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Neonate Movement Is Synchronized with Adult Speech: Interactional Participation and Language Acquisition

Abstract. *As early as the first day of life, the human neonate moves in precise and sustained segments of movement that are synchronous with the articulated structure of adult speech. These observations suggest a view of development of the infant as a participant at the outset in multiple forms of interactional organization, rather than as an isolate.*

In the discipline of kinesics, methods of microanalysis of sound films of human communication have revealed that key elements of interaction exist in the gestures, postures, and configurations of movement accompanying speech (*1–3*). These methods, applied to interaction between neonate and caretaker, have revealed a synchronization of infant movement organization with the articulatory segments of adult speech as early as the first day of life.

Frame-by-frame microanalysis of sound films of adult interaction has led to study of the organization of events within intervals of 1 and 2 seconds—the domain of microkinesics (*2*). A Bell and Howell 16-mm projector (time-motion analyzer) is used to segment and transcribe body motion (*4*). With this projector, film can be manually transported, one frame at a time, or series of frames can be scanned and contrasted with each other. Each film frame has an identifying number at the top (*5*). Body movements—of an arm for example—can be repeatedly reexamined by varying the number of frames scanned until the frame is located in which change in direction occurs. All body parts detected to be moving—including brows, eyes, and mouth—are systematically analyzed in this fashion. Notations are made for each part: lines for frames in which movement in a particular direction is sustained and arrows for the frame in which movement terminates or changes direction. An acoustic sound reader permits location of the film frame numbers of the boundaries of speech segments, such as phones, syllables, and words (*4*). Frame-numbered sound films of the oscilloscope display of the speech provide a check on the accuracy in locating speech segment boundaries in relation to frame numbers. Since the same speech is recorded again on the sound track that accompanies the film of speech visual dislay, the investigator can both hear and see the speech change points in relation to frame numbers.

These procedures permit an analysis of the relation of body movements to each other and to speech in both speaker and listener during interaction. As a person speaks, several body parts are usually moving. Units of behavior were observed: Several body parts, which might be moving in different directions and with different speeds, maintain those directions and speeds in relation to each other for a brief time, usually 0.04 to 0.16 second. This patterning of movement appears to be panhuman in that it has been observed in all films studied, including cross-cultural films. Several of these quantal configurations in infant behavior are circled in Fig. 1. These quantal forms of microorganization of a speaker's motion are isomorphic with the articulated structure of his speech. This has been called self-synchrony (*2*). Further, the configurational organizations or "units" of the listener's body motion are synchronous with the speaker's speech. This has been called "interactional synchrony" (*3*). These synchronies are not readily detectable at normal communication speed, appear to occur primarily in relation to speech,

Table 1. Correspondence of infant movements with live speech. Baby E's motion segmentation was compared with speech segmentation of the adult for the total sequence (study 1) and for the first 336 frames only (study 2). In study 3, baby C's motion segmentation during 336 frames of silence was compared to the first 336 frames of speech segmentation on the sound track of baby E.

Study	Total frames	Total discrepancies	Agreement (%)	Estimated range of agreement* (%)	Breakdown of discrepancies by linguistic categories: Within phone	Phone boundary	Word boundary
1	892	65	93	91.3–94.5	55	5	4
2	336	21	94	90.7–96.4	14	5	2
3	336	119	65	59.0–70.0	51	38	30

* This column gives, for $P = .025$, the maximum risks of overestimating the lower limit and of underestimating the upper limit for random samples having the percentage of misses in studies 1 to 3. Values obtained from (*10*).

Table 2. Correspondence of infant movements with recorded speech and nonspeech sounds.

Study	Sound	Baby	Total occurrences	Total discrepancies	Agreement (%)
4	Speech (word boundaries)	A	146	19	87
5	Disconnected vowels	E	167	97	42
		C	124	51	59
6	Tapping sounds	E	27	15	44
		C	34	16	53

and are usually totally out of the interactants' awareness. In contrast, microanalysis of pathological behavior—for instance, that of subjects with aphasic, autistic, and schizophrenic conditions—reveals marked self-asynchronies (*6*). Delayed auditory feedback also markedly disturbs this self-synchrony.

Research thus far indicates that independent judges can achieve a high degree of reliability in microkinesic segmentation. Four types of binomial reliability analysis were performed, with 86, 90, 97, and 93 percent agreement between independent judges (the estimated range for random samples from a binomial population is 80 to 99 percent at $P = .025$).

We studied whether or not such "interactional synchrony" might exist between sound segments of adult speech and points of change in the configurations of neonate movement. Video tapes were made for eleven normal neonates (sound film was subsequently made from the tape), and sound films were made directly for five normal neonates. A total of approximately 5 hours of recorded infant behavior was obtained, and sections in which the infants were in awake-active state were found most suitable for study of correspondence between adult speech and infant movement, since it is difficult to detect movement in sleep or drowsy states. The amount of speech during which infants stayed in the awake-active state varied for each infant and ranged from several sentences to lengthy utterances. Approximately 1 hour of material suitable with regard to infant state and occurrence of adult speech was studied in detail.

In study 1, a frame-by-frame analysis of the body motion of baby E was performed on a section of a continuous sequence of 89 words spoken directly to the infant by an adult male (study 1 in Table 1). This constituted 892 frames of verbal material at 30 frames per second (pauses between phrases were omitted). The infant was not looking at the speaker, so eye contact could be ruled out. The comparison shows correspondence between analysis of the sound track of the adult's speech and the body movement of the infant. Figure 1 illustrates correspondence over seven words transcribed by the method of analysis described for adult behavior.

For example, as the adult emits the *kk* of "come," which lasts for 0.07 second, the infant's head moves right very slightly (Rvs), the left elbow extends slightly (Es), the right shoulder rotates upward (RU), the left shoulder rotates outward slightly (ROs), the right hip rotates outward fast (ROf), the left hip extends slightly (Es), and the big toe of the left foot adducts (AD). These body parts sustain these directions and speeds of movement together for this 0.07-second interval. This forms a "unit" composed of the sustained relation of these movements of the body. By means of the time-motion analyzer, the sustained movements in this unit can be contrasted with those of the next unit, during the concluding articulation of "come" (Λ *mm*), which lasts 0.1 second. The left elbow increases speed, the right hip adds extension, the left hip adds rotation inward, and the big toe stops moving. The previous head movement continues. Movement of right and left shoulders also continues but changes form exactly at the end of "come." Thus, the infant responds organizationally to adult speech: Two movement configurations are sustained across the two aspects of "come," *kk* and Λ *mm*, shoulder movement is sustained across the total word *kk* Λ *mm*. The next

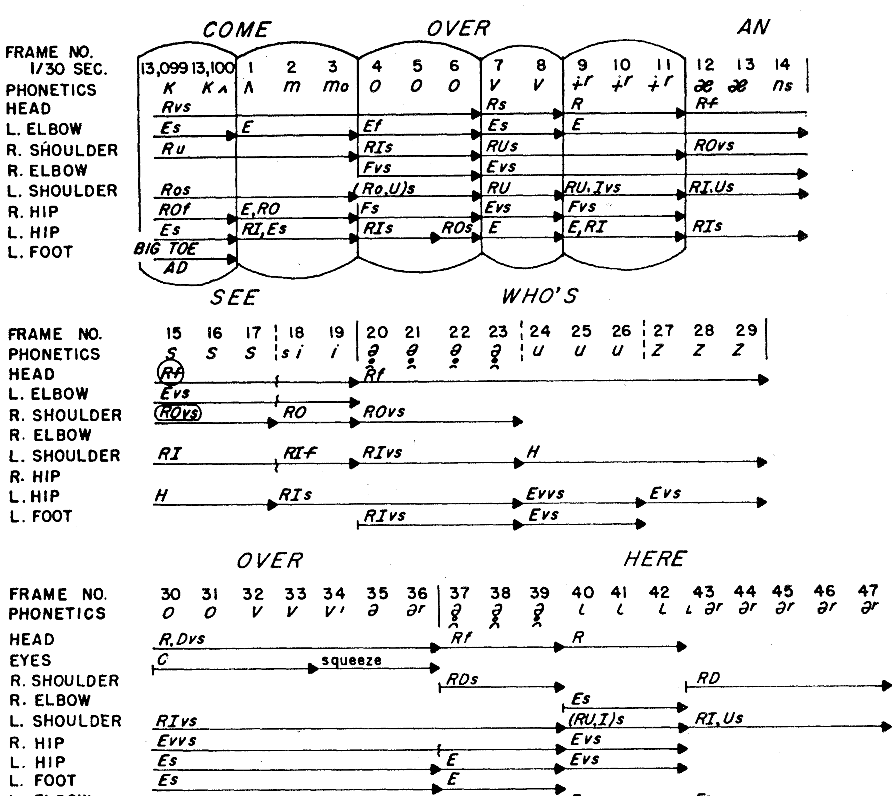

Fig. 1. Two-day-old neonate moving synchronously with adult speaking, "Come over an see who's over here." The transcription read vertically shows that the infant's configurations of movement coincide with the articulatory segments of the adult's speech. Definition of descriptive notation: *F*, forward or flex (depending on body part); *H*, hold; *D*, down; *E*, extend; *C*, close; *RI*, rotate inward; *RO*, rotate outward; *AD*, adduct; and *U*, up. Lower case letters refer to speed: *s*, slight; *f*, fast; and *vs*, very slight.

word, "over," is articulated with three major segments, *ooo, vv*, and *iririr*, which are also accompanied by segments of infant movement exactly synchronous with them. This 2-day-old infant displayed segments of movement synchronous with the adult's speech during the entire 89-word sequence. In other words, this is a sustained and precise concurrence. Another 2-day-old infant sustained similarly synchronous movement throughout a series of 125 words of tape-recorded female speech (*7*).

A test was devised (study 3) to rule out the possibility that such correspondence was a random fitting-together of patterns of infant movement with patterns of adult speech. A film of awake-alert movement of baby C during 336 frames of silence at 30 frames per second, taken from another film made with the same camera, was segmented and compared with the first 336 frames (36 words) of the speech spoken to baby E (study 2). The frame-by-frame analysis of body motion of baby C (filmed during silence) was compared to the analysis of adult speech on baby E's sound track. The correspondence obtained was compared with the correspondence of baby E's body motion to the same speech (studies 2 and 3 in Table 1).

The precision of synchronization in Fig. 1 characterized the correspondence between adult speech and infant movement for all 16 infants. Of these infants, 14 were from 12 hours to 2 days old and 2 were 14 days old. The correspondence occurred whether the adult speaker was present or whether the voice came from a tape recorder. An audio tape containing American English, isolated vowel sounds, tapping sounds, and Chinese language excerpts was used as a stimulus. Two of the infants were held and the rest were supine in their cribs. Chinese presented to American neonates was associated with as clear a correspondence as was American English. Disconnected vowel and tapping sounds, however, failed to show the degree of correspondence associated with natural, rhythmic speech. The possibility that the adult speaker was synchronizing his speech with the infant's movements is thus ruled out by the observation that infants also synchronized movements with speech from a tape recorder. (study 4 in Table 2). The relation between neonate movement and recorded isolated vowel sounds is presented in study 5, and the relation to recorded tapping sounds in study 6 (Table 2).

That this level of interaction is important in relation to the more macroscopic level of regulation and organization of the infant-caretaker system (*8*) is suggested by the observation that correspondence between speech and body movement in the neonate appears when the infant is already in movement. It is not usual that the sound starts the infant moving from a motionless state. However, when the infant is already in movement, points of change in the configuration of moving body parts become coordinated with points of change in sound patterns characterizing speech. Thus, an optimal timing in relation to the state of the infants' exposure to stimulation by speech may provide an essential characteristic of the interactive experience.

This study reveals a complex interaction system in which the organization of the neonate's motor behavior is entrained by and synchronized with the organized speech behavior of adults in his environment. If the infant, from the beginning, moves in precise, shared rhythm with the organization of the speech structure of his culture, then he participates developmentally through complex, sociobiological entrainment processes in millions of repetitions of linguistic forms long before he later uses them in speaking and communicating. By the time he begins to speak, he may have already laid down within himself the form and structure of the language system of his culture. This would encompass a multiplicity of interlocking aspects: rhythmic and syntactic "hierarchies," suprasegmental features, and paralinguistic nuances, not to mention body motion styles and rhythms. This may provide an empirical basis for a new approach to language acquisition.

This perspective provides a descriptive frame and a conception of human behavior and language acquisition differing to some extent from traditional and current perspectives. While the learning theoretical model has emphasized response and operant interaction, it has not seemed totally adequate to the richness and syntactic complexity of language behavior. The comtemporary alternative of transformational grammar approaches tends to emphasize innate acquisition and production devices, although this might be an extreme interpretation of that position.

The observations described in this report suggest that the richness and complexity of the language behavior system develops on the basis of an organized, "hierarchic" response of the infant to the organized pattern of adult speech. They suggest that infant motor organization, entrained by these organized patterns for many months after birth, may prepare operational formats for later speech.

Sustained synchrony of organized correspondences between adult speech and neonate body movement at this microkinesic level within epochs of less than a second raises issues about the nature of communication, and particularly about the role of auditory function in development (*9*). It suggests that the "bond" between human beings should be studied as the expression of a participation within shared organizational forms rather than as something limited to isolated entities sending discrete messages.

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