

Psychological Diversity in Chimpanzees and Humans: New Longitudinal Assessments of Chimpanzees' Understanding of Attention

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Key Words

Chimpanzees · Psychological evolution · Theory of mind · Attention · Mammal

Abstract

We present the results of 5 experiments that assessed 7 chimpanzees' understanding of the visual experiences of others. The research was conducted when the animals were adolescents (7–8 years of age) and adults (12 years of age). The experiments examined their ability to recognize the equivalence between visual and tactile modes of gaining the attention of others (Exp. 1), their understanding that the vision of others can be impeded by opaque barriers (Exps. 2 and 5), and their ability to distinguish between postural cues which are and are not specifically relevant to visual attention (Exps. 3 and 4). The results suggest that although chimpanzees are excellent at exploiting the observable contingencies that exist between the facial and bodily postures of other agents on the one hand, and events in the world on the other, these animals may not construe others as possessing psychological states related to 'seeing' or 'attention.' Humans and chimpanzees share homologous suites of psychological systems that detect and process information about both the static and dynamic aspects of social life, but humans alone may possess systems which interpret behavior in terms of abstract, unobservable mental states such as seeing and attention.

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Introduction

Nothing could be more central to modern evolutionary biology than the notion of diversity. The biological sciences thrive on understanding the genetic, morphological, and behavioral diversity that exists both within and among populations and species. Central to the study of diversity is the idea of specialization – the notion that a great deal of existing biological diversity reflects species-specific adaptations that have resulted from natural selection or other evolutionary processes.

In contrast, the idea of psychological diversity has had a much harder time establishing a foothold in the thinking of biologists and psychologists alike. Even comparative psychologists, researchers seemingly dedicated to understanding the evolutionary diversification of learning and cognition, have historically focused on identifying universal laws of learning and cognition [Beach, 1950; Hodos and Campbell, 1969; Boakes, 1984; Macphail, 1987]. Beginning with Darwin, comparative psychologists have emphasized commonality, similarity, and continuity in psychological functioning among species, and only rarely have given serious consideration to the possibility of genuine differences among species [e.g., Bitterman, 1965; Gallup, 1982]. Recently, however, the notion of psychological or cognitive specializations has gained increasing attention [see Kamil, 1984; Gaulin, 1992; Povinelli and Preuss, 1995; Tooby and Cosmides, 1995; Gallistel, 2000].

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Over the past decade, one cognitive system in particular has received considerable attention from the perspective of evolutionary diversity: the system responsible for representing concepts related to mental states such as attention, emotions, desires, perceptions, intentions and beliefs [Premack and Woodruff, 1978; Gallup, 1982; Whiten and Byrne, 1988; Heyes, 1993; Povinelli, 1993, 2000; Tomasello et al., 1993; Tomasello and Call, 1997]. Premack and Woodruff [1978] coined the term 'theory of mind' to succinctly refer to the ability to make inferences about mental states: 'A system of inferences of this kind,' they noted, 'may properly be regarded as a theory because such states are not directly observable, and the system can be used to make predictions about the behavior of others' (p. 515). Humans, at least, reason about such states in every culture that has been examined thus far, suggesting that the construal of the self and others in terms of unobservable mental states may be part of the core architecture of the human mind [for discussions of the cross-cultural data on theory of mind, see Avis and Harris, 1991; Povinelli and Godfrey, 1993; Lillard, 1998a, b; Vinden and Astington, 2000; Wellman et al., 2001]. Thus, regardless of whether such states are 'real' [that is, whether they refer to ontologically real entities; see Churchland, 1981], the human penchant for thinking about the self and others in such psychological (subjective) terms can hardly be denied.

Is theory of mind a uniquely derived feature of the human lineage, or is it (or at least some components of it) shared with some wider taxonomic group or groups? Although specific proposals for the evolutionary history of theory of mind are scarce [e.g., Gallup, 1982], it is at least in principle possible that this is an ability that humans share with the great apes, or even a wider taxonomic group. Part of the difficulty in addressing the evolutionary history of theory of mind is that its functioning cannot be directly observed, but must be inferred from behavior. But what kind of behavior will suffice? Some scholars have attempted to use the spontaneous behavior of animals to infer whether they are reasoning about the mental states of conspecifics. The most widely heralded evidence of this sort involves the well-documented practice of deception in the spontaneous behavior of various species of non-human primates [see Whiten and Byrne, 1988]. On the basis of such observations, some researchers have proposed that the system for reasoning about mental states evolved in an inherently social context to sub-serve strategic competitive practices (e.g., deception) and that deception can be taken as *prima facie* evidence that various aspects of this system are wide-

spread among primates [e.g., Whiten and Byrne, 1988; Baron-Cohen, 1995]. However, complex acts of deception can be identified in many non-primate species, and even non-mammalian taxa such as ravens [see Bugnyar and Kotrschal, 1997]. Thus, if spontaneous acts of deception are evidence of theory of mind, the phylogenetic ubiquity of such behaviors suggests either that there have been multiple instances of parallel or convergent evolution, or that the ability to reason about mental states such as beliefs is a shared, primitive feature of a very large taxonomic group indeed.

It is possible, however, that the spontaneous behavior of organisms is not well suited to address the question of the presence or absence of various aspects of theory of mind. Indeed, some theoretical considerations have concluded that even careful, detailed observations of the spontaneous behavior of animals will lead to only very weak inferences concerning the presence or absence of such systems, whereas controlled experimentation can provide much stronger inferences [Premack, 1988; Povinelli and Giambone, 1999]. The underlying difficulty in relying on spontaneous behavior is that when an organism reacts to a social partner, the organism may be reasoning about both the behavior and the mental states of its partner, or simply the behavior alone. Indeed, the mental states of the social partner are only relevant insofar as they lead (or have led in the past) to some observable behavior. Once this latter fact is acknowledged, it becomes clearer why the reliance on spontaneous behavior will not suffice: in uncontrolled circumstances it is impossible to know which process generated a given behavior. Indeed, a growing dissatisfaction with a reliance on spontaneous, uncontrolled behavior has led to an increasing focus on experimental approaches to studying whether any aspects of theory of mind exist in other species – especially the closest living relatives of humans, chimpanzees [see Call and Tomasello, *in press*; Povinelli, 2000; Suddendorf and Whiten, *in press*].

The most thoroughly experimentally explored facet of other species' understanding of the mental states of others concerns whether chimpanzees (and some other species of non-human primates) conceive of others as possessing perceptual states related to visual attention; that is, whether they realize that others 'see' things [e.g., Premack, 1988; Cheney and Seyfarth, 1990; Povinelli et al., 1990, 1991, 1999; Povinelli and Eddy, 1996a, b; Call et al., 1998; Reaux et al., 1999; Theall and Povinelli, 1999; Tomasello et al., 1999; Hare et al., 2000]. Research specifically targeting chimpanzees has yielded conflicting results. An intensive, longitudinal investigation of a group

of seven chimpanzees conducted by our research group has provided convergent evidence that they do not. For example, in one procedure we probed whether, when faced with two familiar human experimenters, our chimpanzees would selectively deploy their visually-based, species-typical begging gesture to the person who could see them. Assessments were made at 5–6, 7, and 8–9 years of age [for results, see Povinelli and Eddy, 1996a; Povinelli, 1996; Reaux et al., 1999]. The results of nearly 20 experiments showed that although the chimpanzees actively used their communicative gestures, they did not seem to appreciate that only one person could see them. This is not to say that the chimpanzees failed to learn the contingencies involved. On the contrary, in virtually every case, after enough experience and feedback, the animals succeeded in learning to gesture to the correct person. However, follow-up tests consistently indicated that these rules were about the postures, not the mental states, of the people involved. Other research with these same animals, using different methodologies, has converged on a similar interpretation [e.g., review by Povinelli, 2000].

It is important to note, however, that these same chimpanzees have been shown to be extraordinarily sensitive to surface manifestations of the visual attention of others as exhibited by, for example, their spontaneous ability to follow the gaze of others, as well as modification of their gestures and searching patterns depending on the direction of a familiar human's gaze direction [see Povinelli and Eddy, 1996b,c, 1997; Povinelli et al., 1999, in review]. Aspects of this sensitivity to the gaze-direction of others has been demonstrated in a range of non-human primate species [e.g., Itakura, 1996; Emery et al., 1997; Tomasello et al., 1998; Ferrari et al., 2000]. Because of the sheer extent of overlap in the details of the functioning of these gaze-following behaviors in humans and chimpanzees, we have suggested the neuropsychological system controlling these behaviors is a shared primitive feature of the chimpanzee-human clade (and, most likely, an even larger clade). In contrast, however, we have suggested that only humans interpret these behaviors as being connected to a set of unobservable mental states related to the experience of visual perception – in short, that at least this aspect of theory of mind is a uniquely derived feature of the human lineage [e.g., Povinelli, 2000].

Other researchers question this conclusion, and have highlighted results which suggest that sensitivity to the surface behavior of the visual attentional system of others may indicate the presence of an ability to reason about 'seeing' [e.g., Call and Tomasello, in press]. Perhaps the most direct evidence contrary to the hypothesis described

above, comes from a recent study by Hare et al. [2000] who placed subordinate chimpanzees in one-on-one competitive situations with dominant rivals over two food items, where one food item was visible to both participants, but the other was visible only to the subordinate (e.g., food placed behind an opaque barrier). Subordinates were released slightly before the dominants, and were more likely to select and obtain the hidden food items than the visible ones. On the basis of these tests and certain control conditions, Hare et al. concluded that chimpanzees explicitly know what others can and cannot see.

In a series of experiments that we recently conducted to replicate and extend the Hare et al. findings, however, we regularly found patterns of results that were inconsistent with the idea that subordinates were reasoning about what the dominant could or could not see [Karin-D'Arcy and Povinelli, in review]. Although the subordinate animals obtained more hidden than visible food items by the end of a trial, they did not initially approach the hidden item before the visible one. The food item selected first is the crucial issue, because the subordinates may obtain more hidden items by the end of the trial simply because the dominant will typically take the visible one, leaving only the hidden one for the subordinate. Further studies revealed that even the particular subordinates who demonstrated a marginal tendency to approach the hidden food first did not differentiate between occluders that did and did not obscure the dominant's view [see Karin-D'Arcy and Povinelli, in review, Exps. 6–7].

In this article, we report a series of previously unpublished studies that were conducted with our group of seven chimpanzees when they were adolescents and adults. These studies explored whether they construe others as possessing unobservable mental states related to visual perception, or whether their knowledge of 'attention' and 'seeing' is definable exclusively in terms of their knowledge of the observable regularities in the overt behavior of others and the contingencies that follow from them. These studies complement previously published research by focusing on several aspects of the natural behaviors of chimpanzees (e.g., gaze-following) and utilizing these behaviors to further probe their understanding of the attentional states of others. The new data provide additional evidence that although chimpanzees monitor and respond to the observable postures and motions of the body, head, face, and eyes of others, they may do so without construing these behaviors in terms of unobservable mental states. Thus, these data may offer additional lines of evidence for suspecting that theory of mind may be an evolutionary specialization of the human species.

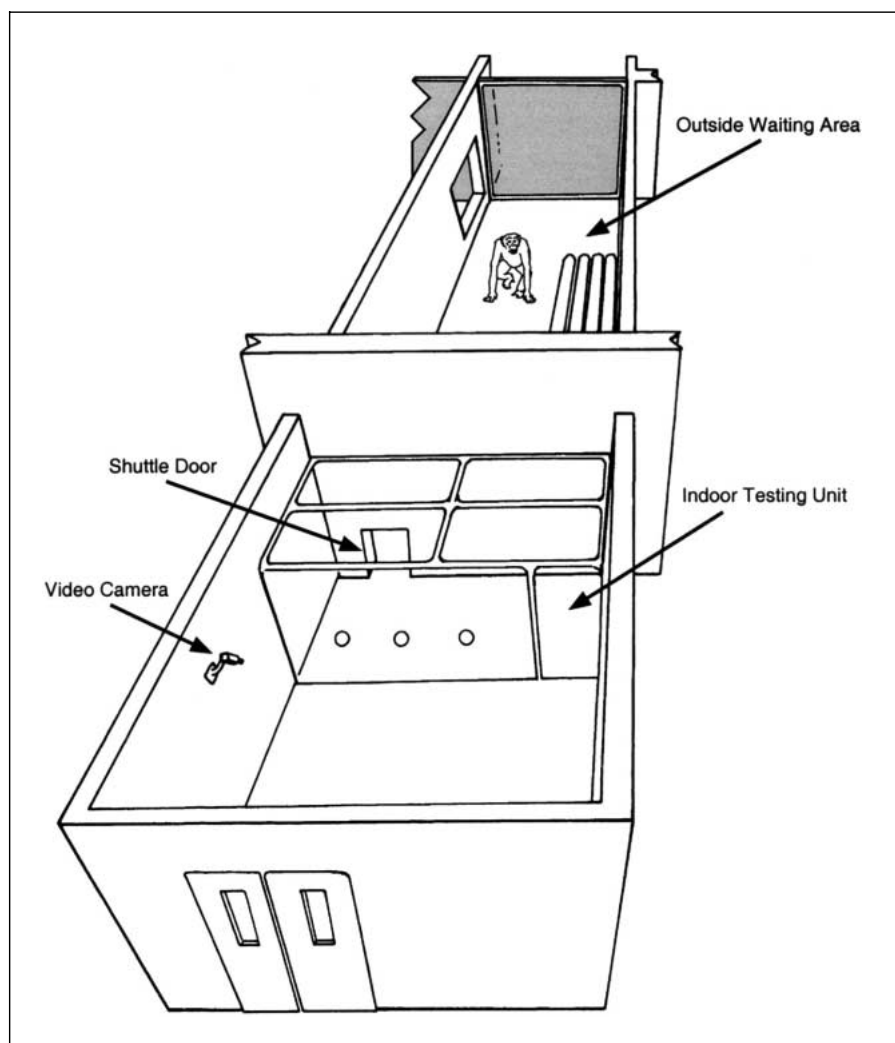


Fig. 1. The outdoor waiting area and indoor testing unit used during testing.

Experiment 1: Understanding 'Attention' as a Modality-General Psychological State (Age 7)

In considering whether chimpanzees understand visual attention, we have previously investigated chimpanzees' appreciation of the modality-general aspects of attention; that is, their ability to understand the partial mental equivalence between attending to something visually (looking at it) and attending to it tactilely (touching it) [see Theall and Povinelli, 1999]. Gomez [1996] described an experiment in which juvenile chimpanzees used their natural attention-getting behaviors (e.g., tapping at a person or vocalizing) differently depending on whether an experimenter was visually attending to them or not. However, research by Theall and Povinelli [1999] that controlled for a serious methodological limitation of

the Gomez [1996] study, showed empirically that this effect was not reliable. Importantly, although children as young as 3 years of age have exhibited an understanding of tactile-based attention-getting behaviors [Flavell et al., 1989], we are not aware of any research examining young children's understanding of the equivalence between tactile and attentional experiences in others.

In the present study, we attempted to further probe this issue by using less scripted behaviors to determine if chimpanzees understand the visual and tactile sensory channels as alternative (and in some ways functionally equivalent) routes to gaining another individual's attention.

Materials and Methods

Subjects. Seven young adolescent chimpanzees (*Pan troglodytes*) (6 females, 1 male) participated as the subjects. At the beginning of

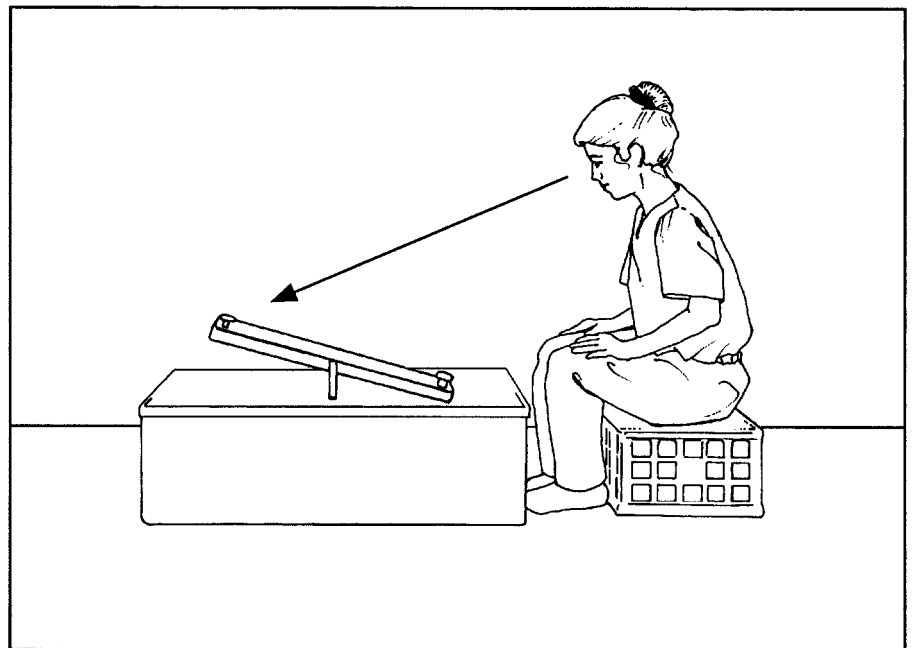


Fig. 2. Apparatus used in Exp. 1. The configuration for the standard trials is depicted, with the raised side of the lever toward the subject.

this study, the subjects' ages ranged from 6 years, 3 months (6;3) to 7;1. All subjects were born at the University of Louisiana, were peer raised in a nursery, and had been housed together in a large indoor-outdoor enclosure since infancy. Detailed descriptions of the subjects' rearing histories and living environment are provided in Povinelli [2000, Chapter 2]. All subjects had previously been trained and tested on a variety of different experimental protocols as part of an ongoing project designed to examine various aspects of how chimpanzees represent and reason about the social and physical world.

General Setting and Apparatus. The subjects were tested by separating individuals from the rest of the group into an outdoor waiting area (fig. 1). The subjects were all thoroughly familiar with this general setting and the procedure of being tested individually. This waiting area was connected by an opaque shuttle door to an indoor testing unit, inside of which the subjects were separated from the experimenters by a Plexiglas panel. The panel contained three large holes arranged horizontally, through which the animals could easily gesture or reach and manipulate various objects.

Two identical, simple apparatuses were constructed for use in the experiment. Each consisted of a box (95 × 46 × 30 cm) with a lever mechanism (60 × 10 × 2 cm) bolted to the center of its surface so that the lever could be operated like a see-saw (see fig. 2). The lever operated silently.

Procedure: Orientation Phase 1. This phase consisted of 6 informal sessions per subject, each containing 8 trials. Each trial proceeded as follows. First, with the subject in the outside waiting area, the apparatus was placed in front of either the left or right hole on the experimenter's side of the Plexiglas (position was alternated across the 6 sessions), and a familiar human partner sat directly behind it on a crate. The lever arm was within easy reach of the subjects through the hole in the partition. Once the human partner was seated, the trainer opened the shuttle door using a remote pulley system in the back of the test room, thus allowing the subject to enter. When the subject pushed down the lever correctly, the human partner reached

behind herself to produce a previously unseen food reward (a cookie or a piece of fruit) and handed it to the subject. Every effort was made in these orientation sessions to have it appear to the subject that his or her partner was watching them, waiting for them to push down the lever, and then rewarding and verbally praising them for doing so. All subjects were performing excellently at the end of 6 sessions.

Orientation Phase 2. During phase 2, the subjects entered the test unit and encountered both of the apparatuses: one positioned in front of the far right hole, and one in front of the far left hole (the lever of one box was approximately 50 cm from the lever of the other). A partner was seated behind one of the two apparatuses and was leaning forward and looking at the lever of the apparatus behind which they sat. Every effort was made to have it appear as if the human partner was visually attending to the chimpanzee's actions. If the chimpanzee completely pushed down the correct lever (i.e., the one in front of the partner) so that it touched the surface of the apparatus, the partner looked up at the chimpanzee, offered verbal praise, and immediately handed him or her a food reward. If the chimpanzee touched the incorrect lever before the correct one, the trainer ushered him or her from the test unit before a second choice could be made. The subjects received 10 trials per session and were trained to a criterion of a minimum 19 correct responses in 2 consecutive sessions before advancing to testing. Six of the subjects met this criterion within 2 sessions; the other subject required 3 sessions. Two different human partners (both very familiar to the subjects) participated in this phase, and the correct side and identity of the partner were randomized within the constraint that each side and each partner participated equally often.

In total, the subjects received between 68 and 78 trials (phases 1 and 2 combined) in which they interacted with the apparatus and learned that when they pushed down the correct lever so that it made contact with the surface of the apparatus, the person watching them handed them a reward.

Table 1. Description of experimental conditions, experiment 1

Condition	Description
Hand On Lever (HO)	<p>Correct Option: E sits on crate behind apparatus with eyes closed and one hand on the lever of the see-saw.</p> <p>Incorrect Option: E sits on crate behind apparatus with eyes closed and hand on far right/left side of table surface. It is impossible for the lever to make contact with the hand.</p>
Hands Under Lever (HU) ^a	<p>Correct Option: E sits on crate behind apparatus with eyes closed and hands on the surface of the apparatus, turned upward in a relaxed position directly under the lever.</p> <p>Incorrect Option: E sits on crate with eyes closed and hands spread apart on the surface of the apparatus, turned upward and in a relaxed position on either side of the lever. It is impossible for the lever to contact the hands.</p>
Hands Above Lever (HA)	<p>Correct Option: E sits on crate behind apparatus with eyes closed and hands suspended in the air within the direct path of the lever if the subject pushes their side down.</p> <p>Incorrect Option: E sits on crate behind apparatus with eyes closed and hands suspended in the air but out to the side, making contact between the lever and the hands impossible.</p>

^a In the HU treatment, the position of the lever is reversed, such that the lowered side of the lever faces the subject. In this condition, the subject must raise the see-saw rather than push it down.

Testing. Testing confronted the apes with occasional trials in which they encountered two human partners, each behind an apparatus identical to the one used in the orientation phases, and neither of whom was looking at the chimpanzee (their faces and heads were pointing to the floor and their eyes were closed). On each test trial (described in detail below), one of the levers when pushed could make physical contact with one of the partner's hand(s), whereas in the other case it clearly could not. Thus, with the channel of visual attention closed, we asked whether our chimpanzees understood that they could still get the attention of one of their partners through the tactile channel.

Each subject received 6 test sessions, each consisting of 6 trials. In each session, trials 1–2 and 4–5 served as standard trials and were identical to those in the orienting phase 2 (the location of the single partner that was present on these trials was determined using the counterbalancing procedures described for orientation phase 2). A probe trial technique, in which test trials were inserted in a background of standard trials, was used to deliver the experimental conditions. Probe trials were administered on trials 3 and 6 of each session. Three types of probe trials (see below) were used, and each animal received each type 4 times (2 probe trials per session × 6 sessions = 3 conditions × 4 trials/condition = 12 total probe trials). The order in which subjects received their 12 probe trials was fully randomized.

The side and identity of the experimenters were counterbalanced within each of the 3 conditions.

The 3 test conditions are described in detail in table 1. These conditions were: Hand On Lever (HO), Hands Under Lever (HU), and Hands Above Lever (HA). In each condition, one (and only one) of the levers could be manipulated to make contact with the hand(s) of one of the potential partners. The overall configurations of the bodies of the two partners were carefully matched, with the crucial difference being the position of their hands relative to the lever. If the subject moved the correct lever, the trainer gave a verbal signal, and both partners looked up, with the correct partner handing the subject a food reward. If the chimpanzee pushed the incorrect lever, they were ushered from the test unit by the trainer to await the next trial. All trials in this (and all following experiments) were recorded on videotape and archived.

Predictions. The attention-as-a-psychological-state model posited that the chimpanzees' initial construal of the situation included an appreciation of the attentional aspect of their partner, and that they understood attention as a modality-general construct. Thus, this model predicted that they ought to (a) recognize that no one was visually attending to their actions on the probe trials, and (b) be biased toward pushing (or lifting, in the HU condition) the lever in front of the partner whose hand(s) could be contacted. On the other hand, the postural configuration model posited that chimpanzees' understanding of attention consists primarily of learned associations between various postures and orientations and various subsequent behaviors. Thus, this model predicted that they would not understand the psychological connection between gaining attention visually and doing so tactilely, and hence their initial choices between the potential partners would be random.

Videotape Analysis. Several dependent measures were coded from videotape. Initially, the tapes were coded for which lever the subjects moved first. A main rater observed all trials (standard and probe trials) and a secondary rater independently coded just the probe trials to establish reliability: 97.5% agreement was obtained (Cohen's kappa, $\kappa = 0.95$). Second, two raters separately coded all HU trials for whether the subjects lifted the lever off the surface of the apparatus. Recall that in the HU condition, the levers were positions in the opposite configuration than what the subjects had previously experienced. The raters agreed on 100% of the trials. Finally, two raters separately coded all trials for each subject for their latency to respond (defined as the duration of elapsed time from the moment the subjects entered the test unit to the point at which they moved a lever). A Pearson's coefficient of determination (r^2) of 0.76 was obtained ($p < 0.01$) for the scores obtained by the two raters. The data from the main raters were used for all analyses.

Results and Discussion

The main results concerned the subjects' performances on the probe trials, and in particular, whether they selectively chose the lever that could make tactile contact with one of the potential partner's hands. The percent correct in each of the 3 test conditions, plus the standard trials, is shown in figure 3. Two things are apparent from this graph. First, the subjects performed at ceiling levels on the standard trials (where the two apparatuses were present, but a human partner was present behind only one of them). This indicates the subjects' general interest and

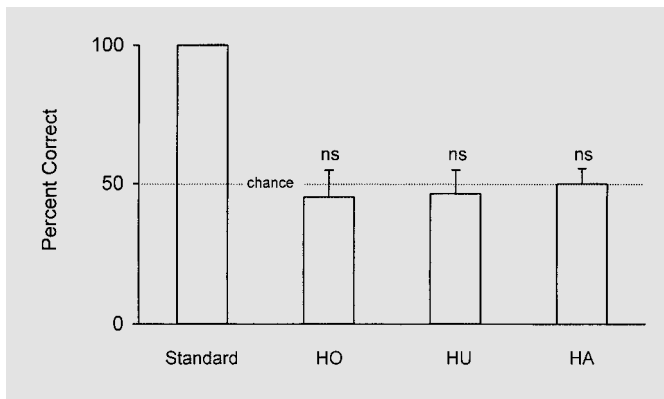


Fig. 3. Mean percent correct (+ SEM) across all subjects ($n = 7$) for standard trials and all probe trial types in Exp. 1. HO = Hand On Lever; HU = Hands Under Lever; HA = Hands Above Lever.

motivation during testing. Second, the subjects' performance in all 3 test conditions did not appear to differ from chance, a conclusion supported by separate one-sample t tests (two-tailed) for the group's performance in each of the 3 test conditions ($t(6) < 0.496$ and $p > 0.69$ in all 3 cases; see fig. 3). Additional analyses confirmed that the subjects' performances (a) did not improve across trials within or across the conditions, and (b) that no individual subjects exhibited a pattern differing substantially from the overall results.

Finally, analysis of the subjects' latency to respond (fig. 4) provided direct evidence that the subjects' chance-level performance was not simply due to their failure to notice the differences between the probe and standard trials. A repeated-measures analysis of variance (ANOVA) comparing the subjects' mean latency to respond on standard, HO, HU, and HA trials, indicated an overall effect ($F(3, 18) = 3.203$, $p < 0.05$). Although none of the post-test contrasts indicated significant differences, a visual inspection of figure 4 suggests that the subjects responded slower on the probe as compared to standard trials.

These results provided no evidence to support the attention-as-a-psychological-state model. It is important to note, however, that when they were confronted with two potential partners, the subjects did not simply react automatically, but frequently hesitated before responding (fig. 4). Indeed, on the HU trials, where the lever arm needed to be manipulated in the opposite direction from what they had previously experienced (lifted up instead of pushed down), the subjects did so on 85.7% of the trials, demonstrating close attention to the individual apparatus

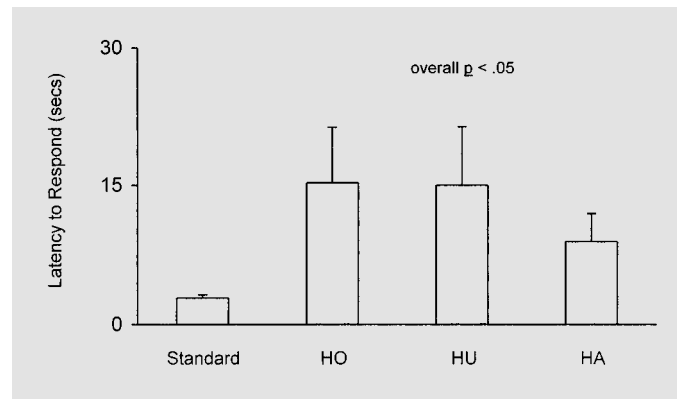


Fig. 4. Mean latency (+ SEM) to first touch of either lever apparatus (in seconds) across all subjects ($n = 7$) for standard trials and all probe trial types in Exp. 1. HO = Hand On Lever; HU = Hands Under Lever; HA = Hands Above Lever.

presented. What they did not do in any of the test conditions was selectively choose the lever that could make contact with one of the potential partners. Thus, although these results are not definitive, they do suggest that previous findings showing chimpanzees to be insensitive to the modality-equivalent aspects of attention [e.g., Theall and Povinelli, 1999] were not solely due to reliance on an overly-scripted, automatized behavior (e.g., their species-typical begging gesture).

Experiment 2: Understanding How Visual Perception Interacts with Opaque Barriers (Age 7½)

When chimpanzees witness someone turn and look at an opaque barrier such as a wall or screen, they selectively look on the side of the barrier that the person can see [Povinelli and Eddy, 1996b]. This finding has now been independently replicated in several laboratories [O'Connell, 1997; Tomasello et al., 1999]. Although this effect is a spontaneous reaction to the experimental condition (i.e., it is not an experimentally trained behavior), it is not clear whether it reflects an explicit understanding of what someone else can or cannot see, or whether it is a fairly automatic response derived from their own gaze-following behavior and their knowledge of the geometry of objects in the world [see Povinelli and Eddy, 1996b]. In this study (see also Exp. 5), we attempted to probe our chimpanzee's understanding of how opaque barriers interact with another's line of sight in the context of an experimenter (their caretaker) attempting to communi-

cate which of several boxes was baited with food by gazing toward it. A large opaque barrier was positioned in several ways, preventing the caretaker from seeing some of the boxes. We compared the actual performance of the chimpanzees (the box they selected) to the patterns predicted by various models of their understanding of the situation (see Predictions).

Materials and Methods

Subjects and Apparatus. The subjects were the same 7 chimpanzees used in the previous experiment. They began this study approximately 9 months after the completion of the previous study, at which point they ranged in age from 7;0 to 7;11.

A large, opaque barrier (66 × 90 cm) was constructed for use during training and testing. In addition, three identical boxes (29 × 18 × 16 cm) with removable lids were used.

Procedure: Orientation. The subjects of this study had previously (in the course of other published research) been tested for their ability to spontaneously select the container (from among an array of two identical containers) at which an experimenter glanced or stared, and had shown evidence of immediately using this cue correctly [see Povinelli et al., 1997, 1999]. Thus, the orientation phase of the current study [which occurred 3½ months after the most recent previous study involving their use of gaze to select a particular container; Povinelli et al., 1997, Exp. 2] was simply designed to (a) re-familiarize the subjects with opening a box in order to take food and (b) introduce them to the opaque barrier which would be used during the later testing phase to impede the experimenter's line of vision.

On each trial, one box was placed within the subject's reach in front of one of the three response holes. It was baited with a food reward and covered with a lid. A familiar experimenter sat 100 cm away from the response hole under which the box was located, leaned forward, and stared intently at the box. The shuttle door was opened from the back of the room by the trainer, allowing the subject to enter and respond. During these trials the opaque barrier was in the room and was randomly positioned at various points behind the experimenter so as to familiarize the subject with the barrier without having it impede the experimenter's line of sight to the box. Sessions consisted of 6 trials. In order to meet the criterion, subjects had to enter the test unit, open the box, and remove the food on 5/6 trials (or more) across 2 consecutive sessions.

Glance Training. The purpose of this phase was to prepare the subjects for testing by familiarizing them with the various elements that they would confront in the test conditions (see below). Thus, we familiarized the subjects with the task of opening boxes located near both sides of the partition in both the presence and absence of an experimenter, as well as re-familiarized the subjects with selectively choosing one of two boxes to which the experimenter was gazing.

After the subjects received 2–3 sessions in which they were allowed to enter the test unit and see the opaque barrier in varying positions at a distance of 100 cm from the Plexiglas partition, the subjects were trained to select the specific box at which the experimenter gazed. Because of the planned testing configuration, the initial training configuration we used was different from what they had previously experienced. Instead of having the caretaker seated equidistant between the two containers/boxes and looking either right or left at one of them [as in, e.g., Povinelli et al., 1997], the caretaker and boxes were arranged in a line parallel to the Plexiglas partition: care-

taker, box 1, box 2. Thus, the caretaker either looked down toward the closest box or slightly farther away toward the other box. Surprisingly, this task proved very difficult for the subjects to learn.

After attempting several variations (the exact details of which are available from the authors) we abandoned this method, slightly revised the planned testing configurations, and used the method described below. On each trial, two boxes were present within the subject's reach in front of the far right and far left response holes (separated by 60 cm) and the experimenter sat midway between the two. As in orientation, the experimenter leaned and looked closely at one of the boxes before the subject entered the test unit and maintained this position for the duration of the trial. The partition was also present behind or to the side of the experimenter but was never placed between the experimenter and the containers. The experimenter's distance from the boxes was increased by 60 cm increments across the trials from a starting distance of 60 cm to a final distance of 230 cm based upon the subject's ability to meet a criterion of 15/16 correct responses across 2 sessions at each distance. All subjects met this criterion within a variable number of sessions (range 9–47), except Mindy, who was dropped from the study because of training difficulties.

Testing. The subjects' understanding of how vision interacts with an opaque barrier was tested using the 4 conditions (A–D) depicted in figure 5. The placement of the boxes and partition in each condition was carefully arranged so that the relationship among caretaker's gaze, the partition, and the boxes was as obvious as possible from the chimpanzee's perspective. Each subject received 4 sessions consisting of 8 trials each. Six of these were standard trials (identical to those used in the glance training phase except that the caretaker was 180 cm away from the Plexiglas partition), and the remaining 2 trials per session were probe trials (during which the caretaker sat behind and to the left of all 3 boxes, at a distance of 180 cm from the Plexiglas wall; see figure 5). Each subject received each type of probe trial twice, for a total of 8 probe trials per subject. Placement of the two probe trials in each session was individually randomized for each subject within the constraint that it occur between trials 2 and 7 and that it be preceded by at least one standard trial.

The subjects entered the testing phase with the expectation that food was available in only one box, and this contingency was continued on all standard trials in the testing phase. However, on probe trials, in order to non-differentially reinforce their choices, food was placed in each of the boxes that were present (although the subjects, of course, did not know this). We chose this approach to avoid training the animals away from any of the particular models under evaluation (see Predictions).

Predictions. Three different models were considered to explain how the chimpanzees might construe the situation confronted in the probe trials. The conceptual understanding model posited that chimpanzees would understand which boxes the experimenter could and could not see. In conditions A and D, therefore, they should choose the container to which the experimenter is specifically attending across conditions (Box 2 in both cases). In both of these conditions (and specifically in condition D, where the focus of the experimenter's gaze was intentionally ambiguous), the chimpanzees should at least selectively restrict their choices to only those boxes that could be the focus of the experimenter's attention, and avoid boxes that could not be (i.e., box 3, behind the partition; see figure 5). In conditions B and C the chimpanzees should choose at chance, as both boxes are equally visible (condition B) or invisible (condition C) to the experimenter. The relevant field of search model posited that the

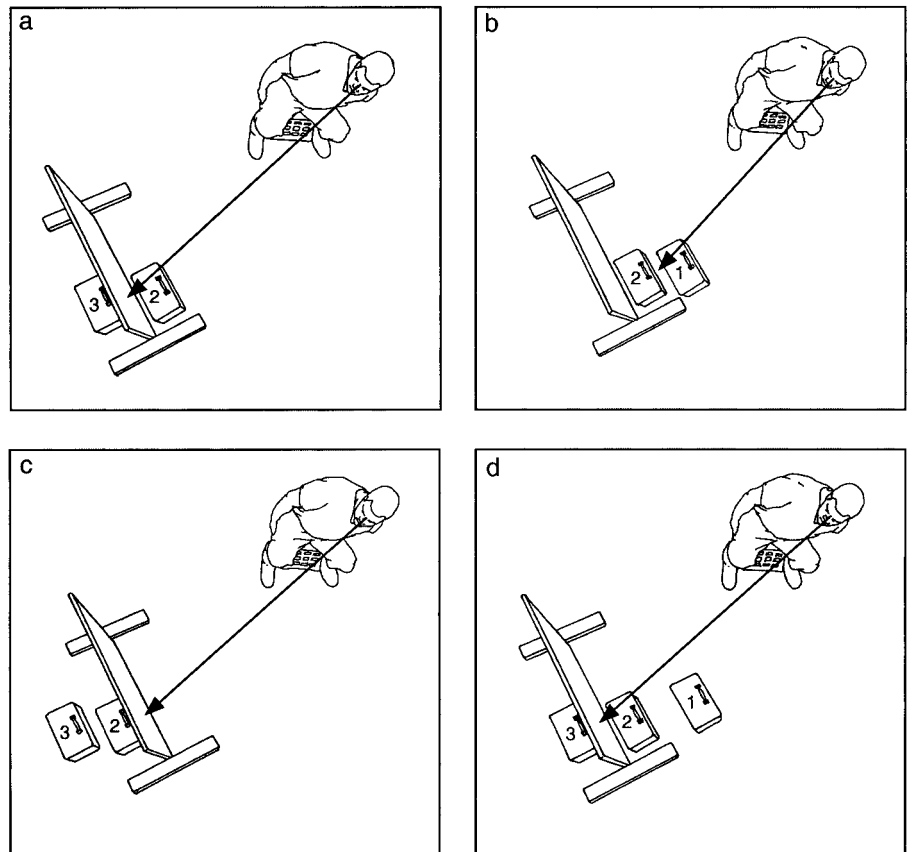


Fig. 5. Test conditions A–D in Exp. 2, showing relative positions of boxes, opaque barrier, caretaker, and caretaker's gaze direction and target.

chimpanzees use the facial/visual orientation of others to target a relevant area in which to search, without appreciating the idea of visual reference per se, predicting random search among the two containers near the partition (in the general area/side of the room toward which the caretaker looked in conditions A, B, and C), and an avoidance of the box outside this area (box 1 in condition D). Finally, a distance rule model posited that the apes would simply choose the box closest to their caretaker, regardless of other factors. This would lead to the choice of box 2 in conditions A and C, and box 1 in conditions B and D.

The predicted distribution of responses to the various boxes in each of the conditions for each model is outlined in table 2. The table also outlines the predictions of several hybrid models, which were generated by pair-wise crossings of the predictions of each of the separate models.

Videotape Analysis. The videotapes were coded for the box in which the chimpanzees searched. One rater coded all 224 trials (both standard and probe trials). A second rater independently coded all 8 probe trials for each subject ($n = 56$ trials) for assessing reliability. Percent agreement was 100% ($\kappa = 1.0$).

Results and Discussion

The subjects averaged 84.0% (range 75.0–100) correct on the standard trials that surrounded the probe trials, a result significantly above chance, ($t(5) = 9.797$, $p < 0.001$).

Given this high level of performance, these results are not discussed further.

The main results are presented at the bottom of table 2. In order to assess which model, or combination of models, best predicted the observed pattern of results, we analyzed the results in several steps. First, we subjected each condition to a separate analysis to determine if the subjects showed a preference for one box location over the other(s) in each of the 4 conditions (one-sample t tests for Conditions A, B, C, and a series of dependent t tests for condition D). The results of this analysis indicated that the subjects exhibited a significant preference for one of the boxes over the others only in Condition C ($t(6) = 3.873$, $p < 0.01$). Next, we compared this observed pattern of results with the patterns predicted by the 3 models under consideration, as well as the hybrid models. As can be seen in table 2 by comparing the obtained empirical results to the patterns predicted by the various models, none of the models, by themselves, correctly predicted the observed pattern in all 4 conditions. However, an examination of the hybrid models implicated the model generated by crossing the predictions of the relevant field of

Table 2. Predicted patterns and empirical results of percent of choices for boxes (1–3) by condition (A–D) for experiment 2

Models and Results	Conditions								
	A		B		C		D		
	box 2	box 3	box 1	box 2	box 2	box 3	box 1	box 2	box 3
Straight Models									
Conceptual Understanding (CU)	100	0	50	50	50	50	0	100	0
Relevant Field (RF)	50	50	50	50	50	50	0	50	50
Distance Cue (DC)	100	0	100	0	100	0	100	0	0
Hybrid Models									
CU × RF	75	25	50	50	50	50	0	75	25
CU × DC	100	0	75	25	75	25	50	50	0
RF × DC	75	25	75	25	75	25	50	25	25
Empirical Results									
M	64.3	35.7	42.9	57.1	85.7*	14.3	42.9	35.7	21.4
SEM	4.3	14.3	13.0	13.0	9.2	9.2	13.0	14.3	14.9

* $p < 0.01$.

search (RF) model with those of the distance cue (DC) model (the RF × DC model). The predictions of this hybrid model closely matched the observed results for 3 of the 4 conditions, although this comparison cannot be sustained statistically. In Condition A, arguably the most straightforward test of the conceptual understanding model, the subjects were statistically just as likely to choose the box that their caretaker could not see (the one behind the barrier) as the one he could see (the one in front of the barrier).

Finally, it should be noted that because several of the straight (and hybrid) models predicted random patterns in some of the conditions, it is perhaps most striking that in the one condition in which the subjects responded in a statistically reliable pattern (Condition C), the results were consistent with the distance cue model and two of the hybrid models (RF × DC and CU × RF), but not the straight conceptual understanding model. On the surface, then, the results of this experiment do not support the idea that chimpanzees understand how someone's subjective experience of seeing is affected by an opaque barrier obstructing their line of sight. We discuss these results more fully in the context of Exp. 5, a related study that we conducted with these same animals when they were 5 years older.

Experiment 3: Postural Cues of Attention: Distinguishing Cues Which Do and Do Not Indicate Attention (Age 7½)

A growing number of experimental studies have explored the ability of chimpanzees, other non-human primates, and even canines and cetaceans, to correctly select a container at which an experimenter is looking from an array of two or more such containers [e.g., Povinelli et al., 1992, 1997, 1999; Call and Tomasello, 1994; Anderson et al., 1995, 1996; Call et al., 1998; Miklosi et al., 1998; Hare and Tomasello, 1999; Tschudin et al., 2001]. Although chimpanzees, along with a number of other species tested thus far, can do so, the significance of such findings is unclear. Do they do so because they have learned how to exploit the postures or eye movements of others, or do they also understand that the experimenter is looking at a particular container, can 'see' it, and is communicating the correct location through the direction of his or her gaze? In addition to distinguishing between these accounts, one would want to know whether the effect of choosing the correct container is simply due to the general direction of eye or head movement (e.g., left or right), or to the specific target of visual gaze [see Povinelli et al., 1999]. We explored this question in the following experiment.

Materials and Methods

Subjects and Apparatus. The subjects were the same 7 chimpanzees. They began the study approximately one month after the com-

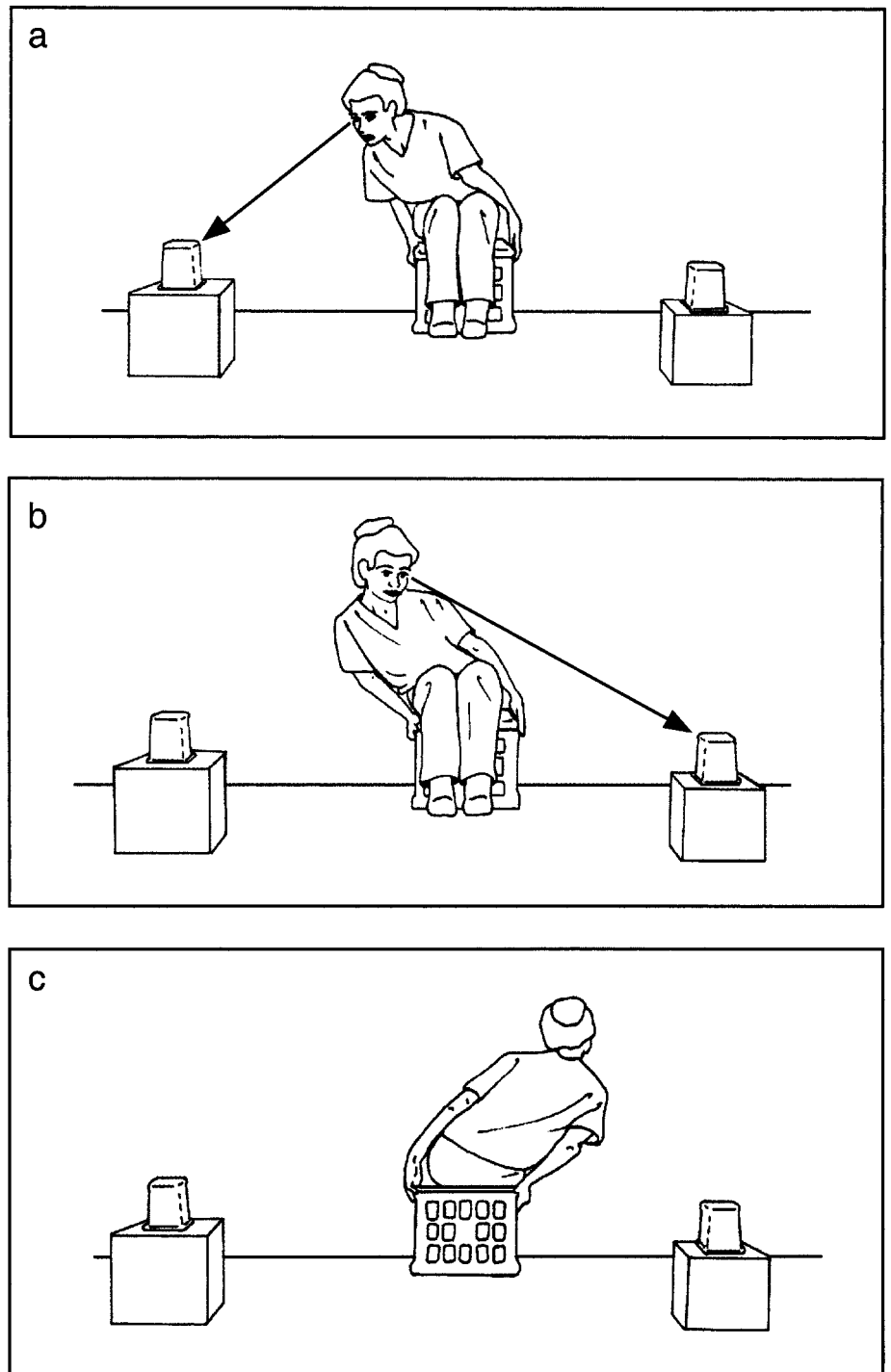


Fig. 6. a Glance training, b Lean vs. Gaze condition, and c Facing Away condition in Exp. 3.

pletion of the previous study (age range 7;2 to 8;1). Two small platforms were used, each of which supported an upside-down cup that the animals could flip over in order to search for food underneath.

Procedure: Orientation. The subjects received a minimum of 2 sessions, each containing 6 trials. During these trials, the experimenter was seated at a distance of 120 cm from the Plexiglas partition and

equidistant from the far right and far left holes. The platforms were located 30 cm directly in front of the far right and far left holes. One of the cups was baited with a food reward according to a randomized and counterbalanced schedule. A familiar experimenter leaned toward and looked closely at the baited container (fig. 6a). Each subject was required to meet a criterion of 16/18 correct responses across

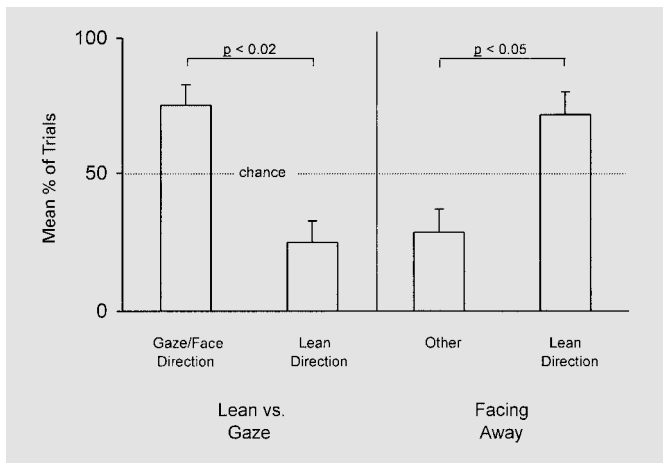


Fig. 7. Mean percent (+ SEM) of trials in which each postural cue was used in box selection, by condition and across all subjects ($n = 7$) in Exp. 3. Trials in which a subject did not respond at all are excluded.

3 sessions in order to advance to testing. This established the subjects' understanding that food was present in only one of the containers. The subjects met this criterion in a variable number of sessions (range 3–7).

Testing. The subjects were tested on two conditions, both of which are depicted in figure 6. In the Lean vs. Gaze condition a familiar experimenter and boxes were situated as in training, except that while the experimenter leaned his body toward one container, his head and eyes were turned toward the other. In the Facing Away condition, the containers and experimenter were again positioned as in orientation, except that the experimenter had his or her back to the subjects.

Each subject received 8 test sessions, each composed of 6 trials. Five of these trials were standard trials, identical to those used during orientation. The remaining trial was a probe trial from one of the two conditions described above. This probe trial was randomly assigned to occur between trials 2–5. The side of the correct container on the standard and probe trials was randomized within the constraint that within each condition the experimenter leaned toward (or looked at) each container equally often. Following the logic described in Exp. 2, both containers were baited during probe trials.

Predictions. Two alternative models were tested. The visual reference model posited that in the Lean vs. Gaze condition, the chimpanzees would use the experimenter's gaze direction (rather than the body direction) to aid them in choosing a container. In contrast, because the experimenter's posture offered no referential aid in the Facing Away condition, the subjects were predicted to choose containers at random with respect to the experimenter's posture [for validation of a similar prediction in a closely related study with 3-year-old children, see Povinelli et al., 1999, Exp. 3]. In contrast, the physical cue model generated no strong predictions in the Lean vs. Gaze condition. The apes might either choose the box associated with a greater number of cues (in which case they would select the box to which both the eyes and face were oriented), or they might weigh the leaning direction cue equally with the face/eye direction cue. However, in contrast to the visual reference model, the physical cue model

predicted that the apes would use the leaning cue in the Facing Away condition (because no other cue is available).

Videotape Coding. For each trial, we coded which container had been flipped by the subject. A main rater coded all 336 trials (both standard and probe trials). A second rater independently coded all 56 probe trials (8 per subject) in order to assess reliability. Percent agreement was 100% ($\kappa = 1.0$).

Results and Discussion

The main results of the experiment are presented in figure 7, which depicts the mean percentage of responses to the two containers in both conditions. The results match the predictions of the physical cue model. In the Lean vs. Gaze condition, the subjects reliably used the face direction cue, selecting the container to which the experimenter's eyes and head were oriented on 75.0% (SD = 20.4) of the trials (one-sample t test, two-tailed, chance 50%; $t(6) = 3.240$, $p < 0.02$). In the Facing Away condition, the subjects also reliably selected one of the two containers – the one to which the experimenter was leaning – on 71% (SD = 22.5) of the trials (one-sample t test, two-tailed, chance 50%; $t(6) = 2.521$, $p < 0.05$).

A number of authors have interpreted the ability of a given species to use the gaze direction of an experimenter to correctly select a baited container as evidence of that species' understanding of the significance of gaze (see above). However, as shown experimentally by Povinelli et al. [1999], chimpanzees may easily exploit various cues related to gaze direction (e.g., direction of the face or eyes) without necessarily interpreting face or eye direction as indicative of an unobservable mental state of attention. They showed that chimpanzees would use the direction of the head and eyes of an experimenter to choose a correct container from trial 1 forward; however, they simultaneously showed that chimpanzees exhibited an equal bias in using the face and eye direction to choose a container when these cues indicated the same side of the room, but were directed at the ceiling. In direct contrast, 3-year-old human children used gaze-direction cues only when they were directed at the containers. In short, in situations such as the one used here, young children discounted postural cues when they were not plausibly 'about' one of the containers.

The current results build upon these previous findings in two ways. First, results of the Lean vs. Gaze condition emphasize the subtlety of the chimpanzees' exploitation of postural cues: when the direction in which their communicative partner was leaning was placed in opposition to the direction in which his or her eyes and face were oriented, the chimpanzees reliably used the information contained in the direction of the face and eyes. Second, the results of the Facing Away condition emphasize that

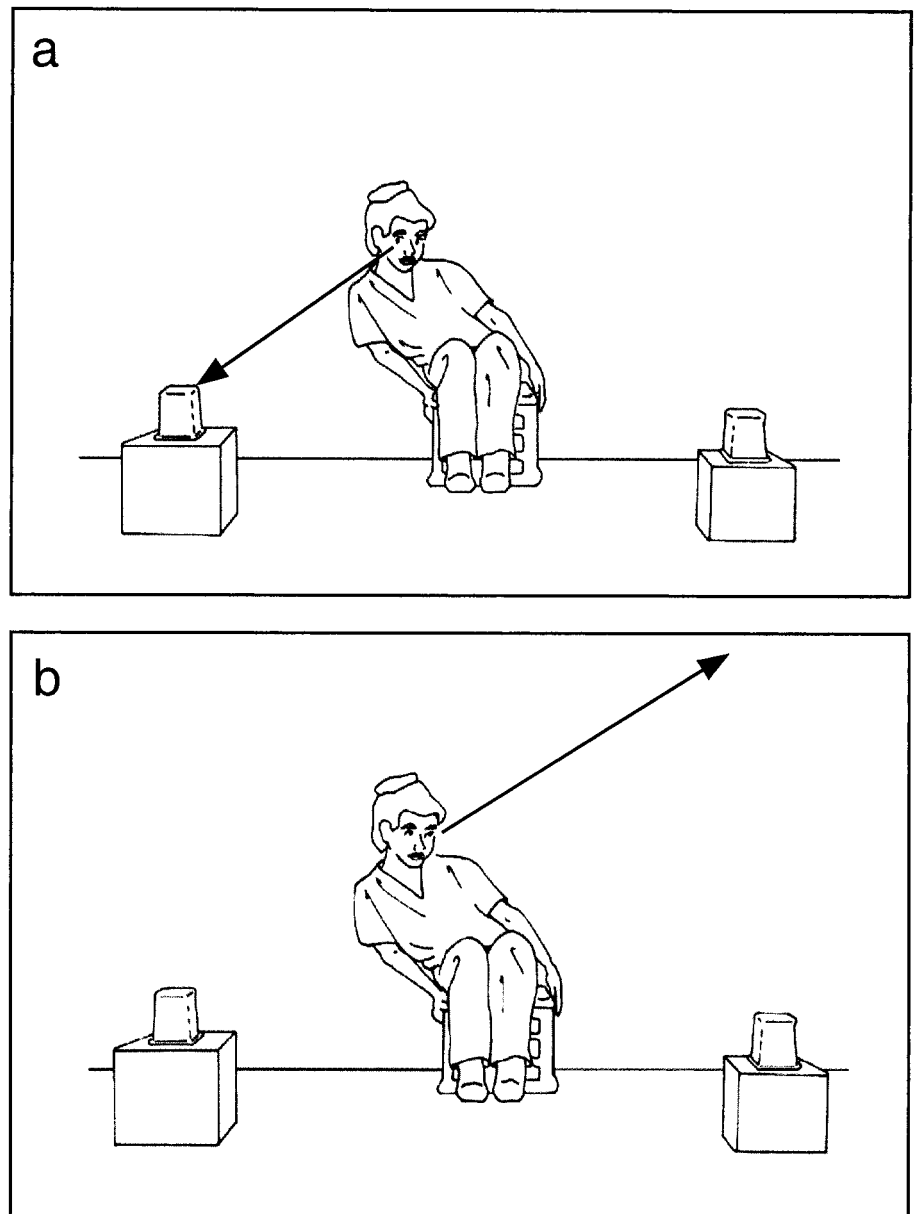


Fig. 8. a Eyes-On-Target and b Eyes-Off-Target test conditions in Exp. 4.

such cue exploitation need not have anything to do with an explicit understanding of seeing or visual attention.

Experiment 4: Postural Cues of Attention: The Role of Eye Direction (Age 8)

The results of Exp. 3 indicated that chimpanzees will use the orientation of the eyes and face (direction of 'gaze') when they are combined (as is the prototypical case

in the real world). But they are not always so linked, and the group of chimpanzees under study here has been shown to actively use eye direction alone in spontaneously following the gaze of others when the direction of the face and body were neutral relative to eye direction [Povinelli and Eddy, 1996b, Exp. 1]. In the context of the setting used in Exp. 3, the next study explored whether, when the direction of the face and body were placed in opposition to the direction of the eyes, the chimpanzees would give primacy to the direction of the eyes in choosing a contain-

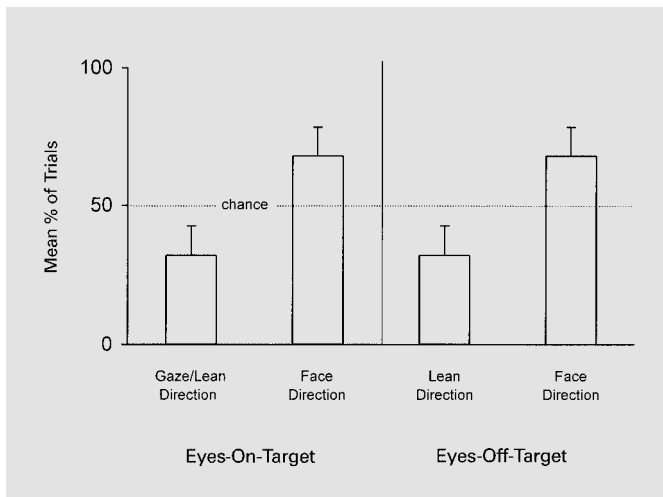


Fig. 9. Mean percent (+ SEM) of trials in which each postural cue was used in box selection, by condition and across all subjects ($n = 7$) in Exp. 4. Trials in which a subject did not respond at all are excluded.

er [for human developmental data on this point, see Cor-kum and Moore, 1995].

Materials and Methods

Subjects and Apparatus. The same 7 chimpanzees participated. They began this study one day after the completion of the previous study (age range 7;4 to 8;3). The platforms with flip-containers (Exp. 3) were used again in this study.

Procedure: Orientation. The subjects received a minimum of one orientation session in which the experimenter was seated at a distance of 120 cm from the Plexiglas wall and an equal distance between the two boxes (both 30 cm from the wall). One of these boxes was baited with a food reward according to a randomized and counterbalanced schedule. The experimenter again leaned toward and looked closely at the baited box. Subjects were required to meet a criterion of 5/6 correct responses in order to move to testing. All subjects met this criterion within 1 session and therefore these results are not discussed further.

Testing. Two testing conditions (fig. 8) were administered to the subjects using the embedded probe trial technique described in the previous studies. In the Eyes On Target condition, the experimenter leaned his or her body toward one of the containers in a manner identical to the orientation session, turned his or her head towards the other container, but oriented his or her eyes back toward the container to which his or her body leaned. In the Eyes Off Target condition, the containers and experimenter were positioned the same as in Eyes On Target condition, except that the experimenter's eyes were directed not back at the container to which he or she leaned, but to a fixed location on the ceiling of the test cage above the box to which the head was oriented.

Testing consisted of 8 sessions of 6 trials each. Five trials per session were standard trials, and were identical to those used during training. One trial per session was a probe trial and was randomly

assigned to occur between trials 2–5. The subjects received four probe trials of each of the two conditions. As in Exps. 2 and 3, both boxes were baited on the probe trials to minimize learning. Counterbalancing procedures followed the procedures outlined in Exp. 3.

Predictions. The visual reference model (see Exp. 3) predicted that the chimpanzees would use the direction of the experimenter's eye gaze to aid them in choosing the container to which the eyes were directed in the Eyes On Target condition; in contrast, they should choose randomly in the Eyes Off Target condition. The physical cue model predicted that the subjects would choose the container consistent with the direction of the lean and eye direction in the Eyes On Target condition (because there were more cues highlighting that container). In contrast, it predicted systematic selection of the container to which the experimenter's face was oriented in the Eyes Off Target condition because (a) face direction is apparently more salient than body direction (see results of Exp. 3) and (b) eye direction (although not specifically on the target) was on the same general side of the room.

Videotape Coding. The videotapes were coded for the box in which the chimpanzees searched. One rater coded all 336 trials (both standard and probe trials). A second rater independently coded all 56 probe trials in order to assess reliability. Percent agreement was 100%. Data from the main rater was used in the analyses.

Results and Discussion

The results are depicted in figure 9. They show that although the subjects did not reliably select one container over the other in the Eyes On Target or the Eyes Off Target condition (one-sample t tests, two tailed, chance 50%; $t(6) = 1.698$, $p > 0.14$, n.s., for both conditions), the overall pattern in the data, although not definitive, matches the predictions of the physical cue model, and not the visual reference model. In both conditions, the subjects tended to rely on the face direction, regardless of the orientation of the eyes. Thus, in the Eyes On Target condition, the subjects tended to ignore the eye direction cue, and instead tended to base their choices on the cue of face direction. Likewise, in the Eyes Off Target condition, rather than selecting randomly (as predicted by the visual reference model), the subjects exhibited the same degree of preference for the face direction cue. This highlights the possibility that subjects tended to interpret the postures and orientations of various aspects of the experimenter as multiple physical cues, not overt manifestations of some unobservable aspect of the experimenter's visual reference to a particular container.

Finally, it is of great importance to note that the subjects were not oblivious to the orientation of the eyes of the experimenters, as a comparison with the results of Exp. 3 clearly show. In the Eyes On Target condition of this experiment (fig. 8a), when the eyes were oriented toward the container to which the experimenter leaned, 4/5 subjects who exhibited a pattern used the physical cue of face direction, instead of the direction of the eyes. In

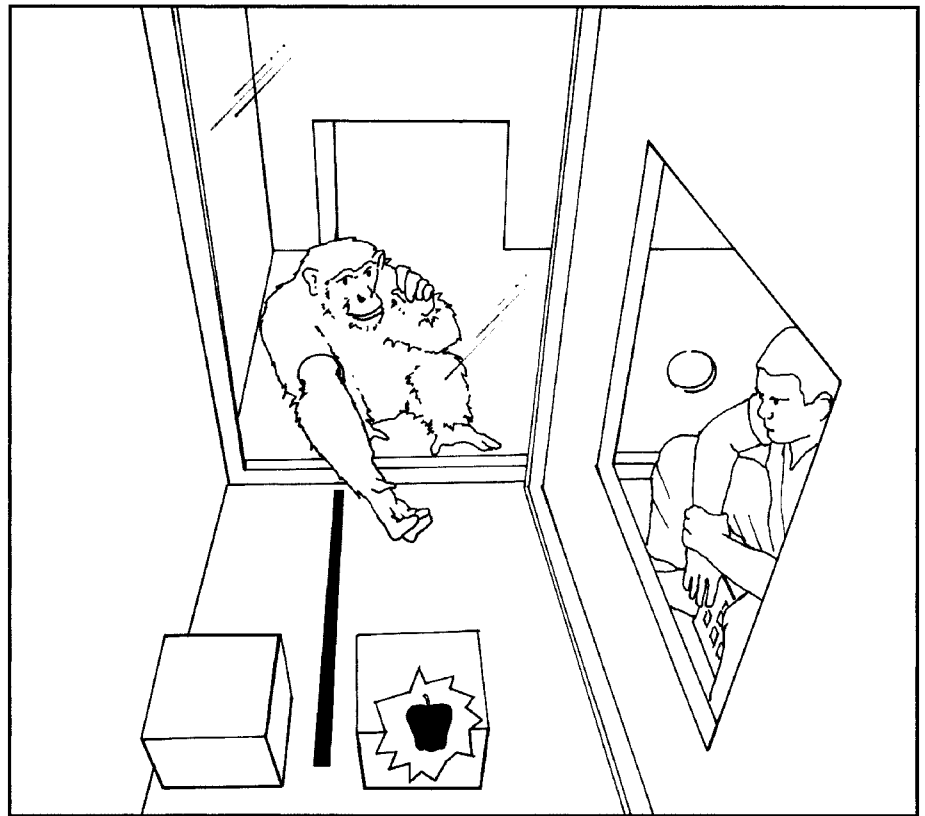


Fig. 10. Open window test condition in Exp. 5. See text for details.

contrast, in Exp. 3, when the face and eye direction cues were combined (in the Lean vs. Gaze condition of Exp. 3; see fig. 6b), these same 4 subjects exhibited the exact opposite pattern. These two conditions differ only in the orientation of the experimenter's eyes (cf. fig. 6b and 8a), thus emphasizing in a rather dramatic way their sensitivity to these cues – even if their interpretation of them differs markedly from our own.

Experiment 5: Understanding Opaque Barriers Re-Visited (Age 12)

Given that the strongest evidence for an understanding of the mentalistic significance of gaze has come from studies of how chimpanzees react to the gaze of others when their gaze 'strikes' opaque obstructions [see Povinelli and Eddy, 1996b; Tomasello et al., 1998], we decided to return to this question when our animals were full adults. We choose a procedure conceptually midway between their demonstrated ability to follow gaze up to (and not through) opaque barriers, and their inability to use an

experimenter's gaze to guide their searches in containers placed around opaque barriers (see Exp. 2). In the present study, we looked at the deployment of their own solicitation or begging gestures in situations in which they could gesture to a desired location when their caretaker could or could not see them through a wall with a window that could be opened or closed. Here, we asked whether the chimpanzees appreciated that their caretaker could see (and hence respond to) their gestures when the window was open but not when it was closed.

Materials and Methods

Subjects and Apparatus. The subjects were the same 7 chimpanzees. They began the study 4 years after the completion of the previous study (age range 11;4 to 12;3). They had participated in numerous other, unrelated studies in the interim [see Povinelli, 2000].

A very large opaque barrier (1.8 × 1.8 m) was constructed from plywood. A large window (92 × 92 cm) was cut out of the barrier at a height of 46 cm above the ground and a removable, opaque screen was also constructed from plywood that enabled the opening to be open or closed, as needed. Two boxes (27 × 27 × 27 cm) with one open side were also used.

Procedure: Orientation. The orientation phase was designed to familiarize the subjects with the opaque barrier and general setting in

which the testing would occur. The barrier was placed at a 90° angle from the Plexiglas partition and abutted against it. The position of the barrier left two holes through which the subjects could reach, one on the right side of the partition, the other on the left. Each subject received 4 orientation sessions during which the trainer encouraged, praised, and occasionally rewarded the chimpanzees for exploring and interacting with the barrier. Each session lasted approximately 5 min.

Testing. For testing, two boxes and the subjects' primary caretaker were positioned as shown in figure 10. The boxes were placed 100 cm in front of the left hole (out of the subjects' reach) and 20 cm apart. Their open sides faced the Plexiglas partition so that their interiors were visible to the subjects. Each subject received 8 trials, but no more than 1 per day. Four of these trials took place with the barrier window open, and 4 trials took place with the barrier window closed (hereafter referred to as the Open and Closed conditions). The subjects' primary caretaker sat on the right side of the barrier, and stared at a point in the center of the window. Thus, when the window was open he was looking directly toward a spot mid-way between the two boxes, but when the window was closed he was staring at the opaque screen that covered the window. The position of the barrier, the boxes, and the caretaker were extensively choreographed ahead of time, with special attention placed upon how the situation appeared from the perspective of the subjects as they entered the test unit and approached the situation. Two other familiar experimenters also participated in each trial, as described below.

Each test trial proceeded as follows. With the barrier (either open or closed depending on the trial type), boxes, and the subjects' caretaker in place, an experimenter at the back of the room remotely raised (~20 cm) the shuttle door to the outdoor waiting area, allowing the subject to look under the door and into the testing unit. From this vantage point, they had excellent visual access to the boxes and the caretaker. As the subject watched, a second experimenter placed a food reward in one of the 2 boxes and then left the test room. The experimenter at the back of the room then opened the shuttle door completely, and, once the subject entered, lowered it behind them. As soon as the shuttle door was closed, the caretaker surreptitiously started a 15-second timer. At the end of 15 s, the caretaker stood up and walked around the barrier to the boxes. During Open trials, the caretaker proceeded directly to the baited box, looked inside, and handed the food reward to the subject. During Closed trials, the caretaker proceeded to a randomly assigned box – on half of these trials the box chosen was the one containing the food reward, and on half it was the empty box. On Closed trials in which the caretaker chose the baited box, he simply handed the food to the subject; on Closed trials when the caretaker first selected the unbaited box, he first looked inside, and finding nothing, he replaced that box, selected the baited box, and handed the food he found inside to the subject. The subject's behavior was videotaped from two perspectives which allowed raters to code the duration and frequency of gestures through the two holes during the 15-second period before the caretaker looked into the boxes, as well as the exact direction of the gestures when the subjects reached toward the boxes.

The location of the food item (right or left box) and trial type (Open vs. Closed) were balanced so that each subject received an equal number of trials of each possible type. The order of trials was determined by first randomly dividing the subjects into 2 groups ($n = 3$ and $n = 4$), one of which received an Open trial first, and the other which received a Closed trial first. After the first trial, the remaining trial types were randomly and exhaustively assigned to each subject.

Predictions. Predictions of two models were evaluated. First, the conceptual understanding model posited that the chimpanzees would understand how the caretaker's vision could be impeded by opaque barriers (see also Exp. 2), and would therefore deploy their gestures differently during the 15-second waiting period in the two testing conditions. In the Open condition, the subjects should gesture first, more, and/or longer through the holes in front of the boxes than the hole in front of the caretaker. In contrast, in the Closed condition, because the caretaker could not see their gestures toward the boxes, the subjects should gesture more frequently to the caretaker than to the boxes. In addition, when the subjects did gesture toward the boxes, the conceptual understanding model predicted that their gestures should be more precisely directed toward the baited box in the Open condition than in the Closed condition, because in this Closed condition the caretaker was unable to see the direction of their gesture. The postural configuration model posited that the chimpanzees would not understand the crucial distinction between the Open vs. Closed trials (namely, that the caretaker could see the area containing the boxes on Open but not Closed trials). If this model were accurate, the chimpanzees should gesture toward their caretaker and toward the boxes with equal frequency and duration, regardless of whether the window was open or closed.

Videotape Analysis. Two raters separately coded the videotapes of the test trials for several dependent measures. The main rater coded all 56 probe trials and the secondary rater coded a sample of 29% of the trials for assessing reliability (all 8 trials for 2 randomly selected subjects = 16 trials total). The measures we used, along with their associated reliabilities, were as follows: (a) location of the subject's first gesture (through the hole in front of the boxes or through the hole in front of the experimenter) (100% agreement, $\kappa = 1.0$), (b) number of times the subjects switched the location of their gestures during the 15-second waiting period (87.5% agreement, $\kappa = 0.75$), (c) specific direction of first gesture (for gestures on the box side of the partition: 'box 1' or 'box 2'; for gestures of the experimenter's side of the partition: 'experimenter' or 'other') (100% agreement, $\kappa = 1.0$). Data from the main rater were used in all analyses.

Results and Discussion

The first step in the data analysis was to calculate the mean percent of trials in which the subjects' first gesture was to the boxes or the experimenter as a function of the experimental manipulation (Open vs. Closed). These results are presented in figure 11, including a category for trials during which the subjects did not gesture during the 15-second waiting period.

We analyzed the data in several ways. First, we used a two-way repeated measures ANOVA to test the main predictions of the two models. The main effect of condition (Open vs. Closed) was not significant ($p > 0.44$), meaning that the subjects did not exhibit different frequencies of first gestures through the response holes when the window was open versus closed. Similarly, the main effect for location (boxes versus caretaker) was not significant ($p > 0.70$), meaning that the subjects did not exhibit a higher percentage of first gestures in front of the boxes versus in front of the caretaker.

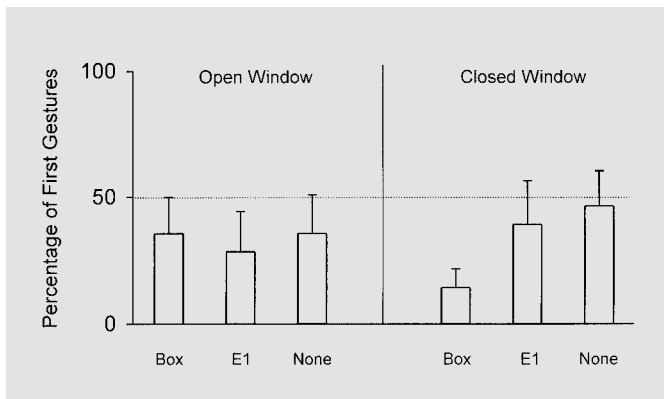


Fig. 11. Mean percent of first gestures (+ SEM) towards either the box or the experimenter, by condition and across all subjects ($n = 7$) in Exp. 5. None = those trials in which a subject did not produce a gesture during the 15 s waiting period.

The main prediction for the conceptual understanding model was that the data for the subjects' first gestures would reveal an interaction between location (boxes, caretaker) and condition (Open, Closed). The results indicated no such interaction, meaning that the subjects' distribution of first gestures to the boxes or their caretaker did not differ depending on whether the window was open or closed. Thus, the main prediction of the conceptual understanding model was not supported. However, a visual inspection of the data for the interaction effect (fig. 12) suggested a possible trend in the direction predicted by the conceptual understanding model. Thus, we explored the effects of each condition (Open, Closed) separately using dependent t tests comparing the mean percentage of first gestures to the boxes vs. the caretaker. Although there were more first gestures to the boxes during the Open condition as opposed to the Closed condition, this difference was not statistically significant ($t(6) = 1.441, p > 0.19$). There were also more first gestures to the experimenter during the Closed condition than during the Open condition, and this difference approached statistical significance ($t(6) = 2.121, p < 0.08$). Thus, exploratory analysis of the interaction effect provided some limited evidence in favor of the conceptual understanding model.

We also examined the data to test the predictions of the two models concerning the accuracy of the subjects' gestures toward the boxes in the Open vs. Closed conditions. Recall that the conceptual understanding model predicted that when the subjects did gesture to boxes, they ought to be more precise in the exact target of their gesture (the

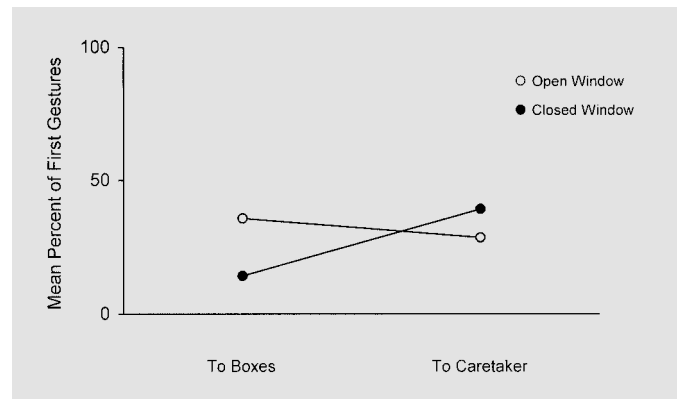


Fig. 12. Mean percent of first gestures towards either the box or the experimenter across all subjects ($n = 7$), plotted to show interaction between condition and target of gesture in Exp. 5.

baited vs. unbaited box) in the Open condition as opposed to the Closed condition. The data do not support this prediction. The subjects gestured to the correct (baited) box on 75% of all of the Closed trials on which they gestured through the hole in front of the boxes. In contrast, the subjects gestured to the correct box on 58.3% of all of the Open trials in which they gestured in front of the boxes (Fisher's exact test, $p = 1, n.s.$).

The results of this experiment generally matched the predictions generated by the postural configuration model, although there were some limited trends that were consistent with some of the predictions of the conceptual understanding model. Taken with the results of Exp. 2, we believe that the most cautious interpretation of the existing findings is that when chimpanzees follow the gaze of others, they naturally account for the presence of opaque structures along the line of 'sight' they are following [e.g., Povinelli, 1996; Tomasello et al., 1998], without conceptualizing this as affecting what the other can or cannot 'see' – perhaps because they do not conceive of others as 'seeing' in the first place. Given that chimpanzees (and certain other species) possess a strong propensity to follow 'gaze', it seems quite reasonable to suppose that this system is modulated by general and/or specific learning mechanisms. Thus, with sufficient experience following gaze in the real world, chimpanzees may quickly learn how gaze interacts with objects and obstructions. In particular, they may learn that when they follow someone else's 'gaze' to an opaque barrier, the space behind the barrier is no longer relevant – especially if they can see directly that the space contains nothing of interest [for

discussions of geometric mechanisms of gaze following, see Butterworth and Cochran, 1980; Tomasello et al., 1998]. Such systems, though sufficient to support appropriate gaze-following behaviors in the presence of opaque barriers, would not necessarily immediately lead to the kinds of performances predicted by the conceptual understanding model in Exps. 2 and 5. After all, those performances depend not on the functioning of gaze-following *per se*, but upon understanding what someone else can and cannot see.

General Discussion

The results of Exps. 1–5 consistently provided evidence that although chimpanzees process information about the eyes and faces of others, and engage in communicative exchanges with others, they do not construe others in terms of underlying mental states such as visual attention or communicative intent. This suggests that the perceptual-cognitive systems of humans and chimpanzees share similarities as well as strong differences. Humans and chimpanzees both share perceptual-cognitive systems that preferentially attend to certain aspects of behavior over others (movement of the eyes, orientation of the face, motion of the hands, etc.). Likewise, the cognitive systems of both species are populated with representations of the behavioral states of others, as well as representations of the contingencies between specific behavioral states and other states and events in the world. However, the research presented here provides additional evidence (at least with respect to the mental state of attention) that, unlike humans, chimpanzees may not generate representations of the internal mental states of others. Indeed, if the conclusions reached here and elsewhere can ultimately be generalized to other species of non-human primates, we may be forced to conclude that theory of mind is a uniquely derived feature of the human lineage.

There are several aspects of our results that favor this conclusion. First, in the absence of relevant information about gaze direction (see Exps. 3–4), the chimpanzees failed to disregard meaningless body position cues – cues that young children do disregard during similar laboratory tasks [see Povinelli et al., 1999; Exp. 3]. Second, in Exps. 2 and 5, the chimpanzees did not exhibit evidence of understanding that opaque barriers affect what another can see (and thus provide no unique evidence that they understand that others ‘see’ at all). Although on the surface this effect seems inconsistent with previous demonstrations that chimpanzees account for opaque barriers in

the act of following the gaze of others [e.g., Povinelli and Eddy, 1996a, Exp. 2; Tomasello et al., 1998], such results need not stand in opposition to each other. After all, chimpanzees may, in the daily course of their lives, learn to modulate their natural gaze-following responses with learned contingencies about the geometry of solid objects along the scan path. In contrast, Exps. 2 and 5 asked, in more direct ways, whether chimpanzees appreciate what their partner can and cannot see (the objects of their partner’s visual attention), and the results indicate that they do not. For example, in Exp. 2, the chimpanzees did not avoid searching in the boxes that could not possibly have been the object of their partner’s visual attention, even though on trials when no barrier was present, they reliably selected just the box at which the experimenter gazed. Karin-D’Arcy and Povinelli [in review] obtained similar results in studies involving chimpanzees reasoning about what other chimpanzees (as opposed to humans) can and cannot see [however, see Hare et al., 2000].

In this same vein, when the visual modality of gaining another’s attention was unavailable, our chimpanzees proved unable to utilize the readily available tactile modality (see Exp. 1). Although this experiment differed from the others in terms of the chimpanzees’ role in the communicative partnership (here the chimpanzee was required to gain the attention of one of two available partners, not merely respond to attentional cues), there was nonetheless a striking lack of insight on the part of our apes into the alternative means of gaining the attention of one of the partners that was available. Thus, rather than construing the original situation as, ‘As soon as she sees me push down the lever, she hands me reward,’ the chimpanzees seemed to have exclusively adopted the concept: ‘Push down the lever and she hands me a reward.’ Thus, there appeared to be no flexibility on their part in the testing phase to recruit attention through the tactile modality.

However, having presented a particular interpretation of the results that we obtained (which is derived from the original *a priori* predictions of the models under investigation), it is worth asking about the evidence from these studies that is consistent with the opposite interpretation; namely, that chimpanzees do appreciate seeing and attention as mental (as opposed to behavioral) states. We highlight two examples. First, in Exp. 3 the chimpanzees reliably used gaze direction over lean direction in the Gaze vs. Lean condition (even though, when no other cues were available, they used the lean direction in the Facing Away conditions, as mentioned above). This result could be interpreted as evidence of a rudimentary grasp of the attentional significance of eye gaze. However, it should be

kept in mind that the two models under consideration did not generate strongly different predictions for this condition (see Predictions, Exp. 3). After all, one version of the physical cue model predicted this bias simply because more cues (face direction + eye direction vs. lean direction) were oriented toward the correct container. In contrast, the predictions of the two models did differ for the Facing Away condition. Thus, whatever system was responsible for the eye gaze cue in the Gaze vs. Lean condition, this system did not also lead the chimpanzees to disregard the available (but a priori meaningless) postural cue in the Back Facing condition.

Likewise, the results of the Lean vs. Gaze condition in Exp. 3 (see fig. 7) in which 4/5 subjects disregarded the head direction cue in favor of the eye gaze cue could be interpreted as evidence of an understanding of the eye's role in attention as predicted by the referential comprehension model. It is important to note, however, that a simple weighing of the number of cues could produce the same result. After all, there are two cues in the correct direction (face direction and gaze) and only one in the incorrect direction (body lean). In fact, it might be possible that the chimpanzees used this simple weighing strategy in the Eyes on Target condition as well, failing to grasp that the upturned eyes were no longer a valid cue [see related finding by Povinelli et al., 1999, Exps. 1 and 2]. Further, in both of the cases just discussed, it is worth noting that chimpanzees may possess an evolved predisposition to favor eye direction over other cues, without any appreciation of attention or seeing as mental states. This is why these conditions alone were insufficient to discriminate between the models under investigation.

Although it may be tempting to think that our chimpanzees were using a simple hierarchical framework to make their choices, such an explanation will not suffice. If this were the case, the chimpanzees would have demonstrated (in the presence of conflicting cues) a descending preference for (a) gaze direction, (b) face direction, and (c) lean direction. As can be seen in fig. 7, this is not the case (i.e., continued preference for face direction over lean direction, even when both lean and gaze direction are inconsistent with face direction). Our general conclusion, then, is that although it is possible to interpret some limited aspects of the results as consistent with an understanding of seeing or attention as mental states, the overall pattern is better understood in terms of the sensitivity of chimpanzees to various behavioral contingencies.

Some researchers may question the validity of using laboratory tasks such as the ones used here for inferring the content of the chimpanzee's cognitive systems, focus-

ing chiefly on questions of motivation and the applicability of artificially constructed test situations to the spontaneous situations encountered in the course of daily interactions [e.g., McGrew, 1992]. Let us address these important issues separately. With regard to motivation, it is important to note that the probe trial technique used in Exps. 1–4 involved surrounding the crucial test trials with superficially similar trials that did not require inferences about mental states. Our chimpanzees performed at ceiling levels on these trials, thus demonstrating a high degree of motivation on the tasks. Even in Exp. 5, where the subjects were not required to do anything to obtain a reward (they were ultimately given the apple after 15 s regardless of whether they communicated by gesturing or not), 5/7 subjects showed a high rate of gesturing (the remaining 2 gestured as well, but at a substantially lower frequency). Further, even in those cases where their responses were essentially random, the subjects' attention to the novelty of the test trials was demonstrated by increases in their latencies to respond (see Exp. 1).

What about the second idea, namely, that such laboratory tests will always provide an artificial portrait of the chimpanzees' cognition, obscuring their higher-level abilities? Given that we have discussed this issue at length elsewhere [e.g., Povinelli, 2000], let us simply note several general factors that mitigate such criticisms: (a) these tests were conducted on chimpanzees born and raised in the context of a rich social life with other chimpanzees, and thus, the kinds of situations confronted in our tests are quite natural to them; (b) our experimental tasks relied, as much as possible, on the chimpanzees' natural behaviors such as gaze-following (see Exps. 2–4) and their natural communicative gestures (see Exp. 5), and even such apparently contrived experimental situations as conflicting eye, face, and lean direction are in actuality not uncommon in everyday observation (consider someone's position as they lean to the left to peer around an obstruction on their right); (c) our chimpanzees were tested with individuals with whom they were very familiar, in a setting they have been exposed to on a daily basis for many years, and (d) even where our chimpanzees were required to interact with apparatuses, they were intentionally kept simple (e.g., cups to be turned over, boxes to be looked into), the subjects were exposed to them before the tests, and the subjects' success or failure was in no case limited by their understanding of how to manipulate them. Thus, in general we find it difficult (albeit not impossible) to imagine that an understanding of attention similar to that present in human preschool children could be so convincingly and consistently masked by the kinds of situations

presented to the animals in these and related studies. Finally, one must critically assess the alternatives. Given that the specific, psychological systems which generate the natural, uncontrolled behaviors of these animals cannot be specified [see Povinelli and Giambrone, 1999], the process of ongoing hypothesis-testing through controlled experimentation (though imperfect) may always be better than the alternatives. Indeed, it may just be the case that scientific attempts to make inferences about unobservable states or processes will always require such experimentation, regardless of whether such inquiries concern the operation of forces such as gravity, or questions concerning whether a given species is capable of making inferences about mental states such as seeing and attention.

We end by offering a broader hypothesis which may explain how it could be the case that humans and chimpanzees share so many homologous behaviors, and yet at the same time, appear to interpret them in different ways. On the basis of mounting experimental evidence such as that presented here, we have speculated that humans may have evolved unique, specialized capacities for representing mental states and other unobservable phenomenon, and that these systems were neurologically woven into existing developmental systems, entangling themselves alongside various ancestral systems we share in common with chimpanzees and other primates. Thus, in

humans, the very same action pattern – for example, following someone else’s gaze – may sometimes be prompted by the mere detection of observable regularities, whereas at other times, it is prompted by a specialized system dedicated to representing why an event occurred in terms of unobservable variables. If true, the uniquely human system for representing unobservable causal states is parasitic on other, ancestral psychological systems that we share in common with our closest living primate relatives, and it imbues the ancestral representations of particular behaviors with particular psychological and causal content – forms of content and meaning not found in other species [for more details, see Povinelli, 2000].

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