

EXPLOITATION OF POINTING AS A REFERENTIAL GESTURE IN YOUNG CHILDREN, BUT NOT ADOLESCENT CHIMPANZEES

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The ability of adolescent chimpanzees and 2- and 3-year-old children to use pointing gestures to locate hidden surprises was examined in two experiments. The results revealed that although young 2-year-old children appeared to have no difficulty extracting referential information from a pointing gesture (independent of gaze or distance cues) and spontaneously using it to search in specific locations, adolescent chimpanzees appeared to rely on cue-configuration and distance-based rules. Thus, although these chimpanzees were trained to respond appropriately to the pointing gestures of a human by searching in a particular location, this ability did not easily generalize to situations in which the distance between the pointing hand and the location were more distal. Furthermore, even those chimpanzees that were able to generalize in this fashion appeared to use distance-based cues, not ones based on an appreciation of the internal attentional focus or mental referent of the experimenter as indicated by his pointing gesture.

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The production and comprehension of the manual pointing gesture—pointing toward an object or event using the extended index finger—appears to be a universal and species-specific trait of the human species (Butterworth & Franco, 1993; Eibl-Eibesfeldt, 1989). With respect to the origins of the production of the gesture, the extension of the index finger with an otherwise closed hand is displayed by human infants as young as 18 days of age (Hannan & Fogel, 1987). However, even by five months this gesture is not coordinated with the infants' gaze direction toward adults or objects in the world (Hannan & Fogel, 1987). It is not until about 12 months of age that pointing emerges as a communicative gesture in which the extension of the arm, the use of the index finger, and gaze coordination with another person are securely in place (Franco & Butterworth, 1996; Leung & Rheingold, 1981; Lempers, 1979; Morissette, Ricard, & Décarie, 1995; Murphy & Messer, 1977).

There are at least two broad explanations of the origins of the production of the pointing gesture. The first explanation maintains that pointing initially serves an imperative or functional purpose in which infants use it to express desires or wants, and that the gesture itself emerges out of more generalized reaching actions (Vygotsky, 1962). A second explanation argues that even in its earliest forms, pointing serves a referential or declarative purpose (Werner & Kaplan, 1963). In support of this second view, Franco and Butterworth (1996) have shown that even in their earliest form, pointing gestures (in contrast to reaching gestures) are triggered by referential or declarative contexts, and are closely coordinated with glances at adults (see also Franco & Wishart, 1995). In addition, researchers have distinguished between proto-imperative and proto-declarative pointing, arguing that proto-imperative pointing may serve a strictly instrumental function (getting someone else to do something), whereas proto-declarative pointing seems to demonstrate an appreciation of internal psychological states of others such as attention or interest (Bates, Camaioni, & Volterra, 1975; Camaioni, 1991). Support for this conceptual distinction has come from research demonstrating that autistic individuals (who are theorized to have a profound impairment in joint attention skills) exhibit proto-imperative forms of pointing, but not proto-declarative ones (Baron-Cohen, 1989; Goodhardt & Baron-Cohen, 1993). Finally, other researchers have argued that to the extent that proto-imperative pointing is accompanied by glances from a desired object to the adult, even in this form, infants seem to be expressing at least some understanding of reference or attention (Gómez, Sarria, & Tamarit, 1993).

A second issue concerns the development of human infants' comprehension of the pointing gesture. To date most studies of infants' comprehension of pointing concerns their ability to look where another person is pointing. Typically, these studies have implicated 12-15 months as the period in which infants develop a robust ability to look at a target to which an adult is pointing (Butterworth & Grover, 1988; Guillaume, 1962; Lempers, 1979; Leung & Rheingold, 1981; Morissette et al., 1995; Murphy & Messer, 1977). On the basis of a longitudinal study of two dozen infants, Morissette et al. (1995) argued for a dissociation

between an ability to look in the general direction where another is pointing (present at about 12 months), and an ability to precisely locate an intended target (present at about 15 months) (see also Butterworth & Grover, 1988).

A number of individuals have argued for a relation between the ability to produce and comprehend pointing, and an understanding of the perspective, reference, or attentional state of others (Baron-Cohen, 1994; Bruner, 1983; Franco & Butterworth, 1996; Lempers, 1979; Leung & Rheingold, 1981; Murphy & Messer, 1977). However, there are a number of limitations of previous research that make it difficult to determine the nature of comprehension of pointing by infants of this age. For example, in most studies to date, pointing has been accompanied by gazing at the target as well (cf. Lempers, 1979). Given that infants progressively elaborate a capacity for gaze-following (or joint visual attention) between 6 and 18 months of age (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Corkum & Moore, 1995; Scaife & Bruner, 1975), this confound prevents a clear interpretation of the contribution of pointing to the infant's response (see discussion in Murphy & Messer, 1977). In one study, Lempers (1979) controlled for this possibility by having the adult maintain eye contact with the infant while pointing and found developmental patterns of pointing comprehension (visually following the pointing to the intended target) similar to those discussed earlier. A second limitation is that in virtually all studies in infancy, researchers have relied on measures of where infants look in response to pointing. Thus, in the same manner that some researchers have argued that early gaze-following in infants (and other species) may occur without an understanding of mental reference or an internal mental state of attention (Baressi & Moore, 1996; Corkum & Moore, 1995; Povinelli & Eddy, 1996a, 1996b; Tomasello, 1995), learning to follow the direction of pointing may likewise occur without such understanding. For example, dissociations between where young children look in response to verbally posed questions on the one hand, versus what they say (Clements & Perner, 1994), suggest that caution is needed in focusing exclusively on one measure.

The studies reported in this article were designed to examine the ability of adolescent chimpanzees to comprehend pointing as a referential gesture. Although wild chimpanzees and other great apes display gestures which are topographically similar (arm outstretched toward others, but no index finger extension), these gestures do not appear to be usefully classified as pointing (see Plooj, 1978; Povinelli & Davis, 1994). Rather, they appear to be communicative signals that are used in the context of reconciliation, recruitment of allies, and food begging (Goodall, 1986; de Waal & van Hoof, 1981). On the other hand, chimpanzees and other great apes reared and extensively tested in captivity do display arm extensions that appear to be somewhat like pointing in that they are directed at particular objects, locations, or persons (Call & Tomasello, 1994; Gómez, 1990; Gómez et al., 1993; Povinelli & Eddy, 1996a; Povinelli, Nelson, & Boysen, 1992; Premack, 1984; Savage-Rumbaugh, 1986). One possible explanation of this apparent difference between humans and great apes is that wild apes possess an underlying under-

standing of mental reference or the mental state of attention in general, but in captivity this understanding broadens to include the human gesture of pointing as the result of experience with another species that uses the gesture frequently. In this sense, the absence of the specific topography of index finger extension in the natural behavioral repertoire of chimpanzees may simply reflect interspecific differences in hand morphology (see Povinelli & Davis, 1994). Another possibility, however, is that extensive experience with humans who respond to the reaching gestures of apes as if they were pointing, causes the apes to conventionalize their arm extensions as a communicative exchange aimed at obtaining desired objects. If true, their gestures may never be accompanied by an attendant understanding of reference (or attention). The fact that the gestures often co-occur with gaze alternation may merely reflect the operation of two separate behavioral mechanisms at work. The research conducted in this article was designed as a preliminary attempt to tease apart these competing interpretations.

The studies we report were conducted as part of a broader research program aimed at reconstructing the evolution of the ontogeny of human psychology related to social understanding—our folk psychological understanding of attention, desire, knowledge and belief (for reviews of this research effort see Povinelli, 1993, 1996a; Povinelli & Eddy, 1996a; Povinelli & Preuss, 1995). Several months before this study began, the seven chimpanzees used as participants had been trained to choose a cup to which an experimenter pointed in order to find a hidden food reward (see Povinelli, Bierschwale, Reaux, & Cech, 1997, Experiments 1 and 2). In addition, many of these same animals had participated in a study several years earlier involving an experimenter pointing to one of three cups. Thus, at the time of this study, all of the subjects were highly reliable at using a pointing gesture to select a correct location to search for food rewards. However, the pointing gestures used in these previous studies were always configured so that the tip of the experimenter's index finger was within several centimeters of the correct cup (hereafter referred to as proximal pointing). These apes had never been explicitly trained or tested for their ability to comprehend pointing gestures in which the gesture was performed at a distance greater than 5 cm from the intended target (hereafter referred to as distal pointing). However, as described below (see Method), they did have extensive experience in their everyday lives responding to spontaneous human pointing gestures.

We attempted to test several hypotheses concerning these chimpanzees' comprehension of the pointing gesture by probing three alternative frameworks that could account for the ability to exploit the pointing gesture. First, despite our chimpanzees' initial inability to comprehend pointing, their later, excellent performance may reflect an underlying understanding of the referential significance of the gesture. In other words, although it is possible to account for their behavior through fairly straightforward learning processes, the animals may also have simultaneously acquired an understanding of the referential significance of the gesture. Thus, if chimpanzees do possess a general understanding of reference (or

attention) as a mental state, they might merely require a bit of experience to apply it to the specific case of human pointing. Our second hypothesis was that the apes had learned a discrimination (without an underlying understanding of reference or attention) that allowed them to anticipate in which location a food reward could be found. Two versions of this possibility exist. One is that the subjects learned a rule of the type “pick the cup+finger/hand configuration”; the other is a more general “cup+something else” rule. Either of these simple rules (hereafter these two ideas are collapsed and referred to as the cue configuration rule) might be generalized to other ecological contexts in which the pointing gesture was used to designate one of two (or possibly more) configurations. A final hypothesis we considered was that the apes were using a relational rule such as “select the cup closest to the experimenter’s finger/hand” (hereafter referred to as the cue distance rule). Although neither of the latter models posits an understanding on reference or attention on the part of chimpanzees, neither do they necessarily assume that the animals are relying on blind trial-and-error learning. They may actively consider the role of various cues in the context of attempting to locate the food rewards, and indeed, may enter the situation already possessing certain dispositions about the kinds of cues to which they will preferentially attend.

The seven chimpanzee used in these studies had participated in a number of relevant studies that investigated their understanding of gaze. These studies yielded three main findings. First, the chimpanzee displayed very clear evidence of gaze-following (Povinelli & Eddy, 1996a, Experiment 12; Povinelli & Eddy, 1996b; Povinelli & Eddy, 1997; Povinelli et al., 1997, Experiments 1 and 2). That is, without training, the chimpanzees responded to shifts in the gaze direction of a human by turning to look in the same direction. The subjects displayed evidence for this effect in response to movement of the head and eyes in concert, movement of the eyes alone, or simply the unusual posture of an experimenter’s head and eyes without witnessing any movement at all. Furthermore, these studies also indicated that in response to gaze directed behind them, chimpanzees look into the same quadrant of space referenced by the human. Finally, Povinelli and Eddy (1996b) also report data that show that, at some level, the chimpanzees understood that when someone else’s gaze strikes an opaque barrier, this gaze does not pass through the barrier. However, despite the sophistication of these gaze-following behaviors, the second major finding was that these same chimpanzees displayed little evidence that they understood the referential (or aboutness) aspect of gaze. For example, in a series of 14 studies in which the chimpanzees were allowed to use their begging gesture to request food from one of two humans—one who could see them, the other who could not—the chimpanzees provided little evidence that they grasped that only one of the individuals could “see” them (Povinelli & Eddy, 1996a). With sufficient experience involving differential feedback, the chimpanzees learned rules to exploit the situation, but these rules did not appear to be about “seeing” per se, and furthermore they were not retained across time (see Povinelli, 1996b). Finally, several more recent studies have revealed that although the chimpanzees

may not understand the attentional states underlying gaze per se, they are able to exploit general head direction in order to locate hidden food (see Povinelli et al., 1997). During the course of these previous experiments, the chimpanzees received a considerable number of differentially reinforced trials ($N = 16$) in which they were tested to determine their ability to use the gaze direction of an experimenter to search in specific locations. Given their spontaneous ability to follow the gaze of others, and their experimental history of using the gaze direction of humans to locate rewards, in the studies reported here we found it necessary to systematically examine the influence of gaze on the chimpanzees' interpretation of pointing.

Because some of the methods used to tease apart these alternative hypotheses involved some unusual configurations of the experimenters, we examined the reactions of young 2- and young 3-year-old children to the same tests given to our apes. Although children much younger than this have been shown to have some ability to follow pointing gestures to specific targets, we were interested in knowing the extent to which they could actively use the gesture to find hidden objects. As noted above, although several studies have explored the age at which infants will follow the direction of the pointing gesture, to our knowledge no studies have explored the age at which they will reliably use pointing to designate a particular location to search for and/or retrieve an object. By testing children of these ages we were not attempting to definitely discern the minimum age at which it would be possible to pass these tests, but rather to begin to assess the validity of the test by determining if young preschoolers, who would be expected to succeed on these tests, would indeed do so.

EXPERIMENT 1

In Experiment 1, we compared the performance of adolescent apes and young 3-year-old children on proximal versus distal pointing trials. However, we intentionally configured the experimenter's finger on the distal pointing trials so that it was closer to the correct location than the incorrect location. Thus, if the apes and/or children succeeded on the proximal pointing trials, but not the distal ones, this outcome would implicate the cue configuration account over either the cue distance or the referential comprehension account. On the other hand, success on both trial types would favor either the referential comprehension or cue distance account over the cue configuration account. Experiment 2 was designed to test the different predictions of these latter two accounts, if necessary. Given that gaze and pointing direction typically covary in spontaneous pointing exchanges between adults, infants, and children, in both experiments we also included gaze treatments in order to assess the relative influence of the experimenter's gaze direction on the apes' performance—independent of pointing per se.

CHIMPANZEES

Method

Subjects. The subjects were seven adolescent chimpanzees (age range 6;9 to 7;8). Six of the subjects were female and one was male. All were born in captivity at the University of Southwestern Louisiana New Iberia Research Center. Five of the participants (Kara, Jadine, Mindy, Brandy, Candy) were raised together by human caretakers from birth in nursery setting with additional peers. Two of the subjects (Apollo, Megan) were reared by their mother in a social group of adult chimpanzees until they were approximately one year old, at which point they were transferred into the nursery with the other chimpanzees; from that point forward they were reared by caretakers in the same fashion as the others. A detailed description of the chimpanzees' rearing and experimental histories are provided in Povinelli and Eddy (1996a). The chimpanzees lived in a large complex of 5 indoor-outdoor housing units that were interconnected by passageways that could be closed off as necessary (floorplan dimensions = 8.3 x 12.6 m; outdoor and indoor caging height = 3.3 and 2.1 m, respectively). These living areas contained ropes, swinging barrels, hard plastic toys, and wooden perches at various heights. The animals had free access to the entire area (except an indoor testing lab) at all times other than during testing periods. The animals were fed a standard diet of monkey chow, fruits and vegetables, and this was supplemented by fruits and vanilla wafer cookies which they received during testing.

As mentioned earlier, the chimpanzees had been exposed to manual pointing by humans in two different contexts. One involved training them to respond to pointing by searching under opaque cups. This formal training occurred once when they were between 3 and 4 years of age and again when they were 6 years of age and involved them responding to proximal pointing cues (the experimenter's finger within a few centimeters of where a food reward was hidden; for a complete description of this training and testing, see Povinelli et al., 1997). Second, these apes had also received extensive experience with the spontaneous pointing gestures of their human caregivers (and later, their trainers) since birth. These gestures primarily occurred in the context of leading the apes from one location to another, or attempting to draw their attention to distant or close objects or events. One such context in which the apes routinely experienced these gestures occurred three or four times each day as their caregivers and trainers ushered one ape into a waiting area at a time for testing, or moved the entire group from one enclosure to the next for cleaning. Other situations included their caretakers requesting objects from them, attempting to draw their attention to one object or location over another, and frequent spontaneous bouts of play with them. They were also frequently exposed to the pointing gesture during the pretraining and training sessions of a wide variety of experiments over the span of 5 years as a spontaneous, unchoreographed attention-getting device (e.g., showing them how to turn over cups, pull ropes, use tools, lift the lids from boxes, etc.). Although it is difficult to

make precise comparisons, these apes were exposed to the gesture in many of the same contexts as human infants and children.

General Setting. Each chimpanzee was typically trained or tested individually once or twice a day. Before each training or testing session, a subject was transferred out of the social group by opening a shuttle door which connected the main colony areas to a waiting area outside an indoor testing unit. A different shuttle door provided a passageway between the outdoor waiting area and an indoor testing room. As the ape passed through this shuttle door, he or she entered a test unit that was separated from the rest of the room by a plexiglas partition. This partition prevented the chimpanzees from entering the portion of the room where the experimenters were situated. The partition contained several holes cut at a level through which the chimpanzees could easily reach. As the result of their participation in previous studies, the chimpanzees were extensively familiar with reaching through these holes. The shuttle door that connected the outdoor waiting area and the indoor test unit was controlled by the chimpanzees' trainer, who used a remote pulley system located on the back wall of the testing room to open and close the door. When this shuttle door was closed, the chimpanzee was restricted to the outdoor area and could not see into the test unit. When the door was opened, the chimpanzee could enter the test unit, approach the plexiglas partition, and respond.

Apparatus and Pretraining. The apparatus used in the study consisted of two identical opaque boxes (17 x 28 x 12 cm). The boxes possessed lids which could easily be removed by the chimpanzees to reveal their contents. In order to familiarize the subjects with the boxes, a preliminary phase was conducted in which the boxes were placed on the experimenters' side of the plexiglas partition within easy reach of the subjects. Each subject was administered a number of sessions in which on each trial he or she remained in the waiting area until the trainer used the pulley system to open the shuttle door. At this point, the subject entered the test unit and was prompted (if necessary) to remove the lid of a box and retrieve a food reward from inside. To advance to testing, the subjects were required to complete five consecutive trials within a session in which they would enter the test unit within 30 seconds of the door opening, remove the lid on the box, and retrieve the food reward. (At this point the subjects received either one or two additional sessions in which the experimenter sat behind the box and pointed to it as the subjects entered the test unit.)

Training. Training trials consisted of placing two identical boxes in fixed locations on the floor outside of the chimpanzee section of test unit, and within easy reach of the subjects. The boxes were positioned directly in front of two holes in the plexiglas partition at a distance of 23 cm from the partition, and were separated from each other by a distance of 74 cm.

The chimpanzees responded to an experimenter who had been the their primary caregiver for the previous six years (since they were approximately one year old).

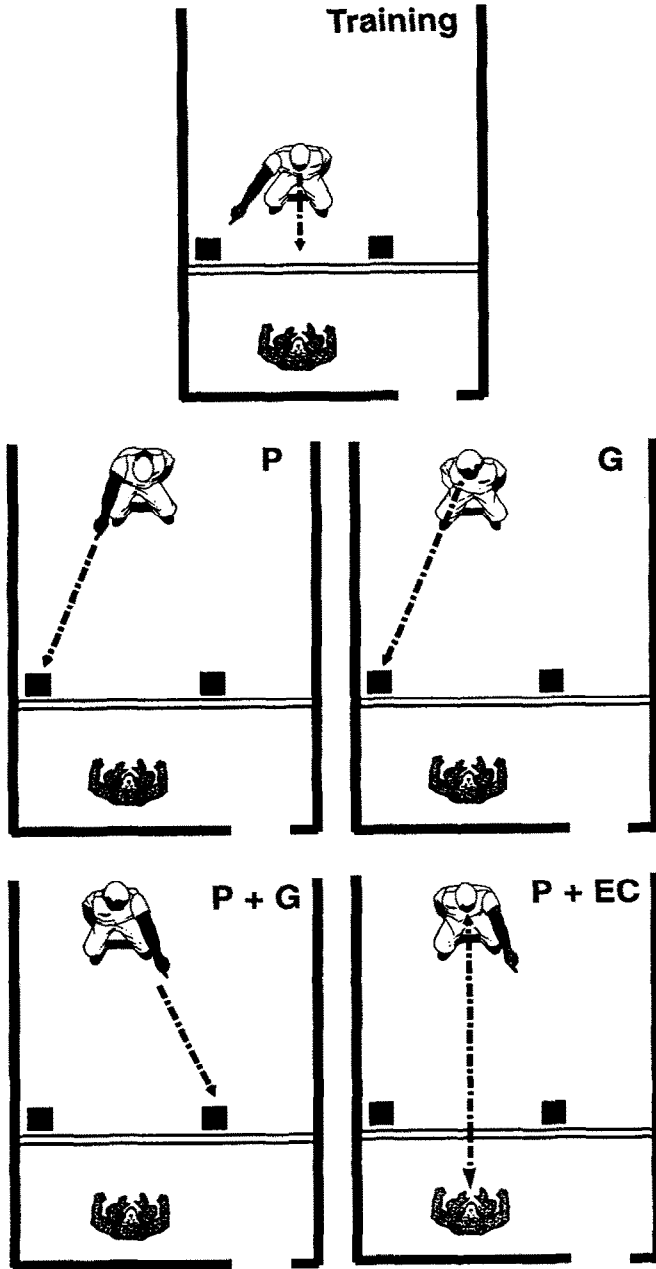


Figure 1. Training and probe trial testing configurations for Experiment 1 (chimpanzees). Dashed line represents experimenter's referential direction.

He sat on a crate that was positioned in between, but just behind, the two boxes so that his torso was 80 cm from the partition (see Figure 1). From this position the experimenter used his right and left arms to point to the right and left boxes, respectively, while keeping his body centered along the mid-line between the two boxes. Each training trial began with a subject in the outside waiting area. A food reward was placed in one of the two boxes and the experimenter positioned himself as described above and pointed to the correct box. In order to avoid covarying eye direction and the pointing gesture, his gaze was fixed on a predetermined target on the plexiglas (halfway between the two boxes). Next, the trainer opened the shuttle door using the pulley system. This trainer remained facing the wall while the subject entered the room and responded. If the subject removed the lid of the correct box and retrieved the reward, the experimenter offered praise as he or she ate the reward and exited the test unit to the waiting area. If the subject removed the lid from the incorrect box, the experimenter typically said, "No, [subject's name], that's not right," and the subject was not allowed to make a second choice. The decision rule for a response was if the subject moved the lid of a box. Once this occurred no further choice was allowed.

Each training session consisted of six trials. The box containing the reward was determined randomly with the constraint that the right and left boxes were each correct on half of the trials in each session. The chimpanzees continued training until they were correct on a minimum of five consecutive trials within each of two consecutive sessions. After achieving this criterion they advanced into testing.

Testing. Each test session consisted of five trials. Three of the five trials were proximal pointing trials and were identical to the training trials described above. These trials were assigned to Trial 1, and two additional, randomly determined trials. The remaining two trials were designated as probe trials and were used as vehicles to deliver the experimental treatments. The ratio of 3 proximal pointing trials (easy) to 2 probe trials (difficult) was chosen in order to maintain the motivation and interest level of the subjects.

Four experimental treatments were created to test the hypotheses outlined earlier: Point only (P), Gaze only (G), Point+Gaze (P+G), and Point+Eye Contact (P+EC). On these probe trials, the boxes remained in the same locations as on the proximal pointing trials but the experimenter positioned himself 225 cm away from the partition, still along the midline of the axis connecting the two boxes. On P+G trials, the experimenter extended his arm and pointed to the baited box. This gesture was standardized so that the tip of his finger was 120 cm from the correct box and 150 cm from the incorrect box. In addition, the experimenter turned his head to look along the line of his point to the correct box. On P trials, the experimenter pointed to the baited box, but turned his head down to fix his gaze at a target on the floor midway between his feet. On G trials, the experimenter configured his body and head as in the P+G trials, but instead of pointing he kept both of his hands behind his back. Finally, on P+EC trials, the experimenter configured him-

self as in the P trials except that he attempted to make and maintain eye contact with the subject as he or she entered the test lab and responded. The P+EC trials were of some theoretical interest given that some researchers have argued that the presence of eye contact is an important component of intentional communication by infants and other species, including chimpanzees (Bates, O'Connell, & Shore, 1987; Gómez, 1990). For all trial types, the orientation of the caregiver's body, head, and arms was carefully choreographed, and monitored before each trial began by an observer in a different room via a remote video camera focused on the experimenter and the boxes. This observer monitored and communicated (over the intercom) with the experimenter in order to insure that his posture was correct before the trainer opened the door. Once the experimental configuration was set, the trainer was instructed to open the shuttle door as usual, allowing the subject to enter and respond. Once the shuttle door opened, no further communication occurred over the intercom. All testing trials were videotaped in a manner that produced a frontal view of the chimpanzees as they entered the test unit and responded.

Each subject received each treatment four times, counterbalanced for side of the correct box. Thus, because each session contained two slots for probe trials, each subject received eight test sessions. The treatments (and side of correct box) were randomly and exhaustively assigned for each subject until each of the sixteen probe trial slots were filled.

Data Analysis. The main data were summarized by determining each chimpanzees' percent correct in each of the four treatments (0, 25, 50, 75 or 100%). First, a one-way repeated measures analysis of variance (ANOVA) was used to determine if the group performed differently in some treatments as compared to others. Second, one-sample *t*-tests were used to determine if the group performed at levels exceeding that expected by chance (50%) in each of the four treatments.

The videotapes of the trials were coded for two dependent measures. First, all trials were coded by a main rater who was administered a standardized set of written instructions. These instructions requested that the rater use a hand-held timer to measure each probe trial ($N = 280$) as well as four randomly selected standard proximal pointing trials (no more than one per session) per subject ($N = 28$) for the elapsed latency from the moment the subject entered the test unit until he or she moved the first box lid. A secondary coder was administered the same set of instructions and was assigned a predetermined 20% of the total number of trials ($N = 56$). Pearson's correlation yielded a coefficient of determination, r^2 of .9999 ($p < .0001$) between the two data sets. Only the data from the main rater were used in the analyses. The second coding was conducted by a main rater who was administered a different set of standardized, written instructions. These instructions specified that the rater should observe each trial and answer the following questions: (1) "Did the subject look at the experimenter before choosing [moving the lid of] a box?" and if so, (2) "Which was the first box the subject looked at after

looking at the experimenter?" A secondary rater was again assigned a predetermined set of 20% of randomly selected probe trials. The main and secondary rater's data sets were compared using a percent agreement formula and yielded an agreement of 92.3% for question 1, and 79.2% for question 2.

Results and Discussion

Training. All of the subjects except Jadine met the training criterion (5/6 consecutive correct choices in two consecutive sessions) within the minimum number of sessions. Jadine required an additional two sessions before advancing to testing. In general, this excellent performance demonstrated the high degree of transfer from previous experimental contexts in which the chimpanzees had been trained to respond to proximal pointing gestures (e.g., Povinelli et al., 1997).

Testing. First, the subjects' performances on the standard proximal pointing trials from all test sessions were averaged and indicated that as a group they were correct on 93.4% ($SD = 10.7\%$) of these trials. This result indicates that the subjects were highly motivated to respond correctly, and did so when the experimenter's pointing gesture was less than 5 cm from the correct box (one-sample t -test, two-tailed, hypothetical mean = 50%, $t(6) = 10.698$, $p < .0001$). Thus, any differential performance on these trials as compared to the treatment probe trials, which were embedded into these same sessions, cannot be attributed to a general lack of motivation or interest in the task.

The main results of the four experimental treatments are presented by subject in Table 1. Although the data sets were too small to analyze individual subject performances within each of the separate treatments, two of the chimpanzees (Apollo, Kara) performed quite well across all four of them. Indeed, Kara's overall correct choices (14/16, see Table 1) departed from chance performance (binomial test, $p = .002$). Thus, although as a group the chimpanzees did not provide evidence of being able to use the experimenter's posture to select the correct location, at least one subject (Kara) was able to do so. This meant that for her, at least, the simple stimulus cue hypothesis did not correctly predict her behavior.

In terms of evaluating the main hypotheses, as a group the chimpanzees provided no compelling evidence that they were able to transfer between their excellent performance on the proximal pointing trials, and the distal pointing trials (treatment P). A one-way repeated measures ANOVA indicated that as a group the apes did not perform significantly better or worse in some treatments as opposed to others, $F(3,18) = 0.604$, ns . However, one-sample t -tests indicated that as a group the subjects performed at levels exceeding that expected by chance in the P+G treatment (one-sample t -test, two-tailed, hypothetical mean = 50%, $t(6) = 2.828$, $p < .03$), but not on any other treatment types. Thus, when the experimenter both pointed and gazed at the correct box, as a group the subjects appeared able to use this posture as a cue to select the referenced location (Table 1). Although as a group the subjects' mean performance was only marginally worse

Table 1. Percentage Correct by Subject (Chimpanzees), Experiment 1

Subject	Treatment			
	P	G	P+G	P+EC
Candy	25	50	75	25
Jadine	50	50	75	75
Brandy	75	50	50	75
Megan	25	50	50	25
Mindy	50	50	50	50
Apollo	75	50	75	75
Kara**	100	75	75	100
<i>M</i> =	57.1	53.4	64.3*	60.7

Note: See text (and Figure 1) for descriptions of treatments P, G, P+G, P+EC. Significant departures from chance (one sample *t*-tests, two-tailed, hypothetical mean = 50%) are indicated: **p* < .05, ***p* < .01.

on P+EC trials (60.7% correct) than on P+G trials (64.3% correct), when the two subjects (Kara, Apollo) who performed well in all treatments (see above) are removed from the data set, the group's performance dropped to exactly chance levels (50% correct). Finally, our *a priori* expectation that the chimpanzees would perform at levels exceeding chance on G trials was not supported (but see Experiment 2). Figure 2 presents the data for the chimpanzees from the four treatments on a trial-by-trial basis. These data were examined for evidence of learning by using separate paired *t*-tests to compare the subjects' performance on Trials 1-2 to their performance on Trials 3-4 for each treatment, but no effect was detected for any of the treatments. Finally, the subjects' data were arranged in the actual order in which they received the trials (irrespective of treatment) to determine if some general learning had occurred across treatments. These data were divided into two blocks consisting of Trials 1-8 and Trials 9-16. A paired *t*-test was used to compare the group's performance on the first half of probe trials as compared to the second half, but again no effect of trial block was obtained.

An examination of the subjects' latency to respond was conducted in several steps in order to help us determine the extent to which they slowed down their responses on probe trials as compared to standard trials. First, two standard trials were randomly selected from each of the eight sessions for each chimpanzee (*N* = 16 per subject). These mean latencies for each subject were compared to the subjects' mean latencies on the probe trials (*N*=16 per subject) using a one-tailed paired *t*-test for related samples. The results indicated that although 5 out of the 7 animals performed in the direction expected (longer latencies on probes than standards, *M* = 11.28 and 5.18 sec, respectively), the difference was not statistically significant, *t*(6)=1.508, *p* < .09. Next, in order to determine if the subjects tended to hesitate more on their first encounters with the probe trials than with the subse-

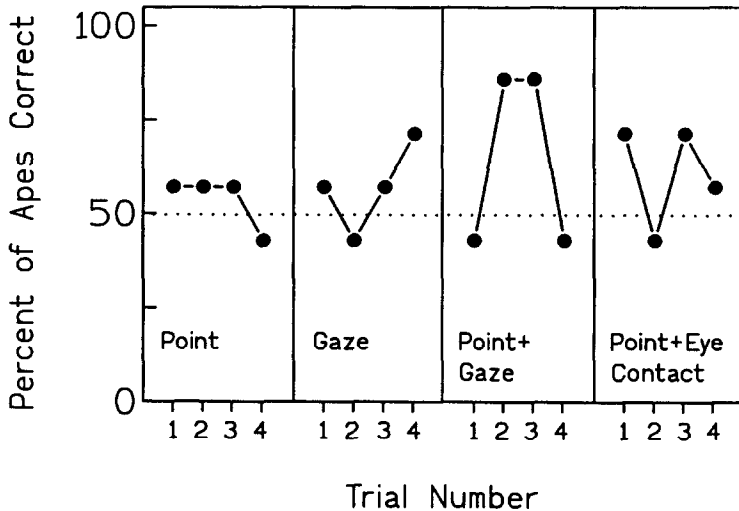


Figure 2. Percent of trials correct (\pm SEM) by treatment and trial for Experiment 1 (chimpanzees).

quent encounters, we examined the data to determine if the chimpanzees showed any trial-by-trial effects on latency across the four probe trials they were administered. Two analyses were performed. First, a two-way repeated measures ANOVA was conducted that looked for effects of trial, treatment, and possible interactions between the two. Although in every treatment the data displayed the predicted pattern, no significant effects were obtained. Second, the data were structured in order to determine if there was an overall effect of trial, irrespective of treatment. To this end, an average latency for each trial number (summed across the four treatments) was calculated for each animal. The results are displayed in Figure 3, and although the overall patterns were in the direction predicted, a one-way repeated measures ANOVA indicated a non-significant effect of trial, $F(3,18)=2.809$, $p < .069$.

The data next were analyzed by examining the main rater's coding of whether the apes looked at the experimenter on each trial, and if so to which box they looked immediately thereafter. These results indicated that the apes looked at the experimenter before making a choice on 100% of all probe trials. Thus, the incorrect choices by the subjects were not due to a simple failure to look at the experimenter before responding. In order to examine the data for possible evidence of an implicit understanding of the correct location (regardless of the subjects' actual overt choice), the data were examined in three steps. First, the percentages of trials on which the first box to which the subjects looked after initially glancing at the experimenter was in fact the correct box, were 48.8, 52.4, 57.1, and 65.5%, for P, G, P+G, and P+EC, respectively. A one-way repeated measures

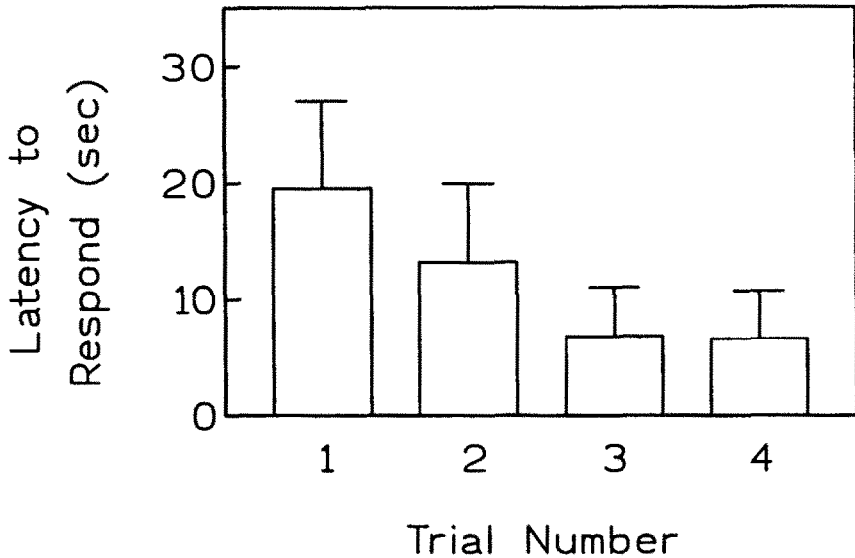


Figure 3. Latency to respond (\pm SEM) averaged across probe trials 1-4 for all treatments in Experiment 1 (chimpanzees).

ANOVA indicated no difference across the treatments, and separate one-sample *t*-tests indicated that in none of the treatments did the group's performance depart from that expected by chance (50%). Second, there was a strong connection between where the subjects looked first (after glancing at the experimenter) and their subsequent overt choice. As a group, the subjects' first glance predicted their overt choice for 80.4% of all probe trials (range = 73.8 to 85.7%), and in three of the four treatments (P, P+G, P+EC) this association was significantly greater than what could be expected if the first glance and overt choice were independent events (one-sample *t*-tests, two-tailed, hypothetical mean=50%, all *ts* > 2.597 < 4.804, all *ps* < .041).

Finally, because there might have been an implicit effect that was restricted only to those trials on which the chimpanzees' overt choice was incorrect, we next examined only incorrect trials, and calculated the percentage of trials in each condition that the subjects' looked at the correct box before making the (incorrect) choice. These data revealed no evidence that the subjects looked at the correct box while choosing the incorrect box (7.14, 20.00, 8.33, and 33.33% of trials for P, G, P+G, and P+EC, respectively). Taken collectively, these analyses revealed little evidence of a dissociation between the subjects' overt choice (removing the lid of a box and reaching inside), and some less active (implicit) choice such as looking at the correct box.

The results of this study indicated that although as a group the combination of pointing and gazing of the experimenter caused these subjects to choose the correct box, in general neither pointing nor gazing alone had this same influence on their choices. Perhaps the clearest and most surprising result of this study was that distal pointing alone (P) did not influence the chimpanzees' choices (except possibly for Kara and Apollo), despite their excellent performance on the standard proximal pointing trials. For the majority of the subjects, these results support the idea that during training the subjects learned a rule related to the stimulus configuration of the finger or hand near a box. However, although these subjects may have been using a simple stimulus configuration to locate the correct box, we suspect that this is not the entire explanation of these results. Recall that the chimpanzees' performance in the P+G treatment exceeded that expected by chance. These results seem to indicate that some aspect of the interaction of the pointing and gazing gestures were sufficient to cause the apes to choose the correct box. However, one possible reason for this result may stem from the fact that in the P+G treatment the experimenter's head and arm were both biased to the same side of the room on which the correct box was located. Thus, from the ape's perspective, this general bodily orientation may have caused them to move to that side of the room, and thus select the box on that side, without any underlying appreciation of the attentional or referential focus of the experimenter (for a similar effect and explanation, see Povinelli et al., 1997).

Thus, in evaluating our *a priori* set of alternative hypotheses concerning these chimpanzees' comprehension of the pointing gesture, the predictions generated by the cue configuration model were upheld for the majority of the subjects, whereas those of the cue distance and referential models were not. In contrast, Kara and Apollo's behavior left open the possibility that they either: (a) learned (or were able to deploy) a slightly different rule based on the distance of the finger from the box (the cue distance account), or (b) interpreted the gesture in a referential manner. In order to distinguish between these latter two accounts for these chimpanzees, as well as to explore the generality and replicability of our findings, we conducted Experiment 2 (see below).

Children

Our attempt to tease apart the relative influences of pointing versus gazing on the apes' behavior forced us to create arguably unusual postures in which their caregiver looked at the floor while pointing. Although unusual, we expected that an organism with a clear understanding of the referential significance of pointing would have no trouble responding to the pointing gesture in this configuration. As a first attempt to explore this assumption, we conducted the same experiment with young 3-year-old children (35-40 mos) to determine if their performance (expected to be at ceiling levels) would be negatively affected by the postures used with the chimpanzees. This age was chosen to set an upper limit on the complexity of the abilities possessed by the chimpanzees, given our expectations that an

understanding of pointing ought to be well consolidated in young 3-year-olds. (Experiment 2 tested young 2-year-old children on an even more difficult version of these tasks.)

Method

Participants. The participants in the study were a group of 24 children who ranged in age from 35 months to 40 months ($M=38$ mos; 12 boys, 12 girls). All of the children were recruited from local preschools, information booths at civic functions, and direct mailings. The children were scheduled for a visit to the Center for Child Studies at the University of Southwestern Louisiana. No systematic data were collected on the race or ethnicity of the children but they were primarily from working and middle class families residing in Lafayette, Louisiana and the surrounding communities.

Apparatus and Procedure. The materials utilized in this study were two identical rectangular boxes of the same dimensions as those used with the chimpanzees. The boxes possessed lids that allowed the inside of the box to be hidden or revealed. Additional materials used in the testing room consisted of two video cameras which offered frontal and rear views of the children as they participated in the test session, and a small chair in which the child sat between each testing trial.

At the time the testing appointment was scheduled with the parents, a staff member gave them a general description of the study. Upon arrival, the parent and child were welcomed into a warm-up play area and introduced to the two experimenters. The main experimenter engaged the child in play to familiarize him or her with the surroundings. The second experimenter explained the testing procedure further to the parent, showed them how the child could be observed during testing through a one-way mirror, and obtained his or her signature of informed consent for the child's participation in the study.

Warm-up Period. During the warm-up period, the two experimenters socialized with the child and the child's parent, and used the boxes to play hide and seek games. The experimenters explained to the child that objects could be hidden inside the boxes. They then proceeded to hide a toy in one of the boxes while the child watched, and then asked the child to locate the missing toy. When the experimenters surmised that the child was comfortable opening the boxes and retrieving the toys, they picked up the two boxes and invited the child to the testing room to "play another game with the boxes."

Testing. Once inside the testing room, but before the actual testing began, the main experimenter showed the child how a sticker could be hidden in one of the boxes, and asked the child to open the box and remove the sticker. Once the child had successfully done so, the formal testing period began.

Each child was tested in two sessions with a brief interval between each session. Each session consisted of five trials, three standard proximal pointing trials and

two probe trials. The same four experimental treatments that were used with the apes were used with the children: Point only (P), Gaze only (G), Point+Gaze (P+G), and Point+Eye Contact (P+EC). Each child received one trial of each of the treatments. On probe trials, as well as on the standard proximal pointing trials, the position of the boxes and the main experimenter were configured using the exact same postures and positions as in the chimpanzee study. Across the two sessions, three of the standard proximal pointing gestures were to the left box and three were to the right box according to a pre-determined, randomized schedule. In addition, a small dot was marked on the floor at the centerpoint between the two boxes to serve as a neutral location on which the experimenter fixed her gaze on the standard trials. Probe trials were never assigned to the first trial of the session, but were randomly assigned to the four trials which remained. The order in which each subject received each type of probe trial, and the side that was correct for that probe trial, were counterbalanced both across and within subjects so that the following constraints were met. First, an equal number of probe trials were correct within participants for the left and right boxes. Second, each treatment was correct equally often across participants for the left and right boxes.

Each trial proceeded as follows. A small chair, in which the child sat between trials, was placed 75 cm in front of and facing directly away from the boxes. Thus, while the child sat in the chair, the main experimenter could hide a sticker in one of the boxes without the child observing. While the main experimenter was hiding the sticker, the other experimenter stood behind the child's chair and held a large poster board behind the child's head after explaining to the child that it was so that "we can't peek while [the main experimenter] is hiding the sticker." The poster was used on all standard and probe trials. A piece of paper with the child's name on it was taped to the wall for the child to place the stickers he or she acquired during the testing period. After the main experimenter was in position in the correct posture for that trial, she said, "okay," thus signalling for the trial to begin. Once this signal was given, the second experimenter lowered the posterboard, moved out from behind the child and stepped toward the wall (away from the boxes) thus allowing the child to stand up, turn around, and walk toward the boxes and look in one of them. The decision rule for the child having made a choice was when he or she moved a lid on either of the boxes. After a box was chosen, the child was praised, the trial ended, and the second experimenter ushered the child back to the chair so he or she could place the sticker on the sticker page. This procedure was repeated until all trials were completed. At the end of the testing period the child was congratulated for playing so well, and escorted back to the warm-up area to show his or her parent the sticker page they had created.

Data Analysis. The main data were summarized by calculating the number of children correct in each treatment and using binomial tests to determine departure from chance (50%). The videotapes of the trials were coded for the same questions as the chimpanzees using a similar set of standardized written instructions. For the

latency to respond measure, a Pearson's correlation yielded a coefficient of determination, r^2 , of .86 ($p < .0001$) for the main and secondary raters' data sets. For the question concerning whether the child looked at the experimenter before responding, and the question concerning to which box the child first looked after looking at the experimenter, the main and secondary raters' data sets were compared using a percent agreement formula and yielded agreements of 95.8 and 95.6%, respectively. Only the data from the main rater were used in the analyses.

Results and Discussion

Three aspects of the results are considered and compared to the chimpanzees' performance. First, in contrast to the results with the chimpanzees, Figure 4 reveals that the children had little difficulty with any of the treatments (all binomial tests, $p < .0008$). The children tended to have more difficulty with the G treatment, perhaps because of the necessity of both understanding the attentional aspect of the gaze, but also appreciating the communicative intent of the gesture as well. Nonetheless, even on these trials 83% of the children selected the correct box. Second, the analysis of the videotapes indicated that, like the chimpanzees, the children virtually always glanced to the experimenter before responding, regardless of treatment ($M=96\%$ of all probe trials, range among treatments=87.5 to 100%). However, unlike the chimpanzees, when they did so they proceeded to

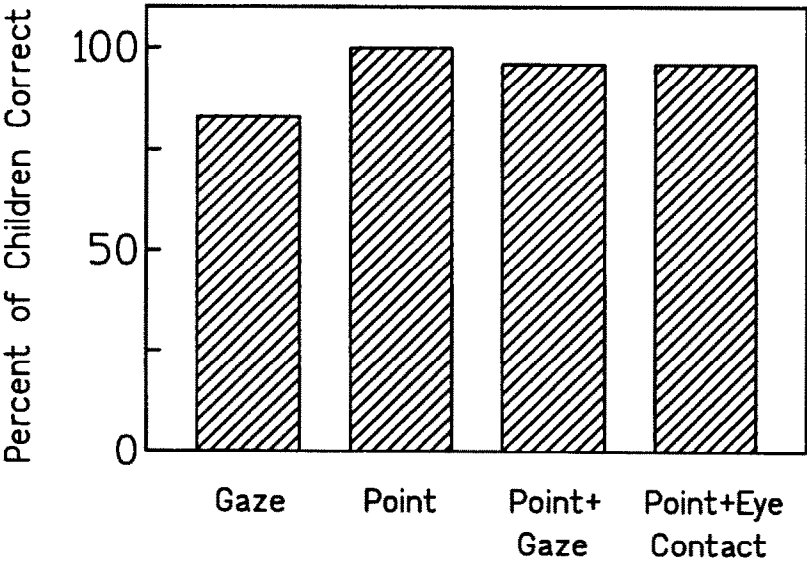


Figure 4. Number of children correct across treatments for Experiment 1 (children).

look at the correct box first on 91% of the trials. Because the children looked so frequently at the experimenter before making a choice, there was not enough variance to examine possible relations between whether the participants glanced at the experimenter and whether they selected the referenced box. Finally, the ANOVA comparing latencies to respond across the four treatment types and the standard trials indicated a marginally significant overall effect, $F(4,92) = 2.398$, $p = .056$. Tukey-Kramer Multiple Comparison post tests indicated that this marginal effect was attributable to the fact that the children hesitated longer on G trials ($M = 4.3$ sec) than on P+EC trials ($M = 3.2$ sec), $p < .05$. No other contrasts yielded statistically significant differences.

In summary, as predicted, young 3-year-olds had little difficulty extracting referential information from the gestures used in this study, even in those cases where the postures were rather unusual (i.e., the experimenter looking at the floor while pointing to a box). In general, these results can be used to argue that whatever the nature of the chimpanzees' understanding of pointing and/or gazing, it is not as sophisticated as the manner in which young 3-year-olds understand these same gestures. Indeed, given the ceiling-level performance of these young 3-year-olds, we might expect to find the same disparity even if the chimpanzees' performances were compared to young 2-year-olds—a possibility we explored further (and in more challenging situations) in Experiment 2.

EXPERIMENT 2

The results from Experiment 1 with the chimpanzees provided slightly different diagnoses for some of the subjects as compared to others with respect to the manner in which they interpreted the pointing gesture. The results of five of the seven subjects suggested that their excellent performance on proximal pointing trials was based upon some fairly straight-forward connection between the presence of a finger (or hand) near a box and the presence of a food reward. However, the results of two of the subjects (Kara and Apollo) on the probe trials (and especially the P trials) required further exploration in order to allow an intelligent choice between the cue distance account of their performance and the referential account. To this end, we created a number of additional treatments to further probe their understanding, as well as that of the other chimpanzee subjects. We also tested young 2-year-olds (24 to 30 mos) on the most challenging of these treatments in order to further explore the minimum age at which young children could appreciate the referential significance of pointing in the kind of search task used with the chimpanzees.

CHIMPANZEES

Method

Subjects. The subjects were the same seven adolescent chimpanzees who participated in Experiment 1. They began training for the current study 3 to 12 days

after completing the testing reported in Experiment 1. When this study began, the chimpanzees were approximately one month older than at the start of Experiment 1.

Apparatus and Setting. The same general setting and boxes described in Experiment 1 were used in this study. The only changes were the nature of the experimental treatments.

Training. To test for retention, each subject received at least one session consisting of six standard proximal pointing trials (see Experiment 1) with the side correct counterbalanced within subjects. In order to advance to testing, the subjects were required to select the correct box on at least five consecutive trials. The chimpanzees' primary caregiver again served as the main experimenter.

Testing. A probe trial technique was used to test the subjects' understanding of the pointing gesture. In order to test the predictions of the two models, nine different experimental treatments were created. First, three of the four techniques used in Experiment 1 were modified slightly and used in this study (P, G, P+G). Each of these treatments were executed either from the same position as in Experiment 1 ("body-centered position"), or from just behind one of the two boxes ("body-biased positions"). From the body-centered position, the three treatments were choreographed as follows. First, in the P treatment, the experimenter positioned himself so that his head was looking at the floor between his feet, and pointed with his opposite arm to the correct box (see Figure 5). This gesture was carefully designed and executed so that unlike in Experiment 1, the tip of the experimenter's finger was equidistant from both boxes, even though it was clearly (at least from our human perspective) referencing one of the boxes and not the other. The same was true for the P+G treatment. However, in this treatment, the experimenter's head was also positioned so that his line of sight was striking the box to which he was pointing. Treatment G was the same as treatment P+G except that the experimenter did not point. From the body-biased positions, the same three treatments were used. However, on half of the trials the experimenter referenced the box directly in front of him (near box), and half of the trials the experimenter referenced the box that was farthest from him (far box) (see Figure 5). This created the following conditions: P(far), P(near), G(far), G(near), P+G(far), P+G(near), where "near" and "far" refer to the box referenced by the experimenter. Slight alterations in the configuration of the experimenter's head and arms were necessary so that he was appropriately referencing the correct box in all six of these body-biased positions. In total, the subjects received nine experimental treatments (three body-centered, six body-biased).

Each chimpanzee received four trials of each of the nine treatments. The treatment trials were embedded into sessions consisting of 5 total trials; three standard proximal pointing trials (see Experiment 1) and two probe treatment trials. The order that each subject received his or her treatments, the specific trials on which

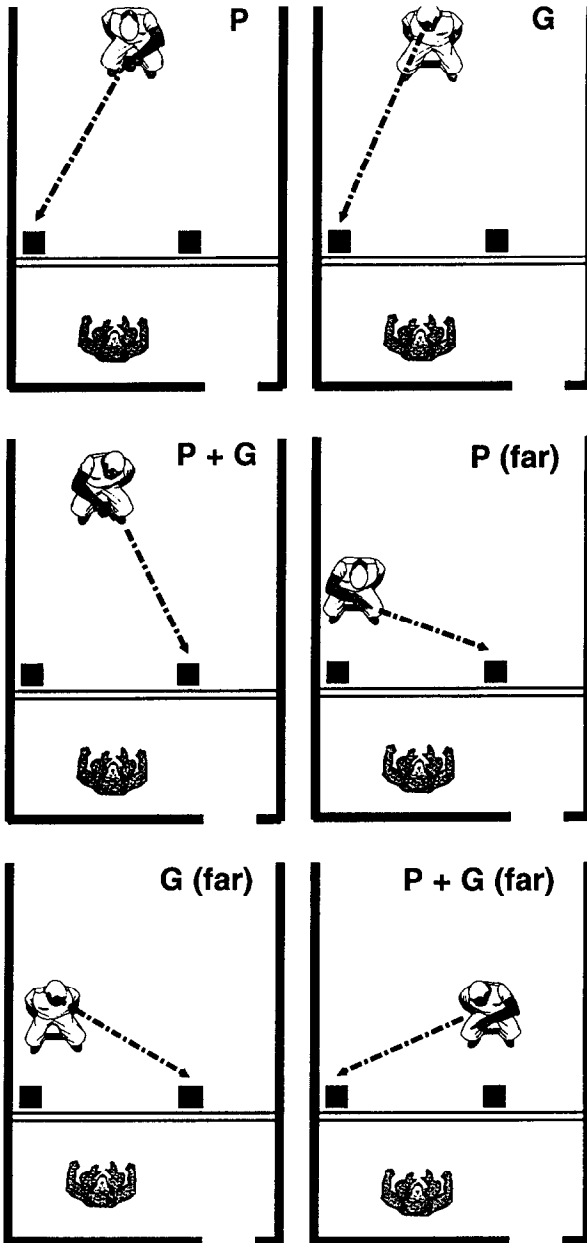


Figure 5. Probe trial testing configurations for Experiment 2 (chimpanzees). Note that the experimenter's hand was positioned at the midline of his body in the P(near) and P+G(near) trials (not shown) similar to the configuration depicted for P+G(far) and P(far) trials. Dashed line represents experimenter's referential direction.

these occurred within a given session, and the box position (left or right) referenced by the experimenter were assigned using the same counterbalancing and randomization techniques described in Experiment 1. For each of the body-biased treatments, on half of the four trials for each chimpanzee the experimenter referenced the right box, and on half he referenced the left box. The steps used in setting up and executing each trial were the same as in Experiment 1.

Predictions. Our predictions concerned both the subjects who had performed at chance levels on the critical probe trials in Experiment 1, as well as the two subjects that had performed well (Kara and Apollo). Both the cue configuration and the cue distance accounts predicted random performance on the P trials (finger equidistant between the two boxes) and below-chance performance on the P(far) trials (finger and body closer to incorrect box, but pointing gesture referencing correct box). In contrast, both accounts predicted above chance performance on the P(near) trials (finger and body closer to correct box). Given the subjects' previous histories of differential reinforcement for searching at the terminal point of an experimenter's gaze (Povinelli et al., 1997), as well as the results from Experiment 1, we predicted above-chance performance in both G and G(near), with slightly worse performance in G(far), where the body was closer to the incorrect box. The same predictions were made for P+G, P+G(near), P+G(far). In contrast, the referential comprehension model predicted above-chance performance on the P and P(far) treatments as well.

Data Analysis. The data were summarized and analyzed in a similar fashion as Experiment 1. The videotapes of all sessions were coded by a main rater and a secondary rater using similar procedures and instructional sets. Thus, average latencies to respond for each probe trial and a comparable number of randomly selected standard proximal pointing trials were obtained for each subject. Pearson's correlation yielded a coefficient of determination, r^2 , of .998, $p < .0001$, between the 20% of the randomly selected data set that the main and secondary raters coded separately. In addition, for each subject a main rater was given a set of standardized, written instructions which specified that he or she should observe each trial and answer the same questions used in Experiment 1 ("Did the subject look at the experimenter before choosing [moving the lid of] a box?" and if so, "Which was the first box the subject looked at after looking at the experimenter?"). A secondary rater was assigned a predetermined set of 20% of randomly selected probe trials. The two data sets were compared using a percent agreement formula and yielded an agreement of 88.1% for question 1, and 78.4% for question 2.

Results and Discussion

First, the subjects performed excellently on the standard proximal pointing trials that served as the background trials into which the probe trials were inserted. Across the 18 sessions, the subjects were correct on 94.7% ($SD = 7.9\%$) of these

trials. There were no effects of subject or session. These data indicate that throughout the experiment the subjects were interested in the task and motivated to respond correctly, thus providing a strong within-session control for the results of the probe trials. The main results provided support for the predictions of the cue distance model of the chimpanzees' comprehension of the pointing gesture, as well as implicating this same explanation for Kara and Apollo's performance in Experiment 1. In contrast, they offered little support for the predictions generated by the referential comprehension model. Figure 6 displays the main results of the nine experimental treatments. These data were subjected to a one-way repeated measures ANOVA which indicated a significant overall effect, $F(8,48) = 5.809$, p

Table 2. Significant contrasts in Experiment 2 (chimpanzees) as revealed by Tukey-Kramer Multiple Comparisons Post Hoc Tests

Body-centered					Body-biased			
	G	P	P+G	G(near)	G(far)	P(near)	P(far)	P+G(near) P+G(far)
G	---	---	---	---	---	---	***	---
P			---	---	---	---	---	---
P+G				---	---	---	**	---
G(near)					---	---	***	---
G(far)						---	*	---
P(near)							**	---
P(far)								***
P+G(near)								---
P+G(far)								---

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

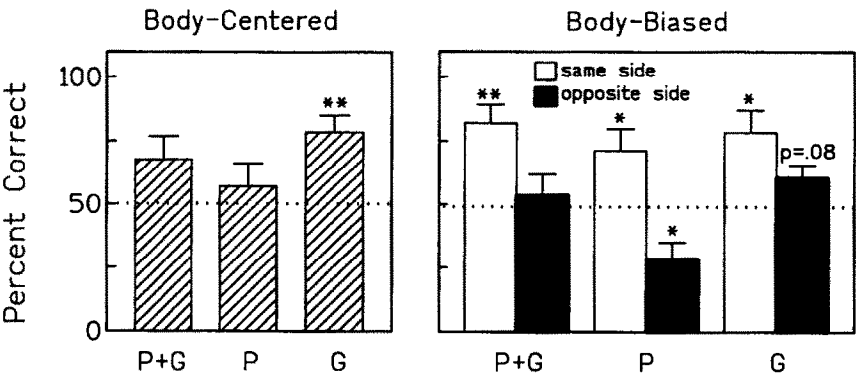


Figure 6. Percent of trials correct (\pm SEM) for Experiment 2 (chimpanzees) for body-centered and body-biased conditions.

< .0001. Tukey-Kramer post hoc tests indicated that this overall effect was due to a number of significant contrasts, all of which involved the P(far) treatment (see Table 2). The importance of these significant contrasts are discussed below.

Body-centered Positions. First, with respect to the body-centered treatments, the chimpanzees performed significantly above chance on the body-centered G trials, averaging 78.6% correct ($SD = 17.2\%$); one sample t -test, two-tailed, hypothetical mean = 50%, $t(6) = 4.382$, $p < .005$). In contrast, their performance on the body-centered P and P+G trials did not differ from chance. Thus, the subjects tended to perform worse on the body-centered P+G trials than on the G trials. This is exactly opposite what the referential model predicted. Curiously, in this case the inclusion of the pointing gesture appears to have interfered with the subjects (presumably) learned ability to use the gaze of the experimenter to select the correct box (see discussion below). In general, these findings are consistent with the results of Experiment 1 in that the subjects were able to use the gazing of the experimenter (even when it was centered equidistant from both boxes) to locate the reward, but that they were not able to exploit the pointing gesture in the same manner. Indeed, even the two animals (Kara, Apollo) who had performed well on the distal pointing trials in Experiment 1, dropped to random performance (50%) in this study when the distal pointing cue was equidistant from both boxes.

Body-biased Positions. There were two versions of each treatment within the body-biased condition; one in which the experimenter gestured to the box immediately in front of him (near box), the other in which he gestured to the box furthest from him (far box; see Figure 5). First, we discuss the results from those trials in which the experimenter gestured to the near box. One-sample t -tests revealed that the subjects performed at levels exceeding chance in all three of the body-biased treatments: G(near), P(near), P+G(near); all t 's $> 2.52 < 4.50$, all p 's $< .045 > .0041$ (see Figure 6). In direct contrast, when the experimenter referenced the far box, the subjects performed at levels significantly *below* chance in treatment P(far), $t(6) = 3.286$, $p < .02$ (meaning that they chose the box closest to the experimenter's finger/hand/body), and at chance levels in treatment P+G(far), $p = .689$. However, in treatment G(far), the subjects' performance tended to exceed that expected by chance, although this trend was not statistically significant, $t(6) = 2.121$, $p < .078$.

These data indicate that in the body-biased treatments, the gazing gesture appeared to assist the subjects in locating the correct box, but that the pointing gesture added nothing to this ability (indeed, contrary to the predictions of both models, the gesture appeared to interfere with the ability). This can be inferred from the linear ordering of the subjects' performance in the body-biased treatments P(far), P+G(far), and G(far): 29, 54, and 61%, respectively. Interestingly, it appears that the addition of gazing to the pointing gesture at least partially allowed the subjects to escape from a cue distance rule deriving from the location of the experimenter and/or his finger/hand. Thus, even though the subjects performed at

only chance levels in the body-biased P+G(far) treatment, and only tended toward a significant departure from chance in the body-biased G(far) treatment, this represented a considerable improvement over their performance in the comparable P(far) treatment. Indeed, it can be seen from Figure 6 and Table 2 that the subjects performed significantly better on the G(far) trials than on the P(far) trials.

Next, the data were examined for possible learning effects. In order to do so, the data were structured in two ways. First, the results within each treatment were examined on a trial-by-trial basis across the four trials each subject received (see Figure 7). As can be seen in Figure 7, there were no indications that in the treatments in which the group's performance departed from chance—G, G(near), P(near), P+G(near)—that learning had occurred during repeated exposure to those trial types. Next, we structured the results of the probe trials by session (irrespec-

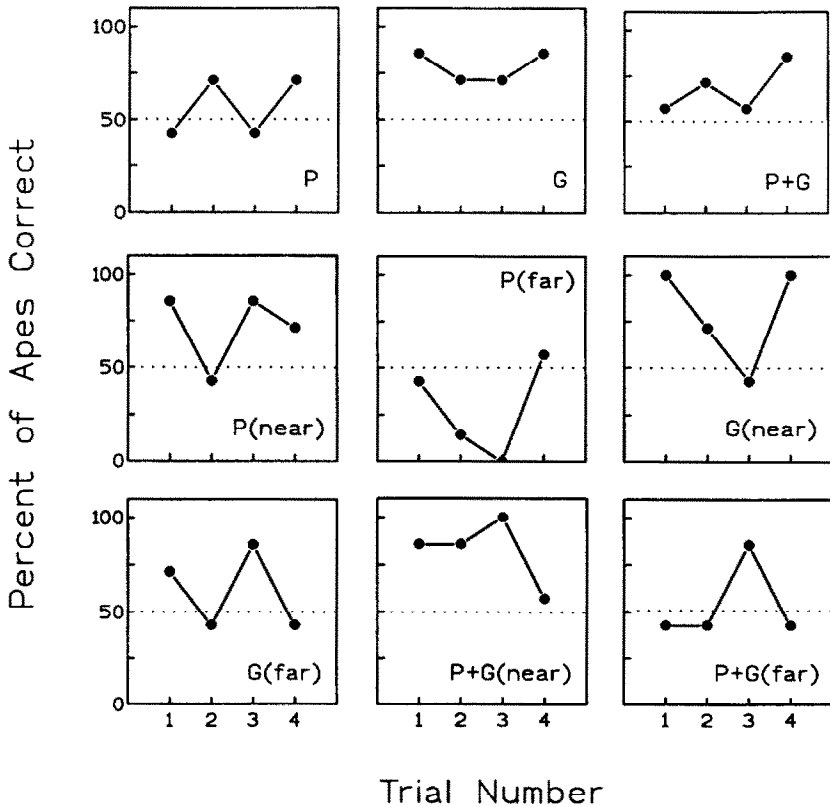


Figure 7. Percentage of chimpanzees correct by treatment and trial number (Experiment 2). Dotted line represents performance expected by chance.

tive of treatment) and used a paired *t*-test for related samples to compare the group's performance during the first half of the experiment (sessions 1-9) to the group's performance in the second half (sessions 10-18), but no significant effect was obtained. Thus, it seems reasonable to conclude from the results of these analyses that the effects obtained were not the result of practice (learning) effects that occurred during the course of this experiment.

Finally, the two data sets that were derived from videotape to determine to what extent the subjects attended to the differences between the background proximal pointing trials and the various treatment probe trials were examined. First, with respect to average latency to respond, the subjects showed no significant differences among the various treatments, or between the probe trials and standard trials. In addition, several analyses revealed that there were no effects of trial number either across or within the various treatments themselves. Second, the results of the main rater's coding revealed that the subjects looked at the experimenter before responding on 94.4% of all probe trials, and the few cases where they did not were more or less evenly distributed among the individual treatments (range = 89 to 100%) and animals (range = 78 to 100%). In addition, the percentage of correct trials was approximately the same for those trials where the subjects did glance at the experimenter before choosing a box (64%, $N = 238$), and those trials when they did not (71%, $N = 14$).

As in Experiment 1, we examined the data for possible evidence that the subjects displayed implicit comprehension by glancing at the correct box, even when their overt choice (searching inside a box) was incorrect. We again examined the glancing data in three steps. First, we restricted the data set to only those probe trials (94.4% of the total) when the subjects looked at the experimenter before making a choice. Table 3 presents the frequencies of the subjects' glances (after first looking at the experimenter) to the location referenced by the experimenter (whether through pointing, gazing, or both). In general, the results reveal that the subjects tended to look at the correct box after glancing at the experimenter. However, there are really only two strongly informative contrasts. First, assuming that each case is an independent event, a comparison of the body-centered P and G trials (see Table 3), reveals that whereas on the G trials the subjects looked at the correct box far more frequently than the incorrect box, the subjects showed no such pattern in the P trials, although the contrast was not statistically significant (Fisher's Exact Test, $p = .086$). The second informative comparison involves the body-biased P(far), G(far), and P+G(far) trials where the correct choice involved choosing the box furthest from the experimenter. Here, a chi-squared test for independence indicated a significant effect, $\Delta^2(2, N = 79) = 6.783$, $p = .034$. An examination of the relevant rows in Table 3 reveals that the effect is due to the fact that on P(far) trials the subjects did not follow the pointing gesture to the correct box, whereas on more than half of the G(far) and P+G(far) trials, the subjects did follow the gazing gestures to the correct box. We find this especially interesting because just as in the analysis of the data involving the subjects' overt choices, the

Table 3. Relationship between Glancing at Experimenter and Looking at Correct Box in Experiment 2 (Chimpanzees)

treatment	Did subjects look at correct box immediately after glancing at experimenter?		binomial <i>p</i>
	Yes	No	
Body-centered			
P	14	12	ns
G	21	6	.003
P+G	18	9	.061
Body-biased			
P(near)	18	8	.04
P(far)	8	20	.02
G(near)	21	5	.002
G(far)	16	10	ns
P+G(near)	22	5	.0008
P+G(far)	14	11	ns

combination of the two gestures (pointing and gazing) did not increase the probability that the subjects looked at the referenced location—if anything, it tended to interfere with it. One possible explanation for this finding may be that on these trials the subjects' attention was divided between the gaze cue and the (uninterpretable) pointing cue.

Next, as in Experiment 1, there was a strong connection between where the subjects looked first after glancing at the experimenter and their overt choice. As a group, the subjects' first glance predicted their overt choice on 70.9% of all probe trials (range across treatments = 64.3 to 82.1%). A one-way repeated measures ANOVA revealed no differences in this measure among the nine treatments. One sample *t*-tests (two-tailed, hypothetical mean=50%) indicated that for P(near), P+G(near), and P+G(far) the percentage of trials on which their overt choice matched where they first looked after looking at the experimenter, exceeded that expected by chance, all $t(6)$'s $> 2.93 < 3.58$, all p 's $< .02 > .01$. Non-significant trends were obtained for G(near) and P+G, $t(6) = 2.004$ and 2.121 , and p 's = .092 and .078, respectively.

Finally, to determine if there was an implicit effect that was solely limited to those trials on which the subjects' overt choice was incorrect, we examined just those trials where the subjects' overt choice was incorrect. We then calculated the percentage of trials in each condition that the subjects looked at the correct box before making their (incorrect) choice. These data revealed that on incorrect trials, the subjects' first look (after glancing at the experimenter) was to the correct location ranged between 20.0 and 62.5% of the cases across the nine treatments. In no case did binomial tests yield results indicating that the subjects looked at the cor-

rect box at levels exceeding what would be expected by chance. Thus, as in Experiment 1, these analyses provided no evidence of a dissociation between the subjects' overt choices and where they looked before making a choice.

Thus far, we have focused exclusively on the group data. However, one subject (Candy) performed noticeably different from the others. Although her chance performance on the P(far), G(far), and P+G(far) trials (i.e., the body-biased treatments) fit the predictions of the cue distance model (50% correct averaged across these three treatments), her performance from the body-centered trials differed strongly from chance. Indeed, Candy scored 100% correct in each of the P, G, and P+G treatments (12/12 correct, binomial test, $p < .0001$). The result from treatment P was especially striking because in this case the experimenter's pointing finger/hand was equidistant from both boxes and there was no gaze cue present. However, by itself this treatment only constituted 4 of the 12 relevant trials and so it is difficult to assess whether this particular result was reliable.

In order to examine Candy's performance further, 4½ months after the completion of this experiment she was re-tested (at age 7;3) using the following procedures (a detailed protocol of this study is available from the authors). She initially received a retention session of 6 trials of the standard proximal pointing trials and met criterion (5/6 or better) to advance to testing. Her testing consisted of 12 sessions, each composed of 5 trials; 3 standard proximal pointing trials and 2 probe trials. The probe trials were drawn from three treatments: P, P(near), and P(far). She thus received eight trials of each of these three treatments. The same counterbalancing and randomization procedures were used.

The results of this follow-up test were as follows. First, the results from the baseline standard proximal pointing trials indicated that Candy was correct on 86% (31/36) of the trials, indicating her general motivation and attention during the task. Second, she was correct on 7/8 (87.5%, binomial test, $p = .035$) of the undiagnostic P(near) trials. The crucial results are from the body-centered P trials and the body-biased P(far) trials, and in both cases Candy scored 2/8 (12.5%, *ns*). We interpret this result as indicating that Candy's performance (4/4) on the P trials in the main experiment was unreliable. Thus, although Candy might have learned some rules about using the gaze of the experimenter (in those treatments where it was available) to predict which box was baited, she did not appear to understand the pointing gesture in a comparable manner.

To summarize, the results of this study were consistent with the predictions generated by the cue configuration and/or the cue distance models, and not those generated by the referential models. Thus, in relation to the *a priori* predictions of the three models, the results are consistent with the idea that our chimpanzees' searching behaviors, even the two that had performed well in Experiment 1, were controlled by rules or dispositions related to (1) the presence of the experimenter's finger/hand in the local cue configuration of the boxes, and/or (2) the distance of the experimenter's hand/body from the boxes. The subjects did appear to learn some rules about using the experimenter's gaze to choose the correct location (see

Treatment G, Figure 7), but as the trial-by-trial analysis from Experiment 1 revealed (see Figure 2), this effect appears to have been learned. In addition, as our previous studies have suggested, even this effect may not be grounded in an understanding of attention or reference per se, but rather a social disposition to orient in a face-to-face manner with others (see Povinelli et al., 1997). More generally, the fact that our chimpanzees did not initially respond in this manner (see Experiment 1) but rapidly learned to do so, combined with the fact that they spontaneously follow the gaze of others, suggests that regardless of whether they are or are not able to understand the referential dimension of gaze, its salience may afford it with a high degree of learnability with respect to tasks such as the ones used here (see Povinelli & Eddy, 1996c).

CHILDREN

Method

Participants. The 12 children who participated in this study ranged from 24 to 30 mos ($M = 26.9$ mos); 7 males and 5 females. The participants were recruited using the same methods described in Experiment 1. The participants and their families were primarily from working- and middle-class backgrounds from Lafayette, Louisiana and the surrounding areas. No data were systematically collected on the racial or ethnic backgrounds of the participants.

Warm-up Procedure. When the parent and child arrived at the center, they were led directly into the testing room. The warm-up period served to familiarize the child with the environment, to allow the child to become acquainted with the two experimenters, and also to introduce the child to the two boxes in the form of a hide and seek game. To accomplish this, the main experimenter showed the child how small animal figurines could be hidden inside either of the boxes and then retrieved when the box lid was lifted. After the child appeared comfortable approaching the boxes and retrieving the small toys, the main experimenter showed them how stickers could be hidden in either box and then located in the same manner. At that point, the main experimenter placed a sticker in one of the boxes, pointed to that box, and asked the child to find the sticker. The warm-up period was determined complete when the child successfully lifted the lid on the referenced box, retrieved the sticker, and carried it to their parent and placed it on their sticker page. While the main experimenter demonstrated the logistics of the game to the child, the second experimenter explained the procedure of testing to the parent and obtained his or her signature of informed consent. The end of the warm-up period signaled the onset of the testing procedure.

Testing Procedure. The two boxes were placed on the floor of the testing room, in the same positions as in Experiment 1. Two video cameras offered frontal and rear views of the children as they were tested. Each participant received a single testing session which consisted of 6 total trials and included three standard and

three probe trials. The standard trials were the same as those used with the chimpanzee subjects. The probe trials consisted of just the body-biased P(far), G(far), and P+G(far) treatments. The body-centered P, G, and P+G trials, as well as the body-biased P(near), G(near), and P+G(near) trials in which the experimenter referenced the near box, were not employed for two reasons. First, pilot testing revealed that it was extremely difficult to execute 12 trials with children of this age. Second, pilot testing also revealed that the children of this age responded at a similar level correct as had the older children on these treatments in Experiment 1. Thus, we chose to administer only the most challenging trials to these young children. After all, if the children could succeed on the body-biased trials this would indicate the relative sophistication of the children's abilities in relation to that of the chimpanzees. The standard trials were administered on Trials 1, 3, and 5. The probe trials, which served as the vehicles for the experimental treatments, were randomly assigned to Trials 2, 4, and 6.

The children were tested as follows. After the warm-up period, the second experimenter placed the parent's chair outside of the testing room and gave him or her the child's sticker page. The parent's chair was located where the parent could not view the testing process and influence the child's behavior in any way, yet he or she remained near enough to the toddler to facilitate a comfortable atmosphere. The chair was positioned alongside the outer wall of the testing room which fully obstructed the parent's view of the testing room. The second experimenter ushered the child to the parent's chair where the child and parent interacted while the main experimenter hid the sticker in the correct box, and then positioned herself according to the predetermined schedule. When she was in position, the main experimenter verbally notified the second experimenter by saying, "okay." The second experimenter and the parent then encouraged the child to enter the testing room and "find the sticker." After the child selected a box (defined as moving a lid), the trial was complete. The main experimenter praised the child and recorded the response. The second experimenter then entered the testing room and escorted the child back to the parent to add the sticker to their page. This procedure continued until all six trials were completed.

Data Analysis. The data were coded, summarized, and analyzed in the same manner as in Experiment 1. The reliability for the question concerning whether the child looked at the experimenter before making a choice was 100%. The reliability for the question concerning which was the first box the child looked at after looking at the experimenter was 88.6%.

Results and Discussion

As explained above, the children were only administered the most challenging treatments in which the experimenter referenced the far box. In general, the results suggest that unlike our adolescent chimpanzees, the young two-year-old children had no difficulty in escaping from a distance cue (based on the position of the

experimenter's finger/hand/body) by exploiting the referential information contained in the experimenter's pointing gesture. The results indicated that the participants had little trouble with either the P treatment (11 of 12 children correct, binomial $p = .003$) or the P+G treatment (12 of 12 correct, binomial $p = .0002$). However, the children experienced more difficulty with treatment G where only 8 of 12 chose the correct box (binomial test not significant). The participants' difficulty in treatment G may reflect the relatively poorly consolidated understanding of even the simplest aspects of visual perspective taking in 2-year-olds, especially young 2-year-olds (see Lempers, Flavell, & Flavell, 1977; Gopnik, Meltzoff, & Esterly, 1995; Povinelli & Eddy, 1996a, Experiment 15). The main rater indicated that in all but one case the children looked at the experimenter before making a choice. In the 35/36 cases that they did look at the experimenter before responding, they looked at the correct box first on 83% of the trials. A disproportionate number of the mismatches between glancing at the experimenter, but then not looking at the correct box, occurred in treatment G (4 of 12 cases), and two of these were from the four children who chose an incorrect box.

The importance of these results are two-fold. First, they show that when an adult is pointing to a far location, even 26-month-old children can avoid choosing a location much closer to the adult's body and pointing hand, even when the adult's head and gaze are neutralized (by having them look down at the floor). These results impressively demonstrate the flexibility of young 2-year-olds' understanding of the referential aspect of pointing. Second, and most critically for the present series of studies, our results indicate that whatever the exact nature of our chimpanzees' understanding of the pointing gesture, it is certainly very different from that of 26-month-old children.

GENERAL DISCUSSION

The studies reported in this article were designed primarily to determine if adolescent chimpanzees who had received extensive exposure to the human pointing gesture (both in previous formal testing as well as informal social interactions) would interpret the gesture in a referential manner. Previous experimental research had demonstrated that chimpanzees (and other primates) are capable both of learning to use their natural reaching and begging gestures in ways that resemble pointing and of learning to use a human's proximal pointing gesture to locate a reward (Anderson, Sallaberry, & Barbier, 1995; Blaschke & Ettlinger, 1987; Call & Tomasello, 1994; Hess, Novak, & Povinelli, 1993; Povinelli & Eddy, 1996a; Povinelli, Nelson, & Boysen, 1992; Povinelli, Parks, & Novak, 1992; Woodruff & Premack, 1979). However, the exact nature of their understanding of these actions has been unclear. Our results are consistent with hypotheses generated by frameworks that posited that despite their familiarity with and use of our pointing gestures, these adolescent chimpanzees did not interpret them in a referential manner. That is, we obtained little or no evidence that our apes understood

that the pointing gesture referred to (or was about) a particular object or location in space. This is not to say that these apes were unable to learn how to exploit the gesture in order to obtain food rewards; as we have seen, they were quite able to do so. However, in each diagnostic experimental situation, the animals' performances fit the predictions of the cue-configuration or distance-based models, and not the model that posited an understanding of reference.

To our knowledge, there are only three previously published experimental reports of the capacity of great apes to understand pointing in a referential manner. First, as part of a larger study of young chimpanzees' leadership and communication skills, Menzel (1974) briefly reported some research involving young chimpanzees' responses to human pointing. In one study, Menzel sought to determine if chimpanzees could discern the location of food in an open field using various cues, including actively showing them the location and, in some conditions, pointing from various distances. However, because Menzel was primarily interested in communication among the chimpanzees, his work does not report crucial methodological information that would allow the results to be interpreted in a straightforward manner with respect to their understanding of the pointing gesture. Furthermore, in the only condition in which the experimenter's pointing gesture did not covary with carrying the animal directly toward the location of the hidden food, the chimpanzees' performances were random, except possibly on those trials in which the subjects were oriented to their extreme right or left as the experimenter held them and pointed along the perimeter of the enclosure (see Menzel, 1974, Figure 20 and pp. 126-127). In these cases, the subjects may have been responding to the human's gaze direction or their own general body orientation as they were held, and then simply traveled along the perimeter of the enclosure upon release. In contrast, when the experimenter pointed out into the field in a particular direction, the subjects essentially wandered randomly upon release (Menzel, 1974, see Figure 20).

In a second study that was designed to explore the capacity for role reversal in chimpanzees, Povinelli, Nelson, and Boysen (1992) trained four subjects either to respond to human pointing and then produce pointing for a human, or vice versa. The most direct evidence for comprehension of pointing comes from a seven-year-old female subject who, after having been trained to gesture selectively for a human partner, upon reversing roles correctly responded to her partner's pointing gesture from trial 1 forward. However, it is important to note that because the underlying purpose of the Povinelli, Nelson, and Boysen (1992) study was not to assess pointing comprehension *per se*, no attempt was made to control for the distance of the experimenter's hand from the baited location (approximately 20 cm; Povinelli, Nelson, and Boysen, 1990, see Figure 4), to which it was considerably closer than the other possible locations.

A third relevant study was conducted by Call and Tomasello (1994, Experiment 2), who investigated the capacity of two orangutans to comprehend pointing. Although one of these apes responded at chance levels, the other subject (who had

been reared and 'enculturated' with humans) performed at levels exceeding chance (52% correct, chance = .33). Although Call and Tomasello (1994) interpret this as being consistent with the idea that human-reared great apes may develop some advanced social cognitive skills (see also Tomasello, Kruger, & Ratner, 1993), they did not control for the fact that when the experimenter initially pointed to one of the locations, the pointing hand was much closer to that location than the others. Thus, like the Povinelli, Nelson, & Boysen (1992) study, their results cannot tease apart a cue-distance explanation from a referential comprehension explanation. Indeed, if we were to ignore the distance confound, our subject Kara displayed better evidence for comprehending pointing in our Experiment 1 than did their enculturated orangutan. However, by using treatments that controlled for distance, the results of Experiment 2 established that even her performance was better explained by a cue-distance model than a referential comprehension model.

One important issue not directly addressed by our studies concerns the experimental and anecdotal reports of chimpanzees' production of gestures toward individuals or objects that they desire (Gómez, 1990). Indeed, some of these reports show that chimpanzees and orangutans can rapidly learn to be fairly specific about the direction of the gesturing (Call & Tomasello, 1994; Povinelli, Nelson, & Boysen, 1992). However, it is important to distinguish between proto-imperative gestures on the one hand, and topographically similar proto-declarative gestures that are governed (or at least attended) by an appreciation of an internal, mental state of attention in the self and other and/or the referential intent of the gesture itself. Not all researchers agree on this point (see Gómez et al., 1993), but one possibility is that early proto-imperative pointing in infants is produced not to influence the mental state of the other (e.g., to coordinate internal attention states), but to instrumentally produce a change in the world (e.g., to obtain a desired object)—a difference highlighted by the apparent dissociation of the two types of pointing in autism (Baron-Cohen, 1989; Goodhart & Baron-Cohen, 1993; Mundy, Sigman, Ungerer, & Sherman, 1986). Given that chimpanzees naturally produce arm extensions in many contexts, these behaviors may be easily shaped or conventionalized in social interactions with humans who bring to bear an interpretation that may not be shared with the apes themselves. Thus, the fact that we frequently witness our chimpanzees gesturing toward out-of-reach objects, while looking back and forth toward someone who could provide it, by itself may reveal no more than a desire to obtain the desired object. Whether such behaviors establish the presence of true joint attention (in the sense of appreciating the internal mental state of attention), remains an open question (see Gómez et al., 1993). However, the fact that the gestures are localized and accompanied by glances to the human, may only indicate that the subject is oriented to what he or she wants, and understands that the human is the means to achieve that end. Although this level of communication may be described as intentional, it does not necessarily imply an understanding of mental reference or the mental state of attention. It may, on the other hand, indicate an understanding of the surface, behavioral manifestations of attention, without an

understanding of an accompanying internal mental state (see Gómez, 1991; Povinelli & Eddy, 1996c).

A related question concerns the relation between the chimpanzee's natural gestures involving arm extensions (used in the contexts of food begging, ally recruitment, and reconciliation), and the human act of proto-imperative pointing. To the extent that proto-imperative pointing can be said to exist as a subset of human pointing actions, then the fact that chimpanzees use their gestures to express their desire to obtain some state of affairs in the physical world, these gestures can clearly be thought of as proto-imperative (Bates et al., 1975). The topographically distinct form of gesturing with index finger extension in human infants could be thought of as the conventionalization of reaches-with-points. This idea can be maintained without taking the position, as did Vygotsky (1962), that such instrumental actions are transformed into proto-declarative pointing. Rather, it is possible to envision that even during the initial stages of pointing in human infants, index finger extension simply "rides along" with the conventionalized reach/request because it is part of the natural repertoire of the hand, or perhaps more specifically, it is part of the very similar act of proto-declarative pointing. Chimpanzees do use their index finger for fine manual exploration of objects, and there are some occasions in which the index finger (or other finger) may be involved in chimpanzee arm gestures (Boysen, Berntson, Shreyer, & Hannan, 1995; Kellog, & Kellog, 1933, see unnumbered photograph on p. 275; Povinelli, Nelson, & Boysen, 1992; Leavens, Hopkins, & Bard, 1996). However, Povinelli and Davis (1994) have demonstrated morphological differences in the resting state of the index finger relative to the others between humans and chimpanzees, thus providing a possible morphological substrate for the preferential extension of the index finger in humans, but not chimpanzees, in early reaching gestures. Although this may be part of the explanation of the developmental origins of the exact topography of the pointing gesture in humans, Povinelli and Davis note that this morphological difference between chimpanzee and human hands cannot explain why chimpanzees do not naturally engage in proto-declarative arm extensions (for example, to comment on distant events).

There are several opportunities to build upon and test the generality of our conclusions. First, we required our chimpanzees to reason about human gestures, not chimpanzee gestures. Although we were aware of this issue from the outset, we were particularly interested in knowing whether, after years of exposure to the pointing gesture in spontaneous, daily interactions with humans, as well as the formal training they received, these apes had come to appreciate the referential significance of the gesture. Furthermore, given that chimpanzees do not spontaneously use their arm extensions in a manner that can be considered proto-declarative, having a human experimenter use these gestures in such a way might serve to confuse the subjects. For example, if we had used more ape-like gestures and our subjects had performed in the same manner as they did here, it could be argued that they had interpreted the gestures in a social or proto-imper-

ative manner, which would in turn preempt their ability to interpret them in a different, proto-declarative fashion. Nonetheless, future research could attempt to identify contexts in which chimpanzees use their naturally occurring behaviors in a manner that may be referential, and explore how they respond to such behaviors. Indeed, in the context of our investigations of their understanding of the referential aspects of gaze, we have begun to explore exactly this possibility (see Povinelli & Eddy, 1996c). In a similar vein, Menzel (1973) offered the speculation that chimpanzees might "point" using their whole body. A second manner in which this work could be extended would be to test older chimpanzees, or chimpanzees reared in different ways. However, the subjects' experimental histories are critical, and developing informed inferences about their understanding of pointing will depend upon our ability to distinguish between conventionalized gestures that occur without an underlying appreciation of their referential or attentional significance, and gestures that occur with such psychological appreciation.

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