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Movement and communication in human infancy: The social dynamics of development *

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Abstract

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The purpose of this article is to bridge the fields of movement science and developmental psychology. Movement science offers a perspective on motor skill that has potential application in the understanding of developmental change. Developmental psychology offers a number of theoretical perspectives on the role of the social context in development that may enhance the understanding of how movements are developed. This paper proposes a theory of human development in which comunication and movement are essential components. The theory proposed here contributes both to movement science and to developmental psychology by hypothesizing specific ways in which the interface between movement dynamics and sociocultural information can induce developmental change.

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1. Introduction

Communication between adults and children is widely recognized as the primary site for the development of specifically human forms of cognition and action (Bruner 1983; Butterworth 1981; Kaye 1982; Papoušek and Papoušek 1984; Vygotsky 1978). Children's movements and postures are regulated by the process of communication with adults, as when adults guide children in the acquisition of culturally organized behaviors such as writing or athletics. Conversely, communication itself is comprised of a series of movements and postures that have specific meanings to participants in discourse.

Developmental research has documented dramatic changes in the movements used in communication by infants during the first two years of life: Starting from newborn facial expressions, cries and spontaneous limb movements, and continuing through achievements like complex emotional expressions, offering and requesting, and conventional speech. From early on adults are implicated in the regulation of infant state and emotion, infants' transactions with objects, postural control and locomotion, and an ever-widening range of task-oriented infant actions.

The purpose of this paper is to examine how developmentalists have conceptualized the ways in which infant movement partakes of the social context as a factor in developmental change. The social context of action development has been relatively neglected in the movement sciences, with notable exceptions (Hinde 1977; Hopkins and Westra 1988; Trevarthen 1986; Whiting 1988). Most human developmentalists, however, take for granted that the social context is essential for understanding the development of action in early childhood. Without adults (or older children), the youngest infants would be capable of virtually no adaptive activity. Adults are required to bring infants into contact with the substances and surfaces that facilitate movement, and to help support the postures and stances that allow movements to unfold. As children become older, adults serve as guides to culturally appropriate forms of movement.

Certainly, the development of movements like walking can be studied without reference to the social context (cf. Thelen 1989). However, the dynamics of leg alternation under different physical contextual conditions is not the whole story. Walking is acquired in social contexts that provide postural supports as well as encourage-

ment and discouragement (Benson 1990; Clark 1990). Walking is subject to social constraints, such as when a child should remain still or is permitted to move about. Walking is limited to socially sanctioned areas such as cross-walks. Finally, only certain styles of walking or running may be allowed, such as walking quickly or quietly in the home or school, etc.

One goal of this paper is to suggest that the development of even highly stereotyped forms of rhythmical movements like walking, as well as sophisticated communicative gestures like words, require a theoretical model that integrates socially communicated information into the otherwise purely physical parameters of movement. Because walking is a cultural activity from the start – that is, it is acquired in social contexts and subject to social supports and contraints – we have to understand how social information gets integrated into the perception–action coupling to modulate and socialize the movement patterns. Simple models of social reinforcement, modelling and imitation are not: as I intend to show, sufficient to explain the data.

Another goal of this paper is to provide a brief tutorial in social developmental theory for students of human movement. I will first attempt to characterize the main theoretical positions as applied to the process of developmental change of movements via social interaction. I group the field into three theoretical positions: schematic interactionism, sociocultural interactionism and dynamic interactionism. Each position has both strengths and limitations, and I propose a theoretical model that combines aspects of each. Finally, I draw on examples from my own work to illustrate this approach. As in any ongoing theoretical discourse, the boundaries between opposing views are never as clear or sharp as our characterizations of them. I presume that the commentators will want to redraw those boundaries in other ways.

2. Schematic, sociocultural and dynamic interactionism

2.1. Schematic interaction

Schemes are abstract representations of actions and thoughts. Depending on the individual theorist, schemes are believed to be partly genetically encoded (Piaget 1952), and supported by specific neural

structures (Trevarthen 1986). The concept of a scheme is meant to capture to regularities in the execution of identifiable movements and postures. In what I call here the schematic interactionist view, development takes place at the level of the schemes and not at the level of the movements. There are two processes that are thought to account for development of schemes. One process is that schemes are developed by maturation of the underlying neurological structures: axons, synapses and neurotransmitters. A second process is that experiences of the individual may modify the way in which actions and thoughts are represented schematically by that individual, within the limits of the individual's state of biological maturation.

For example, the onset of adult–infant face-to-face communication at around 2 and 1/2 months is believed to result from general processes of neural maturation that orchestrates the emergence of cognitive, perceptual, affective and motor components constituting the newly organized social skills of the infant (Papoušek and Papoušek 1984; Trevarthen 1977). Infants gain postural control over their head position around 2 months, and about the same time they also experience marked changes in their visual perception (acuity, convergence, and depth perception), cognitive organization (anticipation) and affective states (social smiling and the decline of neonatal fussiness). These abilities all seem to create the conditions for intense adult–infant face-to-face play – involving mutual exchanges of smiles, coos and gazes – and they are thought to spring from a common neural structural organizer.

The maturational timetable of these specific structural developments is justified by some with appeals to phylogenetic adaptedness (Trevarthen 1986; Izard and Malatesta 1987). Experience may influence the timing of emergence of each of these pathways, or experience may affect the facility with which those pathways are motivated and engaged in context. Examples are the neural structures believed to support each of the discrete facial expressions of emotion, movements such as directing gaze and head posture that underlie attentional processes, and speech motor development (Bates 1979; Derryberry and Rothbart 1984; Izard and Malatesta 1987; Stark 1981).

In some schematic interactionist views, the child must interact with the social and physical environment in order for schemes to develop (Piaget 1952; Papoušek and Papoušek 1984). However, since the schemes are the organizing factors in this theory, movements are

viewed as less important, as mere performance of some underlying competence represented by the scheme. It is a common practice in such work to regard scheme organization, i.e., cognition, as the developmental organizing force. Piaget (1952) for example, explained the development of visually guided reaching as the higher level coordination between schemes for hand movements and schemes for visual perception. In studies of speech and language development, researchers measure general cognitive functions – such as means–end knowledge or conceptual thinking – as predictors of the onset of new linguistic abilities, typically ignoring both the movement aspects of speech and the social context (Nelson et al. 1978).

How is social communication possible in a schematic interactionist perspective? Because the concept of representational schemes places responsibility for behavior and development in some structure within the individual, it is necessary to assume that both partners share species characteristic structures as well as a way of mutually coordinating like structures. The primary mechanisms for this coordination are *imitation* and what has been called *intuition*. Research has shown that adults are able both to match infant behavior, and create patterns of sound and movement that are especially appealing to infants, such as exaggerated facial and vocal displays. These abilities are collectively called 'intuitive parenting' (Papoušek and Papoušek 1984) because they are nearly universal in humans and because they occur often without explicit self-awareness on the part of the adults. Infants, for their part produce a surprisingly rich array of movements that are recognized by adults as socially significant, such as facial expressions similar to those of adults, hand movements and whole body configurations that can be interpreted as reflecting understandable internal states (Izard and Malatesta 1987; Papoušek and Papoušek 1984; Trevarthen 1986). Imitation and intuition provide the basis for an intersubjectivity by which relationships are started and develop.

How do schematic interactionists view developmental change in the social context? The basic mechanism of social influence is via mutual matching and reinforcement that may affect the timing of displays, the social significance of displays, and the inhibition vs. expression of displays (Izard and Malatesta 1987; Malatesta et al. 1989; Trevarthen 1977). In some views, intuitively generated movements on the part of the adult elicit specific actions in the child, which then lead to modification of the adult's behavior, and so on, to create a continu-

ously updated interactive matching (Papoušek and Papoušek 1984; Trevarthen 1986).

2.2. *Critique of schematic interaction*

A fundamental problem with schematic interaction stems from the assumption that both behavior and developmental change is based on the social matching of species characteristic structures. With respect to movements in real time, a considerable body of theory and research has raised important questions regarding the merit of abstract representational structures as a foundation for movement (cf. Van Wieringen 1986). Alternatives include dynamic systems approaches (cf. Kugler et al. 1980; Turvey 1990) and ecological perceptual approaches (cf. Reed 1988). I can best illustrate why the schematic assumption creates problems for a theory of development with some examples: social smiling and linguistic naming.

As mentioned above, schematic perspectives often rely on structures and their gradual change (either through maturation or through interaction) to account for the sequence of development of new actions. It is not actions themselves that develop, but rather the structures that underlie the actions. It becomes a difficult problem, then, to explain the richness and variability of movements. Studies in which individual facial movements are coded during smiling show that the smile configuration with mouth corners drawn back and raised can be created using different combinations of muscles. In other words, smiles that are perceptually similar to adult observers can be created in a variety of different ways, suggesting that the neural substrate for smiling must be relatively non-specific (Ekman and Friesen 1982; Fox and Davidson 1988; Manstead et al. 1984). Can schemes encode enough information to relate all these variants and alternative pathways?

Developmentally, smiles are assembled from an increasing number of facial muscles that add complexity of form and meaning. For example, a smile blended with a nose wrinkle and knit brows may signal puzzlement, while a smile blended with the inner brows raised may signal mischief (Demos 1982). Bared-teeth smiles are observed in 18-month-olds in the company of an attentive adult, but close-mouth smiles are more likely to occur when the child is alone with toys (Jones and Raag 1989). If we assume that schemes develop via an

interactive process, how does the scheme recognize that specific movement patterns should become allied with it at a later point in development? If the infant matches, say, the experience of smile with the observation of another's brow movements, this could be one process by which specific schemes become related to each other in development. On the other hand, it is hard to imagine that this process could account for all of the complex movement combinations that individuals develop. Similarly, if we believe that the primary process of schematic development is maturation, then whatever executive process that controls maturation needs to have a pre-existing 'slot' in which to integrate new information and new actions, especially those experienced in social situations. One would further have to hypothesize the existence of some schemes specifically tied to social processes and for receptivity to social information (Trevarthen 1986).

The notion of schemes as executive substrates for actions looks less attractive as we acquire more knowledge about the actual workings of genes and neurons. In contast to the notion of epigenetic schemes, new evidence from biology suggests that if something like genetic codes exist (the idea of a genetic code is a schematic notion), they are relatively non-specific. It appears from studies of embryological development, that there is not enough information in the genes to specify even the first few cell divisions. The genes encode very simple properties, such as sensitivity to concentrations of particular growth activators or inhibitors, but not the final form of the cell or organ. Thus, the substantiation of the genetic code into protoplasm requires the constant dynamic interaction of the developing embryo with its local cellular and extra-cellular environment (Antonelli 1985). Similarly, recent discoveries suggest that neurological circuitry is non-specific, that is, the brain does not encode all of the information necessary to move a limb, cry or say a word (Singer 1986; Skarda and Freeman 1987). Movements are realized as emergent outcomes when neurological structures interact with the effector systems available to the infant, and with the contextual supports provided in the environments in which the infant spends time.

The problem with schematic interaction is that it relies on the scheme to do the theoretical work of organizing movement and experience into developmental change, ignoring the details of the process by which this might occur. Schemes assimilate, accommodate, differentiate and integrate; they are activated and inhibited by envi-

ronmental contingencies. While this reflects a plausible metaphor for what we see in developmental change, it leaves us lacking in knowing how, when and why these changes occur in schemes. It would also be helpful to better understand the process by which adults intuit what they do in the company of children, simply because not all adults are equally intuitive and many infants and children send conflicting messages that are not intuitively decodable (Van Beek and Geerdink 1989; Vermeer et al. 1989). So long as we think of intuition and matching as an ability supported by some unspecified schematic metaphor, we will get no closer to understanding social process and development in social contexts.

The second example I will use to illustrate the problems with schematic interactionism is that of the development of linguistic naming. The use of conventionalized words to name objects occurs typically in the middle of the second year of life, well after the use of directed movements such as pointing and grasping to indicate an infant's interest in an object. For this reason, linguistic naming is thought to derive from mental representations of objects that become cognitively associated with conventionally used sound patterns. Schematic views of language emphasize the development of naming in social contexts in which adults make special efforts to isolate in the infant's visual perceptual field – through pointing, showing and offering – the object to which they are referring. These movement and word coordinations of the adult are thought to facilitate the emergence of naming in infants. Adults, however, are doing this sort of thing well before the infant can name, so why doesn't the infant pick up the skill earlier? Schematic theorists rely on the hypothetical maturation of symbolic representational skills in the infant. These representations prepare the infant to integrate the information coming from the adult. Development from a schematic perspective, therefore, involves the linking up of internal and external (i.e., social) strings of symbols to create adaptive information processing.

For readers not familiar with research on language development, one of the traditional indices of the age at which infants possess the schematic ability to represent symbols is the onset of pretend play. To pretend that a block is a car, for example, one has to divorce the actual block from its physical appearance and treat it as a symbol for something else. While it is generally true that pretend is necessary for naming, it is clearly not sufficient (Bates et al. 1975). Some children

who pretend can do so non-verbally and possess no ability to name (e.g., pretending a block is a car by moving it along the ground and making car-like noises). Clearly, representational ability is not enough to spur the onset of language: something else is needed.

McCune (1990) has recently discoved that linguistic naming only emerges after the child has acquired certain motor movements. First of all the child must have acquired what McCune calls 'vocal motor schemes (VMS)'. The VMS are defined as at least 10 observed instances of the child using the identical articulated consonantal syllable sound over a 3-month period. The VMS, therefore, is a tendency to make and repeat similar speech motor movements (we needn't assume the child has a scheme, but simply a preferred speech motor pattern). VMS plus pretend play are necessary, but still not sufficient. The final component necessary for the development of naming is also related to movement. Early in the first year infants will grunt while expending effort. By the middle of the first year, these effortful grunts become communicative, they express effort to others. Only after infants acquire communicative grunts, VMS and pretend play (in any order of acquisition), does naming emerge. One has to conclude that language is founded not only on cognition, but also on proprioception within the oral cavity, and the personally experienced linkage between self-produced sounds and self-produced action (in this case, grunting during effortful activity). Perhaps the grunting is the first situation in which the infant can associate self-produced sound with self-produced action, establishing the general concept that sounds can be related to actions, and can then be used communicatively.

With respect to language and other communicative uses of speech sounds, one can postulate a developmental sequence that emerges spontaneously from a set of simpler component processes (oral proprioception and movement, sound–movement associations, and symbolic representation), none of which carry an explicit prescription for language development. In the company of adults who further demonstrate to the child the linkages between sound and sense (in this case the sounds produced by others and meaningful infant actions), all of these processes conspire to make it highly likely for language to develop out of relatively simple experiences.

In summary, the development of schemes lacks sufficient theoretical precision to explain the ways in which movement develops and

becomes incorporated into communicative actions. The fact that communication involves the use of movement patterns for transmitting messages socially in no way requires us to place the explanation of developmental change entirely within social and cognitive psychology. It remains a fundamental theoretical challenge to show how emotions, motives and concepts are translated into movement that is communicative, and how communication enhances the development of movement. For example, once the child gets the idea that sounds can be used to communicate, it immediately leads to a rapid expansion of the speech motor repertoire and a further articulation of both sound and movement. Similarly, as smiles and other facial expressions are used communicatively, we see that the facial movements develop in scope and complexity. Manual and postural forms of communication (including gesturing, athletics, dancing, etc.) cannot be understood outside of this social-motor dynamic interchange. Schematic interaction – relying on maturation, and learning, or on differention and integration – is simply not up to the theoretical challenges presented by these social developmental phenomena.

2.3. Sociocultural interaction

Sociocultural interactionist approaches to human development are relatively silent regarding the constraints on development imposed by the physical task, and by neuromotor and genetic processes, focusing instead on the influence of sociocultural experience in shaping movement. These authors (Bruner 1983; Kaye 1982; Rogoff 1990; Vygotsky 1978) confine themselves to showing that particular forms of child development take place under particular forms of adult guidance. They study social interaction and developmental changes in social action, they hypothesize developmental change to arise in the social interactive process, but they typically do not examine the individual differences in outcome in relation to forms of guidance on the one hand, or in the biologically-based constraints in the child on the other hand.

Much of the work on sociocultural interaction is based on studies in which the development of culturally patterned skills are observed. Observers record parent–child or teacher–child interaction with individual dyads over time to study the process by which the child acquires complex skills and movements in the company of the adult. Examples

are Bruner's (1983) descriptions of the guided use of language and gesture during mother–infant social play, and Rogoff's (1990) presentations of the child's appropriation of tool use and cultural understanding by active participation with adult guides. These case descriptions are used to illustrate general processes by which information is exchanged and shared between adults and children. Another approach is to compare adult–child interaction with peer interactions (Heckhausen 1987; Rogoff et al. 1987; Ross and Lollis 1987). This comparison tends to highlight the specific features of guidance found in adult–child communication.

These studies show that adults do more than model, imitate and reinforce. First, adults provide supportive frames in which children can operate at a higher level of performance than if alone or with peers. For example, with infants, parents provide postural support that enhances alertness and helps to organize attention and movement. In the development of play routines involving complex movement patterns, parents start off by playing both roles in the game or by asking and answering their own questions. Gradually, as children acquire the necessary skills these supportive functions are taken over by the child in a process called 'uptake' (Bruner 1983) or 'appropriation' (Rogoff 1990). A related concept is Vygotsky's (1978) 'zone of proximal development', that refers to the fact that children and adults co-participate in activities that the child is in the process of mastering.

These concepts differ from imitation and learning in conceptually important ways. It is assumed by sociocultural interactionists that the child is motivated to perform some types of culturally available activities. The adult encourages this motivation by initially allowing the child to perform such action on his or her own and in whatever form the child can manage. For example, the child might produce idiosyncratic speech sounds that have no conventional meaning, which the adult interprets as meaningful. Or the child might want to 'walk', to 'cook', or to 'clean house', perhaps initially being more of a nuisance than a help. By using these initially rudimentary but motivated child actions, and creating a supportive frame in which the adult complements the child's skill and makes it meaningful, children come to identify those aspects of tasks that need to be mastered. Thus, the development of new movements comes out of the child's own activity and desire to achieve goals and also to be part of the culture of the family or school. Complex actions become appropriated through the

active organizing efforts of a motivated child in an adult-structured context, and not simply because of schematic maturation or adult modelling. The adult guidance must be precisely geared to highlight and support those aspects of the child's skill that need to be developed.

2.4. Critique of sociocultural interactionism

The main contribution of the sociocultural interaction view is the explicit inclusion of social processes into many aspects of human development. There is growing evidence that the ontogeny of even simple motor acts in infancy may not develop outside of the social context, and that the physical substrate that supports action (exteroception, stances, surfaces, and textures) is provided by the orchestration of adults (Fogel 1990a; Kaye 1982; Papoušek and Papoušek 1984). Prior to postural control, infants' bodies must be arranged vis-à-vis the environment in order for action synergies to emerge (Fivaz 1987; Thelen and Fogel 1989; Van Wulfften-Palthe and Hopkins 1984). Later, all forms of human movement development – not to mention social and cognitive development – are culturally mediated. Examples are reaching and object manipulation (Fogel 1990a; Lyra and Ferreira 1987), sitting and walking (Bril and Sabatier 1986; Hopkins and Westra 1988), climbing (Valsiner 1987), tool use (Bruner 1972; Rogoff 1990), and sexual behavior (Miller and Simon 1980).

Furthermore, sociocultural interactionism has gone a long way towards specifying the general properties of social interaction that support developmental change. These views have made us aware that the synergies of interest to human development are those observed in social interaction, rather than the action synergies of the decontextualized individual. The proponents of this view have worked hard to distinguish their ideas from historical roots in developmental social psychology: moving away from concepts such as socialization, internalization, imitation, reinforcement, and the like.

The concept of the motivated child who already adopts some rudimentary but organized ativity suggests, however, that sociocultural interaction relies on some prior organizing scheme into which children appropriate their own interpretation of the cultural practice. What might such a scheme look like? Kaye (1982) is one of the few

proponents of sociocultural interaction who makes an explicit attempt to reconcile scheme-based views with sociocultural views. Kaye makes schemes into open systems that incorporate part of the environment in order to function. Such schemes develop, according to Kaye, as new sub-routines are added in hierarchical and sequential fashion to existing sequential patterns. Bruner (1983) expresses a similar notion in his tree diagrams of social interaction in which he shows that social routines get established and repeat themselves; for example, a peek-a-boo game. In time, new routines are inserted into the interstices of games: the mother may say a word at the termination of an act like uncovering her face ('boo'). Later the infant inserts his or her own 'boo' in a similar place in her own sub-routine for uncovering.

Both Kaye and Bruner ignore a problematic theoretical issue in this developmental scenario. They have not provided an adequate explanation of where and how such social schemes are stored (schemes, by definition, are structurally encoded entities). Are social routines encoded in the mother? Kaye suggests that this might be the case, with his notion of the mother as the carrier of the dyad's 'shared memory'. That still leaves the problem of how and in what form these routines become internalized in the child. If the social schemes are simply transferred, albeit in small and guided chunks, from mother to child, that seems to reduce the problem to the co-imitation of similar schemes between individuals. We are thus back to the same problems encountered in the schematic interactionist perspective. Rogoff (Rogoff et al. 1987), on the other hand, denies the need for conceptualizing schemes as the basis for organizing individual action and social interaction. Rather, individuals can collaborate on a task, each playing different roles, without a clear understanding of either their own or the other's behavior. Clarification of one's goals and abilities, as well as specifying what needs to be done in the immediate future to improve the skill, emerges spontaneously through social discourse. Nevertheless, her model assumes that the adult has a more comprehensive view of the interaction than the child, so that the adult can structure the situation to make possible the child's spontaneous discovery. Adults need to have some form of representing a more skilled action that might be possible, for representing the not-yet-articulated goal of the child, and for breaking down the task into manageable elements. It would seem, therefore, that the adult is required to carry a representation of both current action and possible future develop-

ments of the action (although the representation need not be accessible in symbolic form).

If it is denied that the concept of scheme is being assumed, then how does the theory explain the organized patterning of social interaction (e.g., games or work routines), and the universal properties of adult guidance? Either one must assume some kind of organizing cognitive schemes, or one must provide a mechanism for how these social processes tend to converge in similar types of outcomes.

Another problem is that sociocultural theories often seem to apply to ideal, motivated guidance situations. With few exceptions, little attention is devoted to understanding individual variation. Nor does the theory apply directly to developmental change that occurs in other kinds of social situations that have nothing to do with guidance, e.g., disciplinary encounters, coercive interactions, and in more egalitarian relationships such as during play and friendship interactions (Fogel et al. in press-c; Gottman and Parker 1986; Lock 1980; Patterson and Bank 1989). A general theory of how the social context functions for development must encompass all types of social situations. Such a theory must also clearly articulate the ways in which perception–action couplings are capable of being modified in social contexts, and how information and symbols come to regulate the development of action. Although sociocultural interactionists have recognized the role of culture in the acquisition of action, with few exceptions (Valsiner 1987) they have not made explicit the links between social interaction and individual action in a way that explains – rather than simply describes or assumes – developmental change.

A related problem with the sociocultural perspective is that the origins of adult guidance are not explained. By some unspecified process adults intuit the child's needs and provide just the right kinds of supportive actions. One possible origin of adult guidance is the species characteristic intuitive behavior described by some authors (Papoušek and Papoušek 1984; Trevarthen 1986). As explained in the previous section on schematic interaction, this puts the problem of explanation into a structural black box. Adults could learn from other adults schemes for interacting with children, but the sociocultural theory is typically silent in this regard.

Some researchers have tried to explain cultural variations in parenting styles with respect to differences in beliefs, ecologies and social systems (Harkness and Super 1983; Hopkins and Westra 1988; LeVine

1977; West and King 1987). Perhaps the best example of this approach, in which the behavior of parents as well as children, is subject to interactive and environmental constraints and local variations in context is that of Goodnow (1988). These approaches may yet yield an understanding of the process of formation of individual and cultural differences in styles of guidance. Still, what is ultimately needed is an articulation of the theory of guidance to be able to better understand how adult guidance can be used effectively in a variety of intervention programs, for example, with premature infants or handicapped infants and children (Vermeer et al. 1989). Current theories of guidance are simply not specific enough to meet these applied needs (Beek and Geerdink 1989).

I propose, in the remainder of this paper, that adults' action, no less than children's, is constructed as part of a process of mutual dynamic interaction. Adult behavior is likely to be in a continuous state of adjustment in relation to the child's responses: not a mere response to the child's changes, but a dynamic co-construction of the support in the context of the activity.

2.5. Dynamic interaction

In this section I present the outlines of a theory of how communication facilitates the development of movement that is based neither on genetic preprogramming, the updating of schematic structure, nor the appropriation of whole routines and sub-routines of cultural activities. In this *dynamic interactionist* perspective, the development of movement arises out of (1) the identification and regulation of the those parameters whose changes affect the quality and quantity of movement, and (2) the identification of the information required to coordinate perception and action. Information is that which is needed to specify the relationship between the perceptual aspects of a task and the action parameters responsible for executing the movement (Turvey 1990).

If this dynamic view of perception and action is correct, *we should find developmental change arising in social interaction that converges toward a mutual co-regulation of either the movement control parameters or the informational requirements of the perception–action linkage, or both*. Interactions that focus on whole movement routines and their social transfer, or in which one individual controls the relevant param-

eters more than another, or in which action is not directly related to perception, are not likely to lead to developmental change. For example, when Gorillas interact with human caretakers, the Gorillas signal requests by grasping the human's hand and moving that hand to the object desired by the Gorilla: the animal seems to communicate by referring to a whole routine of action (Gomez 1990). This type of communicative act would rarely be seen in humans who would signal a request by a more abbreviated iconic gesture, such as holding the hand out, palm up, or by pointing to a desired object. The abbreviated gesture specifies information about the spatial location of an object, and it also allows for the localization and movement of the object in space to be jointly determined by both partners. Thus, there is room for development to occur either in the specificity of the signalling process, or in the specificity of the information communicated about the object or about one's desires regarding the object.

It is assumed that movements are assembled from components that are loosely linked, none of which carries an explicit code for the final macroscopic form of the movement. Movements are therefore self-organizing, emergent from the constraints imposed between the elements of the system as they interact with each other. Since no single component carries the instructions for the movement, and since the movement as a whole has no prior schematic encoding, the main organizer of the movement is the set of parameters linking together the elements of the task, and both the physical and informational aspects linking those elements with relevant aspects of the context. These assumptions follow directly from dynamic systems approaches to movement organization that were developed as a response to Bernstein's degrees of freedom problem (Singer 1986; Bernstein 1967; Kugler et al. 1980; Nicolis and Prigogine 1977; Skarda and Freeman 1987; Turvey 1990).

In earlier work, Esther Thelen and I suggested that adopting a dynamic systems perspective on movement leads to a re-conceptualization of how movements and actions change in developmental time (Fogel 1990a, Fogel 1990b; Fogel and Thelen 1987; Thelen 1989; Thelen and Fogel 1989). Essentially, the non-prescriptive and self-organizing conceptualization of sequences of movement was applied to sequences of change in development. We illustrated how a non-prescriptive self-organizing process could explain the development of walking and the development of expressive movements, without ap-

peals to genetic preprogramming of developmental pathways. In this paper, I continue a similar theoretical analysis in an attempt to explain the social embeddedness of human development, the cultural specificity of developing movements, and the role of communication in the development of movement.

2.6. Why is it necessary to have a dynamic theory of co-regulation?

It is not enough, theoretically, to say that partners jointly co-regulate each other's' behavior. This statement is too broad to constitute a viable theory of development. We can state the notion of co-regulation in more dynamic terms as follows.

(1) *The co-regulation has to converge on a location, an object, a movement parameter, or information that has some kind of recognizable significance for both individuals. This will either be a simple bodily state, or a directly experienced ecologically relevant affordance.* A related view is that shared meaning emerges from the co-regulated convergence of adults' and infants' perceptions of Gibsonian-like invariants in the physical environment, i.e., directly experienced perception–action affordances (Butterworth and Cochran 1980; Stern 1985). In research on the development of joint reference in pointing (how do adults and infants recognize that they are both pointing at the same or that when one points one means a particular object?), Butterworth and Grover (1988) found that infants behave as if space is shared because they can follow the direction of an adult's point even at 6 months. As they get older, infants appear to use information from the mutual orientation of own and adult's body and direction of point to correctly identify the specific target of the point at varying distances and within 45 degrees of visual angle. Thus, they can extract information from the local socially co-regulated visual field to locate objects in more distant space.

These views differ from schematic and sociocultural interactionism because they presume that development arises as a process of linking perception and action by discoving the parameters by which those processes are regulated. They presume that adult and infant can first establish a communicative tie via a mutual discovery of those parameters. Neither partner has a foreknowledge or scheme of the underlying

parameters and task invariants: they must be discovered via interaction.

(2) *Co-regulation is a self-organized dynamic process. Adults are not following a graded curriculum, nor are infants and children merely copying a model. Rather, the developmental sequence by which the young acquire increasing responsibility for their own movement is the result of a gradually changing dynamic: a developmental outcome rather than a planned prescription.* Universal sequences of developmental change, both within individual ontogeny and within relationships (e.g., from guidance to appropriation), are natural outcomes of a social system that continually seeks its fundamental dynamic parameters each time the individuals meet and interact. Mother and infant continue to re-constitute the terms of the dialogue in ways that converge to the best solutions – those containing the best approximations to task invariants – without overtly seeking such solutions.

2.7. Why is it necessary to have a social dynamic for the development of human movement?

(1) *Many forms of human movement (not to mention ideation) are so complex that the the discovery of their dynamics, that is the discovery of all the parameters needed to master the movement, would be highly unlikely without the influence, not only of specific interactive partners, but of a cultural history of complex movements and tools related to those movements.* Even relatively stereotyped infant movements could not be used to their fullest potential without access to a culture. If one lists all the ways the hand is used by the age of one year, that list would be far beyond the imagination of the one-year-old – left to his or her own resources – to discover alone.

(2) The previous point, although important to the argument presented here, is the weakest statement one could make. The second point is a much stronger statement about the role of social communication in development. It is quite possible that the social situation contains unique types of affordances, ones that speed up the individual's ability to isolate the important dynamic parameters of movement and/or focus on the relevant information linking perception and action. *The fact that joint social action is not entirely self-produced, leads to a heightened awareness of precisely those aspects of action that are not under one's full control, and precisely those aspects of informa-*

tion that are not directly available. We have assumed that development is the acquisition of sensitivity to and control over parameters of a task. Once the child 'feels' the inherent parameters of a dynamic process, he or she should be able to reproduce the movement by controlling the correct parameters of the movement (Newell 1986). When adults share in the creation of dynamic movement equilibria with the child (allowing the child to experience it without a loss of control) this may not only give the child clues about how to regulate the specific movement, but more general clues about how to regulate movement by seeking its invariant parameters. Social interactions that lead to developmental change, therefore, should function to highlight specific dynamic parameters, and ways to identify others.

In summary, this perspective suggests that social communication plays a crucial role in the development of human movement. Additionally, a distinction has been made between dynamic interactionism and earlier theories of how communication is implicated in development. First, dynamic interactionism assumes that the fundamental properties of movement, even culturally defined movements like gestures and words, can be perceived directly in the context of social interaction, without need for schematic theoretical baggage. Second, dynamic interactionism suggests that development in social contexts is most likely to occur in aspects of movement that the child does not have under complete control. Unlike sociocultural interactionism, which is primarily descriptive of the macroscopic progress of discourse over time, dynamic interactionism specifies a non-prescriptive process by which this progress might happen. Furthermore, there is nothing in the dynamic perspective specifying that the relationship needs to be tutorial, asymmetrical, motivated, or even positive. So long as the discourse uncovers (explicitly or implicitly) a dynamic parameter or new ecologically relevant information, developmental change can occur. This can happen between parent and child or between peers, under conditions of empathy or of manipulation, in dyads and in larger groups. The precise specification of how these types of relationships alter the ways in which dynamics are discovered allows for the theoretical analysis of the formation of individual differences in development and in relationships. A fully articulated developmental theory must explain both universal patterns and individual variations (Fogel 1990a, Fogel 1990b; Hopkins and Kalverboer in press).

In the following section of this paper, I present evidence from my

own work in support of this perspective. The data are related to both observational and experimental studies on the role of posture in the development of communicative movements during adult–infant face-to-face interaction between 2 and 6 months. Although the evidence is by no means conclusive, I think there is some support for the view that communication is constituted by a dynamic interaction, rather than regulated by a set of schematic rules or simple imitations.

3. Evidence for dynamic processes of movement and communication

Postural factors are known to affect the quality of face-to-face communication in children and adults. By changing their relative co-orientations – using head direction, trunk and whole body orientation – adults and children create a variety of dyadically constructed spaces that are endowed with communicative significance (Bull 1987). One meaning is communicated if people's heads are facing and directly aligned, but their trunks are not, while quite another meaning is experienced if trunks are aligned and facing each other, but the heads are not. Postural co-orientation not only has communicative significance in its own right, but it interacts with other aspects of the communicative exchange. For example, adults will actively modify their speaking turns – inserting long pauses, repeating opening sentence fragments, or changing loudness and pitch – in order to wait for a listener to establish eye contact (Goodwin 1981).

In mother–infant discourse we find similar patterns, except that infants have poor postural control. Nevertheless, via communicative processes to be discussed presently, infants can take part in the co-regulation of the postures in which their mothers place them.

We know that infant postural position has important relationships to communicative processes. Upright postures facilitate alertness in neonates (Frederickson and Brown 1975; Gregg et al. 1976), and head control is linked to attention to mother during face-to-face interaction at two months (Van Wulfften Palthe and Hopkins 1984). The ability to maintain standing postures significantly increases the amount of social interaction in 8- to 12-month-olds, regardless of whether the standing is independent or supported (Butterworth 1981; Gustafson 1984). In addition, postural supports can enhance the communicative effective-

ness of developmentally delayed children (Campbell 1987; Harris 1982).

Within the context of face-to-face interaction with mother, there are developmental changes in the mother's use of the infant's postural position that are related to change in infant gaze direction. Kaye and Fogel (1980) found that mothers changed the infants' posture more frequently when the infants were looking away, compared to looking at mother. This occurred at 6 and 13 weeks, but not at 26 weeks. When infants turn their heads away after engaging in a bout of face-to-face play with mother, some mothers make it relatively easy for infants to attend to other foci by holding infants in a postural position facing away from mother's body. Other mothers make it relatively more difficult for their infants to gaze away from them, by continuing to hold the infants in mother-facing postural positions. How mothers hold their infants in relation to the infant's intended focus may have a marked effect on the infant's resultant emotion expression and later communicative action (Fivaz 1987; Stern 1981).

As a first step in studying the effects of posture on face-to-face interaction we induced an experimental manipulation of infant postural position (Fogel et al. in press-a). Twenty infants each were observed at 3, 4 and 5 months of age. Infants were placed in an infant seat while interacting face-to-face with mother in the absence of toys. The angle of inclination of the infant seat (and hence postural position) was adjusted from 0 deg (supine), to 45 deg (recline), to 90 deg (sit) in half the subjects and in the reverse order in the other half. Mothers were asked to play with their infants as they would normally do at home, and they were requested to maintain a similar style of interaction across all three postural positions. Duration of gaze at mother was coded in each trial by coders who were blind to the hypotheses of the study. Order had no effect, and neither did the infant's age, but there was a main effect of postural position. Infants gazed less at their mothers when sitting (28% of the trial), an intermediate amount when reclining (50%), and the most when supine (64%). Manipulation checks showed few differences in maternal behavior across the three conditions, and no effects on gaze at mother related to maternal behavior.

We cannot, from this study, determine exactly why sitting postures led to a decline in looking at mother. It was not due to a lack of head control, since all infants in this study had adequate head control.

Rather, when sitting upright the infants appeared to search for things to look at other than the mother's face, including the chair, clothing and hands.

What is surprising is that this study did not replicate earlier research done on face-to-face interaction in more naturalistic settings in the home. In those studies 3-month-olds gaze almost exclusively at mother when toys are not present, but there is a declining amount of a gazing at mother over the next three months as infants seek out objects (Cohn and Tronick 1987; Kaye and Fogel 1980; Keller and Gauda 1987). Thus, in the experimental situation when mothers were not able to control the infant's posture, even 5-month-olds who normally look little at mother, spend 64% of a trial looking at her when they were placed in supine. Three-month-olds who typically look a lot at mother were only looking at her 28% of the time when placed in a sitting position experimentally. This suggests that in a naturalistic context as infants get older, they must be doing something to avoid getting placed in supine positions.

In order to investigate further the relationship between posture and gazing during face-to-face interaction, we made longitudinal videotapes of mothers and their infants interacting while mothers sat on a chair and held the infants on their laps (Fogel et al. in press-b). No objects were provided, and videotapes were made of the same couples weekly between 1 and 6 months. Mothers were asked to 'play and talk with your baby', and they were allowed to adjust the infant's posture freely. Each observation session lasted approximately 5 minutes. The tapes were coded for the onsets and offsets of actions using a digital clock on the screen on 3 passes through the videotape. On pass 1 we coded infant gaze direction (MOTHER'S FACE, AWAY, eyes CLOSED). On pass 2 we coded infant emotion expression (POSITIVE = smile, laugh, NEGATIVE = fuss, cry). On pass 3 we coded the infant's postural position as held by the mother (SUPINE, UPRIGHT facing MOTHER, UPRIGHT facing AWAY).

At each age, the transition probabilities of the mother's changes in the infant's postural position were analyzed with log-linear modelling as a function of infant's current affective state at the time of a postural position change, and infant's current gaze direction at the time of a position change. The resulting cross-classification table is shown in table 1. In general, when the infant was looking at the mother, there were few position changes. Those that occurred ended

Table 1
Number of instances of a gaze shift to LOOK AT mother, LOOK AWAY or CLOSED, as a function of infant affective state (POSITIVE/NEUTRAL or NEGATIVE) and prior and next body position (SUPINE(SUP), UPRIGHT FACE MOTHER (UFM), and UPRIGHT FACE AWAY (UFA)). The total number of gaze shifts in the entire sample was $N = 2660$. A '+' indicates that the cell is greater than expected by chance ($p < 0.01$) and a '−' indicates that the cell is less than expected ($p < 0.01$).

		POSITIVE/NEUTRAL			NEGATIVE		
	Prior position	Next position SUP	UFM	UFA	Next position SUP	UFM	UFA
LOOK MOTHER	SUP	73 +	71 +	10 −	7 +	4	2
	UFM	53	59	51	4	7	1
	UFA	8 −	117 +	8 −	3	1	0
LOOK AWAY	SUP	91	113 −	102 −	10	11	6
	UFM	112 −	163 −	548 +	12	17	17
	UFA	133	463 +	138 −	13	13	4 −
EYES CLOSED	SUP	36 +	23	8	15 +	11 +	13 +
	UFM	20	19 −	10 −	8 +	14 +	8 +
	UFA	9	11 −	2 −	5 +	3	0

in mother-facing positions. When the infant looked away, there were many more position changes, mostly between upright facing mother and upright facing away. What seems to be happening is the following: when the infant looks at the mother, she is likely to leave the infant in the same posture to encourage continued looking at her. When the infant looks away, she may shift the infant to a position that faces away from her, but soon after tries to regain the infant's attention to her face by shifting the infant's posture to supine or facing towards her.

Developmentally, however, the infants in this sample spend an increasing amount of time looking away from the mother and the mother spends an increasing amount of time holding the infant upright and facing away from her (and in the direction of the infant's gaze). This can be seen in the graphs showing the proportion of each weekly session spent in gazing away and in facing away positions (see fig. 1, showing two subject pairs).

Now, based on the results of the experimental study it would seem that mothers could always get their infants to gaze more at them simply by placing them in supine, assuming of course that mothers discover this relationship. The fact that mothers in the longitudinal

study, and in other cross-sectional studies (Kaye and Fogel 1980), change their infant's posture more when the infant looks away from them suggests that they indeed have discovered a relationship between gaze and infant posture. So why does the dyadic interaction system tend developmentally toward increasing amounts of gaze away from mother and upright postures?

To answer this question we have to examine the dynamic process by which the postural position of the infant is determined during the interaction. If that position is entirely regulated by the mother, there would probably be more supine positions used. Somehow the infant must play a role such that postural position is co-regulated. The series of photographs in figs. 2 and 3 were made from the videotapes to show sequences of maternal postural adjustment of her infant's body observed in our longitudinal study. In the photos the mother is supporting the postural position of her baby, Linda, in such a way as to ensure face-to-face interaction.

In the first series of photos taken at 13 weeks (fig. 2), Linda is held in a semi-upright position and facing mother in frames 1–3. In frame 4, mother tips Linda to one side, leans Linda back into a semi-supine posture (frame 6), and supports her head (frame 7). This position shift causes Linda to open her mouth wide (frame 5) and then to initiate a bout of smiling and gazing at mother (frames 6-8). Mother's head moves in order to keep the distance between their faces constant. What we see in this series of photographs is a smooth shift in infant posture toward a more supine position. What we don't see is that this smooth shift is actually co-determined by a very dynamic process of interaction.

In order to understand this, we have to compare it to a situation in which an intended position shift by the mother did not end up the same way. In the second series of photos made at about the same age (fig. 3), Linda's mother tries to attract the infant's attention to her face by turning Linda's head, which mother supports with her left hand. Mother succeeds in capturing Linda's gaze in frames 2–5. In frame 6, however, Linda looks down, then puts her hands to her mouth and turns away again, which is accomplished as mother gently relaxes her grip on Linda's neck.

Although we do not have precise measurements, we have seen many instances of dynamic mutual postural adjustments such as these. Precisely how much pressure mother applies to the back of Linda's

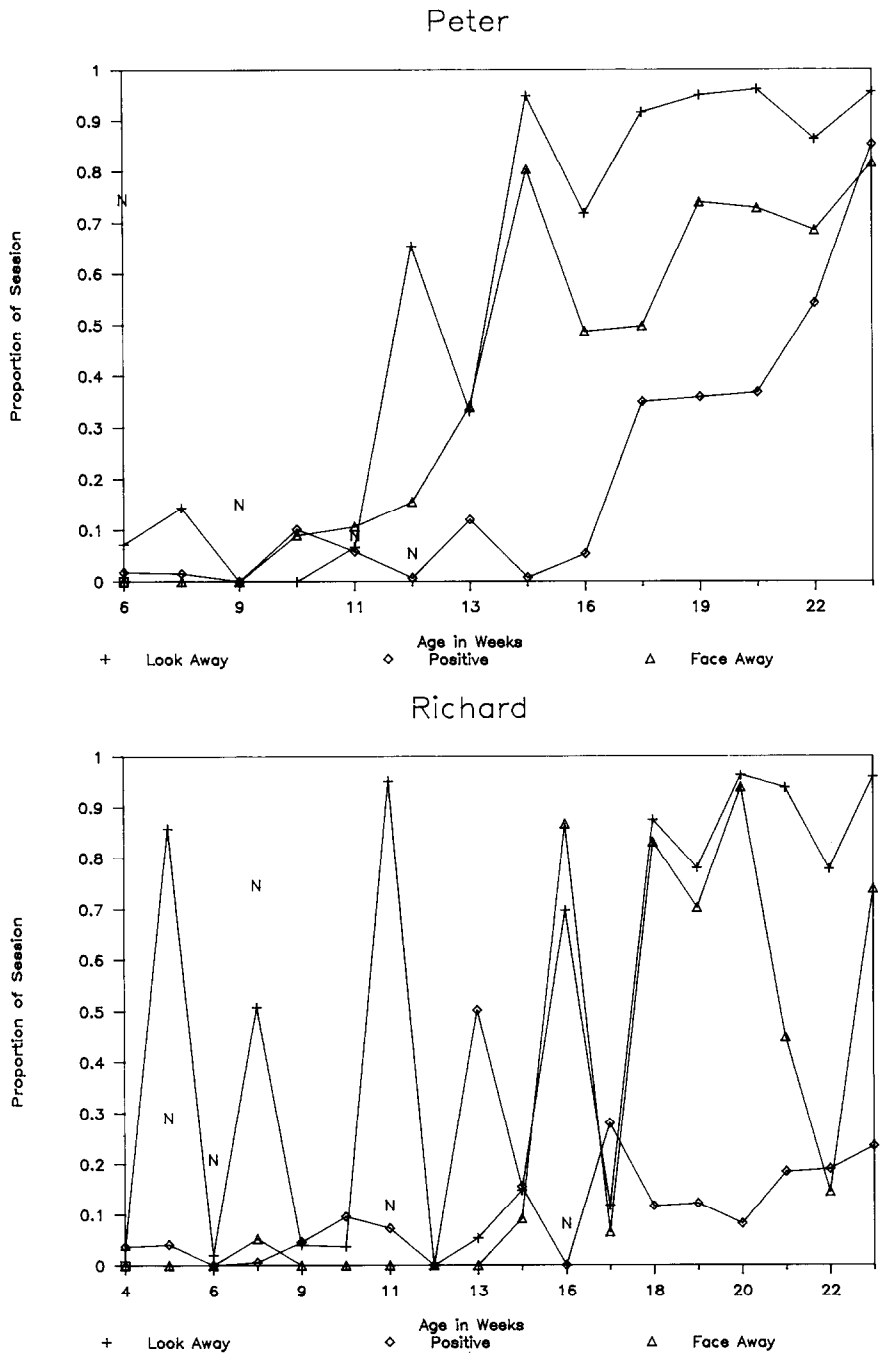

Fig. 1. Weekly data from two dyads are shown. Plots are of FACE AWAY, △; LOOK AWAY, +; POSITIVE, ◇; and NEGATIVE, N. The *x*-axis is the infant's age in weeks, and the *y*-axis is the proportional duration of each observation session. NEGATIVE occurs only in the sessions marked with an N, and the height of the N above the *x*-axis corresponds to the proportional duration of NEGATIVE.

Fig. 2. Linda and her mother (3 months). Mother shifts Linda's body into a semi-reclining position, leading to a positive communicative exchange, and a maintenance of the new postural position.

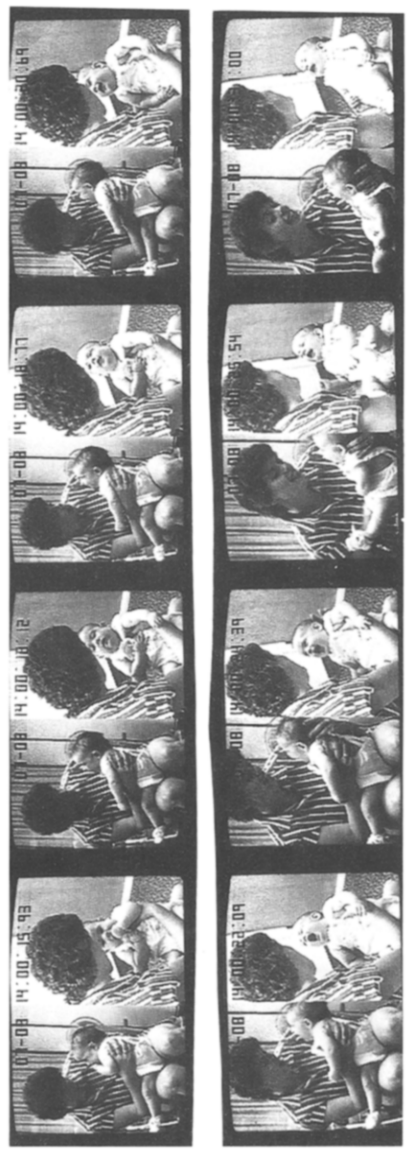

Fig. 3. Linda (3 months) and her mother are shown. Mother supports Linda by holding her head and making small adjustments in Linda's head direction. Linda's head returns to original position as mother relaxes her grip on the infant's neck.

neck (fig. 3) depends, it would seem, on the effort Linda makes at turning her head to the side. Mother does not force her recalcitrant infant to look at her by exerting strong contrary pressure to the head or body. Rather, mother times her support for an infant head turn to when the infant is already turning toward her and relatively relaxed. A similar mutual dynamic exists for larger body position shifts shown in fig. 2. We have also observed that very small variations in the mutual timing and direction of exertion makes a large difference in the resulting psychosocial content of the communication. Linda's smile in fig. 2 would not have occurred if the mother attempted a position shift that was not timed to her perceptions of the infant's readiness for such a shift.

It is instructive to interpret these observations in terms of each of the theories outlined earlier. A schematic interactionist approach would assume some kind of matching process between infant orientation preference and an intuitive interpretation by the mother about how to best achieve that orientation, i.e., by changing the infant's position. The sociocultural approach would also suggest that the mother should find the best position to encourage the infant's orientation preferences in order to guide the infant into the development of attention and object exploration. The photographs, however, show a much more dynamic process. It is not at all clear that the infant in fig. 2 intends to look at mother, while the infant in fig. 3 does not. Nor is the action of the mother entirely predictable from the start. Although this is speculative, I suggest that the orientation preference of the infant and the ultimate postural position is dynamically emergent from the unfolding co-regulation process shown in the photographs. In the first series the infant may look at mother and smile because the postural shift was smooth by virtue of a direct linkage to the infant's muscle exertion and general state. As the shift takes shape in a matter of fractions of a second, the mother's continued movement of the infant's body is the direct result of the dynamic convergence of the two individuals toward this social equilibrium state.

A similar analysis could be done for the second series of photographs. Indeed, it is from the second series that one can infer a process by which the mother and infant developmentally might arrive at an equilibrium between position and gaze that is oriented away from mother and toward objects. Thus, developmental change in the infant may be directly related to how his or her attentional prefer-

ences are embedded in social interaction and subject to a dynamic process of co-regulation.

One of the difficulties of exploring this hypothesis experimentally is that the attention–posture synergy is itself embedded in other aspects of the social relationship, forming a complex multi-dimensional system of social interaction. We have seen this in further analysis of these same longitudinal dyads (Fogel et al. in press-b). We find that not all the dyads in the study show the same developmental match between infant gazing away and postural facing away seen for those two infants shown in fig. 1. Fig. 4 shows two other dyads in which the infant looks away from mother developmentally earlier than the age at which the mother allows the infant to face away from her.

Our results show that about half the dyads have the synchronous developmental pattern shown in fig. 1 and half show the asynchronous developmental pattern shown in fig. 4. It appears that looking away from mother in the synchronous infants occurred developmentally after the infant began extended bouts of positive smiling during face-to-face interaction. In these infants, the facing away matched the duration of looking away. In the asynchronous dyads, positive interaction and lengthy smiling occurred developmentally later than extended looking away from mother. Apparently, for this group of infants, the communicative information related to the lack of infant smiling somehow altered the dynamics of the attention–posture synergy, such that the mothers were more likely to override the infant's preference for looking away by turning the infant back toward the mother and attempting to use supine positions. Eventually, however, all the infants in the sample acquired smiling and eventually all the dyads negotiated a posture–attention relationship oriented away from the mother (Fogel et al. in press-a; Fogel et al. in press-b).

I suggest that particular forms of social interaction emerge whenever a set of components and connections are present, whether by design or by chance. Patterned social action is nothing more or less than the dynamic interplay of these components and connections. If one component changes, the entire pattern of action may change as the system settles into a new synergy. Some of the components of social systems involve movement and posture – treated in some studies with respect to traditional dynamic properties of mass, displacement and velocity. For a social system, however, the important

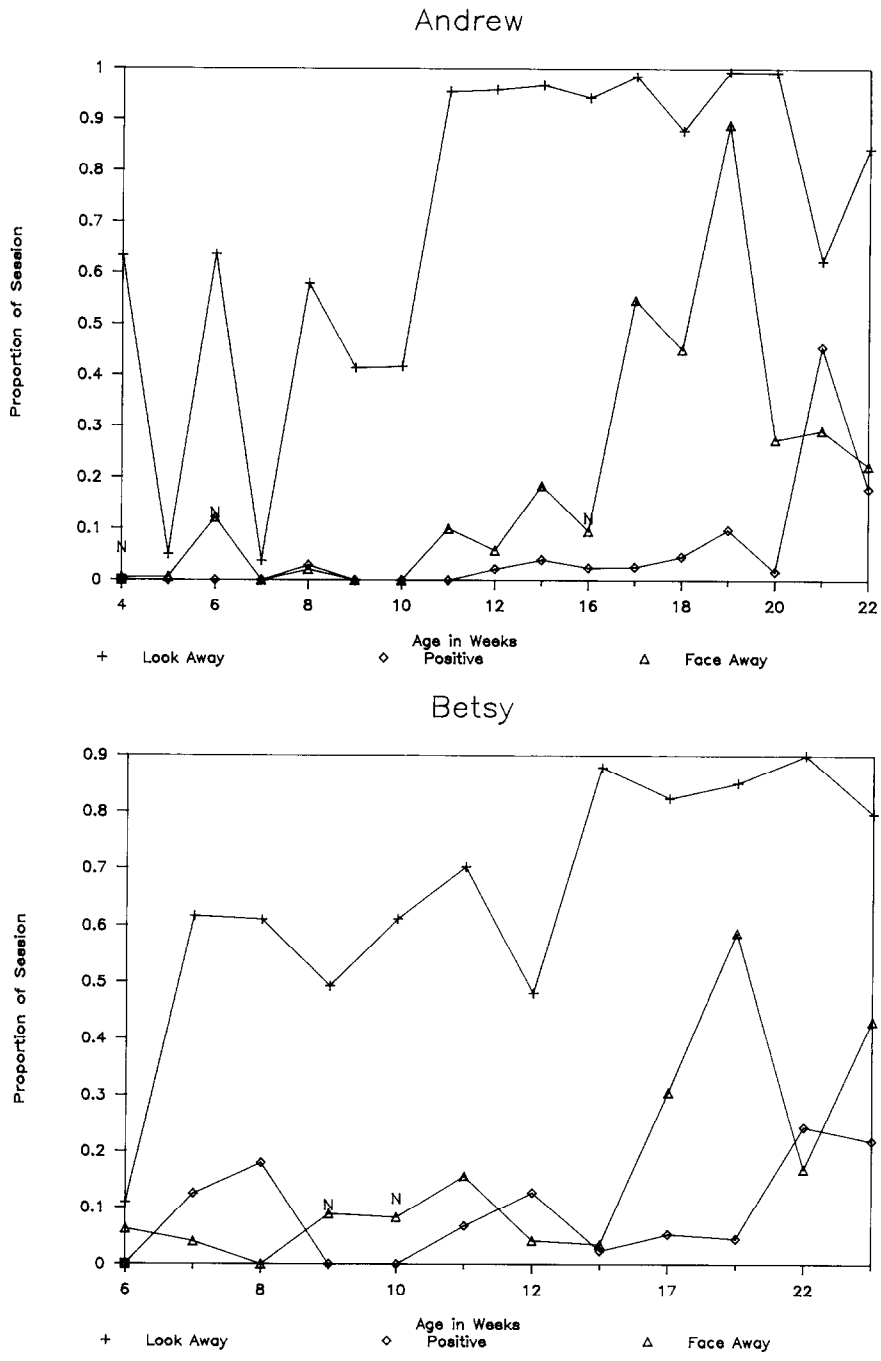

Fig. 4. Two asynchronous dyads are shown. Plots are of FACE AWAY, △; LOOK AWAY, +; POSITIVE, ◇; and NEGATIVE, N. The *x*-axis is the infant's age in weeks, and the *y*-axis is the proportional duration of each observation session. NEGATIVE occurs only in the sessions marked with an N, and the height of the N above the *x*-axis corresponds to the proportional duration of NEGATIVE.

issue is how movement and posture is interfaced with psychosocial information.

The psychosocial meaning of a movement is not genetically pre-adapted, but rather depends on the temporal and spatial relationship of the movement in combination with all other features of the social system, including its cognitive and motivational aspects. A mother's smile has a different psychosocial meaning to a baby who is relaxed, attentive and posturally prepared, compared to a baby who is fussing or distracted. The psychosocial meaning of a man touching a woman will depend on a vast network of components involving social, cultural and motivational factors, not to mention the physical properties of the action (timing, speed, force), its spatial location, and the mutual posturing of the participants.

4. Conclusions: Movement, communication and development

The theoretical perspective outlined in this article has several implications for the study of movement and development. The fundamental hypothesis is that developmental change arises when social partners co-regulate and co-determine movement dynamics and information specifying perception–action linkages. If one wishes to retain a notion of guidance, then this approach suggests that guidance operates by either a direct participation in the co-regulation of a movement (e.g., providing postural support for a toddler's first steps), and/or in the provision of culturally derived information that is directly related to a specific movement parameter (e.g., telling someone to pay attention to their balance as they execute a movement). If the guidance is specific to the parameters underlying the control of the movement, the resulting developmental trajectories can be understood as emergent outcomes of this dynamic co-regulation process. Guidance itself is not organized by the adult and then applied to the child, rather guidance is an outcome of a process of co-regulation in which the adult changes as much as the child. If this did not happen, then the adult would not be a very useful guide.

An example of how such a developmental model can be applied is in interventions with premature and handicapped infants and children. A careful analysis of their movement patterns should lead to specific strategies by which adults might select the relevant movement

parameters, or the appropriate forms of information that meaningfully relate to the child's actions. Then, these strategies need to be embedded into communicative systems to enhance the likelihood that co-regulation can be established in relation to those movements targeted by the intervention. Therapists need to be trained in general communicative skills, and more specifically in getting a 'feel' for establishing socially co-regulated movement dynamics in which the child enters the process at his or her own level of ability. Verbal, tactile and affective information may need to be imposed on the joint dynamics to help both child and adult isolate the relevant parameters of the task, which may be especially difficult when working with the non-conventional movements of handicapped children (Vermeer et al. 1989). Although these suggestions are admittedly non-specific in the absence of data, the theory highlights the need to focus on the relationships between movement dynamics and information in a structured communicative context if one expects developmental change to occur.

A similar theoretical analysis can be applied to understanding normal developmental change. The main implication of the theory of social dynamics presented here is that a description of the macroscopic changes in adult and child behavior over time is not an explanation of development. Those macroscopic changes are driven by a process occurring at a more microscopic level. The microscopic process, however, is not necessarily unobservable or pre-programmed. It is predicted to be found at the interface between movement parameters and parameter-relevant information (information that helps someone to focus on or to regulate a specific movement parameter). Some aspects of the developmental process may be socially mediated via co-regulation, while other aspects may require a more solitary exploration of the state space of the movement parameters to find the local equilibria.

For example, how might we study the development of upright locomotion from this perspective? During walking with adult support, the child may discover that while rhythmical alternation of the legs is already available, regular phasing, weight shifting and balance need to be brought under control. This discovery may not be possible until the child is brought into standing postures and experiences supported walking. There may be more to adult guidance of walking than simple support. While holding the infant upright a careful analysis may show that the adult also assists in weight shifting by moving the infant's

arms and/or trunk rotationally about the body axis and by tilting the body axis from side to side. Whether these movements are essential to the development of walking should be relatively easy to test both in naturalistic longitudinal and experimental studies. What happens to the walking synergy under various types of upright support (with and without yaw, pitch and rotation)? What happens if these dimensions of support are imposed without the child's active cooperation, compared to co-regulated by the child's postural shifts in concert with the adult's movements in different planes and axes? What types of information about posture and surface are communicated by the adult and which aspects of the information actually influence the dynamics of co-regulation? Finally, one could study how cultural information is incorporated into the particular co-dynamics. When, for example, are facial expressions, gestures, vocal and verbal forms of communication read into or out of the dynamics.

Finally, forms of co-regulation in symmetrical social relationships (peers for example) are likely to be different than those found in asymmetrical adult–child or teacher–student relationships. What might such differences be, and can these differing communicative dynamics create different types of movement dynamics? Are there some movements and communication patterns that are only acquired in symmetrical vs. asymmetrical relationships? Can we specify precisely the types of co-regulation and information that are sources of developmental change in each case?

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