# Pointing: Where Language, Culture, and Cognition Meet

*Edited by*

Sotaro Kita

LEA LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS
2003 Mahwah, New Jersey London

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Lawrence Erlbaum Associates, Inc., Publishers
10 Industrial Avenue
Mahwah, New Jersey 07430

Cover design by Kathryn Houghtaling Lacey
Cover sculpture by Stephen C. Levinson
Cover photography by Sotaro Kita ©

**Library of Congress Cataloging-in-Publication Data**

Pointing: where language, culture, and cognition meet / edited by Sotaro Kita.
p. cm.
Includes bibliographical references and index.
ISBN 0-8058-4014-1 (cloth : alk. paper)
1. Pointing (Gesture). 2. Nonverbal communication. 3. Communication and culture.
I. Kita, Sotaro, 1963–

P117.7.P65 2002
302.2'22—dc21 2002070057
CIP

Books published by Lawrence Erlbaum Associates are printed on acid-free paper, and their bindings are chosen for strength and durability.

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

# Contents

# Acknowledgments

The origin of this volume is the Max Planck Workshop on Pointing, which was organized by the Max Planck Institute for Psycholinguistics in 1997. The interdisciplinary atmosphere of the workshop engendered exhilarating synergy among ideas and findings presented by the participants. This volume aims to share this excitement with a larger world by putting together the papers written by the participants and some additional contributors in the field into one volume. The chapters are written for this volume and illustrate state-of-the-art findings and ideas from different disciplines.

I thank Pim Levelt and Steve Levinson, two directors of the Max Planck Institute for Psycholinguistics, for their generous support for the workshop and the production of this book. I thank Edith Sjoerdsma and Mark Floris for helping me organize the workshop. I thank Jürgen Streeck and another anonymous reviewer for very helpful suggestions. I thank all the contributors for patiently tolerating delays and requests. I thank Alex Dukers for helping me put together the indexes. I thank also Marianne Gullberg, Nick Enfield, Andrea Krott, and Daan van Exel for their help in the final stage of putting the volume together.

Chapter 1

# Pointing: A Foundational Building Block of Human Communication

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This volume examines pointing gestures from a multidisciplinary viewpoint. Pointing has captured the interest of scholars from different disciplines who study communication: linguists, semioticians, psychologists, anthropologists, and primatologists. However, ideas and findings have been scattered across diverse journals and books, and researchers are often not aware of results in other disciplines. To date, there have been few opportunities for interdisciplinary exchange of information. The aim of this volume is to provide an arena for such exchange.

The prototypical pointing gesture is a communicative body movement that projects a vector from a body part. This vector indicates a certain direction, location, or object. Why is investigation of pointing gestures important? Because it is a foundational building block of human communication. Pointing is foundational in four respects.

First, it is ubiquitous in our day-to-day interaction with others. When communicating about referents locatable in the speech situation, pointing is almost inevitable. Even when we talk about referents that are distant in space and time, we often point to the seemingly empty space in front of us. Such pointing assigns a certain meaning to the location in the space, and we point back to the same location later in the discourse (see McNeill, chap. 12). The assignment of a meaning to a location by pointing is part of the grammar of signed languages. Pointing in signed languages is equivalent to, and used as frequently as, pronouns in spoken languages ("every

four signs in signed discourse is a pointing sign"; see Engberg-Pedersen, chap. 11).

Second, pointing is a uniquely human behavior. In other words, pointing separates humans from primates, just like the use of language does. Primate behaviors that closely resemble pointing lack some of the key components of human pointing (see Povinelli et al., chap. 3; Butterworth, chap. 2). A careful examination sharply delineates the fundamental difference between primate and human communication.

Third, pointing is primordial in ontogeny. Pointing is one of the first versatile communicative devices that an infant acquires. Pointing emerges out of its antecedent behaviors, such as undirected extension of the index finger, several weeks before the first spoken word (see Butterworth, chap. 2; Masataka, chap. 4).[1] Once infants start uttering words, they produce a word and a pointing gesture together. How infants use pointing predicts their later language development to some extent (see Goldin-Meadow & Butcher, chap. 5; Butterworth, chap. 2). In addition, the caregiver's pointing is probably one of the important cues with which infants establish a connection between a word and its referent.

Fourth, pointing does not merely indicate a vector, but it can serve to create further types of signs. For example, a pointing gesture can create an iconic representation by tracing a shape or movement trajectory (see Haviland, chap. 7). It sometimes even leaves a visible mark, "inscribing" a shape on a surface (see Goodwin, chap. 9).

## CROSS-CUTTING ISSUES

Because pointing is so ubiquitous and we interpret it with such ease, it might appear that pointing is a trivial phenomenon. On the contrary, as demonstrated by all of the chapters, careful examination reveals that the versatility and interpretability of pointing are based on complex underlying biological, psychological, and semiotic processes. Some issues regarding these processes recur in different chapters in the volume.

One such issue is biological determinism and the putative universality of index finger pointing (see Wilkins, chap. 8; Masataka, chap. 4; Butterworth, chap. 2; Povinelli et al., chap. 3). The question is whether humans are biologically programmed to point with an extended index finger, making index-finger pointing universal across cultures. Although it is anatomically difficult for chimpanzees to extend only the index finger (Povinelli et al.,

[1]There seems to be little evidence supporting Vygotsky's (1988) hypothesis that the infant's failed reaching and the caregiver's reaction to it develop into pointing (see the chapters by Masataka and by Butterworth).



chap. 3), human infants produce index-finger pointing from early on in studies conducted in the United States, Europe, and Japan (see Butterworth, chap. 2; Masataka, chap. 4). This might suggest the biological determinism of index-finger pointing. However, in these cultures, adults also frequently use index-finger pointing. Thus, questions still remain. Is infants' index-finger pointing a biologically programmed choice? Or is it due to the input and reinforcement from adults? (See Masataka, chap. 4, for the discussions about the possibility of culture-specific reinforcement.) A more conclusive answer to these questions requires a future study on children's early pointing in a culture where adults do not use index-finger pointing at all or do so only rarely. As noted in Wilkins's chapter, some preliminary reports suggest that such cultures may indeed exist.

Furthermore, Wilkins' chapter notes that even in cultures where index-finger pointing is commonly used among adults, its function vis-à-vis other forms of pointing (e.g., flat-hand pointing) differs from culture to culture. Kendon and Versante's chapter provides a meticulous description of functions associated with different forms of pointing used by Neapolitans. The range of forms used as pointing gestures (i.e., different hand shapes and the choice of other articulators such as the lips[2]) and the form–function mapping in a given culture clearly have to be learned by children.

Another recurring issue in the chapters concerns semiotic processes that underlie interpretation of a pointing gesture. The general problem is that the referent of a pointing gesture can be ambiguous in many ways. Does the pointing indicate a direction (e.g., north)? If so, what is the origo from which the direction should be interpreted: from the location of the gesturer, or from some other reference point? (See Haviland, chap. 7, for discussions on pointing with a "transposed" reference point.) If pointing does not merely indicate a direction, it has a target object or location. If the target is an object, does it simply refer to the object, or does it predicate that the object is located at its location (see Engberg-Pedersen, chap. 11)? Furthermore, which aspect of the object is indicated? To take an example from Clark's chapter (chap. 10), pointing in the direction of a car could be a reference to the car itself, to the color of the car, or to a piece of junk.

There are different suggestions as to how one can narrow down the domain of possible referents. Goodwin (chap. 9) suggests, for example, that an "activity framework" specifies which features of the environment are relevant for the ongoing activity and hence are likely to be the referent of a pointing gesture. In addition, different forms of pointing may correlate with particular types of referents (see Kendon & Versante, chap. 6; Haviland, chap. 7; Engberg-Pedersen, chap. 11; Wilkins, chap. 8; Kita, chap. 13).

[2]Lip pointing seems to be more common across cultures than one would suppose from European perspectives. See Wilkins' chapter as well as Sherzer (1973) and Enfield (2002).

Even if one identifies the referent, further pragmatic inferences may be needed to get to the intended interpretation. First, an associative link from the direct referent to the inferred referent may have to be taken into account. For example, a pointing gesture can be directed toward an empty chair (the direct referent) in order to refer to the person who normally sits in the chair (the inferred referent; see Haviland, chap. 7; Clark, chap. 10). Second, a pointing gesture can be interpreted as a social act such as "imperative," which demands a response from the communication partner. For example, an infant may produce a pointing gesture that can be interpreted as a request, "give me that" (see Butterworth, chap. 2; Povinelli et al., chap. 3). Finally, the accompanying speech can narrow down possible interpretations of a pointing gesture (see e.g., Goodwin, chap. 9). Goldin-Meadow and Butcher (chap. 5) note that infants in the one-word stage often combine a word and a pointing gesture, which together comprise a proposition.

To complicate matters further, a pointing gesture may not have a preexisting target, but may be directed toward seemingly empty space. "Abstract deixis" in cospeech gesture (see McNeill, chap. 12) and "indexical signs" in Danish Sign Language (see Engberg-Pedersen, chap. 11) are such cases. In these cases, a physically empty location is assigned a meaning by virtue of being the target of a pointing gesture. Haviland discusses a related case, which involves pointing gestures directed toward a concrete target. In the description of the structure of a sugar-cane press, the speaker points to a wooden post of a house. However, he does not intend to refer to the house post. He uses the house post as a prop. It stands for a supporting post of an imaginary sugar-cane press, which he "builds" with a series of gestures. These are examples of Silverstein's (1976) "creative" function of indexical signs. The interpretation of such creative pointing gestures is constrained not only by the linguistic context, but also by the "deictic field" (see especially McNeill, chap. 12), which is populated by imaginary entities that are also established by other creative pointing gestures. Note the similarity and the difference between activity frameworks and deictic fields. An activity framework imposes a more abstract structure on a cluttered physical environment, whereas a deictic field projects a richer structure on a physically minimal environment.

## OVERVIEW OF THE CURRENT VOLUME AND BEYOND

Having laid out some of the issues that cross-cut the chapters, we now turn to the structure of the volume. The first four chapters concern the ontogeny and phylogeny of pointing. The first chapter by Butterworth provides an overview of the literature on developmental and primate studies on pointing and joint attention. He argues that index-finger pointing is a



uniquely human behavior (e.g., there has been no report on primates in the wild using index-finger pointing among themselves). He maps out the developmental path of pointing from its antecedent behaviors to the role it plays in early language development.

In the following chapter, Povinelli, Bering, and Giambrone discuss the comprehension of pointing by chimpanzees. The results of their experiments indicate that, unlike young children, chimpanzees lack the understanding that a body part projects a vector toward a particular direction, and, more crucially, they lack the understanding that the communication partner has to mentally represent the direction. The lack of "mentalistic" understanding of pointing by chimpanzees is in sharp contrast to human infants, who check whether the communication partner is attending the same referent (cf. the chapter by Butterworth).

Two chapters on the development of pointing follow. Masataka studies the earliest part of development, namely, the stages that lead up to the emergence of adultlike pointing gestures around the age of 11 months. He proposes that undirected extension of the index finger is one of the key antecedent behaviors for pointing. Index-finger extension tends to be synchronized with speechlike vocalization. In addition, index-finger extensions occur more often when the caregiver reacts to the infant's vocalization in a timely manner and when an infant is confronted with an unfamiliar object. In other words, the situation that leads to index-finger extension is very similar to the situation in which pointing gestures are commonly observed in older infants, namely, verbal communication with a caregiver about a noteworthy object. Furthermore, a longitudinal study has revealed that a sharp drop in the frequency of index-finger extension is immediately followed by a sharp rise in the frequency of pointing.

A later stage of the development is covered by Goldin-Meadow and Butcher, who investigate pointing between the one- and two-word stages. They have found that the onset of utterances in which a word and a pointing gesture refer to two separate entities is a good predictor for the subsequent onset of two-word utterances. In other words, infants package two ideas into a message first in a pointing–word combination and then in a word–word combination.

Four chapters on the ethnography of pointing follow. These chapters examine naturally occurring pointing gestures and contexts of their use, as well as people's meta-knowledge about various types of pointing gestures. Kendon and Versante investigate the relationship between different shape features of pointing and their functions in Neapolitans' gestures. Their analysis of the contexts of use reveals an elaborate system of pointing in this famously gesture-rich culture.

Haviland illustrates various types of semiotic complexity of pointing gestures using data from Tzotzil speakers of Mexico (an 18-month-old child

and adults). He discusses relationships between various pointing forms and their functions, relationships to speech, and the influence of spatial and sociocultural contexts on the interpretation of pointing.

Wilkins problematizes what it means to claim universality of index-finger pointing by underscoring the culture specificity of form–function relationships. He examines form–function relationships in the Arrernte community (Central Australia) from a perspective that emphasizes meta-knowledge. He found that some of the hand shape used for pointing in this culture are unusual from Euro-American perspectives. For example, he reports transitional middle-finger pointing by young children.[3]

The last in the series of chapters on the ethnography of pointing is the chapter by Goodwin. He analyzes pointing by archaeologists at an excavation site and by an aphasic patient. He examines various semiotic and interactional structures that support how interactants interpret pointing. Such structures can be exemplified by "activity frameworks," mentioned earlier, and "participation frameworks," which determine how participants of an activity attend to each other and to things in the environment relevant for the activity.

The following chapter by Clark puts pointing in a larger theoretical context. He proposes a general theory of how people indicate. He contrasts semiotic characteristics of two ways in which people indicate: "directing-to," which includes pointing, and "positioning-for" (or "placing"). One of the fundamental differences between the two is what is manipulated for the purpose of indication. In directing-to, one moves the attention of the communication partner to the referent, whereas in positioning-for, one moves the referent to the location of the communication partner's attention.

Engberg-Pedersen investigates different linguistic functions of pointing gestures with both the hand and gaze in Danish Sign Language. She has found that a pointing sign with the hand serves as a pronoun, a determiner indicating specificity of a referent, or a "pro-form" performed simultaneously with another sign. A pro-form adds a spatial component to the concurrent sign when the sign cannot be modulated spatially (e.g., a sign that has to be in contact with the face). Gaze pointing is also multifunctional: checking the recipient's understanding, reference tracking, imitation of the gaze movement by a quoted person, drawing the recipient's attention to iconic depiction. Furthermore, the conditions under which gaze pointing is accompanied by the turning of the head or the torso are also discussed.

In the following chapter, McNeill discusses a frequent type of gesture in conversation, in which the speaker points to seemingly empty space in

[3]See also Wilkins (2002).



front. This can be labeled "abstract deixis," in the sense that the gesture points to no concrete target. Such pointing creates an imaginary target at a certain location, which can be revisited later in the discourse. McNeill illustrates how abstract deictic gestures structure the speaker's imaginary space. By virtue of the externalization via pointing, this space is shared with the communication partner. In other words, space becomes personal and public simultaneously. Thus, abstract deixis can be seen as the interface between "interpsychic" and "intrapsychic" processes of meaning creation.

In the last chapter, Kita discusses the cognitive processes that underlie the production of pointing gestures and accompanying spoken utterances through the observation of pointing gestures produced in naturalistic route directions. He argues that pointing helps speaking by facilitating the choice between the notoriously confusing concepts *left* and *right*. He also discusses how torso orientation and gaze movement are systematically coordinated with pointing.

In summary, a wide range of investigations from different disciplines is represented in this volume, although it does not cover fields such as experimental psycholinguistics (de Ruiter, 1998; Feyereisen, 1997; Levelt, Richardson, & La Heij, 1985), neuropsychology (Lausberg, Davis, & Rothenhäusler, 2000; McNeill, 1992), and second language acquisition research (Gullberg, 1998, in press). This is a modest but firm step forward in the synthesis of knowledge from various approaches about pointing—where language, cognition, and culture meet.

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*Chapter* 2

# Pointing Is the Royal Road to Language for Babies[1]

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Index-finger pointing is a means of making definite reference that is intimately linked to gesture and speech. This chapter examines evidence for its species specificity to humans, considers the development of pointing in babies, and offers some evidence for the universality of the gesture at least in its earliest form. First, it is necessary to describe the typical posture of the hand in pointing to avoid confusion with other indicative gestures and to define it precisely. In pointing, the index finger and arm are extended in the direction of the interesting object, whereas the remaining fingers are curled under the hand, with the thumb held down and to the side (Fig. 2.1). The orientation of the hand, either palm downward or rotated so the palm is vertical with respect to the body midline, may also be significant in further differentiating subtypes of indexical pointing (see also Kendon, chap. 6, this volume).

*Deixis* is derived from the Greek *deiknunai* meaning "to show" (Collins Softback English Dictionary, 1991). Pointing is a deictic gesture used to reorient the attention of another person so that an object becomes the shared focus for attention. Rolfe (1996) offered three criteria for deictic pointing: (a) It is dialogic in that it requires an audience and is for someone else's benefit, (b) the gesture serves to single something out which the ad-

[1]George Butterworth died before the completion of the book production process. The editor took the liberty of updating the references and making minor editorial adjustments in the text.

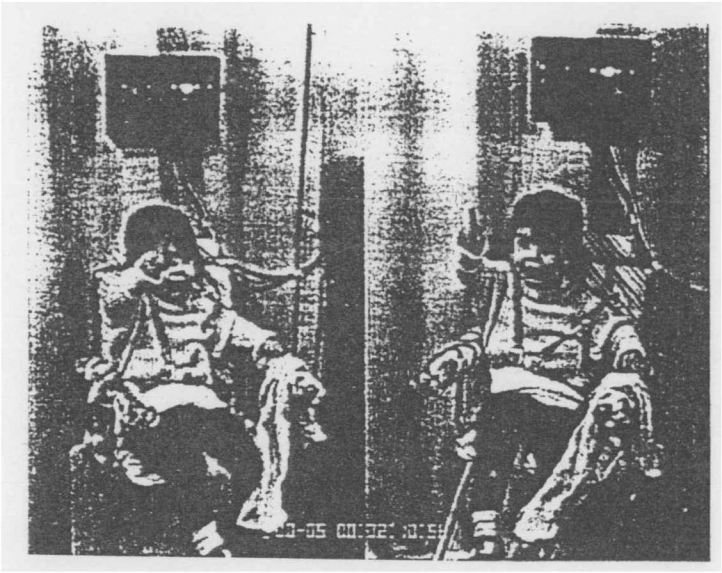

FIG. 2.1. Typical hand posture in infant pointing.

dressee comprehends to be the referent, and (c) the direction of what is being pointed at is seen as away from the pointing hand. These three characteristics constitute the contextual and cognitive requirements for the production of pointing, and they may also be taken as conditions for comprehension of the gesture. In evaluating developmental and comparative evidence, these criteria for deixis need to be borne in mind to differentiate between superficially similar behaviors. We begin by considering when pointing develops in infancy, then turn to some comparative studies to evaluate the claim that pointing is species specific to humans. This gives the background for a new theory of the origins and development of pointing as arising from species-typical human abilities for the precise control of instrumental action.

## THE PRODUCTION OF POINTING

A number of studies now agree on the emergence of canonical pointing (as defined earlier) at an average age of 11 months, although babies as young as 8.5 months have been observed to point (Butterworth & Morissette, 1996; Schaffer, 1984). Approximately 33% of parents of 8-month-old babies



in the United States say that their babies already point (Fenson et al., 1994). Carpenter, Nagell, and Tomasello (1998), in a longitudinal study of 24 babies also in the United States, found that pointing to nearby objects occurred at 11 months, 2 months before more distal pointing. Butterworth and Morissette (1996), in a similar longitudinal study of 27 babies in England, also found the average age for pointing onset to be in the 11th month (11.2 months for females and 11.7 months for males). Ohama (1984), in a longitudinal study in Japan, reported that 5/9 of her sample pointed by 11 months and 8/9 by 13 months. In the standardization sample for the MacArthur test of early language development, Fenson (personal communication, 1997) found that pointing onset occurred at an accelerated rate for female babies between 9 and 12 months, when the number of boys who have started pointing catches up. Pointing begins rather suddenly, as if the gesture emerges after a stage transition. By 12 months it comprises more than 60% of all gestures made by the infant (Lock, Service, & Chandler, 1990). Pointing is accompanied by checking with the adult (3.4% of points at 12 months according to Lock et al. [1990], rising to about 20% at 18 months in Franco & Butterworth [1996]; Ed. note, see also Franco [1997], Franco & Wishart [1995]). Pointing is also accompanied by vocalization (50% of pointing gestures according to Lock et al. [1990], 76% in Franco & Butterworth [1996], 87% in Leung & Rheingold [1981], all at 12 months).

To establish more precisely for this chapter the actual orientation of the hand around the time of pointing onset, the author checked left- and right-handed examples from video recordings of 10 babies. In 19 cases, the orientation of the pointing hand was palm down; in one case, a left-handed point, the orientation was with the hand rotated at the wrist, through 90 degrees in the horizontal plane, so that the palm was vertical. That is, the canonical pointing gesture, with index finger and arm extended, palm down, is by far the most frequently observed hand orientation in babies at the onset of pointing. We may describe pointing as a universal gesture in babies given the geographical dispersion of the longitudinal studies. Most cross-sectional studies also agree that pointing begins by 12 months (e.g., Leung & Rheingold, 1981; Murphy, 1978).

Wilkins (chap. 8, this volume) observed pointing with the middle finger among three aboriginal children ages 22 to 36 months, a gesture replaced by indexical pointing rather later in development. Such middle finger pointing is occasionally observed in Western infants too. It seems that there is a permissible (but narrow) envelope of variation in the form of the gesture, which during development converges on the canonical indexical form. The questions to be addressed are, why does pointing take this indexical form—is it an aspect of our biological endowment or is it socially derived? If there is evidence for a biological base, is pointing species specific to people?

## ANTECEDENTS OF POINTING

It was once widely believed that pointing emerges by the differentiation of index-finger extension from the open-handed waving posture sometime after the seventh month (e.g., Leung & Rheingold, 1981; Murphy & Messer, 1977). Although the canonical form of pointing does emerge toward the end of the first year, there is evidence that antecedents of pointing, in particular the independent extension of the index finger, can be observed much earlier. Isolated extension of the index finger, with the other fingers curled inward in the pointing posture, has been observed in the 3-month-old baby, in close association with speechlike sounds, when the infant is engaged in social interaction (Fogel & Hannan, 1985; Masataka, 1995; Masataka, chap. 4, this volume). Hannan (1987) found that "pointing" in babies 3 to 9 months old tended to be left-handed when the baby interacted with the mother and right-handed when the mother showed the baby a toy. Hannan and Fogel (1987) in a longitudinal single case study observed pointing movements, predominantly of the right hand, from 18 days. "Pointing" was accompanied by movements of the eyes and mouth that occurred as a cluster of orienting behaviors. Fogel (1981) observed pointing, sometimes with extended arm and index finger, in babies ranging in age from 18 days to 6 months when in social interaction. These microanalytic studies of babies reveal that embryonic forms of the pointing gesture are already in the repertoire although mothers are not aware that their babies are pointing. The typical pointing posture of the hand does not emerge from a less differentiated form, but shows the typical hand shape soon after birth.

There are also isolated reports that babies can sometimes be observed making pointing movements for themselves before they engage in pointing for others. Tran-Duc Thao (1984), a Vietnamese philosopher, described such behavior as reinforcing for oneself the "sense certainty" of the object. Such phenomena may be involuntary orienting movements or expressions of interest, which are perhaps related to the transitional phenomena observed by Franco and Butterworth (1996). These authors found that at 10 months babies sometimes point at an object, then turn to the mother as if to check with her, whereupon they point at the mother. It is as if visual checking and manual pointing are coming together in a new coordinated structure comprising pointing and checking, which is not yet appropriately sequentially organized. Checking is strong evidence both for communicative intent and for the deictic nature of the gesture because the audience is being "interrogated" for comprehension of the referent. Thus, it is possible that components of pointing, which are particularly closely linked to syllabic vocalization, can be observed early in development. The difference between the earlier and later forms is that the gesture is not yet used instrumentally. The evidence on the antecedents of pointing therefore takes the



form of the action comprising the gesture into early human development, again suggesting it is of biological origin.

Once canonical pointing emerges, further changes occur in relation to checking. Franco and Butterworth (1996) found that when babies first point, checking follows the gesture, whereas by 16 months they will first check to establish that they have the attention of the adult and only then do they point. The gesture soon acquires a metacognitive aspect in that the older infant knows that having the attention of the other person is a necessary condition for communication. These observations suggest that pointing has the necessary dialogic aspect to qualify as a deictic gesture from the time the canonical form appears.

Further evidence comes from studies in which the social conditions for pointing were investigated (Franco & Butterworth, 1990; Ed. note, also see Franco, 1997; Franco & Wishart, 1995). Babies were tested alone or with a social partner in the presence of two doll figures that moved their arms and legs in a regular cycle. Pointing occurred only under conditions where a partner was available for communication, which again suggests that the gesture is deictic from its inception. Furthermore, pointing by the baby did not require that the adult also point, nor was the rate of infant pointing a function of the adult rate. That is, infant pointing requires an audience, but the incidence of pointing by the infant was not driven by whether the partner also pointed. This suggests that social influence is limited to the audience effect, rather than social transmission being responsible for creation of the gesture by ritualization or transfer of a conventional act. In another study, infants who had recently begun to point were tested in pairs in the presence of an interesting event. Preverbal babies would point and check with each other, which suggests again that there is no necessity for adults to mediate in the production of the gesture. Such observations argue against any simple theory of transgenerational transmission from adult to baby, although this does not mean that adults do not have an important role in the subsequent elaboration of pointing (Franco, Perucchini, & Butterworth, 1992; Ed. note, also see Franco, 1997; Franco & Wishart, 1995). This evidence also runs against the view that pointing is at first performed primarily for the self because a partner had to be present for pointing to occur at all.

In summary, recent evidence suggests that canonical pointing emerges toward the end of the first year, slightly earlier in females than males. The hand posture observed conforms closely to the description just offered, namely, index-finger extension with palm down, thumb tucked in, and other fingers curled under. Associated phenomena, such as checking (and vocalization), show that pointing already has deictic qualities in requiring an audience and in being performed in order to redirect the attention of others. To determine whether pointing is biological in its origin or species specific to humans requires further comparative evidence.

## COMPARATIVE EVIDENCE ON THE SPECIES SPECIFICITY OF POINTING

The precise definition of the pointing gesture is rather important in evaluating comparative evidence. For example, the pointer dog, according to Hewes (1981), has been associated with humans in hunting for at least 2.5 thousand years. The dog aligns its whole body with the target, from tip of nose to extended tail, sometimes with a front paw raised, in a manner partly analogous to human deictic behavior. The orientation of the dog indicates the general direction of fallen wildfowl, which assists the hunter locate the prey. However, it is not the case that the dog engages in a dialogue with the hunter, and furthermore, whole-body orienting differs in other important ways from indexical pointing. For example, the dog does not see itself orienting toward the prey, whereas sight of the hand and the object in the visual field may be integral to the production and comprehension of pointing in humans. Using a part of the body, the arm and hand, to indicate, in lieu of the whole body, may also require a cognitive analysis of part–whole relations.

Chimpanzees (*Pan troglodytes*) and orangutans (*Pongo pygmaeus*) are capable of signaling with manual indicative gestures, in which the arm, open hand, and extended fingers are oriented in the direction of an interesting sight. The behavior is usually made by captive, trained chimpanzees to their human trainers and is rarely seen between conspecifics. Hewes (1981) described an observational study of a pair of captive bonobos (*Pan paniscus*) in which only 21 indicative gestures were observed in 600 hours of filming. The gestures were described as "completely iconic hand movements" made by the male, which served to indicate to the sexual partner that she should move to another part of the enclosure. The question is, should such open-handed, indicative gestures in chimpanzees be considered equivalent to human pointing? Some authors have argued that it is equivalent and that the function of indicating is more important than the form of the gesture (Krause & Fouts, 1997). For the theory to be proposed here, however, it is important that higher primates generally give no prominence to the index finger in making indicative gestures (Blaschke & Ettlinger, 1987; Call & Tomasello, 1995; Menzel, 1974). One factor that may limit index-finger pointing in apes is the anatomy of the hand. Povinelli and Davis (1994) noted that the resting posture of the index finger in anesthetized humans is slightly proud of the remaining fingers, whereas in chimpanzees all the fingers remain aligned when at rest, which suggests that differences in the insertion of the muscles exist in index-finger control.

However, this need not mean that indexical pointing is impossible for chimpanzees, as the literature used to suggest (Butterworth, 1991a). It has recently been shown that chimpanzees (*Pan troglodytes*) can signal with an



index finger (Leavens, Hopkins, & Bard, 1996). The clearest evidence came from a chimpanzee named Clint, age 14 years, who extended the index finger (with left and right hand) apparently as a request to the experimenter for food that had fallen on the ground. Index-finger extension was less frequent (38 occasions) than whole-hand indicative gestures (102 occasions). Indicative gestures were used by Clint as an imperative for food items (i.e., give me that food), and it is possible that his index-finger pointing may have been learned as a particular consequence of social contact with humans. It is interesting that Clint was never observed to use index-finger pointing with conspecifics. Nevertheless, some of his index-finger points were accompanied by checking with the experimenter, suggesting that the gesture required an audience, and he only pointed when the experimenter was facing him. Leavens and Hopkins (1998), in a study of 115 chimpanzees ages 3 to 56 years, found that 47 animals made whole-hand indicative gestures and 6 animals used indexical points with arm extended to single out the location of food for an experimenter. Of 78 chimpanzees who made gestures of any kind, 35% of the gestures were accompanied by vocalization, a figure rather lower than found with babies. High levels of gaze alternation (checking) were observed, however (80% of animals showed checking from 8 years).

Another possibly important factor concerns the species-typical requirements for precision in behavior. Krause (1998) reported indexical pointing, with arm extension, in a 21-year-old captive chimpanzee who was trained to indicate to a naive experimenter which of four possible places contained a hidden object. Under these conditions, which required greater precision than is usually the case for cross-species communication, indexical pointing was used by the chimpanzee. It is possible that the gesture was learned from the human caretakers because the colony contained language-trained animals. Nevertheless, it was perhaps because the testing situation required precision that the chimpanzee used the indexical pointing gesture and not the more common indicative gesture. Feral chimpanzees have not been observed to point indexically, and indeed, whole-body orienting may be sufficiently communicative for the chimpanzee's purposes in the wild (Menzel, 1974). This implies that differential requirements for precision between humans and chimpanzees may be an important factor in determining whether indexical pointing or whole-hand indicative gestures are used.

The contrast in prevalence of pointing in humans is illustrated graphically in a study of congenitally deaf infants by Goldin-Meadow and Feldman (1977). They found that 51% of as many as 5,000 gestures produced by toddlers ages 17 to 47 months were indexical points at things, people, or places (cited in Hewes, 1981). Because the children were being taught language by an oral method and parents avoided signing, the authors concluded that

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.

The fundamental developmental question concerns the mechanisms that operate in joint attention at different ages. The argument to be pursued here is that additional cognitive mechanisms serve joint visual attention after the comprehension and production of pointing. Butterworth and Jarrett (1991) suggested three successive mechanisms of joint visual attention in the age range between 6 and 18 months. At 6 months, babies look to the correct side of the room as if to see what the adult is looking at, but they cannot tell which of the two identical targets on the same side of the room is correct unless it happens to move or in some way be the more salient. The change in the adult's orientation of head and eyes conveys information as to the direction in which to look (i.e., the left or right in the baby's visual field), but the precise location for joint attention is specified by the object itself. This has been called the *ecological* mechanism of joint visual attention (Butterworth & Jarrett, 1991). It depends on the differentiated structure of the natural environment, so that what initially attracts the adult's attention and leads the adult to turn (thus providing the baby with information about *spatial direction* through the change in the adult's postural orientation) is also likely to capture the attention of the infant (thus providing information about *spatial location* through the object's intrinsic properties). The ecological mechanism enables a "meeting of minds" in the self same object.

Between 12 and 18 months the infant begins to localize the target correctly, even when it is further into the periphery than an identical distracter target (Butterworth, 1991b; Butterworth & Jarrett, 1991). This new mechanism was called *geometric* because it appeared to require extrapolation of a vector between the mother's head orientation and the referent of her gaze. The adult's change of gaze then signals both the direction and the location in which to look. The comprehension and production of pointing are more or less coincident in development with the appearance of this "geometric" mechanism. The implication is that a cognitive developmental change has occurred, which leads infants to understand and produce pointing.

Joint visual attention is limited by the boundaries of the babies' visual space even to 18 months of age. The spatial limitation is suggested by the fact that infants only search for targets within their own visual field (Butterworth & Jarrett, 1991). If the mother looks at a target behind the baby, the infant either fixates a target in front or, if the visual field is empty, turns through about 40 degrees and gives up on failing to encounter anything in the periphery of vision (Butterworth & Cochran, 1980). Joint visual attention depends on the infant sharing a visual–spatial frame of reference with others. Furthermore, there are implications for auditory aspects of reference because it seems possible that the space behind the infant is initially specified auditorily. Certainly, babies have no difficulty orienting to a sound behind them, but in joint attention studies, the space behind is silent. Adding pointing to the signal does not help babies search behind them at 12 months, but by 18 months they will search following gaze cues alone as long as the visual field is empty (Butterworth & Jarrett, 1991). Thus, the problem for infants in searching behind them may be to comprehend that the adult's visual signal has made reference to auditory space. The 12-month infant is visually dominated, but by 18 months a representational spatial mechanism becomes available, which serves to integrate the visual space in front of the baby with the auditory space behind. Thus, once the representational mechanism is available, one might theorize that a visual signal, such as pointing, will implicitly carry auditory significance, and this could be an important requirement for the transition to speech.



In summary, as far as the comprehension of gaze is concerned, there is evidence in the first 18 months of life that three successive mechanisms are involved in "looking where someone else is looking." The ecological mechanism is available well before there is comprehension of pointing, but it may encode from the adult's signal only the general spatial direction of a potential target. It requires the intrinsic attention-capturing properties of objects for completion of the reference triangle among infant, adult, and object. At around 12 months, there is evidence for the beginning of a new geometric process, whereby the infant from his or her own position extrapolates, from the orientation of the mother's head or gaze or pointing arm, into the periphery of visual space. This transition has many of the qualities of a stage change within the process of cognitive development. There is a further stage in the development of joint attention to a represented space, which surrounds the infant and other objects like a container. This amodal space serves to link visual signals to the silent auditory space behind the baby. It is interesting to note that children with severe auditory handicaps have difficulty in localizing targets at the periphery of the visual field (Netelenbos & Savelsbergh, 1991), which may support the theory that visual signals become linked to a represented auditory space between 12 and 18 months.

## COMPREHENSION OF POINTING IN BABIES

Researchers have distinguished between processes involved in the comprehension and production of manual pointing. Many studies agree that the comprehension of pointing, at about 10 months, slightly precedes its production, but this may simply reflect relative lack of knowledge about the precursors of pointing production (Franco & Butterworth, 1996; Leung & Rheingold, 1981; Messer, 1994). There is evidence that the spatial conditions of testing influence whether infants comprehend pointing. An early study by Lempers (1976, 1979) found that babies of 9 months comprehend

pointing to nearby targets and by 12 months they comprehend pointing to more distant targets. Morissette et al. (1995), in a longitudinal study, also found that comprehension of manual pointing to relatively distant targets begins at about 12 months. The most frequent error of babies was to look at the pointing hand rather than at the designated target. Murphy and Messer (1977) found that pointing comprehension was earlier (9 months) for targets on the same side of the room as the pointing hand than when the point was into the contralateral half of the infant's visual space, across the body midline of the adult (12 months). Butterworth and Grover (1989) showed that pointing was understood by 12 months. In contrast, infants at 6 or 9 months were as likely to fixate the pointing hand as the designated target. Carpenter et al. (1998) found that pointing is understood significantly earlier for targets on the baby's right-hand side than on the left, a finding that was replicated in Butterworth and Itakura (1998b). Mothers go to a great deal of trouble, with exaggerated hand movements, to lead the young infant's gaze from the mother's hand onto the target (Murphy & Messer, 1977). Grover (1988) showed that the infant's latency to fixate the correct target significantly decreases between 9 and 12 months, and babies at 12 months were significantly more likely to respond when the signal included a point and to fixate a target further into the periphery of vision. The likelihood of a response to pointing increased from 69% to 80% of trials when the number of targets in the field of view was increased from one to two. When the salience of the targets was experimentally manipulated, by setting them into motion, either singly or in pairs, the infant's response to pointing increased to ceiling level. Target motion was sufficient to eliminate hand fixation in 9-month infants, although babies then went on to fixate only the first target along their scan path from the adult's hand. By 15 months, however, babies did alright on the second, more peripheral target in a sequence of fixations. Thus, infants are not merely fixating the first object they encounter after the adult's hand when they comprehend pointing. Rather, they appear to be extrapolating a vector through space to intersect with a potential target based somehow on the angular orientation of the gesture or the movement of the pointing arm.

Butterworth and Itakura (1998b) reported a series of studies that tested the vector extrapolation hypothesis. Infants were 6 months, 12 months, and 16 months old, and the accuracy with which they could locate one of two identical targets was compared at angular separations between pairs ranging from 25 to 55 degrees. Mother and baby sat *en face*, and one target was always at 10 degrees to the left of the baby's midline (the first target along their scan path from the mother), with the second at a more peripheral leftward position on a semicircular distribution at 2.76 m. The mother either looked at the target (with head and eye movements) or looked and pointed at the target. For all three age groups, there was little evidence that babies



could accurately select the more peripheral of the pair just on the basis of head and eye movements. However, from 12 months, manual pointing had a significant effect on the accuracy of the response, and by 15 months, there was a clear advantage to pointing in localizing the more peripheral target at all angular separations. Infants' success following the pointing cue, despite the narrow angular separation between the targets, suggested that they might be solving the problem by vector extrapolation.

In further experiments with 4.5-year-old children and adults, Itakura and Butterworth (1997) and Butterworth and Itakura (1998b) tested the vector extrapolation hypothesis more stringently by presenting targets three at a time on each side of the visual field. The angular separations between targets varied from 4 to 45 degrees for adults and it was held constant at 10 degrees for children, again at 2.7 meters. The task required the participant, who sat next to the experimenter, simply to state the color of the target that was being singled out by a pointing gesture or by combinations of head and eye movements. Children were accurate following pointing but not accurate for head and eye movements. Pointing allowed accuracy only to the inner and outer periphery of each visual hemifield, and children were inaccurate to the intermediate targets. Adults were generally as accurate following head and eye movements as following pointing, but again they were inaccurate for the intermediate targets positioned at separations of 15 degrees or less. That is, the pointing gesture successfully drew attention to the peripheral boundaries of vision, but did not allow precise target localization of intermediate targets either by adults or children.

The results imply that precise linear vector extrapolation is not used in following pointing because there is no reason that a linear vector should be less accurate for intermediate than peripheral positions. Butterworth and Itakura (1998b) explained the added effect of manual pointing in terms of the movement of the lever formed by the arm. For any given spatial separation between a pair of targets, the angular excursion of a long lever, like the arm, will be greater than that of a shorter lever, like the head and nose, or a pair of very short levers, like the eyes. Thus, a part of the body, the arm and pointing hand, may have become specialized for referential communication because it is particularly useful in taking attention further to the extreme periphery (Butterworth, 1997a). The paradoxical finding that adult observers were actually more accurate in following head movement with sunglasses can also be explained by the amplifying effect of the spectacle frames on the observed extent of lateral movement of the head. Thus, following pointing is not completely precise. The mechanism does not operate by extrapolation of linear vectors, and accuracy in a cluttered environment requires supplementary attention to worthy cues from the object of joint attention to help single it out as the referent. Hence, ecological and geometric mechanisms interact even in adults.