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Cues that chimpanzees do and do not use to find hidden objects

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Abstract Chimpanzees follow conspecific and human gaze direction reliably in some situations, but very few chimpanzees reliably use gaze direction or other communicative signals to locate hidden food in the object-choice task. Three studies aimed at exploring factors that affect chimpanzee performance in this task are reported. In the first study, vocalizations and other noises facilitated the performance of some chimpanzees (only a minority). In the second study, various behavioral cues were given in which a human experimenter either touched, approached, or actually lifted and looked under the container where the food was hidden. Each of these cues led to enhanced performance for only a very few individuals. In the third study – a replication with some methodological improvements of a previous experiment – chimpanzees were confronted with two experimenters giving conflicting cues about the location of the hidden food, with one of them (the knower) having witnessed the hiding process and the other (the guesser) not. In the crucial test in which a third experimenter did the hiding, no chimpanzee found the food at above chance levels. Overall, in all three studies, by far the best performers were two individuals who had been raised in infancy by humans. It thus seems that while chimpanzees are very good at "behavior reading" of various sorts, including gaze following, they do not understand the communicative intentions (informative intentions) behind the looking and gesturing of others – with the possible exception of enculturated chimpanzees, who still do not understand the differential significance of looking and gesturing done by people who have different knowledge about states of affairs in the world.

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Introduction

The ability to extract information about the environment from conspecifics plays an important role in a number of social species. One of the possible sources of this information is based on following the gaze (i.e., head and eye direction) of conspecifics that may alert individuals to the presence of predators or novel food patches. Gaze following in nonhuman animals has been studied using two different paradigms. One paradigm consists of following the gaze into distant space which entails animals using the gaze direction of an "informant" into a location generally situated above and behind the subject. Chimpanzees and other nonhuman primates reliably follow the visual gaze direction of conspecifics (Emery et al. 1997; Tomasello et al. 1998) and humans (Anderson and Mitchell 1999; Call et al. 1998; Itakura 1996; Povinelli and Eddy 1996a, 1997). They do not just do this in some general way, for example, by turning to match the conspecific's bodily orientation in a general fashion and then looking for something interesting on their own, but they actually track the specific direction and target of the other's gaze. The most compelling evidence for this more specific type of gaze following – sometimes called geometric gaze following (Butterworth and Jarrett 1991) – is supplied by studies in which chimpanzees follow the gaze direction of conspecifics and humans to locations behind various kinds of occluders and barriers (Hare et al., in press; Povinelli and Eddy 1996a, 1997; Tomasello et al., in press).

The second paradigm – sometimes called the object-choice paradigm – involves a human hiding desirable food in one of several opaque containers and then allowing the subject to choose one container, whose contents she then obtains. In different conditions the subject is given different hints or cues about which container contains the food (e.g., staring at the container). Chimpanzees and other nonhuman primates do not fare as well in this second paradigm, perhaps because it may impose a different set of cognitive requirements (Anderson et al. 1995, 1996). First and most simply, Call and Tomasello (1998), Call et al. (1998) and Itakura et al. (1999) found that when a human experimenter stares at one of the opaque containers, most chimpanzees and orangutans do not then choose that container more than any other – even though they often follow the human's gaze to it before making their choice. Adding a pointing gesture to the gaze behavior (Itakura et al. 1999) or pointing alone does not help either (Tomasello et al. 1997). Overall, across three different studies, 58 chimpanzees (in some cases the same individual participated in different studies) were given either a gaze direction or a gaze direction plus pointing cue and only 8 (14%) were able to use this cue reliably to find the hidden food – even though virtually every subject on virtually every trial was highly motivated throughout. Tomasello et al. (1997) also gave two additional cues they thought might help. In one case they placed a wooden marker on top on the container containing food, and in the other case they held up an exact replica of the container containing food (in this study the three different containers were all perceptually highly distinctive). Of eight different subjects, all of whom were naive to these cues, not one could use either cue reliably.

Itakura et al. (1999) tried three variations. First of all, they replaced the human experimenter with a trained conspecific. Chimpanzee subjects still did not use the gaze direction cue reliably (which also included pointing in the form of an extended arm). The second variation produced more positive results. In this experimental condition, either a human experimenter or a trained conspecific physically approached one of two opaque containers (placed approximately 1.5 m apart) and visually inspected it, staying in that same location as the subject made its choice (the human experimenter also alternated gaze between the container and the subject). In this condition three of four subjects performed above chance for both the human and conspecific experimenters, and the other subject performed above chance for the conspecific only. One interpretation of these results involves seeing the object-choice task as basically a simulated foraging situation. In this interpretation, simple gazing and/or pointing are not cues that chimpanzees naturally use when foraging, but the actual physical location of others (especially when they seem actively engaged with something at that location) is a familiar cue in this situation – indeed, local enhancement is a cue used by many animal species in foraging (Zentall 1996). Finally, the third variation also produced positive results. A human experimenter gave the simple gaze direction cue (i.e., stared at the container containing food) and then vocalized – using either a simulated chimpanzee "food bark" or a human nonsense word. Irrespective of the specific vocalization, half of the chimpanzees tested reliably used the same gaze direction cue that they had earlier not used. Since vocalizations often occur during chimpanzee feeding bouts (e.g., Hauser and Wrangham 1987), it is possible that the simple addition of vocalizations made the gaze cue more salient and relevant to foraging (and, of course, this cue also contained additional directional cues based on the direction of the vocalization).

Call et al. (1998) tried two other variations and also found some more positive results. They reasoned that perhaps the "staring at opaque containers" cue was insufficient for chimpanzees because in fact the experimenter, whether human or chimpanzee, was not actually looking at food but only at an opaque container. They therefore devised two variations in the experimental set up. In one, they simply substituted two-dimensional barriers for opaque containers so that the experimenter could see the food that was behind the barrier (from the subject's point of view), but the subject could not. In the other, they used tubes blocked in the middle and arranged so that the experimenter could look into his end and see food but the chimpanzee looking from its end could only see inside a blocked, empty tube. Surprisingly, none of the six subjects performed above chance in the barrier condition, but four of six subjects performed above chance in the tube condition. Continuing with the analysis in terms of foraging, one interpretation of these results is that the tube represents a likely foraging place for chimpanzees; in their natural habitats chimpanzees quite often poke sticks in holes in probing for honey, ants, termites, and water (see Tomasello and Call 1997 for a review). In the tube condition, therefore, the subjects followed the experimenters gaze and then saw a good place to forage. In the barrier condition, on the other hand, they followed the experimenter's gaze but then saw only a barrier.

Although these initial investigations are still clouded by much variability in performance across studies (and individuals), they have started to address the important question of which conditions enable chimpanzees to extract information from the gaze of conspecifics in object-choice situations. It is important to emphasize that object-choice situations are not necessarily equivalent to gaze following into distant space. An important question that those studies have not directly addressed is the level of understanding chimpanzees have of someone else's gaze direction. In other words, what is the level of cognitive sophistication underlying gaze following? One possibility is that individuals simply perceive gaze direction as a simple discriminative cue. Alternatively, chimpanzees may understand something more about others' gaze, in particular that seeing leads to knowing, and that humans commonly use gaze as an intentional communicative behavior.

There is one study that has addressed the question of whether chimpanzees understand that seeing leads to knowing. Povinelli et al. (1990) had four chimpanzees, all with much human experience, witness an experimenter (the "knower") bait one of four cups behind an occluder. Another human (the "guesser") remained outside the room and consequently did not see which cup was being baited. After the guesser entered the room, he pointed to one cup and the knower pointed to another. Three of the four chimpanzees correctly chose the knower's cue more often than the guesser's cue, but only after some hundreds of trials. The interesting twist in this experiment was that there now came a transfer phase in which a neutral experimenter baited the cups. The difference was that this time instead of remaining outside the room during the baiting process, the guesser now stayed inside the room but with a bag over his head; the knower again watched the baiting process. In the first five trials of this transfer phase subjects behaved randomly, only later coming to choose the knower consistently (Povinelli 1994). These results raise the possibility that in the transfer phase, as in the original phase, subjects were simply learning a discriminative cue for obtaining the food rather than having some understanding that seeing leads to knowing.

In the current series of studies we systematically explored the effectiveness of various vocal and behavioral cues and investigated the level of cognitive understanding of gaze following in object-choice situations in the same subjects. In the first study we followed up the finding that vocal cues help chimpanzees to use gaze direction cues. In the second study we attempt to clarify and extend the finding that local enhancement cues are especially helpful to chimpanzees in this task. Finally, the third study investigated chimpanzees' understanding of others' gaze direction using a variation of the Povinelli et al. (1990) paradigm concerning knowledgeable and ignorant human informants. The goal of the entire series of studies is to try to understand why chimpanzees, who are so skilful at gaze following into distant space, should behave so inconsistently when presented with a task which simply requires them to use this skill in an object-choice paradigm.

Study 1: vocal and gaze cues

Itakura et al. (1999) found that when a simple gaze direction cue was amplified by a vocalization – the human looked at the container containing food and vocalized in one of two different ways (one chimpanzee-like and one human-like) – chimpanzees' performance improved dramatically in the object-choice paradigm. In the current study we paired a number of different types of sounds with gaze direction in this same paradigm, and we tried combining a sound with gazing behavior involving the eyes only (not head and eyes). We also tried sequencing the sound and the looking behavior in different ways. The question here was whether the auditory cue only worked when the human first obtained the subject's attention vocally and then gave the gaze cue, or whether it would work even if the gaze cue was given first followed by the vocal cue (so that the subject had to, in effect, remember the gaze cue at the time of the vocalization – since the vocal cue gave no directional information). In another experimental condition, we also gave a directional vocal cue with no gaze cue; that is, the human's face was covered so that his vocalization went toward the container containing food but there was no visual or other cue.

Method

Subjects

Fifteen adult and sub-adult chimpanzees (*Pan troglodytes*) housed at the Yerkes Regional Primate Research Center Field Station participated in the study – 14 females and 1 male. All subjects were housed in group cages, with access to indoor and outdoor areas. Subjects were tested in their indoor cages and were fed according to their normal daily routine. Two subjects, Ericka and Peony, had extensive experience with humans from an early point in their development. Their experiences included manipulating complex objects, participating in household routines, and using symbolic systems to communicate with their caregivers. All subjects had participated in at least one

Table 1 Age, sex, birthplace, rearing, and experimental histories of the subjects included in each of the experiments

Subject	Age (years)	Sex	Birthplace	Participation in experiments[a]	Rearing history	Experimental history
Anja	18	Female	Captivity	2–4	Mother	3
Atlanta	33	Female	Captivity	1	Unknown	
Barbara	26	Female	Captivity	All	Unknown	1, 7
Borie	34	Female	Captivity	2–4	Unknown	
Buffy	14	Female	Captivity	1	Nursery	1
Cissie	22	Female	Captivity	1–3	Nursery	1,3,4,5,7
Ericka	25	Female	Captivity	All	Home	1,3,4,5,6,7
Gwennie	29	Female	Captivity	1	Unknown	
Jesse	16	Female	Captivity	All	Nursery	1,2,3,5,7
Kate	9	Female	Captivity	2,3	Mother	
Peony	30	Female	Wild	All	Nursery-home	3,6,7
Phineas	32	Male	Wild	1–3	Mother	
Rita	11	Female	Captivity	All	Mother	
Sheila	26	Female	Captivity	1	Unknown	7
Sonia	39	Female	Captivity	1–3	Unknown	1,4,5,7
Tai	31	Female	Wild	All	Mother	1,3,4,7

[a] *1* object permanence, *2* tool use and social learning, *3* comprehension of communicative signs, *4* distinguishing intentional from accidental actions, *5* false belief task, *6* language acquisition, *7* gaze following

other object-choice study, and so they all were familiar with the basic procedure (many had participated in other types of studies as well; see Table 1). For each of the individual tests of study 1 described below 12 of the 15 subjects served as subjects (see Table 1).

Materials and design

In the current object-choice paradigm each subject was individually tested for its ability to find food under one of two opaque containers (12 cm × 7 cm × 7 cm) placed on a wooden board about 1 m apart. The human experimenter (E) interacted with the subject from a location in front of the cage with the apparatus between the subject and himself. Experimental conditions were defined by the cue that E gave to the subject just before a choice was to be made. Eight different cues were given:

1. *Vocalization then gaze*: E made eye contact with the subject and gave a simulated chimpanzee food bark five to seven times. E then turned his head toward the location of the food and remained looking there for 5–10 s, with no further barking. He then turned back and looked straight ahead at the subject – at which point he pushed the apparatus to the cage so that the subject could make its choice.

2. *Gaze then vocalization*: E made eye contact with the subject and then turned his head toward the location of the food and remained looking there for 5–10 s. He then turned back and looked straight ahead at the subject and gave a simulated chimpanzee food bark five to seven times – at which point he pushed the apparatus to the cage so that the subject could make its choice.

3. *Eyes only*: E made eye contact with the subject and then turned his eyes toward the location of the food – his head and body remaining in a straight-ahead direction – and alternated eye direction between the container containing food and the subject for 5–10 s. He then focused straight ahead at the subject for a few seconds – at which point he pushed the apparatus to the cage so that the subject could make its choice.

4. *Eyes and vocalization*: E made eye contact with the subject and then turned his eyes only toward the location of the food – his head and body remaining in a straight ahead direction – and gave a simulated chimpanzee food bark five to seven times. He then focused straight ahead at the subject for a few seconds quietly – at which point he pushed the apparatus to the cage so that the subject could make its choice.

5. *Vocalization only*: E made eye contact with the subject and then covered his face with a piece of cardboard while giving a simulated chimpanzee food bark five to seven times. He then focused straight ahead at the subject for a few seconds quietly – at which point he pushed the apparatus to the cage so that the subject could make its choice.
6–8. *Snap, slap,* and *horn*: In all three of these conditions E made eye contact with the subject and then turned his head toward the location of the food and made some kind of noise five to seven times – either a snap of his fingers, a slap of the ground (a common chimpanzee gestural signal: Tomasello et al. 1994), or a tape recorded sound of a bicycle horn (coming from E’s chest pocket and activated by pressing a button on that location). He then focused straight ahead at the subject for a few seconds quietly – at which point he then pushed the apparatus to the cage so that the subject could make its choice.

All trials had the same duration and E did not modify his pre-determined gaze pattern during the trial. Each subject received 24 trials in each condition, given consecutively and typically run within a one day session. There were never more than a few days (1–3) between sessions for the first four conditions above, and then the latter four were given some days or weeks later. The order of the first four conditions was counterbalanced using a partial Latin squares design. After these four conditions were completed, the four other conditions were given in the following order: vocalization only, snap/slap (alternating order), and horn. Food location was randomly varied among the two bowls, the only constraint being that the reward was never placed in the same bowl for more than two consecutive trials. The number of subjects included in each condition varied depending on who was available for testing (see Table 2).

Procedure and scoring

Every session began with four warm-up trials to make sure that subjects knew what to do and were motivated (and four more warm-up trials were given at the midway point of each session as well). For each warm-up trial E placed food in one of the containers in full view of the subject, and then presented the apparatus for a choice. Subjects were almost 100% correct in these warm-up trials – including those in the later studies). For all experimental trials, no matter the specific cue given, a single procedure was followed. E baited one of the two containers while shielded behind a large occluder, sham baiting the other one at the same time. He then removed the occluder, made eye contact with the subject, gave his cue, and then presented the apparatus to the subject to make its choice. The first container touched by the subject was scored as its choice. These responses were entirely unambiguous, so the single E simply noted after each trial which container the subject had chosen.

Because E’s behavior was not totally rigidly controlled in terms of exact number of noises and their loudness, 10% of all trials were viewed on videotape by a “blind” observer who was asked to determine for each trial (1) the number of noises given, and (2) their amplitude on a scale of 1–7. *t*-tests on these two measures between all different conditions (except the eyes-only condition which had no sound) revealed no differences among conditions. All statistical tests were one-tailed.

Table 2 Number correct in each condition (out of 24) for each subject in study 1

Name	Vocalization > gaze	Gaze > vocalization	Eyes only	Eyes and vocalization	Vocalization only	Snap	Slap	Horn
Anja						15	12	
Atlanta	13	14	10	10	10	–	–	10
Barbara	14	19*	9	15	13	12	13	13
Buffy	13	15	8	11	11	12	19*	10
Cissie	19*	19*	15	15	9	15	17	17*
Ericka	19*	19*	20*	14	15	23*	22*	20*
Gwennie	13	12	15	11	10	–	–	13
Jesse	14	17*	19*	22*	14	22*	14	15
Kate						14	13	
Peony	23*	24*	18*	22*	11	24*	24*	22*
Phineas	15	17*	18*	16	12	17*	17*	18*
Rita						15	11	
Sheila	19*	15*	16	14	12	–	–	14
Sonia	14	11	10	12	14	12	9	12
Tai	15	13	10	11	9	15	12	12
Mean	15.92*	16.25*	14.00	14.42*	11.67	15.25*	16.33*	14.67*

* Above chance performance, binomial probability (or t for groups), $P < 0.05$

Results

Table 2 presents the results for each of the 12 subjects on each of the eight cues. For purposes of statistical analysis, each subject in each condition was compared to chance using binomial probabilities (assuming a 50% chance of choosing either container). With 24 trials, a subject had to choose correctly 17 times to score above chance (one-tailed binomial probability). As can be seen in Table 2, seven of the eight cues had from two to six individuals above chance, whereas no subject performed above chance in the vocalization-only condition.

In terms of group performance, the 12 chimpanzees as a group performed above chance (assuming 50% chance in a one-sample t-test) for the following cues: vocalization then gaze, $t(11) = 4.16$, $P < 0.001$; gaze then vocalization, $t(11) = 4.01$, $P < 0.001$; eyes and vocalization, $t(11) = 2.08$, $P < 0.05$; snap, $t(11) = 3.48$, $P < 0.01$; slap, $t(11) = 2.45$, $P < 0.05$; and horn, $t(11) = 3.21$, $P < 0.01$. The vocalization-only and eyes-only conditions were not above chance for the chimpanzees as a group.

Discussion

The results of this study basically confirmed those of Itakura et al. (1999). Noises of all types – vocalizations, snapping/slapping noises, and artificial noises – all led to relatively good performance by chimpanzees relative both to chance performance and to performance in the face of a simple gaze cue, as in previous experiments. The order in which the auditory cue was given with respect to the gaze cue made no difference. And finally, it is not the case that the auditory cue works by helping subjects to localize the food; in the vocal-only condition subjects did not know where the food was located. Consequently, the most plausible hypothesis to account for these findings is that noises of various types help chimpanzees focus their attention on the testing situation. Perhaps sounds may even inform chimpanzees that this is a foraging situation in which it would be useful to attend to what others are doing. However, it is not totally clear why any type of sound (including a bicycle horn) would convey such information.

Study 2: behavioral cues

In this study we compared the chimpanzees' performance in the object-choice paradigm with three new kinds of behavioral cues, all used in combination with gaze direction (and all compared to a condition in which gaze direction was the only cue). The three cues were: (1) E physically approached and stared at the bowl [with a slight modification from Itakura et al. (1999), in that there was no gaze alternation]; (2) E lifted the bowl and looked under it [a cue sharing some features with those presented in Call et al. (1998), but with some important differences as well]; and (3) E reached out and touched the bowl [more unequivocal than a pointing gesture; similar to the cue that capuchin monkeys failed to follow in the study of Anderson et al. (1995)].

Method

Subjects

Twelve adult and subadult chimpanzees participated in the study (see Table 1). Eleven of the subjects also participated in study 1, with a twelfth (Borie) new to this study.

Materials and design

The apparatus consisted of two opaque red bowls (as in study 1) separated 40 cm from each other and placed upside down on the platform used in the previous experiment. E sat behind the apparatus facing the subject as in study 1. The specific behavioral cues used in this study were as follows:

1. *Gaze only (control)*: E stared at the baited bowl for 10 s.

2. *Lift*: E partially lifted the baited bowl and bent down so he (but not the subject) was able to see its contents and stared at it for 10 s. After the 10 s had elapsed, E replaced the bowl to its original position and while he was still staring at it pushed the platform forward to let the subject choose.

3. *Touch*: same as the lift condition but E touched and stared (without lifting or bending) at the correct bowl.

4. *Approach*: same as the lift condition but E moved sideways while seated so that he sat directly behind the correct container and stared directly at it for 10 s.

Each of the three experimental conditions was tested in one daily session and compared to control trials conducted during the same session. Testing order for the three experimental conditions was the same for all subjects: lift, touch, approach. A fixed order was deemed appropriate because each experimental condition was compared to a control condition obtained within the same session. Each session consisted of 12 control trials and 12 experimental trials alternated during the session. Overall, subjects received 36 control trials (12 trials × 3 sessions) and 36 experimental trials (12 trials × 3 conditions/sessions). Food location was randomly varied among the two bowls, the only constraint being that the reward was never placed in the same bowl for more than two consecutive trials.

Procedure and scoring

Every session began with four warm-up trials (nearly 100% correct for all subjects) to make sure that subjects knew what to do and were motivated (as in study 1). For all experimental trials, irrespective of the specific cue given, a single procedure was followed. E baited one of the two containers while shielded behind a large occluder, sham baiting the other one at the same time. He then removed the occluder, made eye contact with the subject, gave his cue, and then presented the apparatus to the subject to make its choice. The first container touched by the subject was scored as its choice. These responses were entirely unambiguous, so the single E simply noted after each trial which container the subject had chosen. All statistical tests were one-tailed.

Results

Table 3 presents the results for each of the 12 subjects with each of the three experimental cues (along with each same-session control cue). For purposes of statistical analysis, each subject in each condition was compared to chance, using straight binomial probabilities (assuming a 50% chance of choosing either container). With 12 trials, a subject had to choose correctly ten times to perform above chance (one-tailed binomial probability). As can be seen in Table 3, there were two individuals who performed above chance for the lift and touch conditions, and three individuals who performed above chance in the approach condition. There was one individual who performed above chance in each of the control sessions – in each case either Peony or Ericka, the two chimpanzees raised in their infancy with extensive human interaction.

Table 3 Number correct in each condition (out of 12) for each subject in study 2

	Lift	Gaze 1	Touch	Gaze 2	Approach	Gaze 3
Anja	8	7	8	6	8	6
Barbara	6	8	4	9	8	8
Borie	5	7	6	5	6	5
Cissie	9	9	7	7	9	8
Ericka	9	12*	11*	7	12*	9
Jesse	8	9	11*	6	8	9
Kate	6	6	6	7	9	6
Peony	10*	7	8	10*	11*	12*
Phineas	7	8	9	6	9	7
Rita	7	8	2	5	10*	9
Sonia	10*	6	6	3	5	5
Tai	2	6	5	6	5	8
Mean	7.25*	7.75*	6.92	6.42	8.33*	7.67*

* Above chance performance, binomial probability (or *t* for groups), $P < 0.05$

In terms of group performance, the 12 chimpanzees as a group performed above chance (assuming a 50% chance in a one-sample *t*-test) for the lift and approach cues: $t(11) = 1.88$, $P < 0.05$, and $t(11) = 3.69$, $P < 0.01$; but they were also above chance for the gaze cue associated with each of these two experimental cues: $t(11) = 3.54$, $P < 0.01$, and $t(11) = 2.87$, $P < 0.01$, respectively. The touch condition and its associated control condition were not above chance. Moreover, there were no significant differences between each of the experimental conditions and its associated control (*t*-tests: lift = 0.75, $df = 11$, $P > 0.20$; touch = 0.57, $df = 11$, $P > 0.20$; approach = 1.30, $df = 11$, $P > 0.20$).

An overall 2 (condition: experimental, control) × 3 (cue: lift, touch, approach) ANOVA on the percentage of correct responses revealed a significant effect of type of cue, $F(2,22) = 4.02$, $P < 0.05$ (with no other main effect or interaction). Post hoc comparisons indicated that subjects produced an overall higher percentage of correct responses in the approach compared to the touch conditions ($P < 0.05$), with none of the other conditions differing from one another significantly. We reanalyzed the data leaving Ericka and Peony out because of their special rearing history with humans. The remaining chimpanzees still performed above chance for the approach cue: $t(9) = 3.04$, $P < 0.05$, its associated control condition: $t(9) = 2.28$, $P < 0.05$, and the control condition associated with the lift cue: $t(9) = 3.77$, $P < 0.01$. All other conditions were not above chance. The overall ANOVA still indicated a significant effect of type of cue, $F(2,18) = 2.68$, $P < 0.05$ (with no other main effect or interaction) and post hoc comparisons showed that subjects produced an overall higher percentage of correct responses in the Approach compared to the touch conditions ($P < 0.05$), with none of the other conditions differing from one another significantly.

Finally, we calculated the confidence interval ($P < 0.05$) for each experimental condition using the scores of non-enculturated chimpanzees (lift: 8.41–5.19; touch: 8.23–4.57; approach: 8.97–6.43). All of Ericka's scores and the lift and approach scores for Peony (see Table 3) fell outside their respective intervals. This confirmed that both Ericka and Peony outscored the remaining (non-enculturated) chimpanzees.

Discussion

The behavioral cues given in this study – all given in combination with gaze direction – were not particularly effective in indicating to chimpanzees the location of the hidden food. Erika and Peony, the two human-raised chimpanzees, each performed above chance with two of the experimental cues; of the remaining chimpanzees only one of ten subjects performed above chance for each of the experimental cues. In comparison, the gaze plus auditory cues in study 1 were effective for more than twice as many subjects on average. It is also significant that in the current study the gaze direction alone (control) cue was useful in some sessions for Ericka and Peony (the group as a whole performed above chance in two of the three sessions, and this is not due totally to the influence of Ericka and Peony). In any case, none of the chimpanzees performed much better with the experimental than with the control cues, perhaps indicating that the behavioral "enhancements" of lifting, touching, and approaching did not add significantly to the simple eye gaze cue for many subjects

But there were some differences among the cues themselves. In particular, subjects were more successful with the approach cue than with the touch cue, with the lift cue falling in between those two. The touch cue simply was not effective; group performance, even including Ericka and Peony, was not above chance. This basically replicates the findings of Anderson et al. (1995) who found that a touch cue was not a sufficient cue for capuchin monkeys. The lift cue yielded above-chance performance for the group as a whole, but still was not so useful for most subjects. This finding may be seen as at least somewhat at variance with the findings of Call et al. (1998) in that it did not matter for the current subjects whether the human experimenter could or could not see the food. Finally the approach cue was a bit more helpful for subjects – it was significantly higher than the touch cue, for example – which to some degree supports the findings of Itakura et al. (1999). However, overall a much smaller proportion of subjects in the current study found the approach cue helpful [88% in the study of Itakura et al. (1999), 25% in this study]. The main difference is that in the study of Itakura et al. (1999), E alternated gaze between chimpanzee and food constantly while the cue was given, whereas in the current study he kept his head almost totally still. (Note that this accords well with the possible influence of gaze alternation in the eyes only condition in study 1.) One possibility is that gaze alternation is an especially powerful cue because it fulfils a double function. First, gaze alternation acts as an "attention getter" gesture (Tomasello et al. 1994) by calling the subject's attention toward the experimenter. In this sense, this cue may function in a similar way to the auditory cues studied in the previous experiment. Second, head movement also provides directionality. If subjects repeatedly follow the E's gaze to the correct container, they may be more likely to select that particular container when given a choice.

Finally, it should be noted that even though we found that chimpanzees performed above chance in two of the three gaze-only control conditions, whereas we had not found that in previous studies (e.g., Call et al. 1998), the difference is more apparent than real. The discrepancy is mainly the product of the larger sample size in the current study. The percentage of correct responses in both studies is comparable, approximately 55–60% correct responses. Our group results, however, are still lower than those reported by other researchers for chimpanzees (e.g., Itakura and Tanaka 1998; Povinelli et al. 1999).

Study 3: cognitive mechanisms

In the first two studies some subjects showed some skills at following the gaze of a human experimenter to a container containing food. There are a number of different possible mechanisms for this effect, however. For example, it might be that over our several studies some subjects have learned the gaze direction of the experimenter as a simple discriminative cue. Alternatively, it might be that subjects follow the gaze of the experimenter and then just choose relatively randomly, but quite often, since they have followed the human's gaze, the first container they see is the correct one. Or it might be that successful subjects understand something of the mental significance of E's looking; they know that E is looking at the food (i.e., the container containing food). One way to test these hypotheses is to give subjects a choice between two humans both giving a gaze direction cue simultaneously – with only one of them being knowledgeable about the food's location (as in Povinelli et al. 1990). In this circumstance neither of the very low level explanations (discriminative cue, or gaze follow plus random choosing) can work because the subject is confronted with two conflicting gaze direction cues simultaneously.

One problem with the Povinelli et al. (1990) study, however, stems from something discovered by Povinelli and Eddy (1996b). In the latter study chimpanzees were given the choice of gesturing for food to one of two humans, one of whom could see them and one of whom could not. The question was whether chimpanzees knew who could see them and who could not. Chimpanzees were very good at this task when one human was facing them and the other was turned around completely (back to subject). But under a variety of other conditions, they performed poorly, including a condition in which one human faced them and the other had a bucket over his head. It seems that the chimpanzees equated all forms of frontal bodily orientation with "presence" whatever the disposition of the eyes per se. The problem this created for Povinelli et al. (1990) was that in their crucial transfer test a bag over the head was used as the way of indicating the "guesser", the one who could not see and therefore did not know the food's location. The subjects' poor performance in the transfer trials (random for the first five trials) might thus be explained in terms of their inability to distinguish between the perceptual capabilities of the two humans facing them [since in the study of Povinelli and Eddy (1996b) they did not distinguish two humans disposed similarly]. What is needed, therefore, is a test that allows chimpanzees to choose between one human who is facing them and one who has the back turned – as in the only effective condition of the Povinelli and Eddy (1996b) studies.

In addition, as Povinelli et al. (1990) point out, who hides the food may matter. That is, one way of making a human a "knower" is to have him actually hide the food, with the guesser not watching. But this provides a plethora of other cues that might be used to make a choice. If our question is whether chimpanzees understand that witnessing the hiding process leads a human to know the food's whereabouts, therefore, it is important to contrast the condition in which the knower actually hides the food with one in which he merely observes it being hidden by a third experimenter (while the guesser has his back turned and so cannot observe the hiding process).

Method

Subjects

The eight chimpanzees who performed best in study 2 served as subjects (see Table 1). This group was composed of adult and subadult females.

Materials and design

The apparatus consisted of the two opaque red bowls and the wooden plank used in the previous experiment. Two different tests were administered, in order:

1. *Two-experimenter test*: two human Es sat next to each other behind the platform facing the subject. Each E was situated behind one of the bowls which rested upside down on the platform separated by 40 cm. One E (*guesser*) turned around 180° (with his back toward the subject) while the other E (*knower*) baited one of the bowls behind the screen as in previous experiments. Once baiting was completed, the knower stared at the subject's face and the guesser turned around and stared at the subject's face as well. Once the subject was attending, the knower removed the screen and Es looked at one of three predetermined locations: (1) front, looking directly at the bowl in front of them; (2) side, looking across to the bowl in front of the other E; and (3) above, looking up to the ceiling of the cage. The knower always looked at the correct bowl (either front or side, never up) whereas the guesser never looked at the correct bowl (either front, side, or up depending on the type of trial). This procedure was implemented to create a sharp contrast between the knower, who always provided information regarding the location of the food, and the guesser, who never provided accurate information. There were four types of trials depending on the location looked at by the knower and the guesser (knower performs first member of each pair, guesser second): front-front, front-up, side-side, side-up. After 10 s of looking by both Es, the knower pushed the platform against the fence, letting the subject select one of the bowls.

2. *Three-experimenter test*: this test was conducted after the two-experimenter test, and it used only the two subjects who performed skilfully in that first test (and in previous experiments): Peony and Ericka. Three Es sat next to each other behind the platform and facing the subject. One E (the baiter) sat behind the center of the platform whereas each of the other two Es (the knower and the guesser) sat directly behind one of the bowls on the platform. The guesser turned around 180° (with his back toward the subject) while the knower observed the baiter hiding food under one of the available bowls as in previous experiments. Once baiting was completed, the knower stared at the subject's face, the baiter removed the screen and turned around 180°, and the guesser turned around to his original position facing the subject. At this point, both the knower and the guesser were staring at the subject's face and the baiter had his back turned to the subject. Once the subject was attending, the knower and the guesser looked at one of three predetermined locations (front, side, and above) creating the same four different types of trials as in the two-experimenter test. After 10 s of looking at their predetermined locations, the knower and the guesser simultaneously pushed the platform to the subject for its choice.

In the two-experimenter test, subjects received a total of 64 trials presented in four separate daily sessions of 16 trials each. Each of the four types of trials was presented four times during a session for a total of 16 trials per trial type (front-front, front-up, side-side, side-up). After the first eight trials in a session, the Es swapped positions to the left and right of the subject and conducted the remaining eight trials to complete the session. Each E played both the role of knower and guesser (and their corresponding four types of trials) the same number of times in each session. Food was never placed in the same location more than twice in more than two consecutive trials. The same basic design was used in the three-experimenter test except that each subject received a total of 48 trials presented in four separate daily sessions composed of 12 trials each.

Procedure and scoring

As in the previous experiment, every session began with four warm-up trials (nearly 100% correct for each subject) to make sure that subjects knew what to do and were motivated. For all experimental trials, a single procedure was followed. The same three basic steps of previous experiments were employed: hiding the food, informing the subject of the food's location, and allowing the subject to choose one of the bowls. The first container touched by the subject was scored as its choice. These responses were entirely unambiguous, so the single E simply noted after each trial which container the subject had chosen.

Results

Table 4 presents the results for each of the subjects in each experimental condition in which they participated. For purposes of statistical analysis, each subject in each condition was compared to chance, using binomial probabilities (assuming a 50% chance of choosing either container). In the two-experimenter test, only Ericka and Peony – the two human-raised chimpanzees – performed above chance both when the Es were staring straight ahead and when they were looking across at the bowls in front of the other E. Furthermore, Ericka's (12, 14, 9, 14) and Peony's (13, 15, 13, 15) scores fell outside the confidence intervals ($P < 0.05$) defined by the scores of the non-enculturated chimpanzees in each of the four types of trials (front-front: 11.4–5.9; front-up: 10.6–7.8; side-side: 8.4–5.9; side-up: 8.7–5.6), respectively. Neither of these subjects was above chance in the three-experimenter test, however.

Table 4 Number correct in each condition for each subject in study 3. In the two-experimenter test a score of 32 was possible in each cell; in the three-experimenter test, a score of 24 was possible in each case

Name	Two-experimenter test		Three-experimenter test	
	Front	Side	Front	Side
Anja	15	17	–	–
Barbara	18	13	–	–
Borie	16	16	–	–
Ericka	26*	23*	14	11
Jesse	21	15	–	–
Peony	28*	28*	12	12
Rita	16	11	–	–
Tai	21	14	–	–
Mean	20.13*	17.13	13.00	11.50

* Above chance performance, binomial probability (or *t* for groups), $P < 0.05$

In terms of group performance, there was no overall improvement across sessions (Friedman test: 1.24, $df = 3$, $P > 0.50$). In the two-experimenter test the eight chimpanzees as a group did not perform above chance levels (assuming 50% chance in a one-sample *t*-test) in the side orientation, $t(7) = 0.56$, ns, that is, when each E was looking across at the bowl in front of the other E. They did perform above chance in the trials with a front orientation, however, $t(7) = 2.42$, $P < 0.05$. Comparing the percentage of correct responses for the four types of trials (front-front, front-up, side-side, side-up) indicated that only the front (knower)-above (guesser) combination was above chance, $t(7) = 2.59$, $P < 0.05$. A repeated-measures ANOVA with the knower's gaze direction (front, side) and the guesser's gaze direction (above, bowl) as within-subject factors revealed a significant effect for the knower's gaze direction (in favor of the bowl directly in front of the knower), $F(1,7) = 6.63$, $P < 0.05$, no effect for the guesser's gaze direction, $F(1,7) = 1.72$, ns, and no interaction effects. The finding is thus that subjects only performed well in those trials in which the knower was staring at the correct bowl situated directly in front of him. Dropping Peony and Ericka from the ANOVA analysis due to their special rearing history, did not substantially change the result, although subjects failed to perform above chance in the front orientation, $t(7) = 1.70$, ns.

Discussion

The current study was a partial replication of Povinelli et al. (1990), with two major differences. One is that we did not give subjects enough trials to learn gaze direction as a simple discriminative cue, as was the case in the main study of Povinelli et al. (1990; several hundred trials before reliable performance by the subjects). The second is that we changed the way the humans were deployed. In the crucial transfer phase of Povinelli et al. (1990) the guesser had a bag over his head; but subsequent research has shown that chimpanzees do not consider that this prevents visual perception (Povinelli and Eddy 1996b). Consequently, we had one experimenter turn his back during the hiding process while the other watched the hiding process, a situation in which the two humans' perceptual access is more clearly differentiated for chimpanzees (Povinelli and Eddy 1996b).

What we found was that two subjects – the two human-raised subjects who were the best performers in the previous studies as well – did choose the cue given by the knower over that given by the guesser when the knower was also the baiter (in the two-experimenter test). But even these two subjects did not choose the cue given by the knower when he was not the baiter. This suggests that something about the hiding process must have acted as a separate and relatively powerful cue. One possibility is that subjects focused on the experimenter who *pushed* the food toward them for their choice. Another possibility is that subjects focused on the experimenter who manipulated the food. Note that either of these two alternatives would have produced a positive outcome in the two-experimenter but not the three-experimenter test. Future studies should investigate what are the cues that subjects use to guide their choices.

It is also important that in the two-experimenter test there was a tendency for subjects to do better if the knower was actually seated in front of the container containing food, reinforcing the findings from Itakura et al. (1999) and study 2 that an "approach" (or stimulus enhancement) cue is a powerful one for some individuals. In the trials in which the two experimenters sat in front of one bowl but gaze across at the bowl in front of the other experimenter, subjects had to, in effect, deal with two competing cues: gaze direction and body location. So it is perhaps not surprising that, except for Ericka and Peony, no subject did well in this condition.

General discussion

In the current study we have again found that chimpanzees are not nearly as skilful in the object-choice task as they might be expected to be based on their very strong and reliable skills of gaze following. In Tomasello et al. (1998) and Call et al. (1998) chimpanzees followed conspecific and human gaze on over 80% and 75% of all trials, respectively, and in Tomasello et al. (in press) over half of the chimpanzees tested showed very strong skills in following human gaze to target locations behind barriers – demonstrating that their gaze following skills are more than just some generic tendency to turn in the general direction that others turn (see also Povinelli and Eddy 1996a, 1997). It is therefore puzzling that so many individuals in our and others' studies do not easily and readily learn this relatively natural social cue to locate hidden food in the object-choice task.

In the current studies we found, following Itakura et al. (1999), that basically any kind of noise given along with a gaze cue – in any temporal relation to it – facilitates chimpanzees' use of gaze cues to locate hidden food. It is not that the noise gives directional information itself – indeed we found that a noise directed to the container containing food was not a sufficient cue for even a single individual to successfully locate the hidden food – but rather that it seems to somehow make the accompanying gaze cue more salient or important. Actually approaching the location of the hidden food physically, and sitting behind it while the individual makes its choice, also facilitates performance (especially if accompanied by gaze alternation, as in Itakura et al. 1999) – perhaps because the behavior of approaching and inspecting the bucket is a more natural foraging behavior from which to learn than is simply looking, or even looking and pointing. And Call et al. (1998) also found that when the location of the hidden food is a more natural place for foraging (a "hole"), performance is enhanced as well. And so this *foraging hypothesis* is that, as compared with the fairly neutral situations in which simple gaze following has been investigated, the addition of food in the object-choice situation changes the functional context for chimpanzees. Chimpanzees are now in their "foraging mode", and gaze following apparently is not a cue they normally use in that mode. But when aspects of the situation are changed so as to make the foraging situation more salient – for example, by reminding the subject auditorily that another individual is nearby and foraging, or by having another individual actually approach and inspect a food location, or by hiding the food in a good foraging location – then chimpanzees use the gaze following cue more frequently.

Another hypothesis is that the effect observed in this study is a product of calling attention to certain parts of the situation. This *attention boosting hypothesis* is based on the idea that vocalizations or other behaviors attract attention to the experimenter's head orientation, which the subjects then use to find the food. This hypothesis receives some support from the results with enculturated subjects. Since their rearing history entailed numerous episodes of socialization of attention in which caregivers directed and focused their attention toward particular features of the environment, it is not surprising that they are also the ones who are able to extract the most information from the experimenter. In a sense, the socialization of attention can be understood as the ontogenetic equivalent to the vocal and behavioral cues investigated in the current study.

But none of these effects is very large; in all cases they concern only a minority of individuals, with the majority never making use of any gaze cue in the object-choice task. One explanation for this discrepancy is methodological in nature. Chimpanzees may not cope well with a situation in which a human is attempting to inform them about the location of food. Chimpanzees do not typically point or use head direction to indicate the location of food sources to others. Perhaps a more suitable paradigm would be to present a competitive situation in which subjects have to read the location of the food from conspecifics in order to select the correct container (e.g., Woodruff and Premack 1979). This paradigm could also be used to investigate whether subjects learn to adapt to this situation more readily and start withholding information that may be useful to their competitors to locate the reward. Alternatively, presenting food may interfere with their ability to use or even follow gaze. Unfortunately, we do not know how often chimpanzees follow gaze in an object-choice situation, especially compared to a situation that does not involve food.

Our current view, however, is that there is something fundamentally different about the social situation in simple gaze-following situations and the object-choice task. Most importantly, in simple gaze following, the individual just gathers information from another individual in whatever way it can – by observing its behavior and other happenings in the immediate surroundings. The object-choice situation, however, is a communicative situation in which the subject must understand that the looking behavior of the human is relevant in some way for the foraging task she is facing. To use the cue effectively, a subject should understand that the experimenter intends his gaze to be taken as informative, that is, the subject should understand the experimenter's communicative intentions (Tomasello et al. 1997). Instead, chimpanzees seem to see the task as simply another case of problem-solving in which all things in the context should be taken as potential sources of information – with the gaze direction of another as just another information source. They even take this attitude when the experimenter produces ritualized gestural signals such as pointing to or placing a marker on, the container containing food (Tomasello et al. 1997).

The one possible exception to this interpretation is individuals who have been raised in their early ontogenies in human-like cultural contexts. In Tomasello et al. (1997), the human-raised orangutan Chantek comprehended a human pointing gesture in the object-choice paradigm (see also Call and Tomasello 1994), and in the current study Ericka and Peony were more skilful than the other subjects by several orders of magnitude. Although the mechanisms by which human rearing – sometimes called enculturation (Call and Tomasello 1996) – has its effects on developing apes is not known, it is possible that triadic interactions in which ape, human, and an object of joint attention are involved are particularly important in learning about communicative intentions (Tomasello 1995). It may even be the case that being raised by humans in a human-like cultural context leads ape social cognition down more human-like ontogenetic pathways (Tomasello et al. 1993).

But it should be noted that even these enculturated individuals did not seem to know in the current experiments that the looking behavior of the experimenter during the hiding process meant that he was gaining information about the location of the hidden food. In the third experiment – and even with the methodological improvements over Povinelli et al. (1990) – neither Ericka nor Peony could make use of their observations of who could and who could not observe the hiding process (i.e., when a neutral third experimenter did the hiding and the presenting of choices to subjects). We thus think that no matter how skilful chimpanzees may become at "reading" the social behavior of others, at following the gaze of others, and, in general, at gathering information from the social environment, the understanding of the communicative intentions of others, and the understanding of what knowledge another individual does and does not have – both products of an understanding of others as intentional beings – is not something that even human enculturation can instil in nonhuman primates.

Nevertheless, we should remain open to the possibility that apes have evolved some form of mind-reading that does not entail reasoning about other people's beliefs or knowledge, or an understanding of communicative intentions. Instead, this form of mind-reading may be used to understand what other can or cannot see in particular situations (Hare et al., in press). This form of mind-reading almost certainly does not entail a full-blown human adult-like understanding of other's mental states. However, it represents a significant departure from an ability to simply read the behavior of others. Future studies should compare the socio-cognitive understanding of enculturated and non-enculturated apes, and in particular those aspects that make enculturated subjects more successful than mother-reared apes in the object-choice and other situations.

Our overall conclusion is thus that we have not solved the puzzle presented by chimpanzees' relatively poor performance in the object-choice task, but rather we have added information that may help lead to its solution by identifying some factors that seem to facilitate their searching behavior and some tasks that they seem not to be able to solve whatever the level of social information processing in which they engage.

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