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ORIGINAL ARTICLE

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Understanding of the relationship between seeing and knowing by tufted capuchin monkeys (*Cebus apella*)

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Abstract The ability of four tufted capuchin monkeys (*Cebus apella*) to recognize the causal connection between seeing and knowing was investigated. The subjects were trained to follow a suggestion about the location of hidden food provided by a trainer who knew where the food was (the knower) in preference to a trainer who did not (the guesser). The experimenter baited one of three opaque containers behind a cardboard screen so that the subjects could not see which of the containers hid the reward. In experiment 1, the knower appeared first in front of the apparatus and looked into each container; next, the guesser appeared but did not look into any containers. Then the knower touched the correct cup while the guesser touched one of the three randomly. The capuchin monkeys gradually learned to reach toward the cup that the knower suggested. In experiment 2, the subjects adapted to a novel variant of the task, in which the guesser touched but did not look into any of the containers. In experiment 3, the monkeys adapted again when the knower and the guesser appeared in a random order. These results suggest that capuchin monkeys can learn to recognize the relationship between seeing and knowing.

Keywords Tufted capuchin monkeys · Theory of mind · Social intelligence · Intention

Introduction

Can nonhuman primates make inferences about mental states of other individuals? Premack and Woodruff (1978) presented experimental evidence suggesting that chimpanzees (*Pan troglodytes*) might be able to attribute purpose and intention to human actors. However, researchers using nonhuman primates have so far reached no consensus (see Tomasello and Call 1994, 1997; Heyes 1998 for reviews). Some researchers argue that nonhuman primates are able to understand others' mental states based on observations in the wild or naturalistic situations in captivity; for example, not only apes but also monkeys sometimes deceive other individuals (Menzel 1974; Whiten and Byrne 1988; Hirata 1998). Other researchers, on the other hand, insist that simple trial-and-error learning may account for instances of possible mental-state attribution (Coussi-Korbel and Fragaszy 1995; Mitchell and Anderson 1997; Heyes 1998). At present, there is no conclusive evidence that nonhuman primates can understand another individual's mind.

This controversy may have arisen partly because these studies focus on what nonhuman primates know about various "high-level" psychological processes, such as beliefs or intentions of others. To understand such mental states in others, it is necessary to understand their knowledge. As one's knowledge is changeable, understanding the processes by which knowledge may change is fundamental to various "high-level" psychological processes. One of the most important processes is the relationship between seeing and knowing.

Premack (1988) first asked whether nonhuman primates recognized the relationship between seeing and knowing. Four chimpanzees were tested for discrimination between a "knower" who witnessed a baiting scene and a "guesser" who did not. The subjects would be able to obtain a reward hidden in a container by choosing the knower, who could help open the container. Two of the four subjects eventually came to choose the knower reliably. This result was replicated by Povinelli et al. (1990). Povinelli et al. found a significant preference for the knower trainer in a transfer test phase in which the guesser put on a bag that prevented seeing. Thus, chimpanzees appear to distinguish a person who saw something from a person who did not. On the other hand, rhesus monkeys (*Macaca mulatta*) showed no signs of learning to discriminate between a knower and a guesser after 12–16 weeks (600–800 trials; Povinelli et al. 1991).

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Heyes (1994) criticized that the chimpanzees might simply have learned to choose a knower without understanding the causal connection between a particular sensory input and knowledge formation, because the subjects did not show good transfer to a new situation. In contrast, another study by Povinelli (Povinelli and de Blois 1992) showed that 4-year-old human children quickly discriminated between the two trainers to follow the knower's pointing, although 3-year-olds failed. Povinelli (1994) later accepted Heyes' (1994) conservative view.

Although chimpanzees may not evidence a theory of mind in which a mental state such as ignorance in others is explicitly represented (Whiten 1997), there still seems to be a large gap between chimpanzees and monkeys; chimpanzees at least can learn to recognize the difference between a person who witnesses something and a person who does not, whereas no monkeys succeed in doing so.

Are monkeys totally incapable of understanding, or even learning the relationship between seeing and knowing? Are there any critical differences in the ability to recognize this relationship between apes and monkeys? It is necessary to encode others' gaze direction before understanding this relationship. Evidence shows that capuchin monkeys are better at recognizing gaze cues than rhesus monkeys. Rhesus monkeys exploited a gestural cue consisting of pointing toward a baited object, but they failed to use a gaze cue consisting of head and eyes (Anderson et al. 1996). There is evidence that capuchin monkeys are better than rhesus monkeys at recognizing gaze cues. Itakura (1997) investigated whether chimpanzees, an orangutan (*Pongo pygmaeus*), capuchin monkeys (*Cebus apella*), and 18- to 24-month-old human infants can use experimenter-given cues including eye gaze to choose a baited object in an object-choice task. The following five cues were given to the subjects: 1. *Tap*. The experimenter gazed at and tapped the correct object with the index finger. 2. *Point*. The experimenter gazed at and pointed to the correct object. 3. *Gaze 1*. The experimenter's head and eyes were oriented toward the correct object, at a distance of approximately 15 cm. 4. *Gaze 2*. Similar to gaze 1 but at a distance of approximately 60 cm from the object. 5. *Glance*. The experimenter glanced at the correct object without head movement.

Apes and human infants were able to use all five cues and capuchin monkeys were able to use cues 1–4. Vick and Anderson (2000) also showed that capuchin monkeys learned to use gaze direction as a discriminative cue.

In a recent study, Reaux et al. (1999) found that chimpanzees appeared to learn procedural, stimulus-based rules related to the frontal orientation, the face, and the eyes of the experimenter. They argued that the apes did not attribute the experience of "seeing" in object-choice tasks. It is of course useful for an individual to use another's eye direction to infer what the latter is attending to. However, detecting the orientation of the eyes may not be a prerequisite to recognizing others' attention. Following another individual's head or possibly body orientation may be sufficient. Most primates, humans being an obvious exception, do not have white sclera (Kobayashi and Kohshima 1997) and they usually move the eyes together with the head when they look at objects or events. It may not be ecologically meaningful to ask whether nonhuman primates encode eye orientation in studying their ability to recognize others' attention.

In this study, we asked whether a non-ape primate species can understand the relationship between seeing and knowing, using scenarios in which the knower shows more active inspecting behavior than in the studies by Povinelli et al. (1990, 1991). If the monkeys can recognize the seeing–knowing relationship, they should be able use the knower's inspecting behavior as a discriminatory cue and follow the knower's pointing in preference to that of a guesser. Capuchin monkeys were the subjects in this study. These monkeys typically perform better than macaques in the physical domain including tool use (Izawa and Mizuno 1977; Izawa 1985; Visalberghi and Limongelli 1994; Visalberghi et al. 1995) and object permanence (Schino et al. 1990). If the social intelligence hypothesis stating that "the rudiments of primate society preceded the growth of primate intelligence, made it possible, and determined its nature" (Byrne and Whiten 1988, p. 33) is correct, capuchin monkeys should show better performances than macaques in social tasks, too.

General methods

Subjects and housing

The subjects were one adult male ("Heiji") and three adult female ("Zilla," "Kiki," and "Theta") tufted capuchin monkeys (*Cebus apella*), members of a social group of five kept at the Faculty of Letters, Kyoto University. Heiji and Zilla were 6 years old and Kiki and Theta were 4 years old. They were born in a social group at the Primate Research Institute, Kyoto University and were raised by their biological mothers. All subjects had experience with operant discrimination tasks and all the female subjects had experience with an object-choice task in which they were required to use experimenter's eye gaze and head orientation as cues. The monkeys were not food deprived but received a portion of their daily rations during testing and the remainder in their home cage after testing each day. At the start of the study all subjects were familiar with one of the three trainers described below. Zilla was pregnant throughout the experimental period and gave birth during experiment 3.

Apparatus

The subjects were individually tested in a separate room next to their home cage. A test cage (46×46×52 cm, W×D×H) made of transparent acrylic board with a wire-mesh floor was used. An opening (23×3 cm) in the front panel 8 cm above the floor of the test cage allowed the monkeys to reach out toward three containers (8×8×6 cm) on a tabletop (60×48×30 cm) that was level with the floor of the cage. Three identical transparent containers were secured on a tray out of the subjects' reach during pretraining. These were replaced by opaque brown containers for the experiment. The containers were positioned 36 cm from the front of the test cage and 13 cm apart from each other. In the experimental sessions, rewards were deposited in small cups (3.5 cm in diameter, 2 cm deep) located under each container so that the subjects could not see the reward in the container when the trainer opened it and looked inside.

Preliminary training

Each subject was first trained by successive approximation to respond upon approach of a trainer by reaching toward one of the three identical transparent containers. An experimenter and a trainer were involved in preliminary training, with the combination of experimenter and trainer changing from session to session. To start a trial, the experimenter sat down at the table behind the containers and opposite the monkey. The experimenter showed a piece of sweet potato or apple (the bait) to the monkey and placed the bait under one of the three transparent containers. The experimenter then lifted the container from the table and placed it down again, ensuring that the subject had seen the baiting gesture and the location of the bait. The experimenter then pushed the three containers toward the test cage. This procedure was gradually faded out, and a standard distance of 36 cm between the containers and the test cage was adopted for all trials, which meant that the subject could not touch any of the containers. While the experimenter carried out the baiting procedure the trainer stood with his or her back toward the test area, about 2 m away.

Once baiting was completed, the experimenter stood up, turned around, and went to the far end of the test room. The trainer then approached, sat down at the table, and waited for the subject's response. If the subject reached toward the baited container the trainer lifted that container, picked up the food, and gave it to the subject. If the subject reached toward an empty container, the trainer lifted it to allow the subject to see that no food was hidden under it, and then left the test area, approximately 3 s after which the experimenter returned to the test area to re-present the trial. This correction procedure was continued until the subject chose the baited container.

All four subjects learned to respond to the baited container and receive the food within one session. In the next session three opaque containers were introduced instead of the three transparent containers; otherwise the procedure was identical to that in the previous session.

There were 20 trials per session throughout preliminary training, during which two persons played the role of experimenter and trainer for 10 trials each. Preliminary training ended when all subjects showed mastery of the task (i.e., over 80% of trials correct), which required between five and seven sessions.

Experiment 1

In the first experiment we sought to determine if the capuchin monkeys could learn to choose between a person who looked into each opaque container (the knower) and another person who did not (the guesser).

Methods

Three humans participated in this experiment: an experimenter, a knower, and a guesser. All three humans were present in the test room throughout each session. To start a trial, the experimenter sat in front of the subject and placed a cardboard screen over the three food cups and opaque containers to prevent the subjects from seeing the baiting process. The experimenter hid the food in one of the three opaque containers behind the screen, always lifting and then replacing all containers in the same order to eliminate sound and movement cues. During the baiting process the knower and the guesser both stood about 2 m from the test cage, facing away.

Once the food was hidden, the experimenter removed the cardboard screen and moved to the area where the knower and guesser stood. The knower then turned, approached the test cage, and sat down facing the subject, while the guesser remained facing away in his or her original position. The knower lifted the nearest side of each container in turn, each time bringing his or her head near to it and looking under it. Then the knower got up and stood in a predetermined location behind the table, and gazed at the baited container. The guesser then moved into position behind the table, beside the knower, facing the subject. The experimenter then said "Hai," which served as a signal for the knower and the guesser to each touch the top of one of the containers with the index finger extended. The subjects responded by reaching toward one of the three containers. If the subject chose the container that the knower was touching, the knower lifted the container to remove the food and give it to the subject. If the subject chose the container that the guesser alone touched or the third container, the guesser lifted it to show that it was empty. The knower always touched the baited container while the guesser touched each container quasi-randomly following a predetermined sequence. The knower and the guesser touched the same container on several of the 20 trials per session: three times in session 1, four times in session 2, two times in session 3, and six times per session from session 4 on.

From session 1 to session 10, the three humans played the three roles counterbalanced across sessions. From session 11, the humans randomly switched the three roles on every trial according to a predetermined sequence. The location of the bait was also randomized.

The subjects received 20 trials (plus correction trials) per day. Correction trials (the same trial repeated until the subject made a correct response up to a maximum of 10 trials) were introduced from session 5 for Heiji, from session 39 for Zilla, from session 31 for Theta, and from session 27 for Kiki. After session 11, the subjects were trained until the joint criterion of 80% correct choices in two consecutive sessions and no more than two errors for each individual trainer was reached.

Results and discussion

The results of experiment 1 for each subject are shown in Fig. 1. Although there are considerable individual differences in the number of sessions required to reach criterion, all four subjects eventually learned to respond preferentially to the cue provided by the knower.

During the first 10 sessions, Heiji showed an extreme position preference regardless of the trainers' behavior. This preference faded after the introduction of the correction procedure. The performances of Zilla and Kiki were variable across sessions. In particular Kiki showed a preference for a particular trainer ($\chi^2(2)=51.88$, $P<0.001$), probably because the trainer played the same role within a session. Theta's performances appeared random throughout the first 10 sessions.

After session 11, in which the role of the trainer was switched randomly on every trial, Kiki quickly learned to

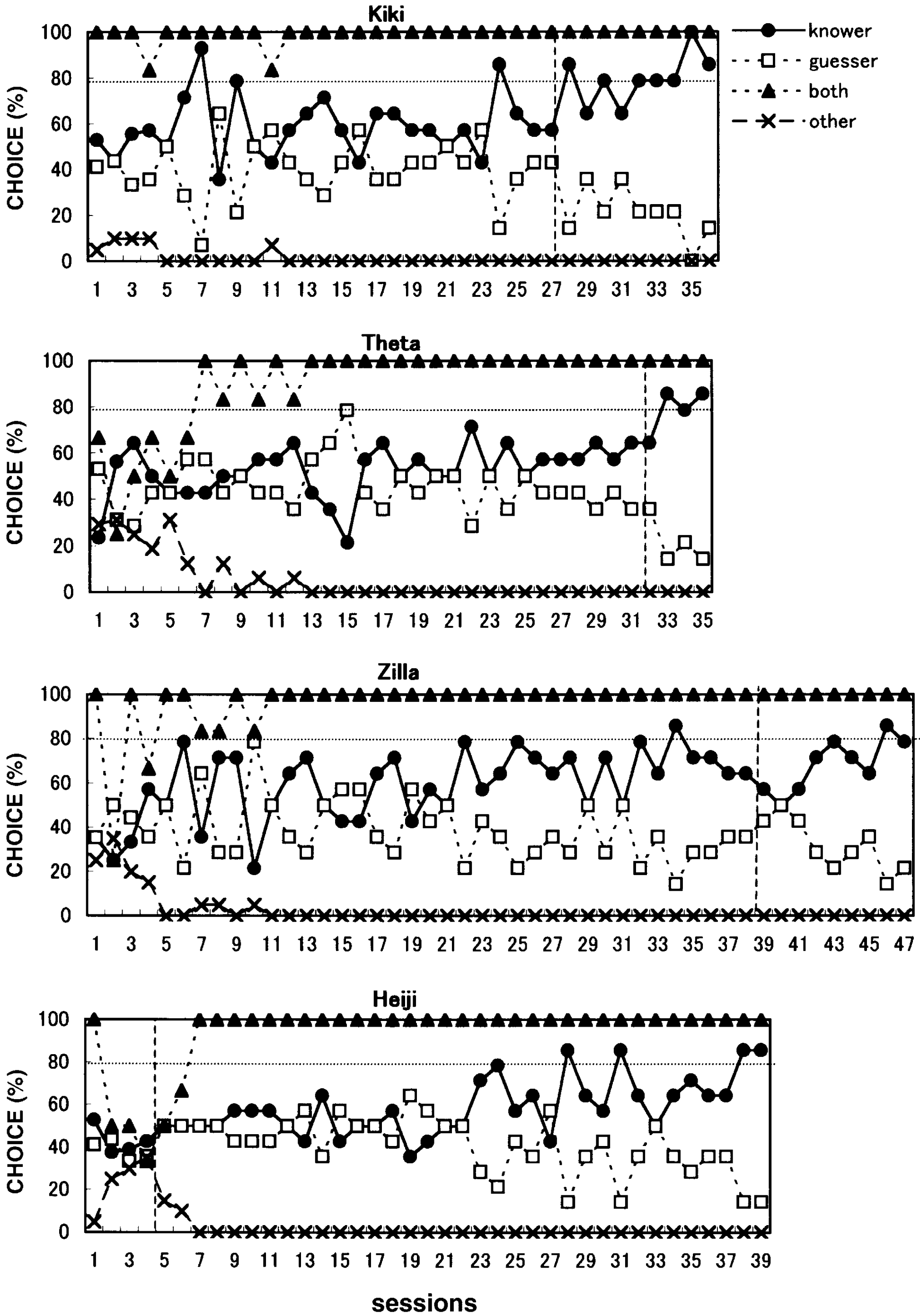


Fig. 1 Percent of choices by each type of container in experiment 1. *Knower* the container the knower touched; *guesser* the container the guesser touched; *both* the container both the knower and the guesser touched; *other* the container neither touched. The *vertical broken lines* denote the first session in which a correction procedure was incorporated and *dotted lines* are the criteria

reach toward the container touched by the knower. She reached criterion in the 33rd session. Kiki carefully watched the knower's actions and excitedly reached toward the containers or tapped on the table as the knower looked into each container. Theta reached criterion in the 35th session. Zilla needed 47 sessions to reach criterion; this was achieved quickly after the correction procedure was introduced, which is reminiscent of Theta's performance. Heiji reached the criterion after 39 sessions but actually needed the greatest number of trials to reach criterion because of repeated correction trials. Heiji's difficulty in learning this task may be due to the fact that unlike all the female subjects, he had no prior experience of using attentional cues of people in choice tasks.

On what basis did the capuchin monkeys discriminate between the knower and the guesser? There were two potentially critical cues other than the knower's looking into the containers. First, only the knower touched the containers before the choice phase of a trial. The subjects may have simply learned to stay with the trainer who touched the containers, paying no heed to the knower's looking behavior. Second, the knower always arrived at the test

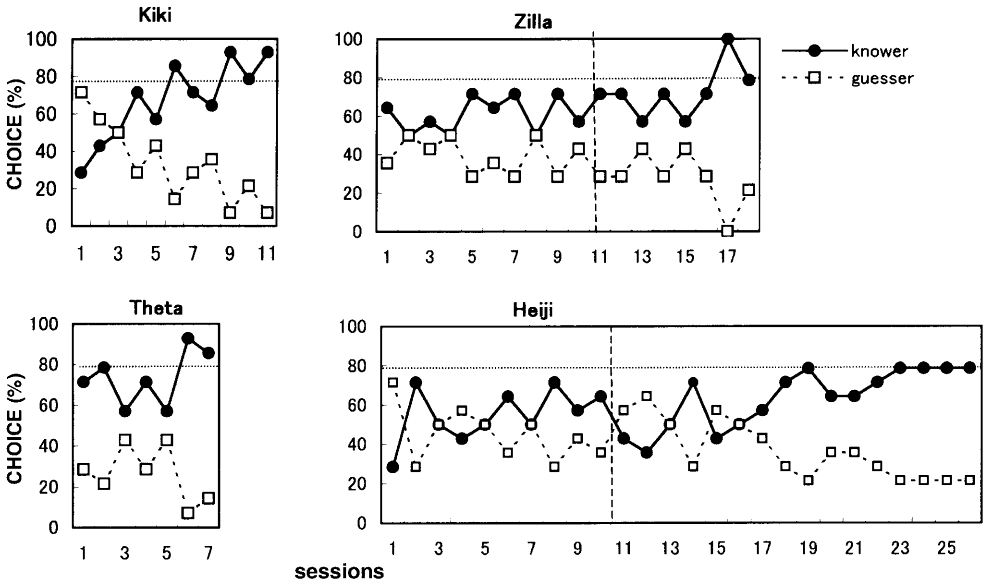


Fig. 2 Percent of choice by each subject for each type of container in experiment 2. Other details as in Fig. 1

area before the guesser. The subjects may have simply learned to track the trainer who appeared first. The following two experiments examined the role of these two potential cues.

Experiment 2

Experiment 2 addressed the potential importance of the fact that only the knower touched the containers. In this experiment, the guesser also touched all the containers, but without lifting them. If the subjects did not simply rely on the knower's touching as a cue, their performance should transfer quickly and positively to this new situation.

Methods

This experiment was conducted immediately after completion of experiment 1. The procedure was identical to that used in the final condition of experiment 1 with the following two exceptions: (1) the knower stood up and turned to face away from the subject after looking under the containers, and (2) the guesser sat on the chair in front of the subjects and then carefully touched the top of each container, using the same hand and in the same order as the knower did during the looking phase of the trial. Immediately after the guesser had touched all three containers, the knower turned around and the two trainers touched a container and waited for the subject to respond.

A correction procedure was employed for Heiji and Zilla after session 11. The other two subjects (Theta and Kiki) were trained without a correction procedure because they learned to discriminate between the two trainers quickly (see below).

Results and discussion

The results of experiment 2 for each subject are shown in Fig. 2. No subject ever chose a container ignored by both trainers, and they always chose a container that both the knower and the guesser touched; therefore the data for these two types of choices were excluded from further analysis.

Theta appears to have shown transfer to this novel situation. In fact, if we combine the first two sessions, Theta's percent of choice for the knower was significantly above chance (binomial test: $P<0.05$). However the other three subjects did not show such generalization. This suggests that Theta did not use the touching action of the knower as a cue for discrimination, whereas the other subjects probably did in experiment 1. As can be seen in Fig. 2, however, all the subjects reached the criterion earlier than in experiment 1. Theta (7 sessions) and Kiki (11 sessions), in particular, learned quickly. Zilla took 18 sessions to reach the criterion, but she always selected the container touched by the knower more often than the container touched by the guesser. After the correction procedure was introduced, Heiji gradually learned to discriminate between the two trainers as well. Thus, at the end of experiment 2, all the subjects clearly used something other than the touching of the containers by the knower as the basis for their discriminatory responses.

Experiment 3

Experiment 3 aimed to examine if the subjects used the temporal order of the trainers' arrival at the test area as a cue for discrimination. In this experiment, the knower and the guesser appeared in random order. If the monkeys did not use order of appearance as a discriminatory cue, their performance should transfer positively and quickly to this new situation.

Methods

This experiment was conducted immediately after completion of experiment 2. The procedure was identical to that used in experiment 2 except that the knower and the guesser appeared in a random order before touching and/or looking under the containers. As before, the guesser touched each container in the same order as the knower looked under them.

Heiji and Zilla were trained using the correction procedure after session 12, Theta after session 11, and Kiki after session 15. Zilla gave birth between the 26th and 27th session.

Results and discussion

The performances of each subject in experiment 3 are presented in Fig. 3. As the subjects never responded to a container neither trainer touched and always chose a container both trainers touched, we exclude the data from these two cases from the analysis.

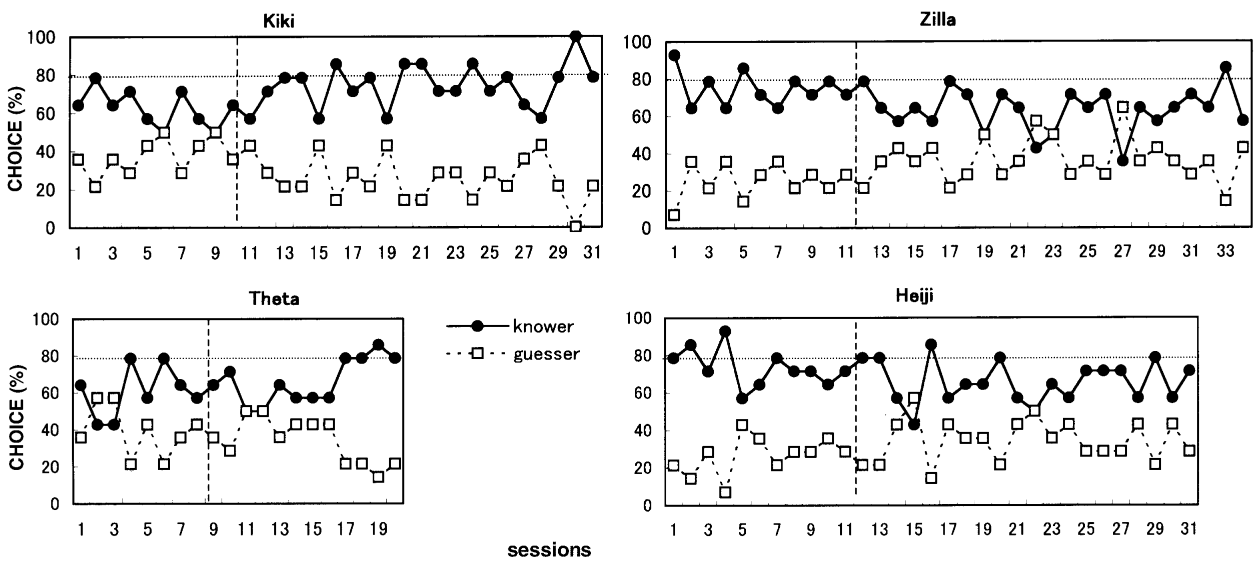
Kiki, Zilla, and Heiji appear to have shown transfer to this novel situation. In fact, if we combine the first two sessions, their percent of choice for the knower was significantly above chance (binomial test: $P<0.05$ for each subject). However Theta did not show such generalization. This suggests that Theta used the temporal order of arrival of the two trainers as a discriminatory cue, while the other subjects did not. It required 18 sessions for Theta to reach criterion and 30 sessions for Kiki. Neither Zilla nor Heiji reached criterion after 30 sessions, but both consistently selected the container touched by the knower. If we combine the final 2 sessions, performances of Zilla and Heiji were significantly above chance (binomial test: $P<0.05$ for each subject). Thus, by the end of experiment 3, all four subjects were using the knower's looking behavior as a cue as the basis for discrimination between the two trainers.

General discussion

The results presented here provide evidence that capuchin monkeys can recognize the relationship between seeing and knowing, a relationship that rhesus macaques failed to show any evidence of learning (Povinelli et al. 1991). All four capuchin monkeys learned to choose by following a trainer who looked into each container in preference to a trainer who simply touched the containers. The results suggest that not only apes but also some monkeys have the ability to learn the relationship between seeing and knowing. How can the difference between the results of the two studies, the present study and Povinelli et al.'s (1991), be explained?

Differences in the procedures of the two studies may be the most important. First, in Povinelli et al. (1991), the knower hid the bait in one of three containers shielded by a cardboard screen. Therefore, the subjects had to infer that the knower, or the hider, saw the bait. In contrast, in the present study, the knower showed the subjects a sequence of acts consisting of lifting, looking into, and putting down each of the three containers. Thus, the subjects directly witnessed the scene in which the knower inspected the contents of the containers; this was not the case in Povinelli et al. (1991). Furthermore, in Povinelli et al. (1991) the guesser was outside of the test room while the knower hid the bait and was then called back after the baiting procedure was completed. This requires that subjects identify the person who left the test room at the start of a trial as the person who comes in after the baiting procedure, which implies memorizing much more complicated information than in the present study. Here, both the knower and the guesser remained in the test room during baiting, which may have reduced cognitive load.

Fig. 3 Percent of choice by each subject for each type of container in experiment 3. Other details as in Fig. 1



Another potentially important factor concerns the social tendencies of the species used in these studies. To stare at another's eyes represents a threat action for rhesus monkeys, whereas this is not such a salient cue for capuchin monkeys. In the test situation, if a rhesus subject perceives the trainer (a human) to be dominant, it may be difficult for the subject to watch the experimenter's eyes. In contrast, capuchin monkeys do not hesitate to make eye contact with humans, and this tendency may be beneficial to capuchins in this kind of task. In fact, rhesus monkeys have greater difficulty in recognizing human eye direction compared to capuchin monkeys (Anderson et al. 1996; Itakura 1997). If the subjects hesitate to examine the others' eyes, it might be difficult for them to recognize the relationship between seeing and knowing.

It should be recalled that three of the four monkeys (Theta, Kiki, Zilla) had previously learned to recognize explicit gestural and postural cues, including eye gaze, to choose a baited object in a procedure similar to that used by Itakura and Anderson (1996). However, although this explicit training might have helped in understanding the seeing–knowing relationship in this study, such training clearly was not necessary for success because the fourth subject (Heiji), with no such prior experience, also succeeded.

Another difference between the present study and that of Povinelli et al. (1991) concerns the apparatus. We used three opaque containers on a tabletop. The subjects could obtain the bait by reaching toward the container being touched by the knower. Povinelli et al. (1991) used an apparatus from which the subjects obtained the bait by pulling on a handle. Thus, there is a difference in the role of the knower in the two studies. In Povinelli et al. (1991) the knower only provided the subjects with a discriminative cue, whereas in the present study the knower not only presented the crucial cue (looking behavior) but also gave them bait. Therefore, the relationship among the knower's behavior, the bait, and the baited container was much more straightforward than in Povinelli et al. (1991).

Finally, the number of training trials between the two studies is noteworthy. The subjects in the present study were trained until their performance reached criterion with a correction procedure. Povinelli et al. (1991) did not use a correction procedure; they established four test phases and changed the test condition every 4 weeks (200 trials). The capuchin monkeys in this study received many more trials than the rhesus macaques in Povinelli et al. (1991). However, no rhesus monkey ever showed any signs of learning throughout the training period (200 trials), which suggests that the difference in the number of trials is not sufficient to account for the difference in performance.

In summary, we have found that capuchin monkeys learned to use the inspecting action of the knower as a discriminative cue. This result suggests that capuchin monkeys also can learn to recognize the relationship between seeing and knowing. However, we must remain cautious in concluding that capuchin monkeys understand completely the causal connection between seeing and knowing. There may be simpler clues to discriminate the knower and guesser other than those addressed in experiments 2 and 3. We suggest that this possibility could be further examined by diversifying the behavior of the knower. For example, by using containers of different shapes, or with lids, the generalizability of the monkeys' discrimination could be assessed. This principle could also be applied to see what behaviors of the guesser are exploited as cues.

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