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ORIGINS OF THEORY OF MIND, COGNITION AND COMMUNICATION

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There has been a revolution in our understanding of infant and toddler cognition that promises to have far-reaching implications for our understanding of communicative and linguistic development. Four empirical findings that helped to prompt this change in theory are analyzed: (a) *Intermodal coordination*—newborns operate with multimodal information, recognizing equivalences in information across sensory-modalities; (b) *Imitation*—newborns imitate the lip and tongue movements they see others perform; (c) *Memory*—young infants form long-lasting representations of perceived events and use these memories to generate motor productions after lengthy delays in novel contexts; (d) *Theory of mind*—by 18 months of age toddlers have adopted a theory of mind, reading below surface behavior to the goals and intentions in people's actions. This paper examines three views currently being offered in the literature to replace the classical framework of early cognitive development: modularity-nativism, connectionism, and theory-theory. Arguments are marshaled to support the "theory-theory" view. This view emphasizes a combination of innate structure and qualitative reorganization in children's thought based on input from the people and things in their culture. It is suggested that preverbal cognition forms a substrate for language acquisition and that analyzing cognition may enhance our understanding of certain disorders of communication.

Educational Objectives: The reader will: (a) be introduced to Piaget's classic theory of infant and toddler cognitive development; (b) understand recent findings that undermine this view; (c) be presented with three theoretical frameworks seeking to replace the classical theory; and (d) consider implications of the new empirical findings for communicative development in normally-developing and atypical populations.

KEY WORDS: Intermodal coordination; Imitation; Memory; Theory of mind; Representation; Language acquisition; Face perception

There has been a profound, even revolutionary, shift in our theory of developmental psychology. The revolution began with challenges to Piaget's theory of cognitive development, particularly his views of infancy. As everybody

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J. COMMUN. DISORD. 32 (1999), 251–269

655 Avenue of the Americas, New York, NY 10010
0021-9924/99/$–see front matter
PII S0021-9924(99)00009-X

who has attended scientific conferences, read technical journals, or monitored the popular media knows, modern research has discovered that young children know more at earlier ages than had been predicted by classical theory. These new findings led to the gradual weakening, and finally the collapse of, classical Piagetian theory (Piaget, 1952, 1954, 1962).

There is now a furious search for a new framework. An analogy can be drawn to the early part of this century when classical Newtonian mechanics was overthrown and physicists were searching for a new model. In our field, we know that the classical framework of developmental psychology, which has reigned for almost 50 years, does not work; we have crucial experiments that have uncovered surprising facts; and we have great excitement in both the laboratories and in society at large, as competing views of early human development are being thrashed out.

The emergence of a new theory will be important, because many fields rely on developmental psychology as a touchstone. Philosophers have begun to draw on infant development, both in epistemological debates and in moral philosophy (Bermúdez, 1996, 1998; Campbell, 1994; Gallagher, 1996). Adult cognitive science draws on developmental findings when discussing memory, categorization, and the perception of objects and people (Wilson & Keil, 1999). Neuroscientists have discovered that human infants, not just cats and frogs, can inform us about brain growth, critical periods, and perceptual-motor couplings (Cole, 1998; Kuhl, 1998). Society in general is fascinated by the new research on early development and the brain, not only because of the intrinsic interest of parents, but because of its policy and educational implications (Gopnik, Meltzoff, & Kuhl, 1999).

Moreover, there has always been an especially close tie between basic developmental research and clinical application. We need to understand normal cognitive and communicative development if we are to discover how and why things develop along alternate trajectories in children with disorders. Conversely, knowledge and experience acquired by clinicians feeds back and enhances theories of normal development. This is a two-way street—information flows in both directions. For example, modern ideas about theory-of-mind development have helped to illuminate the deep mystery of the disorder of autism, while at the same time children with autism have helped to mold our current understanding of social cognition (Baron-Cohen, Tager-Flusberg, & Cohen, 1993, in press). Children with Williams syndrome have informed and been informed by basic research on the relation between language and thought (e.g., Bellugi, Wang & Jernigan, 1994; Johnson & Cary, 1998; Mervis & Bertrand, 1997). My own recent work on children with Down's syndrome and autism has deeply affected my thinking about normal cognitive development, while at the same time uncovering new information about the social skills of children with Down syndrome and their contrast to children with autism (Dawson, Meltzoff, Osterling, & Rinaldi, 1998; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Gopnik, Capps, & Meltzoff, in press; Meltzoff & Gopnik, 1993; Rast & Meltzoff, 1995).

It is too early to discern what shape a general unified theory of developmental psychology will take, but (at least) three alternative visions are clearly in the running for the post-Piagetian era: Modularity-nativism (e.g., Chomsky, 1980; Fodor, 1983); Connectionism (e.g., Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996); and the Theory-theory view of cognitive-communicative development (e.g., Gopnik & Meltzoff, 1997; Gopnik et al., 1999).

The modularity-nativism view emphasizes innate ability, and thus can smoothly incorporate the stunning new findings about the competence of infants and young children. Its drawback is that it has no easy way of explaining qualitative change in development. Behavioral and communicative change is attributed to maturation or automatic *triggering* by environmental events, rather than as qualitative reorganizations. Connectionism presents the reverse case. In this theory there are no innate representations, and the organism comes to reflect the contingencies and associations reflected in the external environment. The connectionist view is good at explaining behavioral change, but it is weaker on explaining the innate competences that have recently been discovered. The "theory-theory" view of cognitive and communicative development is a midpoint between these two extremes. It holds that children have a powerful innate representational system, while at the same time embracing qualitative developmental change. It is a thoroughly developmental view founded on a rich initial state, not a blank slate (for a more complete analysis of the alternative theories, see Gopnik & Meltzoff, 1997; Meltzoff & Moore, 1999).

The name "theory-theory" derives from the fact that it is our *theory* that children have *theories*, hence the double use of the term. We think that cognitive development in young children is like theory change in science. As children develop they change their theories of the world, and they do so on the basis of the data (input) they receive. At any one point in development, the child's theory allows him or her to make interpretations of raw information and to make predictions about novel events. Moreover, children are emotionally invested in their theories in a manner reminiscent of the way scientists are invested in their adult framework. Both are conflicted and turn away from new data that doesn't fit (though children may cry more about it); both actively experiment to see if they can repeat and control things (though the scientist's playthings are more expensive). The theories children start off with are wrong, of course. But like adult scientists, children actively struggle to make sense of the information they are given through collaboration with others in the social environment.

FACIAL IMITATION

A prime example from the new research on infant development concerns facial imitation. The research in this area has helped to change our understanding of the innate foundations of social cognition and nonverbal communication. In the classical view, young infants were initially devoid of the ability to imitate, and they developed through stages. A landmark development occurred at about 8–12 months of age when they first became able to imitate facial gestures, such as lip and tongue movements. Before this age it was said that they could watch the facial gestures of adults, but they had no way of connecting or associating the seen acts of another with the invisible acts of their own.

We discovered that this developmental progression was wrong (Meltzoff & Moore, 1977). Our research showed that 2- to 3-week-olds imitated tongue protrusion, mouth opening, lip protrusion, as well as simple finger movements. Because these findings did not fit with classical theory, they were initially the topic of much discussion in the field. The findings of early behavioral matching have now been replicated and extended in this country and cross-culturally in more than 24 different studies (for a review, see Meltzoff & Moore, 1997). The effects are secure. The question is, how do infants do it?

In followup studies, we tested newborns in a hospital setting. The average age of the infants tested was 32 hours old, and the youngest infant was only 42 minutes old at the time of the test. The results again showed successful imitation of oral movements (Meltzoff & Moore, 1983; Meltzoff & Moore, 1989). Evidently, some primitive capacity for behavioral matching is present at birth.

Meltzoff & Moore (1997) offered a theoretical model of the mechanism underlying facial imitation. We hypothesized that infant imitation depends on a process of active intermodal mapping (AIM). The crux of the AIM hypothesis is that imitation, even early imitation, is a matching-to-target process. The goal or behavioral target is specified visually. Infants' self-produced movements provide proprioceptive feedback that can be compared with the visually-specified target. AIM proposes that such comparison is possible because the perception and production of human movements are registered within a common supramodal representational system. Thus, although infants cannot see their own faces, their faces are not unperceived by them. They can monitor their lip and tongue movements through proprioception and compare this felt activity to what they see. Metaphorically, we can say that perception and production speak the same language; there is no need for "associating" the two through prolonged learning, because they are intimately bound at birth.

INTERMODAL MAPPING: ORAL-VISUAL AND SPEECH PERCEPTION-PRODUCTION

If the AIM hypothesis is correct, it should be possible to find converging evidence outside of facial imitation. A first study along these lines involved 29-day-old infants (Meltzoff & Borton, 1979). The infants were given tiny shapes to feel in their mouths. After a 90-second period, the shapes were withdrawn without the infant seeing them. The infants were then shown a pair of visual shapes, only one of which matched the shape they had felt. The results revealed that infants' visual attention was driven by what they felt: They looked longer at the particular shape they had in their mouth (Meltzoff & Borton, 1979). This same effect has also been reported in newborns (Kaye & Bower, 1994). In addition to showing intermodal matching, this work verifies that young infants use their mouth as an exploratory organ. Evidently, infants do not just suck for gratification, as Freud supposed, but as a way of collecting information.

A second study involved speech perception and auditory-visual mapping. We tested 18- to 20-week-olds in a simple lip-reading task. Infants were presented with a film of two faces side by side. One face was articulating the vowel /a/ and the other the vowel /i/ in perfect synchrony with one another. We played one of the vowel sounds, either /a/ or /i/, out of a loudspeaker midway between the faces. Infants were allowed to visually examine the faces for 2-minutes while listening to the soundtrack. The results showed that the infants chose to look longer at the face that matched the sound track they heard (Kuhl & Meltzoff, 1982, 1984). Replications and extensions of this work have confirmed and enriched these conclusions (MacKain, Studdert-Kennedy, Spieker, & Stern, 1983; Walton & Bower, 1993). These experiments not only demonstrate intermodal coordination between audition and vision, but also show that young infants prefer to look at the person who is talking to them.

Finally, we conducted a study involving speech production and vocal imitation (Kuhl & Meltzoff, 1996). Infants at 12, 16, and 20 weeks of age listened to a woman producing one of three vowels, /a/, /i/, or /u/. Each infant heard the tape for a 5-minute session for 3 days in a row. Their vocal responses were recorded and analyzed both by phonetic transcription and spectrographic analyses. The results provided strong evidence of vocal imitation of the vowel sounds they heard.

If 15 minutes is sufficient to influence infants' vocalizations, then listening to the ambient language would be expected to have a powerful influence. Early in their cooing and babbling career, infants sound similar; however, this does not mean that auditory input has no effect on vocal productions. Oller and others have discovered that deaf and hearing-impaired infants babble differently from infants with normal hearing (Kent, Osberger, Netsell, & Hustedde, 1987; Oller & Eilers, 1988; Oller & Lynch, 1992; Locke, 1993; Stoel-Gammon & Otomo, 1986). Moreover, it has been reported that 1-year-olds in different cultures babble differently (de Boysson-Bardies, Halle, Sagart & Durand, 1989; de Boysson-Bardies, Sagart & Durand, 1984). As in these other studies, our vocal imitation data reaffirm how important hearing is to vocal productions: in our short-term laboratory study, we discovered that exposure to sounds is sufficient to alter the nature and quality of infants' vocal productions.

THE MUTUAL IMITATION GAME AND WHY IT'S IMPORTANT

Once we begin to take seriously that infants can use intermodal matching to detect the equivalence between their own behavioral productions (movements, vocalizations, etc.) and the behavior they perceive, several other pieces of the developmental puzzle begin to fall into place. For example, a common observation in the social-developmental literature is that parent-infant games are often reciprocally imitative in nature. Infants shake a rattle and parents shake back; infants vocalize and parents do likewise. There has been discussion about the turn-taking aspect of these games, the "rhythmic dance" between mother and child (Bruner, 1983; Stern, 1985). I don't dispute that timing is important, but I think that there is an additional special value in the similarity in the *forms* of the participants' behavior. Reciprocal imitative games provide the infant with special information about how it is like another person and how another is "like me."

The importance of such structural congruence in the form of the behavior was tested in a series of studies with 14-month-olds. In these studies the infant sat across a table from two adults. One of the adults matched everything the infant did, and the other busily matched the behavior of a previous infant. Thus, both adults were acting like perfect babies, but only one adult was acting just like the subject being tested. The results showed that infants directed more visual attention and smiled more at the person who was imitating them. They preferred an adult who was playing a matching game (Meltzoff, 1990a).

Why did they prefer the adult playing the imitation game? At issue is whether infants prefer people who are acting just *like* they act (structural congruence) or just *when* they act (temporal contingency). To distinguish these alternatives, I did another study in which both adults' actions were equally contingent on the infant's. Both experimenters sat passively until the infant performed one of the target actions on a predetermined list, and then both experimenters began to act in unison. One of the adults matched the infant, the other performed a mismatching response. The results again showed that the infants looked and smiled more at the matching adult. This proves that infants are sensitive to the matching form of the behavior, not simply temporal contingencies.

This demonstration has several implications for clinical and applied work. In naturalistic interactions parents speak in high-pitched, sing-song "motherese." Within the speech literature, it is often remarked that the high fundamental frequency and pitch swoops may be alerting (e.g. Fernald & Kuhl, 1987). Given the current research, an additional reason that Motherese may be preferred by infants is that it is closer to the form of their own vocal productions. From a broader perspective, there may be deep psychological reasons why infants find mutual imitation games satisfying. It is interesting that therapists and marriage counselors often advise people to mirror back the thoughts and feelings of the patient. Patient: “I feel good today.” Therapist: “You feel good?” Being imitated, having one’s own behavior be reflected by another, is a very salient experience for adults and facilitates communication. What we have discovered is that for the littlest humans mirroring back behavior is also salient and affectively pleasing. It is no wonder then that parents and children gleefully play mutual imitation games for long periods. If imitation is the sincerest form of flattery, infants and young children—like adults—apparently like to be flattered.

ORIGINS OF THEORY OF MIND

People are more than physical bodies. We are more than dynamic bags of skin that can be seen, heard, and weighed. In the adult framework, persons also have beliefs, desires, and intentions that lie below the surface behavior. One cannot directly see, taste, smell, or hear mental states, but it is an essential part of our ordinary adult understanding that other people have them. *Theory of mind* research investigates the development of this framework (e.g., Astington & Gopnik, 1991; Flavell & Miller, 1998; Perner, 1991; Taylor, 1996; Wellman, 1990).

Where does this tendency to treat others as sentient beings come from? Are we born with a theory of mind? Do we learn it in school? One problem with trying to sort out origins is that most of the test paradigms measure verbal responses. If we want to look at origins of theory of mind or its development in nonverbal populations we need another approach.

I recently developed such a nonverbal procedure for examining theory of mind, called the *behavioral reenactment technique.* The procedure capitalizes on imitation, but uses this proclivity in a new, more abstract way. The study involved showing children an unsuccessful act (Meltzoff, 1995). For example, the adult tried to perform a behavior, but his hand slipped. Thus the goal-state was not achieved. Alternatively, the adult accidentally under- or overshot his target. To an adult, it was easy to read the actor’s intention, though he was not able to fulfill it. The experimental question was whether 18-month-olds also read through the surface behavior to the underlying goal or intention of the actor. In essence I wanted to see whether they would be able to infer and produce the act that the adults *meant* to do (even though he failed to reach his goal).

The results clearly showed that they did so. Evidently, young toddlers can read our intentions even if we fail to fulfill them. Subsequent research using a mechanical device to perform the acts revealed that toddlers did not attribute *intention* to the inanimate model. They watched the movements but did not interpret it as implying an effort to do something else. Still further research with infants in the first month of life showed that they did not behave like the older toddlers. Neonates can imitate visible behavior, but they respond at baseline levels if the adult seems to be struggling to put out his tongue but does not show it coming out of his mouth. New research in my lab suggests that intention-reading of the type discussed here—inferring the target acts from the failed attempts—emerges at about 15 months of age. For examle, 9-month-olds fail completely on this intention-reading task. Younger infants imitate behaviors they see, but only by about 15 months of age do they re-enact the goals and intentions of the adult based on unsuccessful acts.

By the second year of life, children have already adopted a fundamental aspect of a theory of mind—persons (but not inanimate objects) are understood within a framework involving goals and intentions. This nascent understanding of intentionality is is an important building block for communicative development, as will be further developed in the conclusions of this paper.

MEMORY

Imitation on the basis of memory, after the model has disappeared, is called *deferred imitation.* In classical developmental theory, the onset of deferred imitation was thought to be 18 months of age, during stage-6 of the sensory-motor period. Deferred imitation was part of a broad stage change involving symbolic play, high-level object permanence, language, and other indicators of the symbolic function (Piaget, 1962).

The new empirical findings have dissociated deferred imitation from these other stage-6 behaviors. I have demonstrated deferred imitation of actions on objects in infants as young 9 months of age (Meltzoff, 1988b). In this test infants simply observed an adult's actions and were not shaped up or conditioned in any way. The results showed robust memory for observed events after a 24-hour delay. Deferred imitation and memory at 9 months old has also been replicated cross-culturally in a Swedish sample (Heimann & Meltzoff, 1996) and has recently been reported at younger ages under constrained circumstances (Barr, Dowden & Hayne, 1996; Meltzoff & Moore, 1994).

Can young infants perform deferred imitation of novel behaviors? Meltzoff (1988a) showed infants an adult who leaned forward and pressed a panel with his forehead. After a 1-week delay the infants were presented with the panel and their behavior was videotaped. Fully 67% of the infants who saw the display reproduced the act after the week's delay, as compared to 0% of the control infants who had not seen the novel display. This shows that toddlers can represent novel behaviors and use this to subsequently guide their own productions (see Figure 1).

If infants are going to use deferred imitation of parental behavior in everyday life, it also requires that they access their memory in a new context. Such

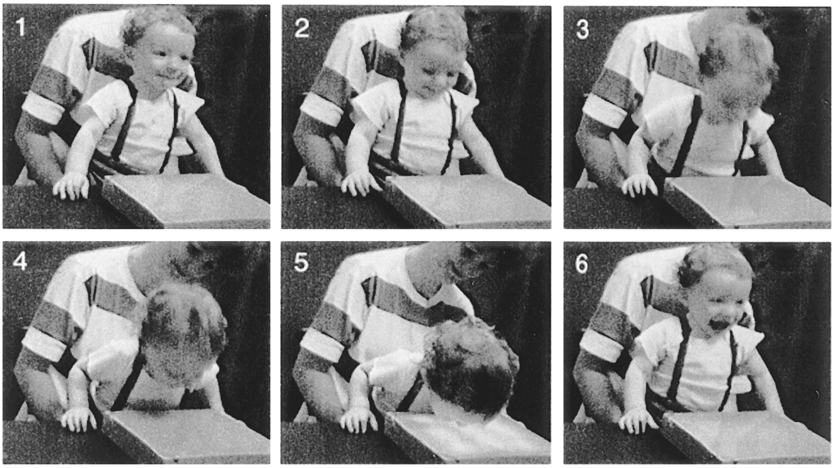

Figure 1. A 14-month-old infant imitating the novel act of head-touching. Infants often react to successful imitation with a smile, as illustrated in panel.

decontextualization is also important for language (Hockett, 1960). Words are not just used in a single context but must be generalized to new settings.

We conducted several studies that involved changes of context and other generalizations. In a test of 12-month-olds, an adult showed target acts in an infant's home, and infants were subsequently given their recall test in the laboratory. The results showed successful imitation of the actions they saw 1 week before (Klein & Meltzoff, 1999). Another study showed successful peer imitation: Toddlers who observed certain acts by classmates in a day-care center imitated these acts 2 days later at home (Hanna & Meltzoff, 1993). In a final study, 14-month-olds imitated after a change in the size and color of the toy (Barnat, Klein, & Meltzoff, 1996).

All this work on deferred imitation establishes that infants and toddlers carefully observe the behavior of others around them. These experiences are represented in long-term memory and subsequently affect the child's own productions. Evidently, recall memory and generalization are capacities normally-developing infants bring to the table in language acquisition, and they would seem to be vital to the job (Meltzoff, 1990b; Meltzoff & Moore, 1998).

COMPONENTS OF A NEW DEVELOPMENTAL THEORY

The modern research establishes a rich innate foundation for infant development. Infants are not blank slates waiting to be written on. They are born with predispositions, perceptual biases, and representational capacities that outstrip those attributed by classical theory. Moreover, there is fundamental change and reorganization in this structure as infants develop. The 1-day-old's construal of events is not the 12-month-old's, or the 18-month-old's—not to mention the adult's.

Intermodal Coordination

Classical theory held that the sense modalities were uncoordinated at birth. The modern research has discovered that they use a supramodal code that unites into one common framework of information that is picked up by separate modalities. Such a code underlies facial matching, oral-visual matching, and early speech perception. It provides a primitive map between perception and production. Infants bring this multimodal processing of information to the task of language learning. This serves well, because language can be seen as well as heard (lip reading), can be picked up through tactile input (prosthetic devices such as tactile aids), and fundamentally refers to multimodal events in the world. If the sense modalities were as separate as classical theory had supposed, language learning would be delayed.

Memory and Representation

Memory is important for language learning (Jusczyk, 1997; Jusczyk & Hohne, 1997; Kuhl, 1998; Kuhl & Meltzoff, 1997). Children must extract rules, acquire new forms, and commit this information to memory for use at a later time, often in a novel context. Moreover, they must initially acquire the new information from perception alone, without conditioning, and often without rehearsing it at the time of acquisition. The classical view of memory development left them wholly unprepared for the rigors of language learning.

We now see that infants are better prepared than predicted. The new research shows that they can form long-lasting representations based on their perception of adult input, and can do so without conditioning. They can recall this information, not simply recognize it. Moreover, they can recall information in novel decontextualized contexts. These new findings make sense, because they bring preverbal cognition into register with what is needed for the formidable task of language acquisition.

Theory of Mind and Imitation Games

Language and communication development depends crucially on being able to read the intentions of others. People don't always say what they mean; they slip, they make mistakes, they fumble. Normal adults are facile at picking up the communicative intent of the speaker, and without this, communication would break down (Baldwin & Moses, 1984; Bruner, 1983; Grice, 1969; Meltzoff, Gopnik, & Repacholi, 1999).

The burgeoning field of theory-of-mind research is focussed on children's understanding of the thoughts, desires, and intentions of others. Most of this research measures verbal responses, but theory of mind has its roots earlier in development. The new research tests theory of mind in toddlers. It shows that 15- to 18-month-olds are able to read below the surface of the adult's actions (the mistakes and slips) to the deep structure underlying this behavior (the goals and intentions of the actor).

However, theory of mind does not arise, de novo, at 18 months. It has its origins even earlier. I believe that infants are given a jump-start in developing a theory of mind through their primordial capacity for nonverbal imitation. Very young infants are launched on their career of being little psychologists with their initial judgment of "Here is something like me." Early imitation is relevant to theory of mind, because it provides the first instance of infants making a connection between the visible world of others and the infants' own *internal states*, the way they "feel" themselves to be.

Social-interactive games provide an engine for elaborating the rich initial knowledge. Imitation is bidirectional: Parents mimic their infants as well as infants imitate parents. When parents "mark" certain behaviors and vocalizations by mirroring them back to infants, this has special significance. Such play is a special channel for early communication in which both the timing and the form of the behavior give both partners an opportunity to share in the exchange. Mutual imitation games give a powerful impression to *both* the infant and the caretaker that they have psychologically "made contact," that they are in a communicative relationship.

My colleagues and I are now investigating the imitative proclivities of children with autism. There are theoretical reasons for predicting that they will be poorer than normally-developing infants in playing imitative games, and that this nonverbal deficit may be fundamentally connected to their communicative disorder (Meltzoff & Gopnik, 1993). Our recent data lends support to this hypothesis—imitative deficits seem to be central to the disorder and highly correlated with other deficits, ranging from neurophysiological to social-interpersonal measures (Dawson et al., 1998; Dawson et al., 1998).

Bridging to Language

Normally-developing infants and toddlers know more at earlier ages than predicted by classical theory. Do these precocious capacities contribute to language acquisition? Fodor (1983) thinks that they do not contribute. He and the other modularity-nativists have argued that language is a separate module, an independent "mental organ," that does not grow from social-cognitive development. It has its own independent origins. On the other hand, Piaget (1962) and Vygotsky (1962) have argued that language emerges from nonverbal cognitive and social development in infancy.

Until recently, it has been difficult to point to *empirical* evidence demonstrating that nonverbal mental structures actually support the growth of language (for attempts to link the two see, Bates, Benigni, Bretherton, Camaioni & Volterra, 1979; Bates, Bretherton & Snyder, 1987; Bloom, 1973; Gopnik & Meltzoff, 1986, 1987, 1992, 1997; Nelson, 1996). Some have abandoned the developmental perspective because of this difficulty. However, I would urge that we not abandon our developmental perspective too easily or too early. We are in a better position today than in the past to investigate how early perceptual-cognitive capacities pave the way for language. The modularity theorists might have been correct that *if* infants lived in a world of "blooming buzzing confusion" without much cognitive structure, and *if* they received the disorganized scraps of "impoverished input" that were traditionally described, then language could not emerge from such chaos. Perhaps a separate module, maturing independently, would be an attractive alternative in this case.

However, if infants live in a much more highly organized psychological world—a world involving nonverbal communication, imitation, cross-modal matching, recall memory, and a primitive grasp of theory of mind—then there is hope for our discovering how these nonverbal capacities help serve language learning. We have made modest headway on this project (Gopnik & Meltzoff, 1997; Gopnik, Meltzoff, & Kuhl, 1999). It will take the help of many others, including basic researchers, clinicians, and artificial intelligence modelers to complete this picture. It is instructive to return to the history of physics for guidance. After the collapse of classical mechanics, a new theory of physics did not emerge all at once or from one source. A grand unified theory of developmental psychology, one that connects early cognitive and cognitive development, will not do so either. Our goals are just as lofty as the physicists'—to understand the origins of mind and language, one of the most profound puzzles in the universe.

I thank Patricia Kuhl, Alison Gopnik, and Keith Moore for longtime collaboration on many of the topics discussed here. I also am indebted to Elena Plante and Carol Boliek for their cooperation in bringing this project to fruition. I am thankful for support from grants from the National Institutes of Health (HD 22514 and the Collaborative Program of Excellence in Autism PO1HD34565).

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