

pointing must have been generated spontaneously by the children. Franco and Butterworth (1996) also found that pointing comprised more than 55% of the gestures of babies ages 14 months, whereas other indicative gestures involving the whole hand, or extended arm and closed fist, or isolated index-finger extension accounted for only 18% of gestures in total. Furthermore, whole-hand indicative gestures and index-finger pointing were uncorrelated in development, with indicative gestures remaining at a low constant level between 12 and 18 months, whereas pointing increased exponentially. A similar low correlation between pointing and other indicative gestures was found by Lock, Young, Service, and Chandler (1990). All this evidence suggests that open-hand indicative gestures and pointing are unrelated and therefore may serve different purposes in communication. For babies, indexical pointing is the preferred means of communication; it occurs with great frequency and may well develop spontaneously given the appropriate social context, rather than being taught by parents or otherwise socially transmitted to the infant.

In summary, pointing may have species-typical biological origins in humans. The recent upsurge of research on pointing in chimpanzees suggests that it is not possible to maintain an absolute divide between humans and other higher primate species with respect to the gesture. Some aspects of the capacity for indexical pointing may be shared with other primates, although the possibility that humans taught chimpanzees to point cannot be ruled out. Assuming that indexical pointing is possible in chimpanzees, and that it was not learned from their caretakers or because they were trained in sign language, this makes explaining pointing all the more interesting. On the one hand, continuity with higher primates roots the gesture firmly in our common primate evolutionary heritage. On the other hand, there are many strong contrasts with chimpanzees, including the incidence of the gesture, its precise form, and the preference for pointing in babies over other means of indicating. In particular, indexical pointing in humans is done for conspecifics, whereas it has never been observed to occur between chimpanzees; in humans it is declarative, whereas in chimpanzees almost all examples are imperative. On the evidence to date, by these broader deictic criteria, declarative indexical pointing is species specific to humans.

Perhaps the question of whether chimpanzees point should no longer be expressed simply in terms of presence or absence of the ability. The more appropriate question is, why is index-finger pointing extremely infrequent and difficult to observe in chimpanzees? More progress in understanding the functional significance of index-finger pointing might be made if it could be ascertained why indicative gestures generally take the whole-hand open form in chimpanzees, but generally involve index-finger extension in humans. To examine this question further, we need to consider the relation between pointing and prehension and different theories of the origins of pointing in human ontogeny.

THEORIES OF THE DEVELOPMENT OF POINTING

Traditional views of the origins of pointing are of two types, which stress either that pointing develops out of prehension (e.g., Vygotsky, 1988) or that it is a communicative gesture from the outset. Within the latter type of theory it is often assumed that pointing is initially performed for the self and becomes ritualized through social interaction until it serves purposes of social communication (e.g., Werner & Kaplan, 1963). Vygotsky believed that pointing derives from unsuccessful grasping movements, which are interpreted by the mother as a request. In coming to her infant's aid, the mother converts the movement into a gesture for others, and it acquires an imperative character. No explanation for the specific hand posture is offered except that it is considered somehow transitional with grasping.

Franco and Butterworth (1996) tested both these types of theory in a study that compared the incidence of pointing and reaching gestures in 10- to 14-month-old babies in declarative and imperative communicative contexts. Babies had the opportunity to point at or make grasping gestures to interesting objects that were both in and out of reach. From the onset, pointing was never confused with reaching gestures. It occurred primarily to distal targets (2.7 m away) and was accompanied by vocalization and checking with the partner. Both these accompanying behaviors increased exponentially with age. Reaching gestures were not strongly correlated with checking and remained at a low level. These findings run against the view of the origins of pointing as theorized by Vygotsky (1988) because pointing was not tied in any way to failed grasping, and there was no evidence that the imperative use of the gesture had primacy. Carpenter et al. (1998) in their longitudinal study also found no evidence that the imperative use of pointing emerges before the declarative. That is, on the detailed empirical evidence to date, the pointing gesture in humans initially serves a proto-declarative purpose (i.e., look at that) rather than a proto-imperative purpose (i.e., give me that).

In a recent reinterpretation of the literature on early communicative development, Camaioni (1993) argued that imperative and declarative pointing gestures may differ in their cognitive complexity. The former implies an understanding of others as "agents of action," whereas the latter implies an understanding of others as "agents of contemplation." Exercising a causal effect on the world through physical contact with a person is said to be intellectually less demanding than understanding that interactions can be causally influenced by distal means. Rather than the declarative function of pointing being derived from the imperative function, she suggested that they may be independent. This distinction may partly explain the use of indicative gestures in chimpanzees, where almost all the evidence shows they are used imperatively and not declaratively.

That is not to say that pointing has nothing at all to do with prehension. A clue to the reasons for the morphology of the human pointing gesture comes from the specific adaptations of the hand. The human hand is highly flexible, with a very great capability for precision based on the fully opposable index finger and thumb, which is considered one of the key features differentiating man from other primates. Napier (1970) argued, from rather minimal evidence based on two 2-year-old chimpanzees clutching a grape, that only humans are capable of the pincer grip. The relative size and position of finger and thumb (the opposability index) sets limits on the extent to which the base of the thumb can be abducted against the tip of the index finger. He gave values for the opposability index of 0.65 for humans and 0.43 for chimpanzees, a difference due mainly to the relatively short thumb of the chimpanzee, which is positioned low down the wrist.

Two studies have recently reported that the pincer grip is in fact in the repertoire of the chimpanzee. In one experiment, 80 captive chimpanzees (*Pan troglodytes*) ages 1 to 25 years were observed picking up raisins measuring 1.0 to 1.5 cm from the cage floor. A humanlike pattern of pincer grip was observed at 2 years, which reached a peak of 10% of all responses at 6 years (Tonooka & Matsuzawa, 1995). The same study showed that males were more likely than females to use the pincer grip once they were over 10 years old. A second study of 13 captive chimpanzees (*Pan troglodytes*) ages 2 to 5 years showed that precision grips involving the thumb and index finger at or below the first, distal joint occurred on 25% of trials (Jones-Engel & Bard, 1996). The humanlike pincer grip with thumb pad to finger pad abduction occurred on 2% of trials.

These studies suggest that chimpanzees are capable of a degree of precision but they do not establish how precision grips develop. In human infants the pincer grip and imprecise opposition of the index finger and thumb above the first distal joint (the inferior forefinger grip typically adopted by chimpanzees) can already be observed at 8 months. The pincer grip is systematically selected by 15 months to grip cubes of 0.5 cm. Power grips, where the object is held between flexed fingers and palm, without thumb opposition, are rarely used by human infants with objects of these sizes after 15 months (Butterworth, Verweij, & Hopkins, 1997). To obtain more detailed comparative evidence, Butterworth and Itakura (1998a) studied 11 captive chimpanzees (*Pan troglodytes*) ages 4 to 20 years who were video recorded grasping cubes of apple measuring 0.5, 1.0, and 2.0 cm. This study confirmed that chimpanzees do have precision grips in their repertoire, at least from the age of 2 years, where the object is held between thumb tip and at or below the first joint of the index finger. Precision grips increase in frequency slowly, until chimpanzees are adult, and they are not systematically selected on the basis of object size at any age. Chimpanzees also use a species-typical precision grip, from about 8 years, in which they

hold a small object between the index and middle fingers (the so-called *cigarette* grip). Power grips are commonly selected in chimpanzees to the age of 8 years even when grasping small objects. This new developmental evidence shows that chimpanzees, in comparison with human infants, lack strongly systematic selection of precise grips for small objects. Their relative lack of precision extends across the age range from 2 years to full adulthood. Although a humanlike pincer grip is in their repertoire, generally the whole index finger is selected and the exact position of opposition of the thumb is relatively uninfluenced by object size. Furthermore, the pincer grip is more likely to be observed in adult male chimpanzees than in juveniles and may occur simply as a function of changes in hand size, which enable the long index finger more readily to be bent toward the thumb in the male than in the female.

Once again, the contrast with human infants is revealing because the chimpanzee makes a developmental transition from predominance of power to precision grips very much later than is observed in babies. In human infants, there is a transition (between 8 and 15 months) when power grips, which do not involve the thumb, are eliminated and the pincer grip is systematically selected by object size (Butterworth et al., 1997). In human infants, the pincer grip develops earlier in females than in males (Butterworth et al., 1997). Thus, just as for pointing and indicative gestures, the repertoire of precise grips in chimpanzees overlaps that of humans, but the rapid rate of development in humans, especially females, ensures that precision grips and pointing will be used consistently even in infancy. In contrast, precise grips are infrequent, not consistently selected, and more typical of adult male chimpanzees.

The theory to be proposed here is that pointing and the pincer grip are coevolved but different aspects of hand function that are specialized, respectively, for precise instrumental action and precise communication (see Butterworth, 1997b, 1998b). The characteristic hand posture observed in human pointing may be related to the pincer grip but as its "antithesis." Darwin (1904) first proposed the principle of antithesis to explain how animal communication often exploits visual signals to convey information. For example, an animal may signal readiness to attack by making "intention movements" that are preparatory to fighting. After a fight, the subdued posture of the defeated dog signals submission because the muscles are activated in the opposite configuration, or antithesis, to those involved in aggression (Marler, 1959).

In the case of pointing, the opposition of the tip of the index finger and thumb in the pincer grip is postulated to have pointing as its postural antithesis. This also involves a change in the focus of visual attention. In precise manual activities with tools, focal attention is on the hand, the tool, and the object in the service of precise control of manipulation. In pointing, in

contrast, attention is outer directed and serves rather precisely to reorient the attention of another person, so that an object at some distance can become a focus for shared experience. On this theory, the emergence of pointing should be related to the development of other precise uses of the hand, and this indeed is what Butterworth and Morissette (1996) established. The pincer grip was invariably in the infant's repertoire, and it was systematically selected by infants approximately 1 month before pointing onset, with females earlier than males. Exploration of objects with the tip of the index finger (tipping) has also been linked to the onset of pointing (Shinn, 1900). Butterworth et al. (1997) showed that tipping and the pincer grip are closely related in development, with the incidence of tipping declining as the pincer grip becomes established.

In summary, the theory that pointing is the antithesis of the pincer grip links precise manual action, pointing onset, and species-specific aspects of hand anatomy and function to the underlying processes governing focused attention. On this argument, precise tool use and precise manual communication through the pointing gesture are coevolved human abilities. Not only do we share some aspects of hand function with other primates, but also there are human species-typical aspects of hand function that harness the human capacity for precision.

POINTING AND JOINT VISUAL ATTENTION

The literature on joint visual attention has been extensively reviewed (Butterworth, 1987, 1995, 1998a, 1998b; Corkum & Moore, 1995; Messer, 1994). Here the discussion focuses on the relation between joint visual attention and the comprehension of manual pointing. Joint visual attention, sometimes called *deictic gaze* or *visual coorientation*, may simply be defined as looking where someone else is looking. There have arisen two contrasting views on the relation between joint attention and pointing. In one account, babies first comprehend signals given by changes in the orientation of another's head and eyes and only then begin to comprehend pointing, whereas in another view, both pointing and head and eye movements are understood simultaneously, relatively late in the first year. Those who favor the hypothesis that joint visual attention is coincident with comprehension of pointing include Moore and Corkum (1994), Corkum and Moore (1995), Morissette, Ricard, and Gouin-Decarie (1995), and Carpenter et al. (1998). Others claim joint visual attention can be observed long before there is evidence for comprehension of pointing (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; D'Entremont, Haines, & Muir, 1997; Hood, Willen, & Driver, 1998; Scaife & Bruner, 1975).

Scaife and Bruner (1975) first showed that 2-month-old infants follow a change in the orientation of gaze of an adult. In their study, babies followed the direction of gaze, to left or right, into an empty visual field. In a more recent study, D'Entremont et al. (1997) showed joint attention in babies ages under 4 months. Babies would look in the direction of a change of gaze of the experimenter, toward a doll carefully placed to be within the baby's visual field. Hood et al. (1998) also showed gaze following in babies of 4 months. These results suggest that joint visual attention is possible long before the end of the first year and before the comprehension and production of pointing if the testing conditions are suitable for young babies. An extensive discussion of the methodological factors that may be responsible is published in Butterworth (1998a). To summarize: Some of the important factors are the angular distance of targets from the infant (because joint attention places demands on the ability of the infant to integrate information over space and time); how robust the ability needs to be before it is accepted as "true" joint attention; and whether the infant's response is classified as accurate not only in following the direction of gaze but also in finding the precise location of the object. The infant before 9 months may be able to comprehend a change in a partner's postural orientation as a signal that there is something of interest but may be limited in the capacity to bridge the gap in space between the adult's signal and the object of interest. The baby under 9 months is also limited in the precision with which the correct target is singled out.

At 6 months, for example, the accuracy of the infant's response depends on ecological factors, such as whether the correct target is in motion or somehow differentially salient. The characteristics of the signal (change in head orientation with eye movements or eye movements alone, or pointing plus head and eye movements) also influence the incidence and accuracy of infant responses (Butterworth & Grover, 1988, 1989; Butterworth & Jarrett, 1991). It is relatively difficult to find evidence for eye movements alone being effective in joint attention in large-scale spaces before about 18 months (Butterworth & Jarrett, 1991; Corkum & Moore, 1995). In fact, even among adults, eye movements are not as effective as eye and head movements in allowing an observer to localize a specific target. Itakura and Butterworth (1997) found that adult observers were more accurate in locating a target when the experimenter was wearing sunglasses than when the eyes were visible. Findings such as these suggest that the eyes are not necessarily the primary source of information for singling out the object in joint visual attention tasks and that larger scale postural cues are important for joint attention (this also seems to be true for chimpanzees; see Povinelli & Eddy, 1996a, 1996b; Povinelli et al., chap. 3, this volume). In summary, joint visual attention is possible before the comprehension of pointing.