mother's lap; and OTHER includes lying horizontally, either cradled in mother's arms or lying on the mother's lap). Due to the large number of different postural positions used by the mother and infant, this dichotomous classification gave the maximum statistical power.

The age in weeks of the first successful infant visually directed REACH was coded from the floor condition by a graduate student. Infants were typically in supine positions when reaching for objects that their mothers held above them. A reach was judged to occur if the infant could grasp objects held by the mother that were slightly beyond their arm's length. Thus, this is a measure of successful reaching, or reaching plus grasping. Following the convention in the literature, visual responses or non-directional hand and arm movements toward objects were not judged to be reaches (White, Castle & Held, 1964; von Hofsten, 1979). All sessions prior to the onset of reaching were given a score of REACH = 0, while sessions following reaching were scored as REACH = 1.

Categories within a pass through the tape were mutually exclusive and exhaustive. Since all the codes were entered into a computer program with respect to their onset and offset times, we could compute the co-occurrence durations of categories from different passes, e.g. the duration of GAZE AT mother while the infant is UPRIGHT. Each pass was coded by a different student who coded all the subjects and sessions for that particular modality.

Reliability

Ten percent of the tapes were recoded independently by a trained graduate student who was naive to the hypotheses of the study. Two different graduate students were paired with the two different undergraduate coders, so that the graduate student coders were also blind to the codings of the other graduate students. Cohen's kappa was used to check the overall agreements between coders within each modality. These were 0.77 for gaze direction (range 0.49–0.96) and 0.94 for postural position (range 0.69–1.00). The proportion of agreements for age of onset of reaching was 1.00, as independently scored by a second graduate student.

Results

Co-occurrence between posture and gaze

For all the analyses reported in this paper, portions of the observation session in which the infant was either sleeping (eyes CLOSED) or crying were deleted from the analysis. In addition, if the infant cried for more than one-third of an observation session, the entire session was eliminated from the analysis. We did this because the study was meant to focus on positively toned face-to-face play, which is consistent with the instructions given to the mothers.

The first phase of the analysis was a study of the real-time co-occurrences of postural position and gaze direction, regardless of age. This was necessary to establish that a connection between the developmental trajectories was based on a temporal link between these two behaviors. For this analysis we used 2 (gaze: at or away) $\times 2$ (posture: upright or other) χ^2 tests run individually for each dyad. Each cell represents the total duration (in seconds) of the two-way co-occurrence. According to Bakeman and Dorval (1989), the violation of the assumption of independence in statistics based on χ^2 for categorical sequential analysis does not have an appreciable effect. χ^2 tests are, however, sensitive to the size of the unit of analysis. We chose seconds as the unit of analysis since microanalytic coding of mother–infant interaction has shown that time sampling needs to be in units less than 5 seconds to capture the important changes of events. Nevertheless, in order to control unit of analysis effects, we report odds ratios, which are independent of the unit of analysis, and their significance.

The relationship between gaze direction and postural position was significant for all 13 dyads ($p < 0.001$). When the infant was in an upright position, the odds of gazing away (the duration of gaze away divided by the duration of gaze at mother) were 8.2, computed as a mean across all dyads (range 1.6–24.8). When the infant was not in an upright position, the odds of gazing away were 1.5 (range 0.5–3.3). The overall odds ratio (the product of the diagonal cells divided by the product of the off-diagonal cells) should be greater than 1.00 if upright position is positively associated with gaze away. This was the case in 12 out of 13 dyads (mean overall odds ratio 9.32; binomial sign test 0.003). Moreover, a paired t test comparing the odds ratio to 1.00 was also significant ($t(12) = 3.20$, $p < 0.01$). In summary, these results show that the infant was considerably more likely to gaze away from the mother when held in an upright position, regardless of the infant's age.

Developmental trajectories of gaze at mother, upright position, and reaching

In the second phase of the data analysis we used multilevel models to study the relationship between developmental trajectories (Byrk & Raudenbush, 1987; Hoeksma & Koomen, 1992) using ML3 software (Prosser, Rasbash & Goldstein, 1991). In multilevel models, data are structured as a two-level hierarchy. Level-1 units are repeated observations (ages) nested within level-2 units (dyads). In these models, statistics are estimated both for dyads separately and for the dyads as a group. The analysis finds the average growth curve (the duration of a response variable as a function of age) of all dyads. Parameters estimated from the average growth curve are called fixed parameters. Fixed parameters are comparable to regression coefficients in a standard regression model. Inclusion of the intercept and a first-order age parameter indicates that development of the response variable is best described by a linear trend.

The individual dyadic developmental trajectories are expressed as deviations from the average developmental curve. Level-2 variability (between dyads) is referred to as random variation. There are three level-2 random parameters associated with this level-2 variation: the intercept variance, the slope variance, and the covariance. There is also a level-1 random parameter for the residual variance.

In order to find the most parsimonious model that describes the observed data for the response variable, the average growth curve is determined. Additional parameters (e.g. age^2, age^3) are added to the model when their estimate exceeds twice its standard error (0.05 significance; the ratio of the parameter to its standard error is distributed as t). The process is repeated until no more significant parameters can be added to the model. Individual differences are tested by comparing the model with and without the level-2 random parameters (intercept variance, slope variance, and covariance). χ^2 statistics distributed with degrees of freedom equal to the difference between the number of parameters with and without the variances, and with and without the covariance, were used.

We used multilevel analysis to predict changes in the duration of infant gaze at mother (the response variable) as a function of age, reaching ability, and the duration of upright position. This analysis tests which of these predictor variables are associated across sessions with gaze at mother. The variables in this analysis were expressed as a proportion of the duration of the observation session. All the predictor variables were continuous except for reaching, which was either 0 for sessions prior to the onset of reaching or 1 for sessions after the onset of reaching. The predictor variable of infant age was adjusted by subtracting a constant representing the lowest observed age in the sample (4 weeks) in order to yield a more interpretable intercept term in the models. This was done so that the trajectories could be compared across dyads regardless of starting age.

The findings from the multilevel models are shown in Table 1. The first model contained only the intercept term and age, showing that gaze at mother had a significant linear decrease with age. The second model showed that including reaching did not reduce the residual variability and that reach was not a significant contributor to the proportional duration of gaze at mother. The third model included upright position but not reaching. When upright position is added to the model, it significantly reduced residual variability by 9.55% over the model containing only age. In addition, more of the variability in gaze at mother was explained by upright position compared to age, which became non-significant. In the final model, the addition of reaching only reduced the residual variance by 0.03% and was not significant. In summary, whether or not the infant could reach did not significantly contribute to the trajectory of gaze at mother either alone or with upright position included. Age was significantly associated with gaze at mother, but only before the addition of upright position in the model. The final model explained 24% of the variance in the developmental trajectory of proportional duration of gaze at mother. There was no significant between-dyad variance in these relationships. The intercept factor was also significant, meaning only that the initial level of gaze at mother was significantly different from zero. The multilevel analysis therefore showed that, during the period between 1 and 6 months, higher proportional durations of gaze at mother were associated with lower proportional durations of upright position.

Figure 1 shows the developmental trajectories for each dyad of the proportional duration of gaze at mother, the proportional duration of upright position, and reach onset. In two of the dyads, the infants rarely looked at the mother and the developmental trajectories had low variability. In order to test the within-dyad synchronization of the developmental trajectories for the proportional duration of gaze at mother and upright position, Pearson product–moment correlations were computed between these two variables across sessions for each dyad. The correlations were negative for all dyads. For 10 of the 13 dyads, the correlations were significantly negative (range −0.44 to −1.00; mean −0.62; p range 0.05–0.001). These data suggest that the trajectories of upright position and gaze at mother are developmentally synchronized, i.e. the developmental increase in upright position is coordinated with a corresponding developmental decrease in gaze at mother.

Discussion

Prior research has shown that, during naturalistic mother–infant play during the first 6 months of life, mothers shift their infants to non-upright positions during periods when infants are looking away from the mothers. Experimental evidence shows that non-upright postures in fact predispose infants to look at their mothers, while upright postures create opportunities for more looking away. It appears that postural position changes are used to successfully alter the infant's gaze direction toward the adult, at least until around the fourth month of life (Kaye & Fogel, 1980; Fogel *et al.*, 1992, 1993).

During the fourth month, the infant–mother relationship changes from a communication pattern that is focused primarily on infant gazing at mother's face to a communication pattern in which infants gaze primarily at objects in the company of the mother. In this study, we asked about the relative developmental timing of the transition of the communication system (indexed by the proportional duration of gaze at mother) and the developmental changes in the proportional duration of upright postures. In addition, we examined whether the infant's ability for visually guided reaching contributed to the developmental transition in infant gaze at mother. We found that the developmental changes in the duration of gaze at mother were associated with the

Table 1 *Parameters (standard errors) and* t *in the multilevel analysis for the response variable (measured as proportional durations) of infant gaze at mother, presented as a function of age and other predictor variables*

Parameters	Fixed parameter estimates (standard error), t			
	Model 1	Model 2	Model 3	Model 4
Intercept	44.99 (4.31) 10.44**	46.49 (4.63) 10.05*	46.77 (3.55) 13.19*	48.19 (3.84) 12.54*
Age	−1.55 (0.32) 4.90*	−1.94 (0.54) 3.60*	0.07 (0.40) 0.18	−0.31 (0.55) 0.56
Reaching		5.75 (6.40) 0.90		5.56 (5.73) 0.97
Upright position			−0.36 (0.06) 6.20*	−0.36 (0.06) 6.19*
% variance reduction		0.00	9.55	9.58

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

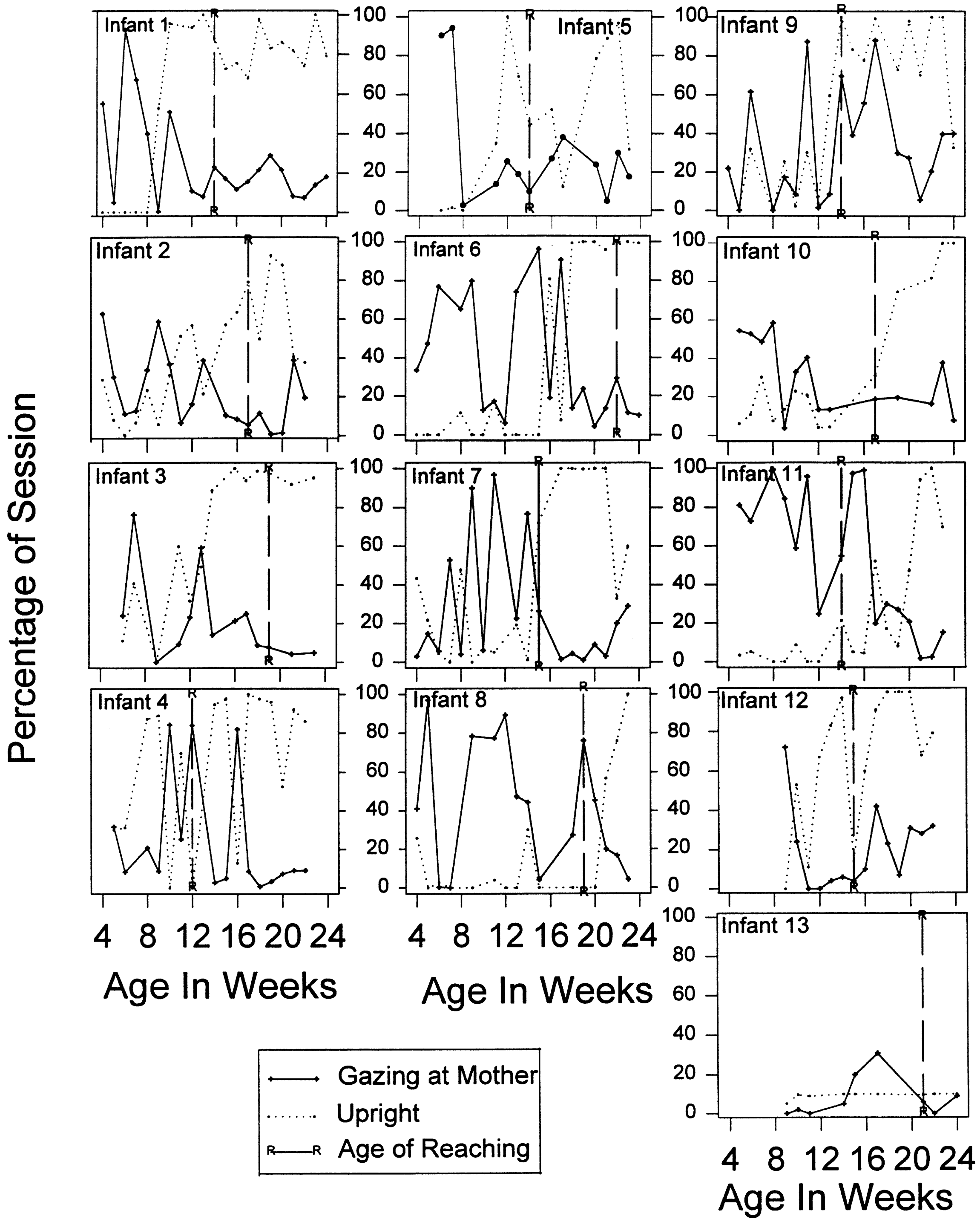

Figure 1 *Developmental trajectories of the proportional durations (percentage of an observation session) of gaze at mother and upright postural position for each dyad. The age of onset of visually guided reaching is indicated by a vertical broken line. The horizontal axis represents infant age in weeks.*

developmental changes in the duration of upright position and not with developmental changes in visually guided reaching.

Why should upright postural position, and not visually guided reaching, be associated with this developmental transition in communication? Upright positions facilitate alertness in neonates (Fredrickson & Brown, 1975; Gregg, Haffner & Korner, 1976). Pre-term infants with postural deficits in head and body control are more likely to have attention and affective deficits during face-to-face play after 2 months (Groot, Hopkins & Touwen, 1992; Beek & Sampson, 1994). Cross-cultural variation in adult's use of carrying postures has been related not only to motor development but also to social development (Kilbride & Kilbride, 1975; Martini & Kirkpatrick, 1981; Whiting, 1981; Bril & Sabatier, 1986; Hopkins & Westra, 1988).

On the other hand, supine positions may promote relaxation. Supine and prone positions induce sleeping in newborns (Fredrickson & Brown, 1975; Gregg *et al.*, 1976; Wolff, 1985). By the age of 3 months, supine positions may still be coupled with the psychological experience of a relative state of relaxation that may enhance receptiveness to positively toned feelings and predispose the individual toward the development of sharing these with another person. Researchers have suggested that the wooing, soft, quality of parental action and speech may be enhanced by the parent's experience of seeing and feeling their babies relax, their eyes brighten, and their whole body becoming receptive (Brazelton *et al.*, 1974; Papousek & Papousek, 1984; Stern, 1985). Our results offer the possibility that this relaxation may be due in part to non-upright postural positions.

We might hypothesize that other forms of interpersonal communication in which one or both partners are lying down or reclining and in close physical contact would lead to similar patterns of positive engagement. Other research, using 9-month-olds (Franco, Fogel, Messinger & Frazier, 1996), found both individual and cultural differences in the amount of lying together and body-to-body contact between mothers and their infants. Those mothers who report more feelings of closeness and affection toward their infants were observed to use more close body-to-body contact and to assume more lying positions on the floor, positions in which the baby's body was resting on top of the mother's and which lead naturally to more physical forms of play and more physical forms of affection. Communication involving lying postures occurs later during peer play, during some forms of parent–child play on the floor, and in other forms of intimate interpersonal communication. Postural position is a possible link between these different relational processes and deserves further study.

This study, however, does not conclusively show why infants begin to sit or stand when they have the opportunity to remain supine and enjoy the shared intimacy and delight of the face-to-face play period. Fogel *et al.* (1992) found that older infants in their sample often resisted being placed in non-upright positions, by straining forward and making discomfort sounds. It is possible that there are developments in the postural control system that allow infants to sit upright more easily and that might serve to motivate change. Infants' resistance to non-upright positions may also be (an as yet unexplained) motive to withdraw from intimate contact with mother without any clear alternative pathway. Once they negotiate more upright positions with their mothers, the communication system offers entirely new and unanticipated possibilities – such as expansion of the range of visual attention – that move the dyad to discover novel ways of relating to each other via objects. The possibility that developmental change can be spurred by a set of unanticipated, emergent consequences is one prediction of a dynamic systems perspective on development (Fogel & Thelen, 1987; Thelen & Ulrich, 1991).

This study shows that the typical laboratory paradigm using upright infant seats and no contact with the mother's body does not give a complete understanding of why face-to-face communication produces such a powerful emotional communication for the participants. Posture is an important and overlooked factor in the early development of face-to-face communication. Further longitudinal studies are needed to assess the role of other social and motor factors in the developmental transition studied here, factors that may contribute to the association between posture and gaze. Further longitudinal work is also needed to study the long-term consequences of individual differences in patterns of gaze and postural position.

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