Infant and Child Development
*Inf. Child Dev.* **9**: 181–198 (2000)

# *The Co-Construction of Joint Action Between Mothers and 2–4-Month-Old Infants: The Mother's Role*

**Agnès Danis*, Cécile Bourdais and Josette Ruel**
*Laboratoire 'Cognition et Développement',*
*Université René Descartes Paris V and CNRS-UMR 8605,*
*71 avenue Edouard Vaillant, 92774 Boulogne Billancourt Cedex, France*

**The purpose of this longitudinal study was to describe object-centred interactions between mothers and their 2–4-month-old infants, before and during the emergence of reaching and grasping movements. We hypothesized that when reaching movements emerge at around 3 months, mothers alternate between attention stimulation and reaching stimulation, before joint actions between mother and infant develop around objects. Twelve dyads were recorded when infants were 2 months, 3 months and 4 months. The interactive sessions lasted 5 min. Three age-appropriate toys the infant could handle were available to the mother. A principal component analysis (PCA) was performed on verbal and non-verbal maternal behaviours, motor infant behaviours and co-occurrences of those behaviours. The developmental course of prehension in infants when playing with their mother follows similar pathways, as was described when they are observed alone. Mothers appeared to early scaffold prehension skills by verbal and non-verbal means. Moreover, maternal behaviours change according to the infant's behaviour, and conversely, infant's behaviours influence maternal behaviours: mother plays first an active part in joint action, while later on, the infant achieves joint action when motor skills develop.** 

*Key words:* joint action; mother–infant interaction; motor development; prehension

The present study analyses object-centred interactions between mothers and infants aged 2–4 months, before and during the emergence of reaching and grasping movements, in order to study the construction of joint action.

One can wonder what is the adult's role in the area of motor development, and particularly in reaching. Is it as a guide, an assistant, or does he/she just participate during a mother–infant interactions course? Fogel responds to that

* Correspondence to: Laboratoire 'Cognition et Développement', Université René Descartes Paris V and CNRS-UMR 8605, 71 avenue Edouard Vaillant, 92774 Boulogne Billancourt Cedex, France. E-mail: agnes.danis@psycho.univ-paris5.fr

*Received 16 August 1999*
*Accepted 22 May 2000*

question in stating: 'My guess is that the agenda for parents of infants this young is just to participate, to do something together without an explicit goal for guidance' (1993a, p. 110).

Most studies about the development of prehension consider infant motor skills when the babies are alone, facing stationary objects or moving ones. Several periods were described. At birth, objects are mostly explored visually, but reaching movements may be elicited visually under specific conditions (von Hofsten, 1982; Mounoud, 1983; Schonen and Bresson, 1984; Ennouri and Bloch, 1996). Next, between the ages of 7 and 13 weeks, while visual pursuit improves, there is a decline in the number of reaching movements (von Hofsten, 1984). Then, three stages of prehension can be distinguished: a stage in which objects are reached but not grasped, a stage in which objects are reached for and sometimes grasped, and a stage in which objects are reached for and grasped (von Hofsten and Lindhagen, 1979; Wimmers *et al*., 1998a).

In the dynamical systems approach, the acquisition of skills emerge from the underlying dynamics of the organism–environment system (Thelen, 1995). Thelen *et al*. (1993) studied the transition between global motor activity to task-directed movements when a toy was presented. They assume that children have to learn the reach trajectory in controlling the degrees of freedom involved in reaching and in contacting object. Wimmers *et al*. (1998a) study the transition from reaching without grasping to reaching terminating with grasping. For these authors, new behaviours are the product of self-organization. They stated that the qualitative changes are induced by quantitative changes in one or more control parameters, such as neural, anatomical and environmental factors. The observed behavioural qualitative changes are discontinuous, non-linear and modelled as a cusp catastrophe. Both studies show major individual differences in the onset, the frequency and the duration of reaching, with and without grasping. Distal motor activity was studied by Rochat (1989), who describes how 2-month-olds can hold passively, with active explorations occurring some weeks later, and how manipulations of objects with both hands appear around 4 or 5 months of age.

Before the achievement of autonomous prehension, objects are most of the time supplied by adults for infants to exert exploration and action. Theoretical claims about the role of the environment in the development of action and knowledge of objects give adults a more or less important role.

In Valsiner's (1987) view, the adult is a guide, an instructor; he/she structures interaction settings in accordance with his/her socialization objectives. Applied to the infant's motor development, it means that infant's goal-oriented ways of acting develops in a social context, the child internalizing the social expectancies and the adult's way of acting within a given setting that include boundaries. Valsiner described three functionally-related zones, which theoretically stated, applied to processes in development within social interaction. The zone of promoted action (ZPA) includes all environmental stimulations which initiate and enhance the child's actions. The zone of free movement (ZFM) specifies the structure of the context; for example, it defines the space within which the child acts, and the zone of proximal development (ZPD), which is a concept originated by Vygotsky (1978), refers to what becomes possible for the child with the adult's help.

In Bruner's (1973) model, the adult's role is to stimulate. In the context of joint activity, Bruner (1975a) suggests that the caregiver has a scaffolding role for the acquisition of attention and motor skills towards objects. He stated that mothers 'standardize' certain forms of joint action with the child, setting up standard

 

action formats. In other words, the mother manages whatever the context requires, as she scaffolds attention and generates concrete conditions leading to successful action. In a study with 7-month-old infants and older, Bruner (1975a) noticed that mothers inferred the baby's intentions of attention and of actions. When an infant looks at an out-of-reach object, it is interpreted by the mother as a query about the object, and her response consists of showing or giving the looked-at object or looking at it herself. When the infant tries to do something by moving his/her arm towards the object, 'mother interprets the infant's behaviour as an intention to carry out some action. In such instances, mothers most often see their role as supporting the child in achieving an intended outcome, entering only to assist or reciprocate or 'scaffold' the action. Scaffolding refers to the mother's effort to limit, so to speak, those degrees of freedom in the task that the child is not able to control—holding an object steady while the child tries to extract something from it, screening the child from distraction, etc.' (p.12). Following Bruner's line of research, Penman *et al*. (1981) demonstrated that infants whose mothers request prehension, and help in the achievement of actions when they are 3 and 4 months old, display at 6 months gestures which are qualitatively more controlled than infants who were not stimulated.

For Fogel (1993a), the adult has no explicit goal for guidance, he/she just participates in the interaction. In the dynamic interactionist perspective, adults' behaviours, as infants' behaviours, are co-constructed in the interactive system. While the achievement of reaching with grasping has an impact on face-to-face interactions, maternal behaviours change as reaching skills develop. Mothers and infants negotiate new patterns of interaction with respect to infant developmental changes (Fogel, 1990). Fogel *et al*. (1992) studied 3–5-month-olds, showing how posture (sitting upright, reclining at 45°, or supine) and the ability to reach for objects (reachers versus non-reachers) have an effect on face-to-face interaction: infants look more at their mother when supine and shorter when they sit, and reachers look less at their mothers than non-reachers, in any posture. West and Fogel (in Fogel, 1990) study infants from 1 to 6 months in supine position, before and after visually guided reaching with grasping is achieved. They show that maternal behaviours to supply objects change with infants' motor skills. West and Fogel observed in mothers a tendency to replace demonstration (shake objects, bang, display out of reach) with support (holding objects within infant reach space, steadying objects as infants manipulate them) as infants increased their objects skills between 3 and 5 months. The authors stressed that changes in maternal behaviours are not simply answers to the infant's behaviours; behaviours of the two partners are co-constructed. Thus, West and Fogel show that relationships between maternal and infant behaviours are complex and non-linear: 'developmental changes in dyadic communication about objects seem to be regulated not by the onset of a single index of infant object skill, nor age alone, but rather by the sequencing of the timing of emergence among several infant skills' (Fogel, 1990, p. 83) Thus, they found that individual differences in the developmental trajectories in infants have an impact on the maternal behavioural change. When in the developmental course, the onset of manipulation (i.e. shake, bang, mouth . . . ) occurs earlier than reach (successful arm extension and grasp of objects within reach space), reaching regulates the timing of the maternal change from demonstration to support. When the onset of reaching occurs earlier than manipulation, the onset of manipulation regulates the timing of the new maternal action.

Most researchers (Trevarthen, 1977; Gray, 1978; Clark, 1978; Penman *et al*., 1981; Fogel, 1990) noted that mothers offer more often objects out of reach

 

before reaching emerges, and more often in the reaching space after. However, their results show differences on what activates the maternal supporting behaviour. Trevarthen (1977), Gray (1978) and Clark (1978) have suggested that object-reaching arm movements are, for the mother, clear signs of an intent to act. However, other authors, such as Penman *et al*. (1981), found that mothers more often bring objects closer when 3-month-old infants are not active, and assumed that reaching was not 'a signal of action's intent'. In addition, Fogel (1990) stressed that, depending on dyads, the ability to manipulate, as well as to reach with grasping, may be signals for the mother.

In order to address the question of maternal changes during the emergence of reaching, the following questions are addressed:

1. What is the developmental course of prehension between 2 and 4 months observed during interaction?
2. What is the developmental course of verbal and non-verbal mother's behaviours towards 2–4-month-old infants?
3. When studying temporal co-occurrences of maternal and infant behaviours or formats, we hypothesized that when infants cannot reach, mothers stimulate visual attention in the distal space; then, when infants can reach without grasping, mothers alternate between stimulating visual attention in the distal space and stimulating reaching in the proximal space; last, when infants can reach and grasp, mothers should keep stimulating reaching.

## METHOD

### *Subjects*

Twelve families were recruited from the birth lists in the 14th district of Paris. All infants were born at term. The mean age of the infants was 8 weeks, 1 day on the first observation, 12 weeks, 1 day on the second observation, and 16 weeks, 1 day on the third observation.

### *Toys*

Three age-appropriate toys were at the mother's disposal: a 4 cm round rattle made of wood and metal, a $10 \times 3$ cm soft toy made of fabric, an 8 cm jumping jack made of wood, with a 1 cm diameter body. The toys were all easily graspable by young infants, and had very attractive colours.

### *Procedure*

The dyads were longitudinally videotaped at home (2 months) or in the lab (3 and 4 months) by a single female experimenter. The infants were positioned semi-reclined in a baby-seat, facing their mother. A mirror was placed behind the child, so that the camera filmed the child and the reflection of the mother. An observation lasted 5 min, and the mother was simply told to interact with her infant as she usually did, using the toys.

### *Data Coding*

The following behaviours (note 1) were detected.

 

*Mother's Verbal Behaviours*

Maternal verbalizations were thoroughly transcribed. They were divided into utterances (defined as a group of words segmented from another group by a clearly audible pause). Then the utterances were classified into four categories, depending on the topic to which they referred: comments about the object (PVO), about the infant's actions (PVA), about the mother's actions (PVM) and others (PVT).

First, for example, *utterances referring to infant's actions upon an object* (PVA):

> 'Take it', 'Shake it', 'Touch it', followed by information about procedures or means for action: 'Try to stretch out your arm', 'To grasp you have to open and close your hand', 'You have to close your hand when you grasp an object', 'If you open your hand you'll drop it!', 'Hands are meant for taking', 'You'll do it with the other hand!', 'That's right, two hands!', or 'Good!'.

Next, *utterances referring to mother's actions upon an object* (PVM):

> 'Look, Mom makes it move!', or 'Now I'll show you another one'.

Then, *utterances referring to an object* (PVO):

> 'Look at the puppet!', followed by descriptions of the object: 'What would you call that one?', or 'It has spots, it's soft, it's red like the one yesterday!'

Finally, other utterances, referring mostly to infant's state (PVT), might include:

> 'You're tired', or 'That's enough'.

The non-verbal maternal, as well as infant, behaviours' categories are mutually exclusive: the onset of a behaviour determines the offset of the preceding one.

*Mother's Non-verbal Behaviours*

Non-verbal behaviours aimed at presenting objects to the infant were classified into four categories, depending on the distance between the object and the infant's hand: *out of reach* (MFVI/PVI), *within reach* (MFPR/PPR), *at hand level* (MFMA/PMA), or *on the body*. Mother touches the infant's body with an object was also classified (MFAU/PAU). When the mother did not act on objects, we coded MFRI/PNO.

*Infant's Non-verbal Behaviours*

(a) The infant's attention was measured by the direction of the gaze, which was either *towards the toy held by mother* (PEOM) *or child* (PEOB), and *towards the mother's face* (PEME) or *elsewhere* (PEAI). When attention shifted from one object to another, a new occurrence started.
(b) The limb movements were coded according to the type of motor activity and the orientation of gaze (towards a toy or not).

These can be further classified into the following categories:

- Without looking at the object: *spontaneous movements* (EDAO/EFAO): gross movements involving the whole body, with arms extending away from the body and legs having alternative movements.

 

- While looking at the object: *global motor activity* (EDAA/EFAA): gross movements, especially involving arm raising and movement of fingers.
- *Exploration* (EDEX/EFPEX): hand action of scanning the object's surface (held by the mother) with his fingertips.
- *Reaching without grasping* (EDOR/EFOR): approach of the object with the hand by an extension of one or both arms in the direction of the object, with no contact.
- *Reaching with grasping* (EDPR/EFPR): approach and grasp of the object. The amplitude of the approach may be very small.
- *Manipulating* (EDPC/EFPC): the object in hand is shaken, banged, squeezed, or rotated.
- *Mouthing* (EDMU/PMU): when the object is brought to the mouth and orally explored.
- *No motor activity* (EDRI/PRI): when no movement is observed.

In such abbreviations, the first D refers to duration, the first P to percentage and F to frequency.

## DATA ANALYSIS

A time tag was put on the video images during recording. Using a jog/shuttle, the beginning and end of each mutually exclusive occurrence of a target behaviour were detected, with a precision level of 0.04 second (25 frames/s; see Appendix). The infant and maternal individual behaviours of four random dyads were coded by two independent judges. All Kappa values (Cohen, 1960) were above 0.87. The Kappa obtained were 0.96 for mothers' verbal behaviours and 0.90 for infant's attention. They were 0.87 for duration and 0.94 for frequencies of infant's movements.

First, we calculated the duration of each maternal non-verbal behaviour. For maternal verbal behaviours, frequencies were derived into proportions. Concerning infant behaviours, both frequencies and duration of each target behaviour were computed. We chose to analyse frequencies for prehension gestures with motor patterns, clearly delimited movements, which may be counted because they can be isolated (exploration, reaching, grasping and manipulation), whereas concerning more global activities, involving continuous and diffuse movements, in which a single pattern is more difficult to isolate, only duration was analysed.

Second, we considered the frequency of maternal transitions from one way of presenting the object to another: from out-of-reach to hand or body (and *vice versa*), from out-of-reach to within-reach (and *vice versa*), and from within-reach to hand or body (and *vice versa*).

Third, files were mixed to detect meaningful co-occurrences between maternal and infants' behaviours. The co-occurrences were computerized by the software Observer (1997), with which the individual behaviours were first coded (i.e. onsets and offsets with time); it calculated any co-occurrence of two target behaviours, lasting at least 0.25 s. The duration of each type of co-occurrence was converted into a percentage of the total duration of the concerned infant behaviour, in order to account for individual variations in infant motor activity.

Last, a principal component analysis (PCA) (Rouanet *et al.*, 1998) was performed using all indexes (infant behaviours, maternal behaviours and co-occurrences).

 

## RESULTS

We shall present the indexes concerning infant behaviours first, then the maternal behaviours, and finally, the co-occurrences. Next, the different results will be related to each other to obtain a descriptive synthesis of the development of dyadic activities with age.

### *Infant's Behaviours*

Two types of behaviours are considered here, gaze (Table 1) and motor activity (Table 2 for the percentages of time, Table 3 for the total frequencies).

Infant gazes at the object (PEOM), presented by the mother, filled more than half of the time at all ages. However, they reached a peak in the 3-month-olds.

Table 1. Mean proportions of infant's gaze during the 5-min interaction

| Infant's gaze | | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|
| At object presented by mother (PEOM) | M | 50.5 | 75.4 | 53.7 | 7.21** |
| | S.D. | (16.5) | (17.0) | (18.7) | |
| At mother's face (PEME) | M | 28.7 | 11.6 | 11.2 | 6.40** |
| | S.D. | (19.9) | (11.1) | (6.5) | |
| At object being held (PEOB) | M | 0.0 | 0.3 | 20.3 | 24.44*** |
| | S.D. | (0) | (0.7) | (20.3) | |
| At own hand (PERM) | M | 0.2 | 0.6 | 0.7 | n.s. |
| | S.D. | (0.6) | (0.7) | (1.0) | |
| At anything else (PEAI) | M | 20.5 | 12.1 | 14.1 | n.s. |
| | S.D. | (18.1) | (11.1) | (11.8) | |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
M = mean; S.D. = standard deviation; n.s. = not significant.

Table 2. Mean proportions of infant motor activity during the 5-min interaction

| Infant motor activity | | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|
| Spontaneous movement without looking at object (EDAO) | M | 8.9 | 3.1 | 1.4 | 5.52** |
| | S.D. | (9.3) | (3.5) | (1.6) | |
| Global motor activity while looking (EDAA) | M | 38.9 | 26.7 | 9.7 | 9.05*** |
| | S.D. | (24.1) | (12.7) | (10.5) | |
| Exploration of object (EDPEX) | M | 2.4 | 9.1 | 10.9 | 3.29* |
| | S.D. | (4.7) | (9.6) | (10.5) | |
| Reaching object (EDOR) | M | 4.5 | 7.5 | 9.7 | n.s. |
| | S.D. | (14.3) | (7.7) | (7.4) | |
| Grasping object (EDPR) | M | 0 | 6.0 | 13.0 | 9.32** |
| | S.D. | (0) | (9.1) | (9.0) | |
| Manipulating object (EDPC) | M | 0 | 1.2 | 20.0 | 28.71*** |
| | S.D. | (0) | (1.9) | (12.4) | |
| Mouthing (EDMU) | M | 0.1 | 4.3 | 13.3 | 3.79* |
| | S.D. | (0.2) | (14.9) | (14.6) | |
| No motor activity (EDRI) | M | 45.2 | 42.1 | 22.0 | 6.69** |
| | S.D. | (22.4) | (14.6) | (11.9) | |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
M = mean; S.D. = standard deviation; n.s. = not significant.

 

Table 3. Mean frequencies of infant motor activity during the 5-min interaction

| Infant motor activity | | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|
| Exploration of object (EFPEX) | M | 1.3 | 5.8 | 7.3 | 4.18* |
| | S.D. | (2.2) | (5.8) | (6.7) | |
| Reaching object (EFOR) | M | 1.8 | 8.7 | 12.6 | 7.18** |
| | S.D. | (4.2) | (6.2) | (9.6) | |
| Grasping object (EFPR) | M | 0 | 2.3 | 7.8 | 18.82*** |
| | S.D. | (0) | (2.8) | (4.7) | |
| Manipulating object (EFPC) | M | 0 | 0.7 | 11.7 | 26.02*** |
| | S.D. | (0) | (1.2) | (7.6) | |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
M = mean; S.D. = standard deviation; n.s. = not significant.

A following Tukey HSD showed a significant difference between 2 months and 3 months ($p < 0.01$), and between 3 and 4 months ($p < 0.05$). Looking at the mother (PEME) decreased between 2 and 3 months (Tukey HSD, $p < 0.05$). Gazing at the object the infants were holding themselves was observed only in 4-month-olds (PEOB). The difference between 3 and 4 months was significant (Tukey HSD, $p < 0.001$).

In considering durations (Table 2), global motor activity without looking at the object (PAO) were virtually only observed in 2-month-olds. A significant difference was found between 2 and 4 months. (Tukey HSD, $p < 0.001$). Global motor activity while looking at the object (PAA) decreased linearly between 2 and 4 months. (Tukey HSD, $p < 0.001$). Finally, periods of no motor activity (PRI) strongly decreased between 3 and 4 months.(Tukey HSD, $p < 0.05$).

Frequencies (Table 3) of object manual exploration (EFPEX) increased between 2 and 4 months. The difference is significant (Tukey HSD, $p < 0.05$). Reaching movements without grasping (EFOR), which were exceptional in 2-month-olds, increased notably between 2 and 3 months (Tukey HSD, $p < 0.05$), and reaching without grasping (EFOR) still increased, while difference for frequencies between 3 and 4 months was not significantly different. Conversely, both object grasping without manipulation (EFPR) and manipulations (EFPC) were significantly different between 3 and 4 months (Tukey HSD, $p < 0.001$).

We found, that at 2 months, one infant out of 12 had 15 reaches without grasping, at 3 months, all the infants could reach without grasping, and 8 out of 12 infants could reach with grasping. At 4 months, all the infants could reach with grasping. However, important variations were found in frequencies and durations. For example, at 3 months, one infant had three reaches without grasping, while another had 24, and at 4 months, an infant had only two reaches with grasping, while another had 16.

### *Maternal Behaviours*

Table 4 gives the time proportions of maternal non-verbal actions in a 5-min interaction. Presenting objects out of reach (PVI) happened very often, at 2 and 3 months, and then decreased at 4 months (Tukey HSD test, $p < 0.05$). Within-reach presentations (PPR) increased between 2, 3 and 4 months. The difference is significant between 2 and 4 months (Tukey HSD test, $p < 0.05$). It may be noted that presentations out-of-reach were systematically dynamic, while presentations within-reach were static. Moreover, the highest duration of presentations at hand level (PMA) was observed at 3 months, while maternal inactivity

 

(PNO) decreased. Thus, mothers stimulated their infants the most, and did so in the greatest variety of ways when the infant was 3 months old. With 4-month-olds, maternal inactivity (PNO) markedly increased. The Tukey HSD test showed a significant difference between 3 and 4 months (Tukey HSD test, $p < 0.001$). Touches on the infant's body (PAU) remained low and constant across the age groups.

Table 5 gives the frequency, at each age, of some meaningful transitions between two maternal non-verbal behaviours.

The transitions from out-of-reach to the hand or body (OH), as its reverse (HO), were typical of the 2 months' interactions. Only a few transitions from out-of-reach to within reach (OW) and their reverse (WO) appeared then. We observed less than one transition from within reach to hand (WH) or its reverse

Table 4. Mean proportion of time of each type of maternal non-verbal behaviours during the 5-min interaction

| Maternal non-verbal behaviours | | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|
| Presents object out of reach (PVI) | M | 70.6 | 58.8 | 34.1 | 10.39*** |
| | S.D. | (16.2) | (24.8) | (18.2) | |
| Presents object within reach (PPR) | M | 6.6 | 18.4 | 24.5 | 3.91* |
| | S.D. | (14.1) | (21.3) | (10.6) | |
| Presents object at hand level (PMA) | M | 3.5 | 6.7 | 2.5 | n.s. |
| | S.D. | (4.4) | (6.7) | (2.9) | |
| No activity on object (PNO) | M | 12.2 | 10.4 | 31.5 | 11.18*** |
| | S.D. | (7.3) | (8.4) | (15.2) | |
| Touches infant's body (PAU) | M | 7.1 | 5.8 | 7.4 | n.s. |
| | S.D | (7.4) | (5.0) | (5.2) | |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
M = mean; S.D. = standard deviation; n.s. = not significant.

Table 5. Mean total frequencies of some types of transitions between maternal non-verbal behaviours during the 5-min interaction

| From | To | | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|---|
| OH | | | | | | |
| Out-of-reach | Hand or body | M | 4.8 | 4.7 | 2.6 | 3.47* |
| | | S.D. | (2.4) | (3.4) | (2.1) | |
| HO | | | | | | |
| Hand or body | Out-of-reach | M | 4.2 | 4.3 | 1.8 | n.s. |
| | | S.D. | (2.1) | (4.3) | (1.7) | |
| OW | | | | | | |
| Out-of-reach | Within-reach | M | 1.4 | 3.9 | 6.3 | 6.43** |
| | | S.D. | (2.9) | (2.9) | (4.1) | |
| WO | | | | | | |
| Within-reach | Out-of-reach | M | 1.6 | 2.8 | 3.3 | n.s. |
| | | S.D. | (2.8) | (2.7) | (2.9) | |
| WH | | | | | | |
| Within-reach | Hand | M | 0.4 | 3 | 2.7 | 5.45** |
| | | S.D. | (0.7) | (2.7) | (2.3) | |
| HW | | | | | | |
| Hand | Within-reach | M | 0.3 | 1.9 | 2.4 | 5.18* |
| | | S.D. | (0.5) | (1.8) | (2.2) | |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
M = mean; S.D. = standard deviation; n.s. = not significant.

 

Table 6. Proportions of each type of maternal verbalizations during the 5-min interaction (based on total frequencies of verbalizations)

| Maternal verbalizations | | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|
| Utterances about object (PVO) | M | 72.4 | 64.4 | 59.3 | n.s. |
| | S.D. | (10.1) | (20.8) | (11.8) | |
| Utterances about infant's actions (PVA) | M | 5.8 | 19.5 | 24.4 | 9.74*** |
| | S.D. | (8.1) | (15.5) | (5.9) | |
| Utterances about mother's actions (PVM) | M | 4.3 | 8.6 | 4.9 | n.s. |
| | S.D. | (4.9) | (6.2) | (3.4) | |
| Other utterances (PVT) | M | 17.4 | 7.4 | 11.4 | 3.97* |
| | S.D. | (9.7) | (7.2) | (9.1) | |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
M = mean; S.D. = standard deviation; n.s. = not significant.

(from hand to within reach: HW). Thus, during the interaction with 2-month-olds, mothers went straight from the out-of-reach space to the most proximal one (hand or body).

At 3 months, the transitions from out-of-reach to the hand or body (OH) and its reverse (HO) were still important, but the transition where mothers brought the object from out-of-reach to within reach (OW) increased markedly between 2 and 3 months, while its reverse (WO) did not significantly increase. The transitions from within reach to hand (WH) also particularly increased at 3 months (Tukey HSD test, $p < 0.05$), as with the reverse transition from hand to within reach (HW; Tukey HSD, $p = 0.06$). The special increase of those transitions, that globally bring the object closer to the infant, confirms mothers' intention to stimulate the infant's reaching and grasping.

At 4 months, mothers brought the object closer from the out-of-reach space to the hand (OH) less often (Tukey HSD, P = .06), as they took the object from hand space to bring it out-of-reach less often (HO). Mothers, particularly, brought the objects closer, without giving the object exactly at hand level: the transition from out-of-reach to within reach (OW), which still increased at 4 months, is the most important transition observed at any age, and appeared to be a typical transition at 4 months. Then, at 4 months, mothers used a shorter spatial span than previously. The difference is significant between 2 and 4 months (Tukey HSD, $p < 0.001$ for OW).

Concerning maternal verbalizations, Table 6 shows that utterances about the object (PVO) predominated at all ages, although the proportion decreased with age. Utterances about the infant's actions (PVA) increased markedly between 2 and 3 months (Tukey HSD, $p < 0.01$) and increased again between 3 and 4 months. Utterances describing the mother's object-related actions (PVM) peaked at 3 months, while other utterances (PVT), mostly comments about the infant's state, tended to decrease with age, more so between 2 and 3 months (Tukey HSD, $p < 0.05$).

### *Co-occurrences*

Table 7 gives the proportion of infant behaviour duration, during which maternal behaviours co-occurred.

The proportion of time the mother stimulated with out-of-reach objects, while the child had global motor activity (AAPVI), decreased with age, although it

 

Table 7. Proportions of co-occurrences between maternal and infant's behaviours (S.D.)

| Infant | | Mother | | Co-occurrences | 2 months | 3 months | 4 months | *F* |
|---|---|---|---|---|---|---|---|---|
| PAA | Global motor activity while looking at object | PVI | Presents object out of reach | AAPVI | 79.9 (17.0) | 72.0 (26.7) | 57.5 (36.6) | n.s |
| PAA | Global motor activity while looking at object | PPR | Presents object within reach | AAPPR | 5.4 (9.6) | 16.0 (19.8) | 15.4 (20.6) | n.s |
| EFPEX | Explores object | PMA | Presents object at hand level | EXPMA | 15.1 (28.0) | 39.3 (33.7) | 7.1 (11.8) | 4.91* |
| EFPEX | Explores object | PPR | Presents object within reach | EXPPR | 6.9 (23.8) | 26.7 (35.3) | 43.3 (37.1) | 3.75* |
| EFPEX | Explores object | PRI | No activity on object | EXPRI | 7.7 (15.0) | 16.0 (17.4) | 17.8 (22.1) | n.s |
| EFOR | Reaches object without grasping | PVI | Presents object out of reach | ORPVI | 21.0 (38.3) | 51.8 (33.0) | 42.4 (31.4) | n.s |
| EFOR | Reaches object without grasping | PPR | Presents object within reach | ORPPR | 11.5 (27.3) | 37.9 (31.7) | 37.8 (22.2) | 3.74* |
| EFPR +EFPC | Grasps and manipulates object | PMA | Presents object at hand level | PCPMA | 0 | 23.8 (37.4) | 1.3 (1.7) | 4.61* |
| EFPR +EFPC | Grasps and manipulates object | PPR | Present object within reach | PCPPR | 0 | 7.3 (12.0) | 15.3 (14.5) | 7.28** |
| EFPR +EFPC | Grasps and manipulates object | MFRI | No activity on object | PCPMR | 0 | 40.2 (38.8) | 58.6 (21.9) | 16.3*** |
| PRI | No motor activity | PPR | Presents object within reach | RIPPR | 6.9 (20.1) | 16.4 (23.8) | 29.2 (38.2) | n.s |

M = mean; S.D. = standard deviation; n.s. = not significant.

was still observed at 4 months. During this same global motor activity, the mother showed the object within the prehension space as early as 3 months (AAPPR). The co-occurrence of infant reaching movements while the mother showed an out-of-reach object (ORPVI) tended to remain constant over ages. The co-occurrence of infant reaching movements while the mother showed a within-reach object (ORPPR) increased from 2 to 3 months (Tukey HSD, $p = 0.06$) and remained constant at 4 months.

When the infants explored objects, the mothers presented them mainly at hand level (EXPMA) at 2 and, particularly, at 3 months. This maternal behaviour was a direct support of the infant activity, which can then be described as a more 'passive exploration' than later. This support decreases at 4 months, with a significant difference between 3 and 4 months (Tukey HSD, $p < 0.05$). At 4 months, during the infant exploration, the mother was mainly in the prehension space (EXPPR), which revealed a more 'active exploration' from the infant; mothers then made the exploration more challenging, not providing the object at hand level. The co-occurrence where the mother let the infant explore the object alone (EXPRI: the object is generally on the infant's chest) remained about the same for all sessions. At 3 months, the mother more often kept the object at hand level when the child grasped it (PCPMA), thus providing a direct help to the infant's activity, while this co-occurrence almost disappeared in 4-month-olds. The difference between 3 and 4 months is significant (Tukey HSD, $p < 0.05$).

The age of 3 months was also characterized by the emergence of a co-activity in the prehension space, when the infant grasped and manipulated the object (PCPPR). This co-occurrence still increased at 4 months, and was typical of this age, revealing a real joint action during infant manipulation, which is now possible because of the skill reached by the infant at this age. The Tukey HSD test shows a significant difference between 2 and 4 months ($p < 0.01$).

Another co-occurrence, typical of the 3 and 4 months interactions, was the particular mother's inactivity during the infant's manipulation (PCPMR). As we can see, at 4 months, dyads either played together with greater coordination (in the same space span or in proximal ones in order to stimulate the activity: PCPPR, ORPPR, EXPPR), or the mother let the infant manipulate the object by himself (PCPMR), challenging autonomous activity, as manipulation already started at 3 months. Finally, mothers presented objects within reach, even when the infant did not move (RIPPR) at all ages.

### *Synthesis of all Indexes: A PCA*

In order to obtain an overall descriptive view of the organizing principles underlying the variability of the data obtained over the 36 observations, we performed a PCA on the entire set of dependent variables, measuring infant behaviours, maternal behaviours and co-occurrences. As co-occurrences measure simultaneous durations of two individual behaviours, they provide a specific information.

The first two factorial axes account for 37% of the total variance, 24% for the first axis and 13% for the second. The first plane, therefore, seems to provide substantial support for synthesizing the basic data.

As the variable graph shows (Figure 1(A)), the first axis opposes the negative pole of maternal non-verbal out-of-reach stimulations (MFVI) and comments about objects (PVO), extending to, on the positive pole, within-reach presentations (MFPR) and action directives addressed to the infant (PVA). For the infant

 

behaviours (Figure 1(B)), axis 1 opposes global movements while looking at the object (PAA), extending to movements enabling object grasping (EFPEX, EFOR, EFPR, EFPC).

The dyad graph (Figure 1(B)) points out a contrast between 2-month-old dyads (negative pole of axis 1) and 4-month-old dyads (positive pole), with 3-month-olds in-between. This means that the infant's age best explains the frequency of the behaviours observed during interaction, and the links between them. With the axis 1 coordinate as a dependent variable, an analysis of variance (ANOVA) on age (3 levels) yielded a significant effect ($F(2,33) = 20.00$, $p < 0.001$).

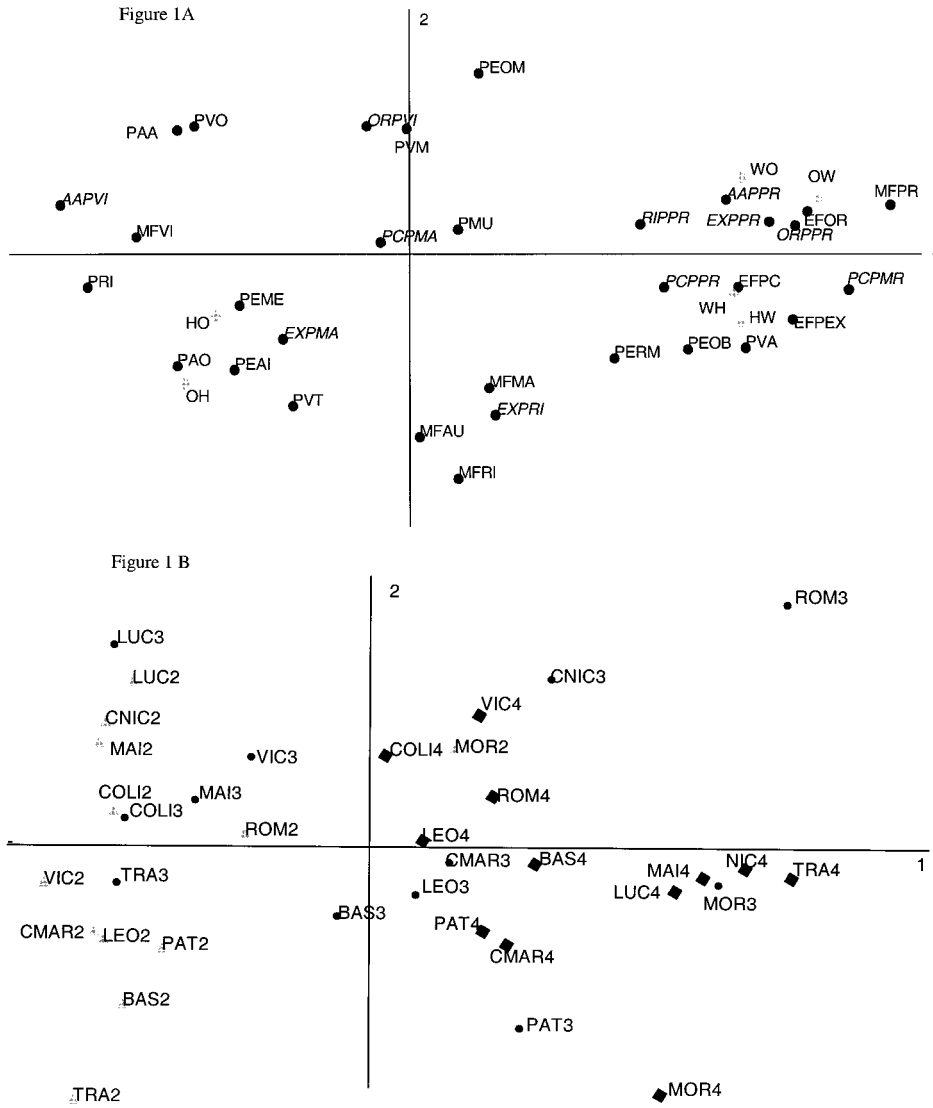


Figure 1. (A) Variable graph; (B) Dyad graph.

 

The second axis (on Figure 1(A)) is more difficult to interpret. It conveys the variability of the maternal level of stimulation (MFRI versus PVM) and the infant's involvement in the situation (PEAI versus PEOM). Thus, a description of the plane, characterized by these two axes, from left to right, can be used to synthesize the development of interactions with age, as follows.

When the infants were 2 months old, the mothers appeared to aim mainly for capturing the infant's visual attention and moving the object out of reach while talking about it (MFVI, PVO). At this age, the typical transitions were from out of reach presentation to hand or body (HO), and its reverse (OH). Some infants displayed global movements while looking at the object (PAA), but a number of infants looked at their mothers (PEME) or somewhere else (PEAI). Inactivity (PRI) was frequent, as were global motor activity without looking at object (PAO). Interestingly, there was only one co-occurrence in 2-month-olds: the mother was presenting an out-of-reach object, while the infant had global motor activity while looking at the object (AAPVI).

With the 3-month-old infants, mothers offered various modes of stimulation (PVI, PPR and PMA); this is indicative of the diversification of maternal strategies and, probably, a change in goal. Mothers made remarks about their own object-oriented actions (PVM). Moreover, utterances about the infant's state (PVT) peaked at this age. The infants preferentially looked at the object held by the mother (PEOM). Four types of co-occurrences were representative of this age group, and included three new infant's motor behaviours: (1) the mother presented an out-of-reach object while the infant tried to reach for it (ORPVI); (2) she held the object at hand level while the infant explored (EXPMA); (3) and took and held it (PCPMA); (4) during maternal inactivity, infants explored objects left on their body (EXPRI). We observe that dispersion was maximal at this age. As Figure 1(B) shows, some of these dyads were close to 2 months old, while others were near to 4 months old.

With 4-month-old infants, the mothers presented objects in the proximal space (MFPR), and talked about their infant's actions on those objects (PVA). Four kinds of transitions appeared to be typical of mothers' non-verbal behaviour at this age: any transitions from or leading to the within reach space (WO, OW, WH, HW). Infant variables at this pole of axis 1 represent the children's autonomy: the children reached for objects (EFOR), explored them (EFPEX), took them (EFPR), and manipulated them (EFPC). Looking at the object being held appeared at this age (PEOB), as did looking at his own hands (PERM). Six different co-occurrences showed that joint action in the proximal space characterized this age group: the mothers kept the objects in the proximal space, while the infants reached for them (ORPPR) or explored them (EXPPR). When the infants grasped and manipulated objects, the mothers kept them within the infant's reach (PCPPR): they played together. Stimulation within the proximal space was observed, even when the infants stayed still (RIPPR), or when they moved globally (AAPPR). A final type of co-occurrence was specific to the 4-month-olds: the mothers let the infants explore by themselves, without intervention (PCPMR).

To summarize, because PCA gives one, and only one, position for each variable on the graph, and because axis 1 has been demonstrated to represent age, this analysis highlights preferential behaviours, and particularly, preferential co-occurrences for each age interaction, even though those individual or dyadic behaviours were, in the first part of the results, registered at several ages.

 

## DISCUSSION

This study aimed at analysing mother–infant interactions when goal-directed movement emerged, i.e. reaching and grasping an object.

Our results showed that prehension in infants observed playing with their mother follows similar pathways, as was described in infants when alone. We observed a stage at 2 months where infants react to objects by global motor activity, before a period at 3 months, when infants begin to reach and sometimes grasp. At 4 months, we noted that all infants of our sample could reach and grasp the object proffered by the mother. Observing the infant alone facing an object, von Hofsten and Lindhagen (1979) found the achievement of grasping for only one infant at 15 weeks, and for several at 18 weeks. This discrepancy stems, probably, from maternal interventions, which regulate the distance of the object presentation: she can move the object closer to facilitate grasping. More recently, in a longitudinal study, where infants were observed weekly from 8 until 24 weeks (Wimmers *et al*., 1998b), it was found, considering individual data, that the onset of reaching with grasping shows a range from 9 to 14 weeks.

Another result of our study concerns changes in mothers' behaviours in the course of the interaction with 2–4-month-old children. The analysis of the content of mothers' talk to infants showed a change according to the development of reaching skills: at the age of 3 months, utterances concerning the properties of the objects tend to decrease, while comments about the infant's hand or how to use it, and directions for acting, emerged in the mother's speech and still increased at 4 months. This shift evidenced that mothers have expectations regarding the development of prehension. Research on parental beliefs about early motor development (Ely *et al*., 1972; Hopkins and Westra, 1989) claims that parents know when their infant can sit, crawl and walk, but nothing is said about the emergence of prehension stages. Only one study before this one, Gray (1978), pointed out the presence of action directives in maternal speech to 3 and 4-month-old infants, but the study involved only three dyads. With 2-month-olds, mothers present objects out of reach, as if the global motor activity which co-exists with visual interest was interpreted as an attentional response. With age, they shift to presentations within reach, they replace demonstration with support. This result is in line with West and Fogel (in Fogel, 1990).

Moreover, when we analysed the content of co-occurrences, we found that, at 3 months, when reaching emerges, mothers allied demonstration and two types of support at hand level and within prehension space. The type of maternal support changes between 3 and 4 months, as grasping increases, showing a transformation of joint action between the child and the mother, from a more passive to a more active one. Hand-level presentations of objects decrease and are replaced by within-reach stimulations: joint actions are progressively carried out at a place where the infant must meet the mother to achieve the action. The object has an intermediate location set progressively between 2 and 4 months by the mother and the infant (Fogel, 1993b). The strategy which consists in supporting the object at a certain distance from the child, and in postponing the moment to release it, makes it possible for their infant's intentions to become actualized, and to get modified when acting upon objects is not possible. Was Fogel (1990) speaking about such a mechanism when he suggested that intentions stem from a social process?

The analysis of successive presentation modes of the object by the mother, between 2 and 4 months of age, indicates that mothers gradually shortened the

 

trajectories and display objects more often in the prehension space. This may contribute, as well as the prehension movement itself, in delineating for the infant the proximal space which ontogenetically follows the proprioceptive postural space (Wallon and Lurçat, 1962).

Notions of ZPA, ZPD and ZFM, when applied to the developing prehension observed in the frame of mother–infant interaction, make it possible to conceptualize the evolution of mothers' role from the offer of objects up to the moment when the infant is able to grasp alone. These three zones are interdependent (Valsiner and Hill, 1989; van Beek and Geerdink, 1989). First, mothers create the ZPA by proffering objects to children so that they can develop actions, and a ZPD by supporting the object, making it possible for the child to perform actions which cannot yet be performed alone (Fogel and Thelen, 1987). Then, when reaching increases, the mother may become a delimiter of the child's actions; she creates then the ZFM, which she enlarges at 4 months by adding more constraints. Valsiner, indeed, stated that the boundaries of the ZFM are set during negotiations between the caretaker and the child. ZPA/ZFM are within ZPD until the child is autonomous. At 4 months, mothers often let their children manipulate on their own. 'Scaffolding fades and disappears when the child, after overcoming difficulties one after the other, becomes autonomous' (Pêcheux, 1994, p. 61).

Although the concepts elaborated by Valsiner (1987) are useful in featuring the development of maternal interventions during action formatting, it is difficult to interpret what the internalization of ZPA/ZFM may be when a motor behaviour is considered. Indeed, some authors (Wimmers *et al*., 1998a,b) claim that the development of prehension is the product of self-organization between different intrinsic and extrinsic components. However, Valsiner's model fits with the appropriation of social conventions (Valsiner and Hill, 1989).

Nevertheless, the increase in co-occurrences between maternal and infant behaviours with age may be interpreted as a greater mutual tuning between partners, showing reciprocal influence of each partner on the other via mutual appropriation.

An unanswered question is: what is the goal adults set for themselves during such object-centred interactions with infants? When analysing the content of the maternal verbalizations, we saw that the mothers decoded the gesture 'reaching towards an object' as a desire to grasp that object. It remains unclear, however, whether she keeps the object at distance from the child in order to stimulate the infant's reaching and grasping behaviour, or to trigger a request for the object, or just to play. This maternal process, consisting of lengthening the time before the proffered object is given to the child (Bruner, 1975b), may contribute to the infant's understanding that 'extending one's arms' means 'asking for an object'. Thus, within a framework of interactive routines and alternating games, object-oriented actions develop along with communicative behaviours, the infant learns conventions about how and in which conditions he can request an object, get it and give an object to someone (Messinger and Fogel, 1998).

## ACKNOWLEDGEMENTS

We would like to thank M.G. Pêcheux for her assistance and valuable advice, and B. Beaufils and E. Devouche for their help for statistical analysis.

 

Table A1

| Time (s) | Infant's gaze | Infant's movements | Mother's presentation | Mother's verbalization |
|---|---|---|---|---|
| 00:00 | Towards object C mother is holding | No motor activity | Object C, out of reach | |
| 00:84 | | | | About object C |
| 01:36 | | Global motor activity while looking at object C | | |
| 03:76 | | | Object C, within infant's reach | |
| 04:55 | | | | About object C |
| 04:92 | | Reaching without grasping object C | | |
| 08:80 | | | Object C, at hand level | |
| 09:12 | | Exploring object C | | |
| 12:24 | | No motor activity | | |
| 15:58 | | | Object C, within infant's reach | |
| 17:32 | | | | About mother's action on object C |
| 17:53 | | Global motor activity while looking at object C | | |
| 20:47 | | Reaching with grasping object C | | |
| 20:57 | At object C being held | | No activity on object | |
| 23:40 | | | | About infant's action on object C |
| 26:41 | Elsewhere | No motor activity | Object B, within infant's reach | |
| 26:75 | | | | About object B |
| 27:30 | Towards object B mother is holding | Global motor activity while looking at object B | | |

## APPENDIX A EXAMPLE OF CODING OF INFANT AND MOTHER'S BEHAVIOURS

Nic at 3 months (see Table A1).

## REFERENCES

van Beek Y, Geerdink J. 1989. Intervention with preterms: is it educational enough? *European Journal of Psychology of Education* **4**: 251–265.
Bruner J. 1973. Organization of early skilled action. *Child Development* **44**: 1–11.
Bruner J. 1975a. The ontogenesis of speech acts. *Journal of Child Language* **2**: 1–19.
Bruner J. 1975b. From communication to language. A psychological perspective. *Cognition* **33**: 255–287.
Clark RA. 1978. The transition from action to gesture. In *Action, Gesture and Symbol: The Emergence of Language*, Lock A (ed.). Academic Press: London; 231–237.
Cohen J. 1960. A coefficient of agreement for nominal scales. *Educational and Psychological Measurement* **20**: 37–46.

 

Ely KP, Healey A, Smith GL. 1972. Mothers' expectations of their child's accomplishment of certain gross motor skills. *Developmental Medicine and Child Neurology* **14**: 621–625.
Ennouri K, Bloch H. 1996. Visual control of hand approach movements in new-borns. *British Journal of Developmental Psychology* **14**: 327–338.
Fogel A. 1990. Sensorimotor factors in communicative development. In *Sensory-Motor Organizations and Development in Infancy and Early Childhood*, Bloch H, Bertenthal BI (eds). Kluwer Academic Publishers: Netherlands; 75–88.
Fogel A. 1993a. *Developing Through Relationships*. Harvester Wheatsheaf Press: Exeter.
Fogel A. 1993b. Two principles of communication. Co-regulation and framing. In *New Perspectives in Early Communicative Development*, Nadel J, Camaioni L (eds). Routledge: London; 9–22.
Fogel A, Thelen E. 1987. Development of early expressive and communicative action: reinterpreting the evidence from a dynamic systems perspective. *Developmental Psychology* **23**: 747–761.
Fogel A, Dedo JY, McEwen I. 1992. Effect of postural position and reaching on gaze during mother–infant face-to-face interaction. *Infant Behaviour and Development* **15**: 231–244.
Gray H. 1978. Learning to take an object from the mother. In *Action, Gesture and Symbol: The Emergence of Language*, Lock A (ed.). Academic Press: London; 159–182.
von Hofsten C. 1982. Eye-hand coordination in the newborn. *Developmental Psychology* **18**: 450–461.
von Hofsten C. 1984. Developmental changes in the organization of prereaching movements. *Developmental Psychology* **20**: 376–388.
von Hofsten C, Lindhagen K. 1979. Observation on the development of reaching for moving objects. *Journal of Experimental Child Psychology* **28**: 158–173.
Hopkins B, Westra T. 1989. Maternal expectations of their infants' development: some cultural differences. *Developmental Medicine and Child Neurology* **31**: 384–390.
Messinger DS, Fogel A. 1998. Give and take: the development of conventional infant gestures? *Merrill-Palmer Quarterly* **44**(4): 566–590.
Mounoud P. 1983. L'évolution des conduites de préhension comme illustration d'un modèle du développement. In *Le Développement dans la Première Année*, de Schonen S (ed.). PUF: Paris; 75–106.
Observer. 1997. *The Observer Video Pro*. Noldus: Wageningen, NL.
Pêcheux MG. 1994. L'adulte comme partenaire dans le développement cognitif du bébé. In *Le Développement Cognitif du Nourrisson*, Lécuyer R, Pêcheux MG, Streri A (eds). Nathan: Paris; 37–65.
Penman R, Meares R, Milgrom-Friedman J. 1981. The mother's role in the development of object competency. *Archives de Psychologie* **49**: 247–265.
Rochat Ph. 1989. Object manipulation and exploration in 2- to 5-month-old infants. *Developmental Psychology* **25**: 871–884.
Rouanet H, Le Roux B, Bernard J-M, Lecoutre B. 1998. Geometric data: from euclidian clouds to bayesian Manova. In *New Ways in Statistical Methodology*, Rouanet H, Bernard J-M, Bert M-C, Lecoutre B, Lecoutre M-C, Le Roux B (eds). Peter Lang: New York; 227–254.
Schonen S, Bresson F. 1984. Dévelopment de l'atteinte manuelle d'un objet chez l'enfant. In *La Lecture Sensori-motrice et Cognitive de L'expérience Spatiale. Directions et Distance*, Paillard J (ed.). Collection Comportements: Paris, CNRS; 99–114.
Thelen E. 1995. Motor development. A new synthesis. *American Psychologist* **50**: 79–95.
Thelen E, Corbetta D, Kamm K, Spencer JP, Schneider K, Zernicke RF. 1993. The transition to reaching: mapping intention and intrinsic dynamics. *Child Development* **64**: 1058–1098.
Trevarthen C. 1977. Descriptive analysis of infant communicative behaviour. In *Studies in Mother–Infant Interaction*, Schaffer HR (ed.). Academic Press: London; 227–270.
Wallon H, Lurçat L. 1962. Espace postural et espace environnement. *Enfance* **1**: 1–33.
Valsiner J. 1987. *Culture and the Development of Children's Action*. Wiley: Chichester.
Valsiner J, Hill PE. 1989. Socialization of American toddlers for social courtesy. In *Child Development in Cultural Context*, Valsiner J (ed.). Hogrefe and Huber: St. Louis, MO; 163–179.
Vygotsky LS. 1978. *Mind in Society*. Harvard University Press: Cambridge, MA.
Wimmers RH, Beek PJ, Savelsbergh GJP, Hopkins B. 1998a. Developmental changes in action: theoretical and methodological issues. *British Journal of Developmental Psychology* **16**: 45–63.
Wimmers RH, Savelsbergh GJP, Beek PJ, Hopkins B. 1998b. Evidence for a phase transition in the early development of prehension. *Developmental Psychobiology* **32**: 235–248.

 