EARLY CHILD DEVELOPMENT IN THE FRENCH TRADITION

Contributions From Current Research

Edited by

André Vyt
University of Ghent–NFSR
Belgium

Henriette Bloch
École des Hautes Études–CNRS
Paris

Marc H. Bornstein
National Institute of Child Health and Human Development
Bethesda, Maryland

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2 Posture and Functional Action in Infancy

Philippe Rochat
Emory University

André Bullinger
Université de Genève

Jean-Jacques Rousseau's work on education, first published in 1762, is widely recognized as having been a revolutionary influence that paved the way to the scientific approach to child behavior and development. Kessen (1965) suggested that Rousseau's *Emile, ou de l'Éducation* (1911) is at the origin of child study as a specific discipline of knowledge. Aside from influencing the establishment of a new discipline, Rousseau's essays on education contain a set of fundamental principles that inspired, and eventually shaped, Francophone perspectives on child development. Claparède (1912) recognized in the Emile of Rousseau critical issues and fundamental principles that dictated his views of child development. The principles included the law of *genetic succession*, which posits orderly stages in development, and the law of *functional autonomy*, which emphasizes the appropriateness of the child's behavior at the various stages of development. The law of functional autonomy refers to the achievements and organizations that are specific to each period of development and is in sharp contrast to the view that children are merely miniature or unfinished adults. Principles of genetic succession and functional autonomy became the cornerstones of Piaget's theory.

The concept of stage and the law of functional autonomy can be viewed as trademarks of past and present Francophone approaches to child development. These principles are commonly taken for granted in the Francophone perspectives, and viewed as necessities of development. By contrast, Anglophone perspectives and theories often question these principles, in particular the empirical grounds and heuristic power of theories that conceive development as a discontinuous progression through an orderly succession of stages and organizations (Brainerd, 1978). In the tradition of Binet, Piaget, and Wallon, Francophone perspectives assume that child behavior and development are marked by both quantitative and qualitative changes. Qualitative changes express "revolutions" or radical transformations characterizing the transition from one stage of development to another (Mounoud, 1976, 1984). Development is characterized by different types of organization at particular moments of developmental time, these organizations expressing qualitatively different "psychologies" that are linked by the law of genetic succession or *developmental filiation*. Piaget's theory of cognitive development is prototypical of such view, specifying the organization of various stages of development and providing a qualitative demarcation of successive levels and periods in development. Within this perspective, the primary task of developmental psychologists is to account for the nature and specificity of child behavior at each particular stage of development, trying to unveil the principles of the transitions among them.

This chapter is an attempt to integrate the major developmental problem of posture and functional action in infancy. Empirical observations suggest that posture and functional action interact in a way unique to infants. It is proposed that an important aspect of the functional autonomy attached to the infancy period is the rapid development of posture and its impact on action development.

POSTURAL CONSTRAINTS AND ACTION IN INFANCY

The lack of postural control is a major constraint of early development. It determines infant behavior and places a formidable burden on the execution of basic acts young infants are prepared to perform immediately after birth. Orienting, sucking, grasping, and the rudiments of reaching and communication, require effort and external body support that are hard to imagine and are easily taken for granted by the healthy adult caretaker or by the student of infancy. When orienting toward a stimulus by turning his or her head toward its source, an infant is faced with the risk of rolling over. At around 4 months of age, when infants begin to reach for visible objects, they are at risk of falling forward. At this age, they still lack the basic ability to maintain a sitting position without external body support. The lack of muscular control that will eventually enable the individual to overcome, counteract, and use the force of gravity, creates a primordial constraint on infant behavior. During infancy, a major developmental achievement is the maintenance of overall body balance and dynamic posture as the scaffolding of functional action. This development culminates with the conquest of verticality and the ability to locomote, which expand the zones of functional action and give infants access to new environmental resources.

In general, any movement pattern is a complex whole that integrates posture and action. The postural aspect of movement refers to the integrity of the whole body while a specific action is carried out. Observation tells us that movement and posture are not controlled separately, but are tightly integrated into what Reed (19[illegible]) called *dynamic posture*. Accumulated evidence shows the importance of studying posture and action in relation to one another rather than separately, as is commonly done (Rochat & Senders, 1991). Considering that human infants have a relatively extended period of postural immaturity, and that postural development parallels progress in the skilled control of action, the question of how posture and action interact in development is of profound importance. A central question of early development is how progress in the control of posture relates to the development of functional action in infancy. *Functional action* is defined here as goal-oriented behavior (e.g., sucking to ingest food; transporting an object to the mouth for feeding or for oral/haptic exploration; reaching for an object to grasp it; and moving eyes, head, and trunk to track a visual target).

Infancy research has revealed that from birth, infants are capable of performing actions of remarkable complexity and organization (see E. J. Gibson & Spelke, 1983; Thelen & Fogel, 1986). Such early behaviors include head orientation to sound (Muir & Field, 1979), visual tracking of moving targets (Bullinger, 1977), and hand extension toward a visible moving object (von Hofsten, 1982). The revelation of precocious competence, however, depends on external body support provided by the experimenter to the young infant, compensating for lack of postural control and, particularly, for lack of head and neck control (Bower, 1989). These procedures suggest that proper postural support is essential for a clear manifestion of early behavior, yet we lack empirical facts regarding the relation between postural development and early behavior.

Virtually from birth, infants learn to overcome and also to use gravitational force to perform movements that are part of functional action patterns. With growing control over posture, they free themselves from external body supports, opening up new possibilities of action and exploration. Experiments with animal and human infants suggest a release of coordinated action under supportive posture conditions. Thelen and Fisher (1983) showed that synergistic movements of the legs, seen in newborn stepping, are restored in 1- and 3-month-old infants by submerging their legs in water, a condition that supports the infant and compensates for a low muscle-to-fat ratio. Gustafson (1984) studied prelocomoting infants placed in a baby walker, and showed that the postural support and mobility provided by the walker is associated with spontaneous reorganization of exploratory activities into more mature patterns.

These observations provide evidence that posture and its control play an important role in the development of skilled action. Progressive control over posture is a potential releaser of action. Conversely, lack of postural control limits the capabilities for action. Pediatricians, proposing a new neurobehavioral assessment of the newborn and the young infant, reported remarkable clinical observations on the relation between posture and action in early development (Amiel-Tison, 1985; Grenier, 1980, 1981). These observations demonstrate the importance of posture and its control in the emergence of sensorimotor skills early in development, in particular the effect of posture on motor behavior and the level of attention in neonates.

By holding the neonate's head firmly in the trunk's axis, Grenier and Amiel-Tison were able to elicit the visuomotor coordination of reaching toward an object lying on a table. According to the authors, the apparent sensorimotor clumsiness and the obligatory responses of the neonate are linked to poor neck control. When experimentally provided with adequate postural support to remedy their "neck impotence," neonates revealed striking sensorimotor aptitudes. These observations demonstrate the inseparability of posture and action from birth, such that postural immaturity emerges as a major constraint in the expression and development of precocious functional actions (i.e., pre-reaching). Further demonstration that postural development is a major determinant of functional action in infancy is based on three bodies of observations—sucking, looking, and reaching—is presented next.

POSTURE AND SUCKING IN NEONATES

Recent investigations reveal that the variety of sensorimotor responses displayed by the neonate moments after birth are integrated and organized, rather than independent and juxtaposed. Studies show that coordinated activities of hands and mouth can be observed in infants only a few hours old. Butterworth and Hopkins (1988) observed episodes in which neonates opened their mouths in anticipation of the contact of hand brought straight toward the oral zone. Rochat, Blass, and Hoffmeyer (1988) observed that hand–mouth coordination at birth was under the control of certain stimulus conditions: Following the administration of a drop of sucrose, neonates doubled the duration and frequency of manual contacts with their mouth. Newborns' heart-rate responses appeared to be correlated with the visual appearance and disappearance of an object moving in front of them (Bullinger, 1977). Further evidence of an intermodal unity organizing different sensorimotor systems at birth are provided by research on head orientation to sounds (Clifton, Morrongiello, Kulig, & Dowd, 1981) and pre-reaching behavior in very young infants (Bower, Broughton, & Moore, 1972; Trévarthen, 1984; von Hofsten, 1982).

In general, these observations suggest that the control of early behavior is relative to a broad intermodal organization orchestrating the early sensorimotor repertoire. They support a molar view of infant action that must be approached as constrained by complex motor synergies and multiple connections among sensorimotor modalities (Bullinger, 1983; Thelen & Fogel, 1986).

From birth, infants display various body postures (Peiper, 1962). These postures reflect different internal and emotional states, as well as an adaptation to physical properties of the environment (Prechtl & Beintema, 1964; Wallon, 1942/1970). Within hours after birth, infants adjust their posture according to the regularities of the environmental circumstances they experience. Alegria and Noirot (1982) have shown that within the first three feeding sessions following birth, neonates orient their mouthing in the direction of a human voice. Furthermore, these authors report that breast-fed newborns orient their mouthing toward the right or left, depending on the source of a voice, whereas the bottle-fed infants orient their mouthing essentially in accordance with the usual location of the caretaker holding them during feeding.

To further assess the precocious integration between posture and oral response in the neonate, we conducted a study in which non-nutritive sucking rate was assessed in relation to two independent measures: head orientation and previous feeding experience (breast or bottle; Bullinger & Rochat, 1984). Two empirical questions guided this study. The first was whether newborn sucking response varied according to head orientation. The second was whether the potential head orientation effect depended on the type of previous feeding experience that imposed either unique head orientation to the infant (bottle-feeding) or alternating head orientation (breast-feeding). A group of 24 full-term healthy newborns with a postnatal age range from 44 to 94 hours were tested. Half were breast-fed and half were bottle-fed 2 to 3 hours before testing. A standard-bottle rubber nipple connected to an air pressure transducer allowed polygraphic recording of the negative pressure variations applied to the nipple. Neonates were securely seated in a 45° reclined infant seat facing a white circular background. The experimenter stood behind the seated infant and introduced the nipple into the infant's mouth for five successive trials of 1 min each. The trials consisted of one baseline trial, followed by three experimental trials, then followed by one more baseline trial. At the beginning of each trial, the experimenter changed and stabilized the infant's head in one particular orientation relative to its torso, following an assigned experimental order. The first and last trials served as baselines to assess the stability of response across testing. Head orientation was the same for the two baselines, and was systematically changed (right, left, center) during test trials.

Initial results showed an overall effect of head orientation on the rate of sucking. In general, the newborns tended to show a decrease in the rate of sucking response when their heads were oriented to the left. When we analyzed the data for the breast-fed and bottle-fed infants separately, however, the results indicated a decrease in sucking in the left head orientation only for the bottle-fed infants. Further analyses revealed that of the 12 bottle-fed infants, 8 sucked maximally with their heads oriented at center, and 4 sucked most with their heads oriented to the right, whereas none favored the left orientation. By contrast, 3 breast-fed infants showed maximum rate of sucking with their heads oriented to the right, 3 did so with a left orientation, and 6 sucked most rate with their heads centered. This observation suggests a bias toward the center and right head orientation for the group of bottle-fed infants only. A right and center head orientation corresponds to what bottle-fed infants experienced during the few feeding sessions they had had, assuming that the caretaker held the bottle with the right hand (as most would be expected to do).

In summary, these results indicate that, from birth, there is an interaction between posture and sucking as part of an overall body engagement. Analogous to the observations reported by Alegria and Noirot (1982), sucking engagement moments after birth is shaped by first feeding experiences, with each newborn picking up the postural invariants attached to the particular circumstances of his or her feeding.

From a theoretical point of view, an important feature of infant behavior at the onset of development is an overall or synergistic bodily engagement (Bullinger, 1981). This account of global (undifferentiated) behavioral engagement in the neonate is common in classic Francophone views on development. Newborns are described as experiencing their body as a totality (de Ajuriaguerra, 1969). Wallon (1985) suggested that early synergistic mobilization is at the origin of the progressive emergence of skilled action, and Piaget (1936/1952) described newborn behavior as "a total reaction of the individual" (p. 27). In support of this view, the observations just reported demonstrate the relation between posture and sucking. Further support can be found in the recent findings of Buka and Lipsitt (1991), who showed that the rate and strength of non-nutritive sucking coincides with the synchronous variations in grasping, breathing, and cardiac activities. Bullinger (1991) proposed that this synergistic engagement provides redundancies and functional regularities among the various sensorimotor systems. He suggested that at the beginning of development, the gleaning of these functional invariants orients infant behavior and feeds action schemes. Bullinger (1983) argued that as development progresses, infants' behavior shows a decrease in synergies; these are replaced by ways of functioning that are differentiated and spatially oriented.

POSTURE AND VISUAL EXPLORATION IN YOUNG INFANTS

The interdependence of posture and vision is evident immediately after birth, when neonates start to move their eyes and show their first visual responses to the world. Immediately after birth, when ambient light hits the neonate's retina, ocular motricity is highly perturbed. In the dark, or in a dimly illuminated environment, neonates reveal organized oculomotricity and saccades covering large portions of the visual field, corresponding to ambient exploration (Haith, 1980). Ambient exploration becomes focal when newborns encounter contrast to look at, focusing on the edges of two-dimensional configurations presented to them. Newborns' visual activity shows orientation and appears readily coordinated with audition. Haith has demonstrated that in the dark, newborns tend to orient their ocular saccades in the direction of an invisible sound source. A few days after birth, the perturbation manifested in the light diminishes, and they start to systematically track objects, and show ambient and focal exploration of configurations' edges, somehow attracted by the zones of sharp contrast in the

stimuli. This attraction and basic orientation of early visual exploration has been interpreted as the expression of mechanisms that yield maximum cortical stimulation (Bullinger, 1991; Haith, 1980). Once the eyes of the newborn are focused on one defined zone, focal exploration occurs in small-amplitude saccades that cross back and forth over the edge of the configuration, optimizing cortical stimulation. These observations indicate that from birth, visual response is not random, but rather organized, oriented, and attuned to particular aspects of the optical environment. Again, a basic constraint on the expression of this precocious visual functioning is the control of posture. The developmental account of young infants' postural engagement while tracking a visual target moving in front of them demonstrates this point (Bullinger, 1977, 1981, 1989).

The overall body postures adopted by young infants when visually tracking and exploring a visual event or configuration can be either symmetrical or asymmetrical. Casaer (1979) described the Asymmetric Tonic Neck Posture (ATNP) as a privileged postural state in which the young infant appears focused and oriented as regards the physical and human environment. Bullinger (1991) observed that in this posture, the young infant's gaze is more stable, and the extended hand, facing the infant sideways, offers a privileged target for visual exploration. Bullinger also noted that when the newborn is seated in a symmetrical posture, head aligned at center, head control is reduced, and the infant appears to huddle up, showing increased oral activity, such as spitting and tongue protrusion. Breathing appears to accelerate and is sometimes blocked for prolonged periods, providing a temporary "pneumatic" tonic state that compensates for the lack of postural support and control.

Asymmetrical postures, by contrast, anchor the young infant, providing stability and bearing points from which progress in the integration of posture and visual action can take place. When infants are solicited to change posture as they track a visual target, an interesting development is observed. Immediately after birth, it is the postural state in which infants find themselves that determines the spatial limits of their tracking. When the object exits the portion of the visual field the infant can attend to, he or she tends to wedge back to the stable and asymmetrical posture he or she was in at the beginning of the tracking motion. Once stabilized in this original posture, the infant appears to engage in intense visual scanning, although no objects are present in the visual field. Posture is not yet totally enslaved to visual events, which explains why caretakers often place themselves in particular locations of the infant's visual field to facilitate stimulation and social interaction.

As development unfolds, vision plays an increased role in determining postural adjustments, and in "shaping" the infant's overall body posture (Wallon, 1970). By the 2nd month, the whole body posture is associated with visual tracking activities. The various postures adopted by the infant are now strictly dependent on the spatial location of the visual target. When the target-object is in the left hemifield and the infant is sitting in a well-supporting seat, the infant's trunk tends to lean to the right with his or her head turned to the left. Movement of the target-object toward the right hemifield causes the infant to move into the reverse posture (leaning to the left with the head turned to the right). At this age, visual tracking is accompanied by a phasic opposition in the lateral movements of the trunk and the moving target-object. At the extreme locations in the right- or left-hemifield of the target-object, the infant manifests asymmetrical posture in the form of ATNP (Bullinger, 1989).

By 3 months, visual tracking by the infant appears to mobilize essentially head movements only, the stabilized trunk becoming the bearing point of the overall visual pursuit. The upper limbs do not participate anymore in the visual tracking, and this progress sets the hands free to capture and manipulate objects.

An important aspect of these developmental observations is the fact that at early stages, infants manifest difficulties in attending visually and stabilizing posturally the median portion of the visual field. When tracking an object, the young infant shows instability of posture and destabilization of gazing while moving through the median plane. This instability and destabilization is present until the infant masters the dissociation of head and trunk movements (A. Roucoux, Culée, & M. Roucoux, 1983). Bullinger (1991) has proposed that this dissociation is an important prerequisite for the development of eye–hand coordination, described extensively in the infancy literature.

The interaction between posture and vision in early development is evident in observations demonstrating that changes in the head posture of the young infant has a significant impact on the mapping of his or her visual space. Bullinger and Jouen (1983) showed that babies aged 10 and 20 weeks demonstrate a differential sensibility for peripheral detection when they are placed with the head at midline, or with it turned 45° to the right or 45° to the left relative to the shoulder line. According to the procedure that was used, in each posture the infants fixated one point at the center of their visual field for each particular posture, in which they were placed. Once the baby was staring at the central fixation point, a mobile was moved from either the right or the left periphery of the visual field starting at about 135°, and moving toward the center. The dependent measure used to assess peripheral detection was the moment the infants stopped fixating at the center point and made the first saccade in the direction of the mobile. In general, the results showed that the field of peripheral detection expands with age. Furthermore, the younger group of infants showed that, although their overall field of peripheral detection was reduced compared to the older infants (approximately 50°, compared to approximately 60°), the left and right hemifields were homogeneous in all three postural conditions. By contrast, when the older infants were placed in either the left or center head posture, their field of peripheral detection was biased to favor the right hemifield (i.e., higher detection when the target-object was coming from the right). In the right head posture, like in the younger infants, they showed homogeneity between the left and right hemifields. This differential effect of posture on peripheral detection in 10- and 20-week-old infants was interpreted by Bullinger and Jouen as the expression of emerging laterality, as the visual field of the infant was becoming progressively calibrated in reference to the dominant hand to determine the perceived limits of the visual periphery. Accordingly, this would account for the right-hemifield bias that older infants manifest in their peripheral detection.

If posture interacts with focal vision and in particular with the ability of the infant to track objects in the environment, there is also good evidence that sensitivity to peripheral visual flux controls for postural adjustment in the young infant and even the newborn (Butterworth & Hicks, 1977; Jouen, 1984). From an early age, presentation of a flux at the periphery of the visual field causes tonic responses and postural adjustment of the infant's head and trunk. Peripheral vision contributes from the onset of development to the control of posture. It plays a crucial role in orienting the infant and in allowing it to adaptively tense the overall body in response to various events, such as the self-motion of perceived self-acceleration and -deceleration. From the onset of development, peripheral vision plays an important role in the regulation of posture and contributes to the emergence and control of basic skills, such as visually guided reaching, control of head movements in tracking, control of sitting and standing posture, and eventually of locomotion (Bullinger, 1991).

In summary, from the earliest age, posture plays a role in the determination of visual behavior, and vision appears to be linked to the control of posture. Recent observations on reaching in infancy and on the relation of this basic action to postural development, further illustrate the functional link between posture and action early in development.

POSTURE AND REACHING IN INFANCY

As mentioned, from birth infants demonstrate propensities to bring the hand in contact with objects in the environment (Trevarthen, 1974; von Hofsten, 1982). By 4 months, infants start to reach systematically and successfully to objects presented in their space of prehension (White, Castle, & Held, 1964). They continue to develop their ability to reach during the first year, demonstrating increased anticipation (von Hofsten & Ronnqvist, 1988), and the ability to use cues other than visual to guide their hands successfully toward an object in the dark (Clifton, Rochat, Litovsky, & Perris, 1991). Parallel to this well-documented development, the end of the first trimester is marked by a major achievement of sensorimotor development, the first conquest of verticality expressed by the emergence of the *self-sitting posture* (at about 6 months, according to the Bayley motor scale).

The emergence of self-sitting, together with the ability to generate lateral and rotation movements of the trunk without losing balance, marks the beginning of what André-Thomas and de Ajuriaguerra (1948) called the construction of a *bodily axis*, which allows upper limbs and hands to explore and manipulate objects, freed from having to maintain posture and balance. Around the time infants develop a self-sitting ability, they also appear to develop fine haptic exploration of objects and differential functioning of the hands (i.e., fingering, Rochat, 1989). The numerous mainstream studies on early eye–hand coordination have overlooked this important aspect of development and, in particular, three important components of infant reaching: (a) postural development, (b) coordination between the hands, and (c) coordination of the upper limbs and trunk (Rochat & Senders, 1991).

In a recent series of studies, we investigated further the impact of emerging self-sitting ability on the development, at about 6 months, of infant reaching and object manipulation (Rochat, 1992; Rochat & Goubet, 1993). This research effort was aimed at broadening the study of early eye–hand coordination in the context of dynamic posture. In particular, infant reaching and its development were approached as an overall body engagement, including the relative coordination of arm, hand, and torso movements during the reach act.

The particular aim of a first study was to document the relative coordination between hands in infant reaching as a function of postural condition, and self-sitting ability (Rochat, 1992). In this study, two groups of 5- to 8-month-old infants, either able to sit (sitters) or yet unable to sit on their own (non-sitters) were videotaped while reaching for objects in four different posture conditions that provided the infants with varying amounts of body support: seated, reclining, prone, and supine. The approach phase of the hands before their first contact with the object was microanalyzed. In particular, the relative alignment of the hands in relation to the object, as well as changes in distance between the hands as they approached the object were computed in a series of frame-by-frame analyses. These analyses revealed a clear difference in the type of manual engagement of non-sitter and sitter infants as they reach for the object. In general, non-sitter infants tended to reach with both hands forward, demonstrating synergistic movements of the hands toward midline, in what was tentatively typified as a "crabbing" motion of the upper limbs. This clearly synergistic and symmetrical bimanual reach was expressed predominantly in the well-supported postural conditions (reclining, supine, and prone), but not when non-sitters were placed in the upright seated-posture condition. In this latter condition, infants were constrained to reach with one hand forward to prevent falling forward. In the seated condition, non-sitter infants typically reached with one hand and tended to throw the other one backward to maintain balance and counteract the forward weight shift.

These results indicate that non-sitter infants are highly dependent on the postural conditions that determine their overall body engagement in reaching. In particular, although young infants appear to be inclined to reach for objects first with both hands forward, in less stable conditions they are forced to change their pattern of action to avoid the risk of falling to the ground. This result illustrates a potentially important feature of the impact of postural immaturity and postural development as a factor in behavioral changes in infancy. Regarding the group of sitter infants, 80% of their reaches were one-handed in all postural conditions. These results indicate that posture is an important factor in determining the morphology of reaching in the non-sitters but not in the sitter infants, who manifested increased posture independence.

It appears that with growing control over self-sitting ability, infants become one-handed reachers, regardless of posture. From a developmental perspective, these results also suggest that postural development might play an important role in breaking the original symmetrical and synergistic use of the hands in reaching, contributing to the emergence of a more differentiated functioning of the hands (Rochat, 1989; Rochat & Senders, 1991). It is interesting to note that a transition from a bimanual to a unimanual organization is not specific to the reach act. A developmental analysis shows an analogous progression in the movement of an object to the mouth by 2- to 5-month-old infants (Rochat, 1993; Rochat & Senders, 1991). This transition may be a general feature of early action development.

In another study, a group of sitter and non-sitter infants were compared for their overall body engagement in reaching. In particular, the coordination among the hand(s), arm(s), and trunk in reaching was assessed and compared between sitters and non-sitters (Rochat & Goubet, 1993; Rochat & Senders, 1990). Infants were placed in an upright infant seat resting on a platform supported by a central axle, allowing movement in the forward and backward direction relative to the infant (as in a seesaw). The movement was constrained by two spring scales, one placed under each end of the platform. After appropriate calibration, this simple device allowed each shift of the infant's center of gravity to be translated into weight gain observable on the forward scale supporting the platform. In this study, frame-by-frame scoring was aimed at the *co-analysis* of center-of-gravity shifts and movements of the upper limbs during the approach phase of infants' reaching (i.e., changes in weight shift, nose-to-object distance, and hand(s)-to-object distance during the 2 sec preceding contact with the object, at a rate of 5 images/sec). In general, results illustrate striking differences in the reaching of non-sitter and sitter infants. The majority of non-sitters (10 of 12), showed an independence between the reaching of the hand and the leaning of the trunk. By contrast, half of the sitter infants (6 of 12) showed remarkable coordination between the trunk and hand(s) in reaching. Analyses of individual reaches showed that, typically, the reaching hands of non-sitter infants move independently of any trunk movement. Their reaches appear to engage the hands and upper limbs, but not the trunk (i.e., there was no shifting of weight, and no reduction of nose-to-object distance). By contrast, the approach phase of half the sitter infants demonstrates a remarkable coordination of reaching and leaning. These sitter infants manifest an unmistakable coordinating (synergistic) action of upperlimbs and trunk. Further statistical analyses comparing values of the different measures, 2 sec prior to contact with the object and at the moment of contact, confirm these results (Rochat & Goubet, 1993).

In a follow-up study (Rochat & Goubet, 1993), a group of non-sitter infants were tested using the same procedure and allowing the co-analyses of upper-limb(s) and trunk movements in reaching. Non-sitter infants were provided with varying amount of hip support while sitting. Inflatable cushions were placed on each of the infants' sides, at hip level. These cushions were connected to a hand pump and a manometer allowing systematic control of the pressure applied on the infants' hips. Infants were filmed while reaching with no pressure applied on their hips, with medium pressure (20 mmHg) and with high pressure (40 mmHg). The rationale behind this design and procedure was to simulate in non-sitter infants the kind of support they will self-generate when they are able to sit on their own. In particular, the question was whether providing hip support would make non-sitter infants reach like sitter infants in coordinating movements of the upperlimbs and trunk. Results confirmed that non-sitter infants do indeed tend to resemble sitter infants in engaging their trunk while reaching as a function of increased hip support. This study demonstrates that the coordination between reaching and leaning is controlled by postural support provided to the non-sitter infant. External body support is potentially a releaser of complex and organized action in the young infant. These results are congruent with the clinical observations reported by Amiel-Tison and Grenier (1986), demonstrating pre-reaching activity and enhanced attention in seated newborns provided with neck support.

The same study also illustrates the freeing of the upper limbs and hands associated with the emergence of self-sitting ability at around 6 months of age. It demonstrates the potential changes in the interaction between the infant and the environment as a function of landmark progress in postural development. Specifically, emerging sitting ability is shown to be accompanied by drastic changes in infants' hand use as they reach, grasp, and explore objects. In this study, 5- to 7-month-old infants were presented with a display of 15 attractive balls attached to a curved board that paved the infant's prehensile space. The center of the board was aligned with the infant's shoulders, the infant sitting in a well-supporting upright infant seat. The experimenter presented the board to a distance of 30 cm in front of the infant for free play with the detachable balls. Three groups of infants were tested. A group of 10 non-sitters, a group of 10 sitters, and a group of 10 "near-sitters" who could sit on their own for up to 30 sec but only while leaning forward with their hands on the floor or leaning against their legs. Analyses of the free interaction of the infants with the display and successive reaches to the balls showed a clearly different pattern of hand use among the groups of infants. Infants demonstrated an expansion of their prehensile space and increased balance in the use of hands as a function of increasing sitting ability. In particular, analysis of the first ball touched by the infant indicates that non-sitter infants tended preferentially to contact balls that were at the center of the board, whereas near-sitters and sitters expanded their first contact with balls that were increasingly at the periphery of the board. Analysis of hand-use in contacting the balls on the display indicated that non-sitter infants used predominantly one hand (i.e., the majority the right hand), crossing midline if necessary to contact a contralateral ball.

Because of their lack of postural control, non-sitters tended to lean against the side of the seat, constraining one of the hands. In general, they showed more crossing of midline with the contralateral hand. By contrast, near-sitter and sitter infants appeared straighter in their seats. This verticality is accompanied by an equally distributed use of right and left hand to contact ipsilateral balls on the board. Bruner (1973) described the "invisible midline barrier" demonstrated by 7-month-old infants, who tend not to cross the midline of prehensile space with the contralateral hand. He viewed this phenomenon as a sign of a differential functioning of the hands, each becoming specialized in attending the ipsilateral hemifield of prehensile space. Our observations suggest that postural development has a role to play in the emergence of this phenomenon, illustrating some of the consequences of the constitution of the bodily axis and its impact on the infant's manual action (André-Thomas & de Ajuriaguerra, 1948).

POSTURE, FUNCTIONAL ACTION, AND THE INFANT'S ECOLOGICAL SELF

Overall, the observations reported here demonstrate that posture is an important control variable in early development and in the expression of functional action in infancy. They demonstrate the functional link between posture and action at the origin of development. Newborns are shown to suck preferentially in postures that correspond to their first few feeding experiences. Peripheral detection and visual tracking by young infants depend on their posture and the relative degree of postural control they have achieved. The development of self-sitting is accompanied by important changes in overall body engagement in reaching, as well as in the morphology of object manipulation and exploration.

In these observations, posture is treated as an independent variable, measuring its effects on the expression of functional action in early development. This does not mean that the functional link between posture and action in infancy is exclusively a one-way phenomenon. Evidence shows that young infants, even before they can sit and locomote, demonstrate postural adjustments when presented with peripheral optic flow (Butterworth & Hicks, 1977; Jouen, 1984) and objects looming toward them (Ball & Tronick, 1971; Caroll & Gibson, 1981). At the level of exploration, 5- to 6-month-old infants presented with a sounding object in the dark, were reported to perform large trunk and head movements in an apparent effort to localize the object in auditory space (Clifton, Perris, & Bullinger, 1991). In all, these observations demonstrate that from the outset of development, posture and functional action are mutually dependent and interact with one another.

From birth, the function attached to posture is not merely reducible to global bodily adjustments or anti-gravitational reactions. Indeed, when neonates and young infants manifest postural changes, it is not simply in response to perturbation but is also to orient, position, and direct their perceptual systems in ongoing interactions with objects, people, or events in the environment. The anti-gravitational and directional positioning (i.e., orienting) functions attached to the postural system (Paillard, 1971) are manifest from birth. The orienting function attached to the neonate's postural system underlies the necessity of considering posture, perception, and action as inseparable phenomena.

From birth, posture is dynamic and an integral part of the perception–action cycle. Postural development and postural constraints attached to the infancy period have to be understood within this context. Infants manifest from an early age remarkable perceptual and cognitive abilities (E. J. Gibson & Spelke, 1983; Spelke, 1991), but future development of these abilities, and the development of functional action in particular, is linked to progress in the development of posture. The sensorimotor systems newborns are equipped with—including visual, auditory, haptic, and vestibular systems—are functioning and attuned to particular features of the environment. Neonatal behavior is best described as a global engagement, in the sense that from the start of development the various sensorimotor systems are organized to function in synergy (Bullinger, 1981).

Furthermore, a central aspect of this organization that has been extensively demonstrated in recent years, is the fact that newborn behavioral organization is pre-oriented and attuned. Newborns, for example, demonstrate preference for their mothers' voice over that of a female stranger, and in general prefer high-pitched over low-pitched speech contours (De Casper & Spence, 1991). They prefer sharp visual contrast and dynamic displays over less contrasted and static visual configurations (Haith, 1980). They show a robust propensity to recover visual interest to a display that contains novelty (Fantz, 1963). These propensities have been fruitfully exploited by students of infancy to unveil precocious perceptual and cognitive competencies.

The newborn's synergistic functioning and the orientation and attunement of this functioning to particular features of the environment are sources of redundant information from which infants can extract invariants. Take, for example, a newborn laying supine in her bassinet, with eyes open and head oriented to the left. This infant hears a sound to her right and turns her head in that direction. This behavior has been extensively demonstrated only hours after birth (Clifton et al., 1981; Muir & Field, 1979; Weiss, Zelazo, & Swain, 1988). This action, which is accurately oriented in space, provides the infant with a complex covariation in the parameters of vestibular, tactile, proprioceptive, visual, and auditory stimulation. Furthermore, this covariation occurs in relation to an identical event in the environment: a particular sound with a particular address in space. Suppose, now, that the sound the baby heard came from a novel colorful music box that was placed on the right side of the bassinet. This covariation would result in a reinforcing visual consequence, eventually enhancing the probability of its repetition.

This simple example illustrates that the original synergistic nature of sensorimotor functioning, when combined with the rudimentary attunement of this organization to particular features of the environment, is a sufficient condition for providing the infant with regularities, invariants, and information about addresses in space. Recent studies with infants suggest an analogous role of invariant structure in perception and in the control of movement. Neisser (1985) proposed that infants are born with the ability to detect amodal invariants he characterized as "abstract spatio-temporal structures that can be embodied in more than one kind of stimulation" (p. 107). If Neisser is correct, then the interaction between the various sensorimotor systems and particular environmental events must indeed constitute the primary source of the rapid progress characterizing early development in general, and, early perception, cognition, and the development of skilled actions, in particular.

The act of perceiving the environment provides information that specifies both the environment and the observer that scans this environment (J. J. Gibson, 1979). When visually tracking a moving target, or when orienting to a sound, young infants learn as much about their body and what it affords for action as they learn about the environmental event that causes them to move. Bullinger (1981) proposed that the body of the infant is an object to be known, like any other object in the environment. By perceiving and acting, infants construct representations, or *schemata*, of their body that enable them to accomplish complex acts requiring great precision and anticipation. Neisser (1991) proposed that, based on information specifying directly their immediate situation in the environment, infants form what he called an *ecological self*. The ecological self is based on self-perception and the information specifying the point of observation of an observer. It pertains to how an observer perceives himself or herself while interacting with the environment. Research shows, for example, that from birth, infants are capable of manipulating their sucking responses to enhance a visual stimulus (Siqueland & DeLucia, 1969) or to trigger a particular voice or speech sound (DeCasper & Fifer, 1980; Eimas, 1982). This precocious ability to recognize the perceptual consequences of their own actions is part of the ecological self infants construct early in development.

CONCLUSION

Based on the observations presented in this chapter, the ecological self of the infant should not be restricted to the knowledge infants have of their immediate situation in the environment. The ecological self must also include knowledge about the resources of the environment and the resources of the body and what they afford for functional action at a particular moment of development (i.e., called the body's *efficiencies*). This knowledge about the body's efficiencies must be constantly revised in the course of perceptual, postural, and action development, as infants start to reach, roll, crawl, sit, and locomote. Postural development is an important determinant of the ecological self. Prior to the development of self-sitting and the construction of a bodily axis as a referential system for the organization of functional action infants adopt postures shaped by preadapted tonic bodily configurations, such as the ATNP described by Casaer (1979). These postures are biologically determined and serve as the original bearings used by neonates and young infants to perform actions, such as visual tracking. By the 3rd month, infants develop actions that are scaffolded by a bodily axis emerging from postural development and viewed as actively constructed by the infant (Bullinger, 1981).

This conceptualization has proved to be useful in early clinical interventions and in establishing new therapeutics for various sensorimotor handicaps (Bullinger, 1992). For example, tonic mobilization is enhanced in hypotonic infants by stimulating their right or left visual hemifield. Such lateral stimulations have shown to stimulate interactions between these infants and their environment, fostering major development. Systematic postural manipulation and efforts to provide infants with bodily support is used successfully for the tonic mobilization of hypotonic infants. Without these supports and manipulations, these infants fall back in a median posture in which they collapse forward in their seat, generating actions that revolve exclusively around the mouth. The success of such clinical interventions illustrate further the importance of posture and its relation to functional action. Posture is indeed the necessary scaffolding of early functional action.

Thus, the observations presented in this chapter demonstrate that posture, perception, and functional action form three inseparable phenomena. Their interaction needs to be viewed as a primary determinant of infant behavior and development.

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3 Pattern and Face Recognition in Infancy: Do Both Hemispheres Perceive Objects in the Same Way?

Scania de Schonen
Christine Deruelle
Laboratoire de Neurosciences Cognitives—CNRS

The various neural networks of the infant brain do not all become functional at the same rate. Some parts of the brain begin to function before birth, and others later on. Investigating the relationships between emerging behaviors and maturational neural events can, therefore, be most instructive. In some respects, this approach to the neural basis of behavior, despite some methodological difficulties, is similar to the neuropsychological approach to adult patients with brain lesions. The double dissociations between emerging behaviors and neural maturational events correspond to the double dissociations studied in adult patients between the localization of lesions and between behavioral deficits. It has become obvious however, that the emergence of a new cognitive ability in an infant cannot be accounted for simply by the functional onset of action of a group of neurons that has remained silent up to that point. Other kinds of neural events very similar or even identical to those underlying adult learning processes are probably involved in the developmental mechanisms. Discovering how learning mechanisms and neural maturation cooperate and are correlated with age-related behavioral changes is the main aim of this developmental approach.

Generally speaking, there exist many different ways of conceiving of the type of filiation between two behaviors that emerge successively in the course of an infant's development. We lack the necessary criteria, however, for deciding whether or not the emergence of a particular competence at a given age depends on the prior acquisition of another type of behavior acting as an "ancestor" (Bresson, 1976; Bresson & de Schonen, 1979). One of the ways of determining the possible filiation between two successively emerging competencies consists of examining the neuronal events correlated with the behavioral acquisitions in question. If the emergence of the latter of the two behaviors requires the matura-