

Do orangutans (*Pongo pygmaeus*) know when they do not remember?

Chikako Suda-King

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Abstract Metacognition refers to the ability to monitor and control one's own cognitive activities such as memory. Although recent studies have raised an interesting possibility that some species of nonhuman animals might possess such skills, subjects often required a numerous number of training trials to acquire the effective use of metacognitive responses. Here, five orangutans (*Pongo pygmaeus*) were tested whether they were able to escape spatial memory tests when they did not remember the location of preferred reward in a relatively small number of trials. The apes were presented with two identical cups, under one of which the experimenter hid a preferred reward (e.g., two grapes). The subjects were then presented with a third container, "escape response", with which they could receive a less preferred but secure reward (e.g., one grape). The orangutans as a group significantly more likely selected the escape response when the baiting of the preferred reward was invisible (as compared to when it was visible) and when the hiding locations of the preferred reward were switched (as compared to when they remained unchanged). Even when the escape response was presented *before* the final presentation of the memory test, one orangutan successfully avoided the test in which she would likely err. These findings indicate that some orangutans appear to tell when they do not remember correct answers in memory tests.

Keywords Metacognition · Orangutans · Escape response

Recent studies have raised an interesting possibility that some species of nonhuman animals might be able to monitor their own cognitive activities, which is the ability called metacognition or cognition about one's own cognition (Nelson and Narens 1990, 1994). For instance, Smith and colleagues investigated whether rhesus monkeys and a dolphin could monitor their own cognitive indeterminacy in perceptual threshold tasks (Smith et al. 1995, 1997; Shields et al. 1997; see also Smith et al. 2003a, b for review). In their experiments, the subjects were asked to assign perceptual stimuli to two categories (e.g., boxes containing exactly 2,950 illuminated pixels vs. those of any fewer pixels). The task difficulty was adjusted such that it approached the animals' perceptual threshold, in which performance level was around chance. The subjects were given three kinds of response choices. The first two responses were primary responses, and designated as the two discrimination categories (e.g., dense vs. sparse), respectively. A correct response (assigning a given stimulus to a correct category) yielded an immediate food reward, whereas a wrong response produced a long time-out. The third response, which was called an uncertainty response, allowed the animals to quit the current trial and receive a guaranteed-win trial in which the animals were always rewarded but after some delay. It was found that the dolphin and rhesus monkeys selected the uncertain response most when a given stimulus fell around their perceptual threshold. That is to say, the animals most likely declined to take tests when their success rate was around a chance level. This pattern was analogous to human subjects who participated in the same perceptual discrimination tasks. In addition, the dolphin's hesitant behaviors (e.g., wavering) peaked around his perceptual threshold, and were distributed like the uncertain response. These findings suggest that rhesus monkeys and a dolphin were able to use the

C. Suda-King (✉)
Think Tank at the Smithsonian National Zoological Park,
Animal Programs Office, Connecticut Ave. NW,
Washington, DC 20008-2598, USA
e-mail: chimpkako@hotmail.com; kingc@si.edu

uncertain response appropriately when their cognitive indeterminacy was presumably intense, raising the possibility that some animals are able to monitor their own uncertainty.

Rhesus monkeys further demonstrated their successful use of uncertain response in different experimental settings other than perceptual threshold tasks. Adopting the serial-probe recognition task, Smith et al. (1998) investigated whether rhesus monkeys could use the uncertain response to escape difficult trials in which their memories were indeterminate. The monkeys were presented with a list of items sequentially, which was followed by a probe stimulus, and were asked to judge whether the probe had been in the list or not, by selecting either of three responses (two primary responses and the uncertain response). The monkeys showed both primacy and recency effects, performing better when the probe had been the first or the last item of the list than when the probe had been in a position elsewhere. Most importantly, the monkeys' uncertain response was the mirror image of memory performance. The monkeys selectively quit trials when the probe had been in a middle position of the list and thus was difficult to judge. The researchers also conducted the same task on the monkeys but forced the subjects to complete all memory trials by not giving them the option of the uncertain response. The monkeys tended to perform better when the uncertain response was available than when it was not, which suggests that the animals selectively escaped trials in which they would likely make an incorrect choice. Moreover, recent studies by Smith and his colleagues revealed that rhesus monkeys generalized their appropriate use of the uncertain response to discrimination learning, mirror-image matching to sample (Washburn et al. 2006) and numerical judgments (Beran et al. 2006). As in the serial recognition task, the subjects used the uncertain response more often on trials in which they would perform poorly. These findings suggest that rhesus monkeys' use of the uncertain response was substantially flexible and was unlikely to be a mere byproduct of extensive training.

Smith's group also found that rhesus monkeys were able to make accurate confidence judgments retrospectively in a perceptual threshold task (Shields et al. 2005). In this study, the subjects were asked to assign visual stimuli to two categories (i.e., dense vs. sparse), and given an opportunity afterwards to judge their confidence in their response. Pink and blue bars, which signified high- and low-confidence respectively, appeared on the computer monitor. A high-confidence response resulted in either a larger food reward (when the monkeys' discrimination response was correct) or a longer time-out (when it was incorrect), while a low-confidence response resulted in either a smaller food reward or a shorter time-out. The monkeys made high-confidence choices predominantly for easy stimuli, whereas

low-confidence choices peaked around their perceptual threshold. In fact, the monkeys' performance was more accurate when they rated their confidence as a high level than when they rated it as a low level. Similarly, Kornell et al. (2007) revealed that rhesus monkeys, which had been previously trained to make retrospective confidence judgments on perceptual tasks, transferred that ability to both a new perceptual task and a delayed matching-to-sample task (see also Son and Kornell 2005). Taken together, rhesus monkeys seem to have the ability to monitor their uncertainty not only prospectively but also retrospectively.

There has been also some evidence that some species of primates can seek critical information appropriately when they lack it. Call and Carpenter (2001) tested three orangutans and 11 chimpanzees in an object choice setting. The apes were presented with two or three tubes that were placed in parallel, facing perpendicularly toward the subjects. The experimenter hid a food reward in one of the hiding locations in full view of the subjects in some trials, while the hiding procedure was occluded with a screen in other trials. The apes looked into tubes more often when the experimenter did not reveal the location of food than when the hiding process was shown. In addition, the subjects more likely looked into tubes when some delay was imposed as compared to when they could immediately make a choice. Call (2005) extended this study by testing bonobos and gorillas as well as other subjects of orangutans and chimpanzees. It was found that subjects of the four species looked into tubes at a greater rate when they did not know the location of food than when they possessed this knowledge. The findings of the looking study were further replicated with rhesus monkeys (Hampton et al. 2004), but interestingly not with capuchin monkeys and domesticated dogs (Bräuer et al. 2004; Paukner et al. 2006). In the same line of investigation but using a different experimental procedure, Kornell et al. (2007) examined whether rhesus monkeys could effectively seek "hints" when they were learning novel sequences of stimuli. The primary task was a simultaneous chaining paradigm in which the monkeys were required to learn to touch four pictures in a predetermined order by trial and error. Once the subjects became proficient in the task, they were introduced to a "hint-seeking" icon, which appeared with four testing items. Selecting the icon resulted in highlighting the item to which the monkeys should next respond. If the monkeys completed a trial correctly without requesting any hints, they were rewarded with a highly preferred candy. If they sought one or more hints to complete the trial correctly, they received a less desirable pellet. If they were not able to touch the items in the correct order, there was no food reward. The researchers found that the monkeys came to seek a hint less often as the accuracy of completing the list increased. Also, they sought a hint more often with novel lists than with a

familiar one. Altogether, these results suggest that apes and rhesus monkeys, but probably not capuchins and dogs, appear to monitor their own memory, and know whether the memory of task-relevant information is available or not.

Although the above studies have explored promising behavioral measures for the empirical investigation of animal metacognition, the findings are still vulnerable to an alternative explanation: Animals might have adjusted their behaviors according to the perception of task difficulty rather than the assessment of their own cognitive components. In other words, it is possible that, having actually faced a primary task, subjects found the task very hard on some trials and made a seemingly metacognitive response based on the degree of uneasiness caused by such difficulty. There have been only two studies that rule out this possibility (Hampton 2001; Inman and Shettleworth 1999). Using a delayed matching-to-sample task, Hampton (2001) investigated whether two rhesus monkeys could decline to take a memory test when they forgot. The monkeys were presented with a sample stimulus that they had to select from among four alternatives (one matched the sample while the others were foils) after the delay. A critical point of this experiment is that the animals were given two response choices and asked whether they would take a memory test or quit it after the forgetting interval and *before* the four stimuli were presented. If the monkeys selected the first response, the memory test proceeded and the four stimuli appeared. A correct choice produced a highly preferred food reward, whereas an error resulted in a time-out. If the monkeys selected the second response (the escape response), the trial terminated and the animals received a guaranteed-win trial in which they were always rewarded but with a less preferred food. The escape response was not available in one third of trials and the monkeys were forced to complete the memory task in these trials, while it was available in the rest of trials. The monkeys performed significantly better with the escape response available, which indicates that the monkeys adaptively chose to decline memory tests when memory for the sample image was relatively poor. Both of the subjects also declined to take memory tests when no sample was presented beforehand. Note that the subjects in Hampton's study had to decide whether they would take memory tests before the presentation of the tests, which rules out the possibility that the subjects' decision were merely based on their direct perception of task difficulty. Inman and Shettleworth (1999) conducted a similar study on pigeons and found that the subjects failed to use the escape response effectively unlike Hampton's monkeys. Given that only two species have been tested in this paradigm, it is necessary to test more subjects and different species in a similar setting.

The purpose of the current study was to investigate whether orangutans could quit a spatial memory test when

they did not remember the location of hidden food in a testing paradigm similar to Hampton's (2001) and Call and Carpenter's (2001) studies. The study was explorative in its nature, and attempted to search for sound methods to examine metacognitive skills in orangutans. I chose a series of spatial working memory tests as primary tests for the current metacognitive experiments because previous studies have shown that orangutans are competent to locate hidden food not only with various retention intervals but also with spatial changes in test stimuli (e.g., Barth and Call 2006; Call 2001, 2003; de Blois et al. 1998, 1999; MacDonald and Agnes 1999). The study also included a relatively small number of trials to minimize the effect of learning. This makes a strong contrast with the previous research in which animals originally required thousands of training trials to learn the effective use of a metacognitive response (but with exceptions of Call and Carpenter 2001; Call 2005).

The experimenter presented orangutans with two identical blue cups and baited one of them with a preferred reward. She then placed a yellow container, which contained a less preferred reward, between the blue cups, and let the subjects select one of the three alternatives. Choosing a blue cup would result in receiving either the preferred reward (if the subjects chose the baited one) or nothing (if they chose the empty one), whereas selecting the yellow container would result in obtaining the less preferred reward. Thus, the yellow container served as an "escape response" or "safe choice" with which the subjects could quit the memory test by receiving the less preferred but secure reward. I systematically modified the following four factors in a series of five experiments: (1) the visibility of the baiting of the preferred reward, (2) the locations of the blue cups, (3) the availability of the escape response, and (4) the timing of the presentation of the escape response. I hypothesized that if the orangutans could tell when they did not remember the location of the preferred reward, they should be able to use the escape response effectively based on their own memory. More specifically, (1) the orangutans should use the escape response more often when they had not seen the baiting of the preferred reward than when they had seen it, (2) they should escape the memory test more frequently when the locations of the blue cups were switched (i.e., when the task was more demanding) as compared to when the cup locations remained unchanged, (3) the orangutans should perform better in the memory test, by effectively escaping the test for which they forgot the answer, when the escape response was available than when it was unavailable because in the latter case they were forced to take the test even when they forgot, and (4) they should maintain such performance even when the escape response was presented *before* the final presentation of the memory test.

Nonparametric tests were used for all subsequent analyses due to the small sample size of the current study. Because I had specific hypotheses, all analyses were one-tailed unless otherwise stated. All *P*-values were exact, and the probability of a Type I error was maintained at 0.05. When there were more than two testing conditions (in Experiments 2–4), which would yield multiple possible comparisons, *P*-values should be adjusted accordingly. However, the sample size of the current study was too small to bear such adjustment. In order to solve this problem, conditions were collapsed to reduce the number of comparisons. In addition, as for the subjects' escape use, planned comparisons were conducted to compare conditions in pairs with all variables constant except for a hypothesis-related one (e.g., the visibility of baiting of the preferred reward).

Experiment 1

The purpose of this experiment was to assess whether orangutans could effectively escape a memory test based on their own memory about the location of preferred reward. I presented orangutans with a pair of identical blue cups and hid a highly preferred reward (i.e., a grape) under one of them. The baiting procedure was visible in some trials, whereas it was hidden in other trials. I then presented a yellow plastic container filled with less preferred food (i.e., dog food) between the blue cups. Selecting a blue cup resulted in receiving either the high-value reward or nothing, whereas choosing the yellow container always resulted in receiving the low-value reward. The latter choice therefore served as an escape response. If the orangutans could tell when they did not remember the location of the preferred reward, they should make the safe choice more often when the baiting procedure was hidden as compared to when it was visible.

Method

Subjects

Six orangutans housed at the Smithsonian National Zoological Park served as subjects (see Table 1 for additional information). There were 1 adult male, 1 juvenile male, 3 adult females, and 1 juvenile female, and all subjects were mother-reared. The subjects had previously participated in various kinds of cognitive tasks such as language acquisition, object permanence (de Blois et al. 1998, 1999), mirror self-recognition (Shumaker and Swartz 2004), and computerized list learning tasks (Swartz and Himmanen 2006), but had never received any experiments assessing metacognitive abilities. The subjects lived together in a social group

Table 1 Age, sex, birthplace, and rearing histories of subjects included in the study

Subject	Species	Age (years)	Sex	Birthplace	Rearing history
Batang	<i>Pongo pygmaeus</i>	10	F	Captivity	Mother
Bonnie	<i>Pongo pygmaeus</i>	30	F	Captivity	Mother
Iris	<i>Pongo pygmaeus</i>	19	F	Captivity	Mother
Kiko	<i>Pongo pygmaeus</i>	19	M	Captivity	Mother
Kyle	<i>Pongo pygmaeus</i>	10	M	Captivity	Mother
Lucy	<i>Pongo pygmaeus</i>	33	F	Captivity	Mother

M male, *F* female

in indoor and outdoor compounds. During the testing, the subjects were separated from their group members and individually tested in their indoor cages. The animals were fed two times a day on a diet of fruits, vegetables, monkey chow, and occasionally meat and eggs, and received various kinds of edible enrichment items in the afternoon. Water was available ad libitum and the subjects were not food deprived during the testing.

Apparatus

I used two opaque blue plastic cups (7 cm top diameter × 6 cm bottom diameter × 10 cm in height) and an opaque yellow plastic container (11 cm diameter × 5 cm in height) as hiding locations of rewards. The blue cups were paired with two blue plastic dishes (9 cm top diameter × 7.5 cm bottom diameter × 1.5 cm in height) so that a grape could be placed on a dish and covered with a cup. The yellow container had a cover, which prevented the subjects from seeing the contents, and were filled with dog food. I also used a four-sided wooden barrier (34.5 cm width × 19.5 cm depth × 20 cm in height) to visually block the baiting procedure from the subjects on some trials (see below).

The cups and container were presented on a Plexiglas platform (94 cm length × 25.5 cm width × 2.5 cm in height), which rested on a wooden table (94 cm length × 61 cm width × 83–92 cm in height) positioned in front of a Plexiglas panel (either 107 cm × 92 cm, 135 cm × 92 cm, 145 cm × 92 cm, or 119 cm × 33 cm, depending on a cage used for testing), which was attached onto cage mesh with hooked metal bolts. Each panel had three circular holes (3.3 cm in diameter and 18.5 cm apart from each other) on its lower part just above the platform so that the subjects could indicate their choices by sticking out their fingers through one of the holes. The platform had two plastic handles on a side facing the experimenter and could be easily slid back and forth on the table. The height of the table could be adjusted appropriately according to a cage used for testing.

A Panasonic video camera was used for filming testing sessions, and the experimenter wore an earphone metronome to count the length of each testing trial. The experimenter also wore a baseball cap throughout testing in an attempt not to give the subjects any social cues. Upon their choice, she looked down at the center of the platform such that the cap's brim partially blocked her upper face from their perspective.

Procedure

Training. Prior to the testing, the experimenter trained the subjects to point at a piece of food (e.g., grapes, dog food, and popcorn) that was placed in front of a hole in the Plexiglas panel. The subjects readily learned to request a reward by sticking out their finger through a corresponding hole. After the pointing training, the experimenter checked the subjects' food preference to determine appropriate rewards for testing. Two types of food items were simultaneously presented to the subjects so that they could select one of the rewards. All subjects preferred grapes to other food items, and grapes were thus chosen as high-value reward. Dog food was chosen as low-value food because the subjects liked it but to a lesser extent than grapes.

Pre-test. After the completion of the training phase, the subjects proceeded to a pre-test phase. The pre-test phase consisted of three tests: *preference test*, *low-value food association*, and *memory test*. The *preference test* was conducted to make sure that the orangutans preferred grapes to dog food. The experimenter stood in front of each subject and placed the platform in front of and about 36 cm away from the Plexiglas panel. She held a grape and a piece of dog food, one in each hand, and placed them in front of two holes in the Plexiglas panel. Finally, the experimenter pushed the platform against the Plexiglas panel for the subject to choose one of the rewards. The selected reward was given to the subject. The locations of the two different rewards were counterbalanced and randomized across trials with a restriction that a grape did not appear in the same location in more than two consecutive trials. The subjects were given 24 trials in one session, and they all preferred grapes to dog food (96%>).

The *low-value food association* was conducted to establish the association between choosing the yellow container and receiving one piece of dog food. The experimenter stood in front of each subject and placed the platform in front of and about 36 cm away from the Plexiglas panel. She placed the yellow container filled with dog food in front of one of the holes in the Plexiglas panel. She then pushed the platform against the Plexiglas panel for the subject to point at the container. Once the subject did so, the experimenter lifted the container's cover, picked up one piece of dog food, and gave it to the subject. The location of

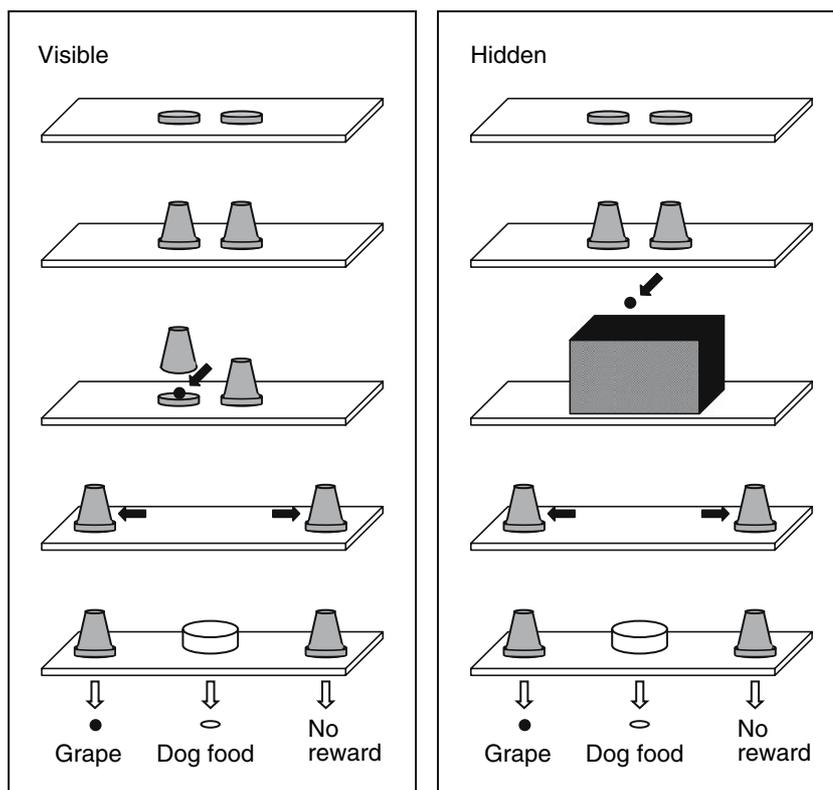
the yellow container was counterbalanced and randomized across trials with a restriction that it did not appear in the same location in more than two consecutive trials. The subjects were given 24 trials in one session and always pointed at the yellow container to receive dog food.

The *memory test* was the last test of the pre-test phase. The purpose of this test was to assess the subjects' baseline performance in a memory task in which a grape was hidden under one of the two blue cups. The experimenter stood in front of each subject and placed the platform in front of and about 36 cm away from the Plexiglas panel. She placed a pair of the blue dishes side by side on the center of the platform and covered them with the blue cups. She then lifted one of the cups, placed a grape on the dish underneath, and covered the reward with the cup in full view of the subject. Once the baiting was completed, the experimenter slid the cups (together with the dishes underneath) from the center to opposite sides of the platform in such a way that the two cups came in front of the far right and left holes in the Plexiglas panel. Finally, the experimenter pushed the platform against the Plexiglas panel for the subject to choose one of the cups. The experimenter gave the grape to the subject only when it chose the baited cup. If the subject chose the empty cup, it was shown the correct location of the grape but did not receive any reward. The location of the baited cup was counterbalanced and randomized across trials with a restriction that a grape did not appear in the same location in more than two consecutive trials. One session consisted of 18 memory trials, six preference trials, and six low-value food association trials, which were mixed and randomized. The testing proceeded once the subject's performance was significantly above chance in the memory trials ($14/18 \geq$, $P \leq 0.031$, Binomial test) in two consecutive sessions. All subjects except for Kyle reached the criterion in 2–13 sessions and proceeded to testing.

Test. The testing consisted of the following two conditions, which differed only in whether the orangutans were able to see the baiting of grape or not (see Fig. 1):

Visible. In this condition, the procedure was identical to that of the pre-test memory test until the experimenter hid a grape under one of the blue cups and slid them from the center to opposite sides of the platform. She then placed the yellow container (which was filled with dog food) in front of the center hole in the Plexiglas panel so that it was located between the blue cups. Finally, the experimenter pushed the platform against the Plexiglas panel for the subject to choose one of the stimuli. The subject received the corresponding contents of the selected stimulus. If the subject selected the baited blue cup, it received the grape. If the subject selected the empty blue cup, it was shown the correct location of the grape but did not receive any rewards. If the subject chose the yellow container, the experimenter lifted its cover and gave one piece of dog

Fig. 1 Examples of trials from the two testing conditions in Experiment 1. Each subject received 24 trials per condition



food to the subject. Each trial was timed by the metronome and lasted about 10 s from the moment when the experimenter covered the grape with the blue cup until the platform touched against the Plexiglas panel (retention interval = about 10 s).

Hidden. This condition was identical to the Visible condition except that the baiting of the grape was hidden from the subject. After presenting the blue cups with the blue dishes underneath on the center of the platform, the experimenter covered them with the wooden barrier with its two opening sides facing down and towards the experimenter. She then showed a grape to the subject, and lifted each cup behind the barrier, surreptitiously hiding the grape under one of them out of the subject's view. The experimenter removed the barrier, and the rest of the procedure was identical to the Visible condition. Each trial was timed by the metronome and lasted about 10 s from the moment when the experimenter removed the wooden barrier until the platform touched against the Plexiglas panel (retention interval = about 10 s).

I conducted 24 trials for each condition per subject. Besides the testing trials, I interspersed 24 pre-test preference trials among the trials of the two testing conditions on the purpose of assessing the orangutans' food preference and maintaining their motivation throughout the testing. Each subject received four sessions consisting of 18 trials each, for a total of 72 trials. Each session was a random mixture of 12 testing trials (six trials per condition) and six

pre-test preference trials. The position of a hidden grape was counterbalanced and randomized with a restriction that it did not appear in the same position in more than two consecutive trials.

Results

Memory performance and escape response

The orangutans as a group during the test selected a grape instead of dog food significantly above chance in the preference trials, $M = 92.5\%$, $SEM = 3.81$, $z = 2.04$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. When choosing a blue cup rather than the yellow container, the group selected the baited one significantly above chance in the Visible condition, $M = 92.2\%$, $SEM = 3.58$, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test, whereas their performance did not significantly differ from the chance level in the Hidden condition, $M = 49.6\%$, $SEM = 5.38$, $z = 0.14$, $N\text{-ties} = 5$, $P = 0.500$, Wilcoxon signed rank test. The orangutans as a group performed significantly better in the Visible condition than in the Hidden condition, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. Therefore, the subjects were competent in the memory test when they had seen the experimenter placing a grape under one of the blue cups, whereas they did not know the location of the grape when the baiting was invisible. However, contrary to the prediction, the group did not select the escape

response (i.e., the yellow container) significantly more often in the Hidden condition than in the Visible condition: Visible, $M = 9.2\%$, $SEM = 4.81$; Hidden, $M = 12.5\%$, $SEM = 8.63$, $z = 0.18$, $N\text{-ties} = 4$, $P = 0.500$, Wilcoxon signed rank test.

Individual analyses

Table 2 presents the performance of each subject in the two testing conditions and preference trials. Consistent with the results of the group analysis, all subjects showed a significant preference for a grape over dog food in the preference trials, $P < 0.008$, Binomial test, two-tailed. Likewise, when taking the memory test (i.e., when choosing a blue cup), all subjects performed significantly above chance in the Visible condition ($P < 0.02$, Binomial test, two-tailed), whereas none of them significantly exceeded the chance level in the Hidden condition.

As for the use of the escape response, one adult female, Bonnie, was significantly more likely to select the yellow container in the Hidden condition than in the Visible condition, $P = 0.035$, McNemar test. Had she had learned to

Table 2 Subjects' performance in two testing conditions and preference trials in Experiment 1

Subject	Frequency			Success (%)	Escape (%)	Preference (%)
	Correct	Wrong	Escape			
Batang						91.7**
Visible	15	4	5	78.9*	20.8	–
Hidden	11	10	3	52.4	12.5	–
Bonnie♣						79.2**
Visible	18	1	5	94.7**	20.8	–
Hidden	4	9	11	30.8	45.8	–
Iris						100**
Visible	24	0	0	100**	0.0	–
Hidden	14	10	0	58.3	0.0	–
Kiko						100**
Visible	22	2	0	91.7**	0.0	–
Hidden	14	9	1	60.9	4.2	–
Lucy						91.7**
Visible	22	1	1	95.7**	4.2	–
Hidden	11	13	0	45.8	0.0	–

Success (%) = a percentage of trials in which the subjects selected the baited blue cup when they selected one of the blue cups; Escape (%) = a percentage of trials in which the subjects selected the yellow container; Preference (%) = a percentage of trials in which the subjects selected a grape in the preference trials

* $P < 0.05$, ** $P < 0.01$, above chance. Binomial tests (two-tailed, exact P -values) were used. ♣ = the subject who significantly more likely selected the yellow container in the Hidden condition than in the Visible condition, $P = 0.035$, McNemar test

escape the memory test in the Hidden condition, she should have gradually increased her escape choice during the course of trials. However, this was not the case. Table 3 presents Bonnie's performance in each trial of the two testing conditions. In the Hidden condition, Bonnie chose the escape response eight times in the first half of the trials, while doing so only three times in the second half. Furthermore, although she took the memory test on the first trial, choosing the empty blue cup, she escaped the memory test five times in a row afterwards. In comparison, in the Visible condition, she escaped the memory test only three times in the first half of the trials, while doing so two times in the second half. Therefore, Bonnie chose the escape response more often in the Hidden condition than in the Visible condition from the beginning of the experiment, and there seems to be little evidence of gradual learning in her performance. The other subjects did not show any clear evidence of such difference in the use of the escape response. Three of them rarely used the safe choice, whereas the remaining 1 used it almost equally often between the conditions.

Table 3 Bonnie's performance in two testing conditions in Experiment 1

Trial	Visible	Hidden
1	○	×
2	○	E
3	○	E
4	○	E
5	×	E
6	E	E
7	○	○
8	E	E
9	○	×
10	○	○
11	○	E
12	E	E
13	○	E
14	○	×
15	○	×
16	E	E
17	○	×
18	○	E
19	○	○
20	E	×
21	○	×
22	○	×
23	○	×
24	○	○

○ = trials in which Bonnie chose the baited blue cup; × = trials in which she chose the empty blue cup; E = trials in which she escaped the memory test by choosing the yellow container

Discussion

The orangutans showed their preference for a grape when it was simultaneously presented with a piece of dog food. They were also highly successful at selecting the baited blue cup when the baiting of grape was visible, whereas their performance in the memory test did not differ from the chance level when the baiting was visually blocked by the barrier. These findings suggest that the orangutans were good at remembering the location of the preferred reward when they had witnessed the baiting, whereas they could not accurately tell its location when the barrier had been presented.

However, contrary to the prediction, the orangutans as a group did not use the safe choice significantly more often when the baiting of the preferred reward was hidden as compared to when it was visible. At the individual level, however, one adult female (Bonnie) was significantly more likely to escape the memory test when she had not seen the experimenter hiding a grape than when she had seen it. There was also little evidence that she gradually learned to select the escape response in the Hidden condition. These findings indicate that Bonnie was able to escape the memory test effectively when she did not remember the location of the preferred reward.

There seems to be at least two reasons why the group analyses failed to detect any clear evidence for the effective use of the escape response. First, given that 3 of the tested subjects rarely selected the escape response, it is possible that its contents (i.e., dog food) were not attractive enough for these apes to choose frequently. Second, as for the remaining 1 subject who used the escape response almost equally often across the conditions, her success rate in the Visible condition was relatively lower than the others'. It is therefore possible that she did not actually remember the correct location of a grape on some trials in the Visible condition and used the escape response accordingly.

In the next experiment, I used the larger and smaller amounts of grapes as high- and low-value rewards, respectively, so that the subjects' food preference would not influence their choice of escaping the memory test.

Experiment 2

The current experiment investigated the same question as experiment 1, but I used two grapes and one grape as high- and low-value rewards respectively in order to prevent the subjects' food preference from confounding their performance. I presented the orangutans with a pair of identical blue cups and hid two grapes under one of them. The baiting procedure was visible in some trials, whereas it was hidden in other trials. I then presented a yellow cup

between the blue cups. Selecting a blue cup resulted in receiving either two grapes or nothing, whereas choosing the yellow cup always resulted in receiving one grape. The latter choice therefore served as an escape response. The current experiment also made the low-value food contingency more salient, by placing one grape and covering it with a yellow cup in full view of the subjects in some trials, to encourage the subjects to make the escape response more often. If the orangutans could tell when they did not remember the location of the preferred reward, they should use the escape response more often when the baiting procedure was hidden as compared to when it was visible.

Method

Subjects

Same as in experiment 1 except for Kyle.

Apparatus

I used the following materials from the previous experiment: the blue cups, blue dishes, wooden barrier, platform, wooden table, and Plexiglas panels. In addition, I used an opaque yellow plastic cup (7 cm top diameter \times 6 cm bottom diameter \times 10 cm in height) filled with grapes. The yellow cup was covered with a yellow plastic lid (7.8 cm diameter \times 0.7 cm in height), which prevented the subjects from seeing the contents. Another yellow cup (7 cm top diameter \times 6 cm bottom diameter \times 10 cm in height) was paired with a yellow dish (9 cm top diameter \times 7.5 cm bottom diameter \times 1.5 cm in height) so that a grape could be placed on it and covered with the cup. In addition, two green plastic dishes (9 cm top diameter \times 7.5 cm bottom diameter \times 1.5 cm in height) served to present two grapes and one grape in order to examine the subjects' preference.

Procedure

Pre-test. The basic procedure of the pre-test phase in experiment 2 was identical to that of experiment 1. The *preference test* was conducted to make sure that the orangutans preferred two grapes instead of one. The experimenter stood in front of each subject and placed a pair of the green dishes side by side on the center of the platform and presented two grapes and one grape respectively on the dishes. She then slid the dishes from the center to opposite sides of the platform in such a way that the two dishes came in front of the far right and left holes in the Plexiglas panel. Finally, the experimenter pushed the platform against the Plexiglas panel for the subject to choose one of the dishes. The contents of the selected dish were given to the subject.

The locations of the two different quantities were counter-balanced and randomized across trials with a restriction that two grapes did not appear in the same location in more than two consecutive trials. The subjects were given 24 trials in one session, and they all preferred the larger quantity of reward (87%>).

The *low-value food association* was conducted to establish the association between choosing the yellow cup and receiving one grape. The procedure was identical to that of the low-value food association in experiment 1 except that the experimenter presented the lidded yellow cup filled with grapes instead of the yellow container. Once the subject pointed at the cup, the experimenter lifted the lid, picked up one grape, and gave it to the subject. The subjects were given 24 trials and always pointed at the yellow cup to receive one grape.

The *memory test* was conducted to assess the subjects' performance in a memory task in which two grapes were hidden under one of the two blue cups. The procedure was identical to that of the memory test in experiment 1 except that the experimenter hid two grapes under one of the blue cups. The contents of the selected cup were given to the subject (i.e., the subject received two grapes only when it selected the baited blue cup). One session consisted of a random mixture of 18 memory trials, six preference trials, and six low-value association trials. All subjects proceeded to testing as they reached the criteria of performing significantly above chance in the memory trials ($14/18 \geq$, $P \leq 0.031$, Binomial test) within a single session.

Pilot test. Prior to the test, I conducted a pilot test consisting of two testing conditions. These conditions were the same as those of experiment 1 except that I used two grapes and one grape as high- and low-value rewards [see Visible (–) and Hidden (–) conditions below]. However, the frequency of escape use was still very low (≤ 2 out of 24 trials) with 2 subjects never using it, while those who made the safe choice at least once did so more often when the baiting was hidden as compared to visible. Consequently, in the following test, I added two conditions in an attempt to make the low-value food contingency more salient (see Visible (+) and Hidden (+) conditions below).

Test. Experiment 2 had the following four conditions (see Fig. 2).

Visible (–). In this condition, the procedure was identical to that of the Visible condition in Experiment 1 except that the experimenter hid two grapes under one of the blue cups and used the lidded yellow cup (which was filled with grapes) as the escape response. If the subject selected the baited blue cup, it received two grapes. If the subject selected the empty blue cup, it was shown the location of the two grapes but received no reward. If the subject chose the yellow cup, the experimenter lifted its lid and gave one grape to the subject.

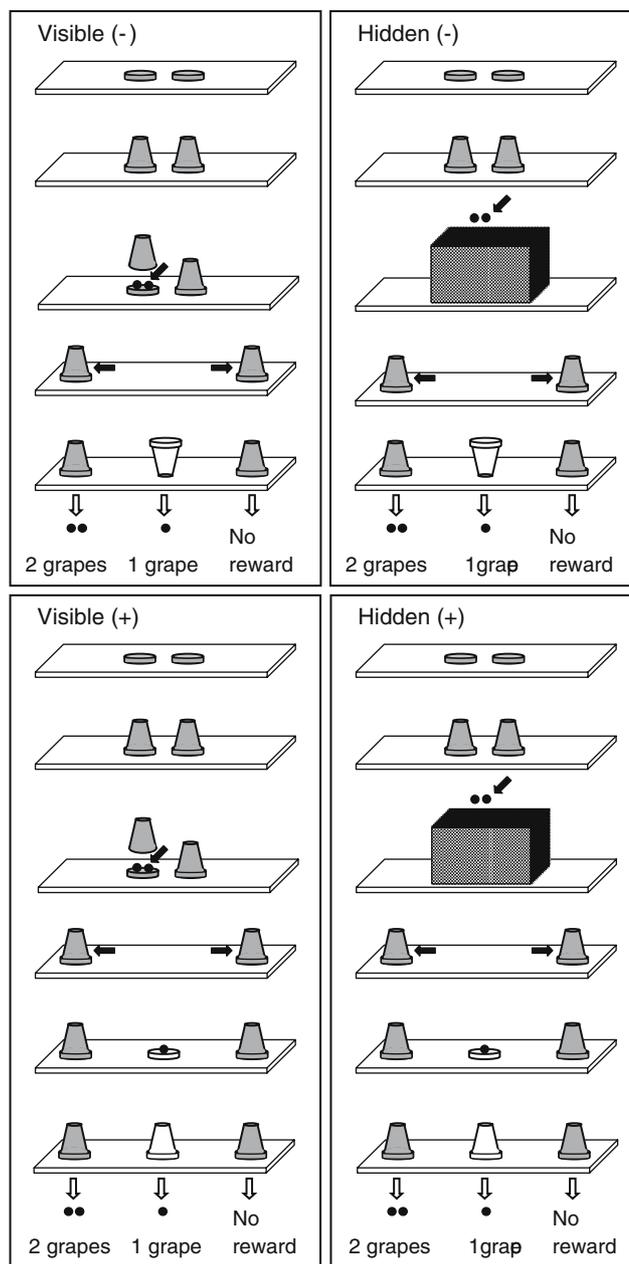


Fig. 2 Examples of trials from the four testing conditions in Experiment 2. Each subject received 24 trials per condition

Hidden (–). This condition was identical to the Hidden condition of Experiment 1 except that the experimenter hid two grapes under one of the blue cups and used the lidded yellow cup as the escape response. The subject received the corresponding contents of the selected cup.

Visible (+). The procedure was the same as in the Visible (–) condition except that the subjects could see the contents of the escape response. After hiding two grapes under one of the blue cups and sliding them from the center to opposite sides of the platform, the experimenter placed the yellow dish containing one grape in front of the center hole

in the Plexiglas panel so that it was located between the blue cups. She then immediately covered the grape with the yellow cup. Finally, the experimenter pushed the platform against the Plexiglas panel for the subject to choose one of the cups. The subject received the corresponding contents of the selected cup.

Hidden (+). The procedure was the same as in the Hidden (–) condition except that the subject could see the contents of the escape response. After removing the wooden barrier and sliding the blue cups from the center to opposite sides of the platform, the experimenter placed the yellow dish containing one grape in front of the center hole in the Plexiglas panel so that it was located between the blue cups. She then immediately covered the grape with the yellow cup, and pushed the Plexiglas panel for the subject to choose one of the cups. The subject received the corresponding contents of the selected cup.

I conducted 24 trials for each condition per subject. Besides the testing trials, I interspersed 48 pre-test preference trials among the trials of the four testing conditions on the purpose of assessing the orangutans' preference for the larger quantity of grapes and maintaining their motivation throughout the testing. Each subject received eight sessions consisting of 18 trials each, for a total of 144 trials. Each session was a random mixture of 12 testing trials (three trials per condition) and six preference trials. I also presented three low-value food association trials prior to each session as warm-up and a reminder of the contingency between selecting the lidded yellow cup and receiving one grape. The position of two grapes was counterbalanced and randomized with a restriction that they did not appear in the same position in more than two consecutive trials. A retention interval was about 10 s for all the conditions.

Results

Memory performance

The orangutans as a group significantly more likely selected the larger of the two quantities of grapes when presented in a pair of the green dishes, $M = 94.2\%$, $SEM = 1.79$, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. The orangutans therefore continued to prefer the larger quantity of grapes when the two quantities were simultaneously presented.

When choosing a blue cup, the group selected the baited one significantly above chance in both of the two Visible conditions: Visible (+), $M = 93.1\%$, $SEM = 4.65$, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$; Visible (–), $M = 98.3\%$, $SEM = 1.05$, $z = 2.07$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. (Trials in which the subjects selected the yellow cup were excluded from this analysis.) In contrast, their performance did not significantly differ from the chance level in

the two Hidden conditions: Hidden (+), $M = 48.7\%$, $SEM = 5.03$, $z = 0.37$, $N\text{-ties} = 4$, $P = 0.438$; Hidden (–), $M = 48.5\%$, $SEM = 2.01$, $z = 0.55$, $N\text{-ties} = 4$, $P = 0.375$, Wilcoxon signed rank test. Therefore, the subjects were highly competent in the memory test when they had seen the experimenter placing two grapes under one of the blue cups, whereas they seemed to be guessing the location of the preferred reward when the baiting was invisible.

Friedman test revealed significant differences among the four conditions in the orangutans' memory performance, $\chi^2 = 12.75$, $df = 3$, $P = 0.001$. In order to reduce the number of comparisons, I calculated the mean of the two Visible conditions and that of the two Hidden conditions, and compared them by Wilcoxon signed rank test. The orangutans as a group were significantly more successful at selecting the baited blue cup when they could see the experimenter hiding two grapes as compared to when the baiting procedure was visually blocked, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$.

Escape response

Figure 3 presents the mean percentage of trials in which the subjects selected the yellow cup as a function of condition. Unlike in experiment 1, Friedman test detected significant differences among the four conditions in the use of the escape response, $\chi^2 = 11.82$, $df = 3$, $P = 0.001$. In order to reduce the number of comparisons, I calculated the mean of the two Visible conditions and that of the two Hidden conditions, and compared them by Wilcoxon signed rank test. The orangutans as a group significantly more likely selected the yellow cup when the baiting of two grapes was hidden as compared to when it was visible, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$. A planned comparison revealed that the orangutans chose the yellow cup more often in the Hidden (+) condition than in the Visible (+) condition although the difference did not reach the significant level, $z = 1.84$, $N\text{-ties} = 4$, $P = 0.063$, Wilcoxon signed rank test. Likewise, they were significantly more likely to select the escape response

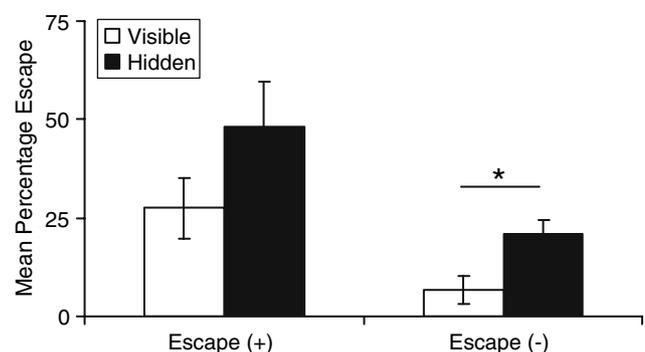


Fig. 3 Mean percentage (\pm SEM) of trials in which the subjects selected the escape response in the Visible (+), Visible (–), Hidden (+), and Hidden (–) conditions. * $P < 0.05$, significant difference

in the Hidden (–) condition than in the Visible (–) condition, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. These findings suggest that the orangutans as a group were able to escape the memory test effectively, by making the safe choice of receiving one grape for sure, when they did not remember the location of two grapes.

Learning effect

However, it is still possible that the orangutans gradually learned to escape the memory test more often when the blue cups had been covered with the barrier as compared to when they had remained visible. In order to assess the learning effect on the orangutans' use of the escape response, I divided 24 trials of each condition into two phases, and compared the apes' escape use in the first half of the trials with that in the second half. In the Visible (–) and Hidden (–) conditions, there was no significant difference in the orangutans' use of the escape response between the first and second phases: Visible (–), $M_{1st} = 11.7\%$, $SEM = 7.74$, $M_{2nd} = 1.7\%$, $SEM = 1.66$, $z = 1.13$, $N\text{-ties} = 4$, $P = 0.250$; Hidden (–), $M_{1st} = 33.3\%$, $SEM = 9.13$, $M_{2nd} = 8.3\%$, $SEM = 5.27$, $z = 1.49$, $N\text{-ties} = 5$, $P = 0.094$, Wilcoxon signed rank test. In the Visible (+) and Hidden (+) conditions, the orangutans escaped the memory test significantly less often in the second phase than in the first phase: Visible (+), $M_{1st} = 38.4\%$, $SEM = 10.73$, $M_{2nd} = 16.7\%$, $SEM = 5.89$, $z = 2.03$, $N\text{-ties} = 4$, $P = 0.031$; Hidden (+), $M_{1st} = 63.3\%$, $SEM = 11.37$, $M_{2nd} = 33.3\%$, $SEM = 11.48$, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. These findings indicate that the orangutans became more reluctant to use the escape response as they received more trials both in the Visible (+) and Hidden (+) condition. Therefore, there was not clear evidence that the orangutans gradually learned to escape the memory test more often when the baiting of two grapes was visually blocked by the barrier.

Individual analyses

Table 4 presents the performance of each subject in the four testing conditions and preference trials. Consistent with the results of the group analyses, all subjects showed a significant preference for the larger quantity of grapes in the preference trials, $P < 0.001$, Binomial test, two-tailed. Likewise, when taking the memory test (i.e., when choosing a blue cup) all subjects except for Kiko performed significantly above chance in both of the two Visible conditions ($P < 0.001$, Binomial test, two-tailed). Kiko's memory performance was significantly above chance in the Visible (–) condition ($P < 0.001$, Binomial test, two-tailed), while he failed to perform significantly better than chance in the Visible (+) condition, $P = 0.146$, Binomial

Table 4 Subjects' performance in four testing conditions and preference trials in Experiment 2

Subject	Frequency			Success (%)	Escape (%)	Preference (%)
	Correct	Wrong	Escape			
Batang						
Visible (+)	21	1	2	95.5**	8.3	–
Hidden (+)	8	11	5	42.1	20.8	–
Visible (–)	22	1	1	95.7**	4.2	–
Hidden (–)	10	8	6	55.6	25.0	–
Bonnie♣						
Visible (+)	17	0	7	100**	29.2	–
Hidden (+)	4	3	17	57.1	70.8	–
Visible (–)	22	1	1	95.7**	4.2	–
Hidden (–)	8	10	6	44.4	25.0	–
Iris						
Visible (+)	20	1	3	95.2**	12.5	–
Hidden (+)	11	7	6	61.1	25.0	–
Visible (–)	23	0	1	100**	4.2	–
Hidden (–)	10	12	2	45.5	8.3	–
Kiko						
Visible (+)	9	3	12	75.0	50.0	–
Hidden (+)	4	8	12	33.3	50.0	–
Visible (–)	19	0	5	100**	20.8	–
Hidden (–)	8	9	7	47.1	29.2	–
Lucy♣						
Visible (+)	15	0	9	100**	37.5	–
Hidden (+)	3	3	18	50.0	75.0	–
Visible (–)	24	0	0	100**	0.0	–
Hidden (–)	10	10	4	50.0	16.7	–

Success (%) = a percentage of trials in which the subjects selected the baited blue cup when they selected one of the blue cups; Escape (%) = a percentage of trials in which the subjects selected the yellow cup; Preference (%) = a percentage of trials in which the subjects selected two grapes instead of one in the preference trials

* $P < 0.05$, ** $P < 0.01$, above chance. Binomial tests (two-tailed, exact P -values) were used. ♣ = the subject who showed clear differences in the use of the escape response among the four testing conditions, $P < 0.001$, Cochran's Q test

test, two-tailed. None of the subjects significantly exceeded the chance level in the Hidden conditions.

With regard to the use of the escape response, all subjects except for Batang showed significant differences among the four testing conditions: Batang, $Q(3) = 7.85$, $P = 0.069$; Bonnie, $Q(3) = 26.51$, $P < 0.001$; Iris, $Q(3) = 8.40$, $P = 0.049$; Kiko, $Q(3) = 8.44$, $P = 0.042$; Lucy, $Q(3) = 34.43$, $P < 0.001$, Cochran's Q test. Further analyses revealed that Bonnie was significantly more likely to select the escape response in the Hidden (+) condition than in the Visible (+) condition, $P = 0.006$, McNemar test. She also escaped the memory test significantly more often in the Hidden (–) condition than in the Visible (–) condition,

$P = 0.031$, McNemar test. Similarly, Lucy chose the yellow cup significantly more frequently in the Hidden (+) condition than in the Visible (+) condition, $P = 0.006$, McNemar test. She also escaped the memory test more often in the Hidden (–) condition than in the Visible (–) condition, but failed to reach the significant level, $P = 0.063$, McNemar test. Such differences were not found significant for Iris and Kiko, although they showed the same pattern of selecting the escape response more often when the baiting was invisible than when it was visible.

Discussion

The orangutans continued to prefer the larger quantity of grapes. They were also highly competent in the memory test, successfully choosing the baited blue cup in more than 93% of trials, when they could see the experimenter baiting it with the preferred reward. In contrast, their performance did not significantly differ from the chance level when the baiting was visually blocked, which suggests that they did not know the location of the preferred reward.

As predicted, the orangutans as a group were significantly more likely to escape the memory test when the baiting of two grapes was invisible than when it was visible. These findings indicate that the orangutans were able to use the escape response effectively when they lacked a critical piece of information for the memory test (i.e., the location of the preferred reward). However, the orangutans had received similar tasks in Experiment 1 and the pilot test and it is therefore possible that they gradually learned an association between making mistakes in the memory test and the presence of the barrier, despite the lack of evidence for learning within the current experiment. In the next experiment, I modified the task difficulty by sometimes switching the locations of the two blue cups, and investigated whether the orangutans could generalize their effective use of the escape response to this slightly different situation.

Experiment 3

The previous experiment had suggested that the orangutans could effectively use the escape response when they lacked a critical piece of information in a spatial memory task. The current experiment investigated whether the apes could continue to do so in a slightly different experimental setting. I hid two grapes under one of the blue cups in full view of the subjects, and sometimes switched the locations of the cups prior to the subjects' choice. If the orangutans could judge their own memory about the location of the preferred food, they should use the escape response more often when the locations of the blue cups were switched as compared to when they remained the same, as the former

was presumably more demanding than the latter. This experiment also assessed whether the subjects could perform better when the escape response was available than when it was unavailable, selectively escaping the test in which they would likely make mistakes.

Method

Subjects

Same as in Experiment 2.

Apparatus

I used the same blue cups, blue dishes, yellow cups, yellow lid, yellow dish, green dishes, platform, wooden table, and Plexiglas panels as in Experiment 2.

Procedure

The basic procedure was identical to that of Experiment 2 except for three differences. First, the baiting procedure of two grapes was always visible to the subjects. Second, the locations of the blue cups were sometimes switched. Third, the escape response was not available in some trials, in which the orangutans were forced to take the memory test.

Experiment 3 had the following six conditions, which were created by generating two factors: type of escape response (the lidded yellow cup, a pair of the yellow cup and dish, vs. no escape response available), locations of blue cups (remain vs. switched).

Remain (–). Same as in the Visible (–) condition of Experiment 2. The locations of the blue cups remained the same. The lidded yellow cup filled with grapes served as the escape response.

Remain (+). Same as in the Visible (+) condition of Experiment 2. A pair of the yellow dish and cup containing one grape served as the escape response.

Remain Forced. The procedure was the same as in the above conditions until the experimenter hid two grapes under one of the blue cups and slid them from the center to opposite sides of the platform. She then stood still in a neutral expression, looking down at the center of the platform for four seconds, and pushed the platform against the Plexiglas panel for the subject to choose one of the cups. Hence, the escape response was not presented and the subject was forced to take the memory test by picking up one of the blue cups. The subject received the corresponding contents of the selected cup.

Switch (–). The procedure was the same as in the Remain (–) condition except that the experimenter switched the locations of the blue cups in a clockwise direction right after hiding two grapes under one of them. She

then separated the blue cups and placed the lidded yellow cup (which was filled with grapes) at the center of the platform. Finally, she pushed the platform against the Plexiglas panel for the subject to make a choice.

Switch (+). This condition was identical to that of *Switch (-)* except that the subject could see the contents of the escape response before making a choice. After switching the locations of the blue cups and sliding them from the center to opposite sides of the platform, the experimenter placed the yellow dish containing one grape at the center of the platform and immediately covered it with the yellow cup. Finally, she pushed the platform against the Plexiglas panel for the subject to make a choice.

Switch Forced. This condition was identical to that of the other *Switch* conditions except that the experimenter did not present any escape response. After switching the locations of the blue cups and separating them, the experimenter stood still with a neutral expression, looking down at the center of the platform for four seconds. She then pushed the platform against the Plexiglas panel for the subject to make a choice.

Each trial was timed by the metronome and lasted about 10 s from the moment when the experimenter covered two grapes with the blue cup until the platform touched against the Plexiglas panel (retention interval = about 10 s). I conducted 24 trials for each condition per subject. Besides the testing trials, I interspersed 24 pre-test preference trials among the trials of the six testing conditions with the purpose of assessing the orangutans' preference for two grapes and maintaining their motivation throughout the testing. Each subject received eight sessions consisting of 21 trials each, for a total of 168 trials. Each session was a random mixture of 18 testing trials (three trials per condition) and three preference trials. I also presented three low-value food association trials prior to each session as warm-up and a reminder of the contingency between selecting the lidded yellow cup and receiving one grape. The position of two grapes was counterbalanced and randomized with a restriction that they did not appear in the same position in more than two consecutive trials.

Results

Memory performance

The orangutans as a group significantly more likely selected the larger of the two quantities of grapes when presented in a pair of the green dishes, $M = 93.3\%$, $SEM = 3.39$, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. When choosing a blue cup, the group selected the baited one significantly above chance in all of the six conditions: *Remain (+)*, $M = 92.4\%$, $SEM = 3.44$; *Remain (-)*, $M = 93.3\%$, $SEM = 2.83$; *Remain Forced*,

$M = 89.2\%$, $SEM = 3.63$; *Switch (+)*, $M = 78.7\%$, $SEM = 7.77$; *Switch (-)*, $M = 76.2\%$, $SEM = 9.39$; *Switch Forced*, $M = 75.0\%$, $SEM = 5.11$; for all conditions, $z > 2.02$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. (Trials in which the subjects chose the escape response were excluded from this analysis.)

Friedman test revealed that there were significant differences in the percentage correct among the six conditions, $\chi^2 = 13.63$, $df = 5$, $P = 0.007$. In order to reduce the number of comparisons, I calculated the mean of the three *Remain* conditions as well as that of the three *Switch* conditions, and compared them by Wilcoxon signed rank test. The orangutans as a group were significantly more successful at selecting the baited blue cup when the locations of the blue cups remained the same as compared to when they were switched, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$. Therefore, the orangutans had greater difficulty in the memory task when the locations of the blue cups were switched than when they remained the same, although they were generally skillful in the memory task across the six testing conditions.

Forced vs. Escape conditions

Next, to investigate whether the orangutans performed better with the escape response available, I calculated the mean of the four conditions in which the escape response was available and that of the two *Forced* conditions in which it was unavailable. No significant difference was found between these two types of conditions, $z = 0.94$, $N\text{-ties} = 5$, $P = 0.219$, Wilcoxon signed rank test, although they performed slightly better in the *Escape* conditions than in the *Forced* conditions (see the section of memory performance).

Escape response

Figure 4 presents the mean percentage of trials in which the subjects chose the escape response as a function of condition. Friedman test detected significant differences in the use of the escape response among the four conditions in which the yellow cup was available as a choice, $\chi^2 = 7.54$, $df = 3$, $P = 0.041$. On the purpose of reducing the number of comparisons, I calculated the mean of the *Remain (+)* and *Remain (-)* conditions and that of the *Switch (+)* and *Switch (-)* conditions, and compared them by Wilcoxon signed rank test. As predicted, the orangutans were significantly more likely to select the escape response when the locations of the blue cups were switched as compared to when they remained the same, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$. In other words, they were able to effectively escape the memory task when it was more demanding. A planned comparison revealed that the orangutans used the escape response more often in the *Switch (+)* condition than

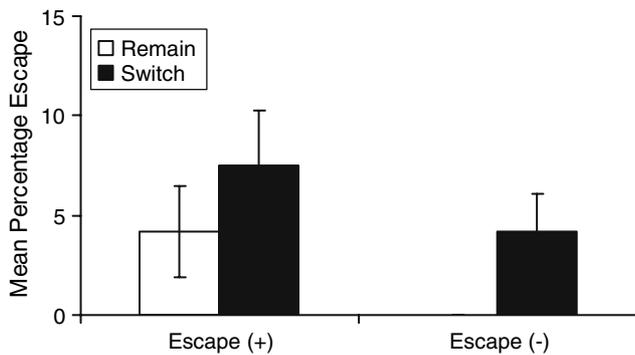


Fig. 4 Mean percentage (\pm SEM) of trials in which the subjects selected the escape response in the Remain (+), Remain (-), Switch (+), and Switch (-) conditions

in the Remain (+) condition although the difference did not reach the significant level, $z = 1.86$, $N\text{-ties} = 4$, $P = 0.063$, Wilcoxon signed rank test. The group's mean of the escape use was also higher in the Switch (-) condition than in the Remain (-) condition, but the difference was not significant, either, $z = 1.63$, $N\text{-ties} = 3$, $P = 0.125$, Wilcoxon signed rank test.

Learning effect

In order to examine whether the orangutans gradually learned to escape the memory test more often when the locations of the blue cups were switched as compared to when they remained unchanged, I divided 24 trials of each condition into two phases, and compared the apes' escape use of the first half of trials and that of the second. No significant difference was found between the first and second phases in any testing condition: Switch (+), $M_{1st} = 3.3\%$, $SEM = 3.34$, $M_{2nd} = 11.7\%$, $SEM = 3.34$, $z = 1.63$, $N\text{-ties} = 3$, $P = 0.125$; Switch (-), $M_{1st} = 3.3\%$, $SEM = 2.03$, $M_{2nd} = 5.0\%$, $SEM = 3.34$, $z = 0.45$, $N\text{-ties} = 2$, $P = 0.500$; Remain (+), $M_{1st} = 3.3\%$, $SEM = 3.34$, $M_{2nd} = 5.0\%$, $SEM = 2.03$, $z = 0.00$, $N\text{-ties} = 3$, $P = 0.625$; Remain (-), $M_{1st} = 0.0\%$, $SEM = 0.0$, $M_{2nd} = 0.0\%$, $SEM = 0.0$, $z = 0.00$, $N\text{-ties} = 0$, $P = 1.00$, Wilcoxon signed rank test. Therefore, there was little evidence that the orangutans gradually learned to escape the memory test more often in the Switch conditions than in the Remain conditions during the course of the current experiment.

Individual analyses

Table 5 presents the performance of each subject in the six testing conditions and preference trials. Consistent with the results of the group analyses, all subjects showed a significant preference for the larger quantity of grapes in the preference trials, $P < 0.003$, Binomial test, two-tailed. When taking the memory test (i.e., when choosing a blue cup), all

Table 5 Subjects' performance in six testing conditions and preference trials in Experiment 3

Subject	Frequency			Success (%)	Escape (%)	Preference (%)
	Correct	Wrong	Escape			
Batang						
Remain (+)	21	3	0	87.5**	0.0	–
Switch (+)	16	8	0	66.7	0.0	–
Remain (-)	22	2	0	91.7**	0.0	–
Switch (-)	14	10	0	58.3	0.0	–
Remain forced	19	5	–	79.2**	–	–
Switch forced	15	9	–	62.5	–	–
Bonnie						
Remain (+)	23	0	1	100**	4.2	–
Switch (+)	21	1	2	95.5**	8.3	–
Remain (-)	23	1	0	95.8**	0.0	–
Switch (-)	16	6	2	72.7	8.3	–
Remain forced	22	2	–	91.7**	–	–
Switch forced	18	6	–	75.0*	–	–
Iris						
Remain (+)	22	2	0	91.7**	0.0	–
Switch (+)	20	3	1	87.0**	4.2	–
Remain (-)	24	0	0	100**	0.0	–
Switch (-)	22	0	2	100**	8.3	–
Remain forced	22	2	–	91.7**	–	–
Switch forced	22	2	–	91.7**	–	–
Kiko						
Remain (+)	19	4	1	82.6**	4.2	–
Switch (+)	12	10	2	54.5	8.3	–
Remain (-)	20	4	0	83.3**	0.0	–
Switch (-)	13	11	0	54.2	0.0	–
Remain forced	20	4	–	83.3**	–	–
Switch forced	16	8	–	66.7	–	–
Lucy						
Remain (+)	21	0	3	100**	12.5	–
Switch (+)	18	2	4	90.0**	16.7	–
Remain (-)	23	1	0	95.8**	0.0	–
Switch (-)	22	1	1	95.7**	4.2	–
Remain forced	24	0	–	100**	–	–
Switch forced	19	5	–	79.2**	–	–

Success (%) = a percentage of trials in which the subjects selected the baited blue cup when they selected one of the blue cups; Escape (%) = a percentage of trials in which the subjects selected the yellow cup; Preference (%) = a percentage of trials in which the subjects selected two grapes instead of one in the preference trials

* $P < 0.05$, ** $P < 0.01$, above chance. Binomial tests (two-tailed, exact P -values) were used

subjects performed significantly above chance in the three Remain conditions, $P < 0.008$, Binomial test, two-tailed. Two of the subjects (Iris and Lucy) also performed significantly better than chance in the memory test in all of the

three Switch conditions, $P < 0.008$, Binomial test, two-tailed, whereas 2 others (Batang and Kiko) significantly exceeded the chance level performance in none of these conditions. The remaining 1 subject (Bonnie) performed above chance in the Switch (+) and Switch Forced conditions, $P < 0.03$, while failing to do so in the Switch (–) condition, $P = 0.052$, Binomial test, two-tailed.

With regard to the use of the escape response, all subjects except for Batang selected the yellow cup at least once and all of them used it more often in the Switch conditions than in the Remain conditions, although the difference was statistically significant for none of the subjects, Cochran's Q test. Batang did not escape the memory test at all, selecting a blue cup in all testing trials.

Discussion

The orangutans continued to prefer the larger quantity of grapes. They were also skillful in the memory test overall, performing better when the locations of the blue cups remained the same than when they were switched. No significant difference was found in the subjects' memory performance between the Forced and Escape conditions, which seems to indicate that the orangutans did not improve their memory performance by selectively escaping the test in which they forgot the location of the preferred reward. However, the memory tasks in the current experiment seemed to be too easy for the orangutans to escape frequently enough. That is, in the most of cases, the subjects might have found it unnecessary to escape the test because they had a good chance of receiving the preferred reward. It is possible that the infrequent use of the escape response hindered any significant difference between the Forced and Escape conditions.

Most importantly, the orangutans escaped the memory test significantly more often when the task was more demanding than when it was easier. Furthermore, there was no clear evidence that the orangutans gradually learned this within the current experiment, which suggests that the apes were able to transfer their effective use of the escape response to a different experimental setting. These findings suggest that the orangutans escaped the memory test depending on the strength of their own memory. However, it is still possible that the subjects quickly learned an association between errors in the memory test and the switching movement of the blue cups. Also, the apes might have used the escape response differentially according to their direct perception of task difficulty. The next experiment was designed to illuminate these two alternative explanations for the orangutans' successful use of the escape response. Also, the memory task was made more difficult such that the orangutans became more willing to use the escape response.

Experiment 4

The previous experiments had suggested that the orangutans could effectively use the escape response when they lacked a critical piece of information and when a task was relatively demanding. However, those experiments did not disprove the possibility that the orangutans adjusted their behavior based on associative learning. For instance, the apes might have simply learned that they were prone to make mistakes when the barrier was placed (as opposed to when it was not presented) or when the locations of the blue cups were switched (as opposed to when they remained the same). It is also possible that the orangutans learned to select the escape response when their perception of task difficulty was strong and they subsequently felt uneasy.

The current experiment was designed to eliminate these alternative explanations for the orangutans' successful performance. As in Hampton's (2001) study, the subjects were required to make a metacognitive decision prior to the final presentation of the memory task. After the experimenter hid two grapes under one of the two blue cups, the subjects were asked whether they would take a memory test or quit it *before* the memory test further proceeded (i.e., before the positions of the blue cups were changed). Because the end results of the memory test were not available yet, the subjects could not decide to use the escape response based on their direct perception of task difficulty. Instead, they had to predict their performance in the memory test and decide whether they would be better off escaping the task. Furthermore, the escape response was unavailable in some trials, in which the subjects were forced to take the memory test. If the orangutans could tell whether they knew the location of the preferred reward or not, they should decline to take the memory test when they forgot the answer, and thus should perform better when the escape response was available as compared to when it was not.

Method

Subjects

Same as in Experiments 2 and 3.

Apparatus

I used the same blue cups, blue dishes, yellow cups, yellow lid, yellow dish, green dishes, platform, wooden table, and Plexiglas panels as in Experiment 3.

Procedure

Experiment 4 had the following three conditions (see Fig. 5):

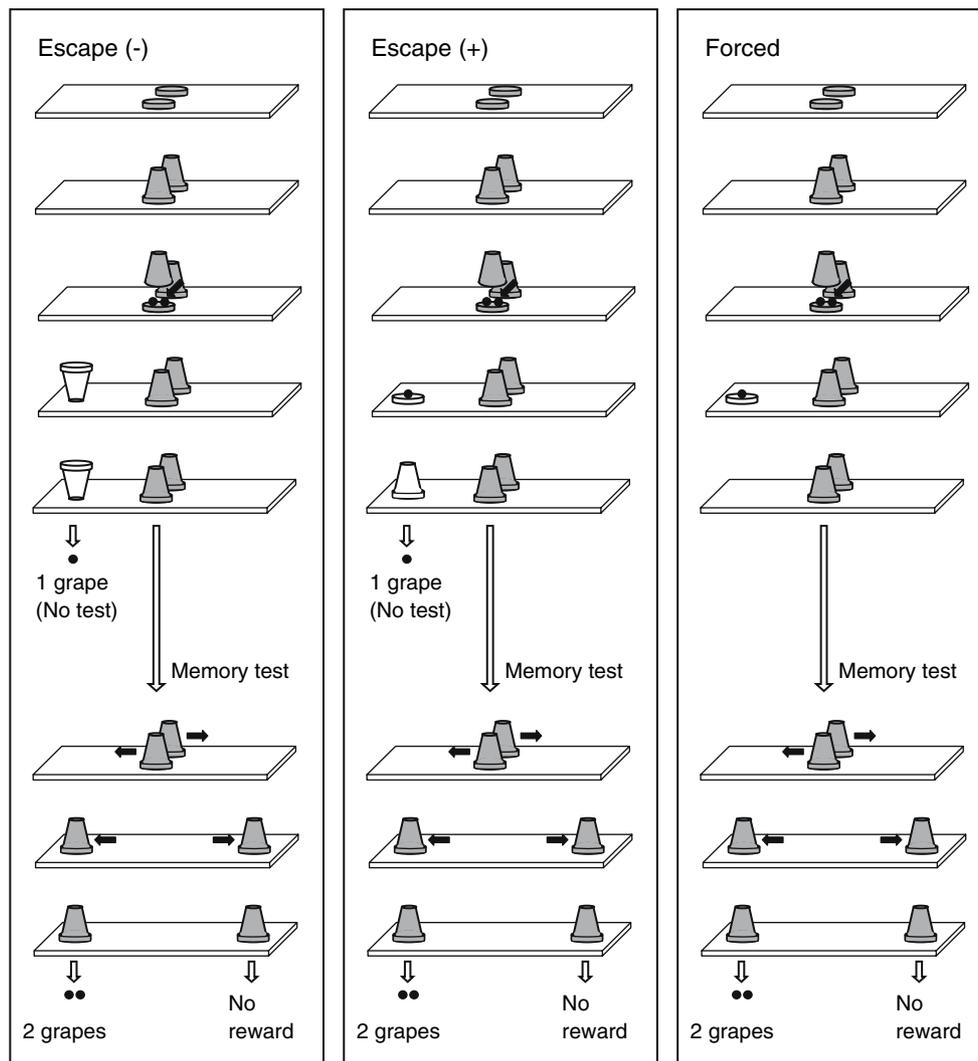


Fig. 5 Examples of trials from the three testing conditions in Experiment 4. Each subject received 72 trials per condition

Escape (-). The experimenter stood in front of each subject and placed the platform in front of and about 36 cm away from the Plexiglas panel. She placed a pair of the blue dishes at the very center of the platform so that they were adjacent to each other and lined up perpendicularly toward the subject, and covered them with the blue cups. Hence, unlike in the previous experiments, both of the blue cups were lined up in front of the center hole of the Plexiglas panel. The experimenter then hid two grapes under one of the blue cups in full view of the subject, and placed the lidded yellow cup (which was filled with grapes) in front of either the left or right hole of the panel. Next, she pushed the platform against the Plexiglas panel for the subject to stick its finger through one of the holes. If the subject selected the yellow cup, the experimenter lifted the lid, picked up one grape, and gave it to the subject. The trial was terminated, and no memory test proceeded. This choice thus served as an escape response because the subject could

receive one grape immediately without taking any risk of receiving no rewards. If the subject selected the center hole instead, the experimenter pulled back the platform and removed the yellow cup, and the following memory test proceeded. After making sure that the subject was paying attention, she slid the blue cups (together with the dishes underneath) from the center to opposite sides of the platform in such a way that the two cups came in front of the far right and left holes in the Plexiglas panel. The cups were slid either one of the following directions: (1) the front cup moved toward right with the back one moving toward left from the subject's perspective, and (2) the front cup moved toward left with the back one moving toward right from the subject's perspective. Finally, the experimenter pushed the platform against the Plexiglas panel for the subject to pick one of the blue cups. If the subject selected the baited blue cup, it received the two grapes. If the subject selected the empty cup, it was shown the correct location of the two

grapes but did not receive any rewards. Each trial was timed by the metronome so that six seconds elapsed from the moment when the experimenter covered two grapes with the blue cup until the platform touched against the Plexiglas panel for the subject's first choice. When the memory test proceeded (i.e., when the subject chose the center hole in its first choice), 10 seconds elapsed from the moment when the experimenter started to pull back the platform until it touched against the panel again for the subject's second choice. Hence, each trial lasted for about six seconds when the subject declined to take the memory test by selecting the escape response, whereas it lasted for about 16 seconds in total when they decided to take the memory test by selecting the center hole (retention interval = about 6 or 16 s).

Escape (+). The procedure was identical to that of the Escape (–) condition except that the contents of the escape response was shown to the subject. After hiding two grapes under one of the blue cups in full view of the subject, the experimenter placed the yellow dish containing one grape in front of either the left or right hole of the panel. She then covered the grape with the yellow cup and pushed the platform against the Plexiglas panel for the subject to stick its finger through one of the holes. If the subject selected the yellow cup, the experimenter gave its contents (i.e., one grape) to the subject. This choice thus served as an escape response. If the subject selected the center hole instead, the experimenter pulled back the platform and removed the yellow cup together with the yellow dish and grape. The rest of the procedure was the same as in the Escape (–) condition and the memory test proceeded.

Forced. The procedure was identical to that of the Escape (+) condition except that the escape response was taken away before the subject's first choice. After placing the yellow dish containing one grape, the experimenter immediately removed the yellow dish with its contents. She then pushed the platform against the Plexiglas panel for the subject to stick its finger through one of the holes. Therefore, the escape response was not available for the subject's first choice and only the blue cups were present in front of the center hole. Once the subject selected the center hole, the experimenter pulled back the platform. The rest of the procedure was the same as in the previous two conditions and the memory test proceeded.

I conducted 72 trials for each condition per subject. Besides the testing trials, I interspersed 72 pre-test preference trials among the trials of the three testing conditions to assess the orangutans' preference for two grapes and maintain their motivation throughout the testing. Each subject received 18 sessions consisting of 16 trials each, for a total of 288 trials. Each session was a random mixture of 12 testing trials (four trials per condition) and four preference trials. I also presented three low-value food association trials

prior to each session as warm-up and a reminder of the contingency between selecting the lidded yellow cup and receiving one grape. The starting and final position of two grapes was counterbalanced and randomized with a restriction that the preferred reward did not appear in the same position in more than three and two consecutive trials, respectively. Likewise, the position of the escape response was counterbalanced and randomized so that it did not appear in the same position in more than three consecutive trials.

Results

Memory performance and escape response

The orangutans as a group significantly more likely selected the larger of the two quantities of grapes when presented in a pair of the green dishes, $M = 95.3\%$, $SEM = 1.79$, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$. When choosing a blue cup, the orangutans as a group selected the baited one significantly above chance in all the three testing conditions: Escape (+), $M = 72.8\%$, $SEM = 7.97$, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$; Escape (–), $M = 77.1\%$, $SEM = 8.17$, $z = 2.02$, $N\text{-ties} = 5$, $P = 0.031$; Forced, $M = 73.6\%$, $SEM = 5.95$, $z = 2.03$, $N\text{-ties} = 5$, $P = 0.031$, Wilcoxon signed rank test. However, contrary to the prediction, there was no significant difference in the orangutans' memory performance among the conditions, $\chi^2 = 1.20$, $df = 2$, $P = 0.691$, Friedman test. Therefore, the group performed well across the conditions regardless of the availability of the escape response. Also, no significant difference was found in the use of the escape response between the Escape (+) and Escape (–) conditions: Escape (+), $M = 38.9\%$, $SEM = 7.72$; Escape (–), $M = 47.2\%$, $SEM = 8.21$, $z = 1.21$, $N\text{-ties} = 5$, $P = 0.156$, Wilcoxon signed rank test. The orangutans used the escape response equally often regardless of whether the contents of the escape response was shown or not.

Individual analyses

Table 6 presents the performance of each subject in the three testing conditions and preference trials. Consistent with the results of the group analyses, all subjects showed a significant preference for the larger quantity of grapes in the preference trials, $P < 0.001$, Binomial test, two-tailed. When taking the memory test (i.e., when choosing a blue cup), 3 subjects (Iris, Kiko, and Lucy) performed significantly above chance in all of the three conditions, $P < 0.02$, Binomial test, two-tailed. Another subject (Batang) exceeded the chance level only in the Forced condition ($P = 0.013$, Binomial test, two-tailed), whereas the remaining one (Bonnie) failed to perform significantly above chance in any of the conditions.

Table 6 Subjects' performance in four testing conditions and preference trials in Experiment 4

Subject	Frequency			Success (%)	Escape (%)	Preference (%)
	Correct	Wrong	Escape			
Batang						98.6**
Escape (+)	31	20	21	60.8	29.2	–
Escape (–)	23	14	35	62.2	48.6	–
Forced	47	25	–	65.3*	–	–
Bonnie						94.4**
Escape (+)	14	13	45	51.9	62.5	–
Escape (–)	11	9	52	55.0	72.2	–
Forced	40	32	–	55.6	–	–
Iris						95.8**
Escape (+)	52	8	12	86.7**	16.7	–
Escape (–)	39	8	25	83.0**	34.7	–
Forced	62	10	–	86.1**	–	–
Kiko						98.6**
Escape (+)	30	13	29	69.8*	40.3	–
Escape (–)	46	8	18	85.2**	25.0	–
Forced	54	18	–	75.0**	–	–
Lucy♣						88.9**
Escape (+)	37	2	33	94.9**	45.8	–
Escape (–)	32	0	40	100**	55.6	–
Forced	62	10	–	86.1**	–	–

Success (%) = a percentage of trials in which the subjects selected the baited blue cup when they selected one of the blue cups; Escape (%) = a percentage of trials in which the subjects selected the yellow cup; Preference (%) = a percentage of trials in which the subjects selected two grapes instead of one in the preference trials

* $P < 0.05$, ** $P < 0.01$, above chance. Binomial tests (two-tailed, exact P -values) were used. ♣ = the subject who performed significantly better in the Escape (–) condition than in the Forced condition and showed a higher success rate in the Escape (+) condition than in the Forced condition, $P = 0.021$, $P = 0.135$, respectively, Fisher's exact test

To examine whether the orangutans showed better memory performance when the escape response was available (than when it was unavailable) by selectively escaping the test in which they forgot the location of two grapes, each subject's correct and wrong choices were compared across the three testing conditions (3×2 cells) by Fisher's exact test (two-tailed). Only one adult female, Lucy, showed significant differences in her test performance across the three conditions, $P = 0.037$. Further comparisons revealed that she was significantly more successful at selecting the baited blue cup in the Escape (–) condition than in the Forced condition, $P = 0.021$, Fisher's exact test, one-tailed. Her performance was also better in the Escape (+) condition than in the Forced condition, although the difference did not reach a significant level, $P = 0.135$, Fisher's exact test, one-tailed. When the two escape conditions were collapsed, Lucy performed significantly better when the escape response was available than when it was not, $P = 0.016$, Fisher's exact test, one-tailed.

Descriptively, in the Escape (–) condition, Lucy took the memory test in 32 trials in which she always made a correct choice, while escaping the test in the remaining 40 trials. In the Escape (+) condition, she escaped the memory test in 33 trials and took the memory test in the remaining 39 trials in which she made only two mistakes. These two mistakes occurred on the 29th and 51st trials during the course of 72 trials. Before making the first mistake in this

condition, she had taken the memory test in 14 trials and had been always correct. Therefore, Lucy showed her effective use of the escape response from the beginning of the experiment rather than through trial-and-error learning. Moreover, the original position of two grapes had little effect on Lucy's use of the escape response. In the Escape (–) condition, she selected the yellow cup 18 times when two grapes were originally under the front cup (from her perspective), and chose the escape response 22 times when two grapes were hidden under the back cup. Likewise, in the Escape (+) condition, she used the escape response 17 times when two grapes were hidden under the front cup, and escaped the test 16 times when two grapes were originally positioned under the back cup. Taken together, these findings suggest that Lucy was able to escape the memory test when her memory about the hidden preferred reward was poor, while selectively taking the test when her memory was reliable.

Discussion

Although the group level analyses did not reveal any clear evidence of the effective escape use, one adult female, Lucy, performed significantly better when the escape response was available as compared to when it was unavailable. The results suggest that Lucy was able to avoid the memory test when she forgot the location of the preferred

reward, while taking the test when her memory was reliable. Associative learning is unlikely to be responsible for her performance because there were no obvious visual discrimination cues that were correlated with the degree of her memory strength within each of the Escape conditions. That is, Lucy could not follow any simple rule such as avoiding the memory test when the barrier had been presented because all trials were identical within condition. Furthermore, Lucy could not make escape decisions simply based on her direct perception of task difficulty as the current experiment required her to decide whether she would take the test or quit it *before* the final presentation of the test. In other words, she could not decide to quit the test after actually trying to point at the baited blue cup through either the right or left hole. When the escape response was presented, the two blue cups were still lined up in front of the center hole in the Plexiglas panel and Lucy could not tell the final destination of the baited blue cup. Instead, she had to predict the reliability of her memory performance when deciding whether to take the test or not.

It is still possible that, while the two blue cups were lined up at the center, Lucy tried to fix her eye on the baited one, escaping the memory test when she was not able to do so. In other words, she might have gradually learned the correlation between her own gaze and memory performance (i.e., she was prone to mistakes when she was unable to pick up a blue cup with her eyes), adjusting her escape use according to her own gaze. However, her performance in the two Escape conditions was not compatible with this gaze-learning account. In the Escape (–) condition, she did not make any mistake after deciding to take the memory test, which means that trial-and-error could not explain her performance. Also, in the Escape (+) condition, she made only two mistakes in the memory test, and before making the first mistake, she had been successful at selecting the baited blue cup in all 14 trials in which she had chosen to proceed to the memory test. Therefore, Lucy was able to use the escape response effectively from the beginning of the current experiment, which indicates that any account of trial-and-error learning is unlikely to explain her performance.

There seems to be at least two reasons why the other subjects failed to show such effective use of the escape response. As for one adult female, Bonnie, her memory performance did not exceed a chance level in the Forced condition, which means that she was merely guessing the location of the baited blue cup when she decided to take the memory test. It is therefore not surprising that she did not escape the memory test effectively. If she had no clue where the preferred food was in all trials, she could never selectively escape the test for which she forgot the answer. The remaining 3 subjects performed significantly above chance in the memory test in the Forced condition, yet failed to effectively use the escape response. They did escape the

memory test in 16.7–48.6% of trials though, which indicates that their escape decision did not depend on the reliability of their memory. However, due to the current experimental design, one should be cautious about concluding that those subjects were not able to judge their own memory. The orangutans could obtain two grapes with a good chance of 50% even when they simply guessed the location of the preferred reward, which might have resulted in their apparent random use of the escape response. One solution for this problem would be to decrease the probability of receiving two grapes by increasing the number of hiding locations (i.e., the blue cups). Before conducting such experiments, it remains unclear whether these subjects can also monitor their own memory just as Lucy demonstrated.

General discussion

The current study explored whether orangutans were able to escape spatial memory tasks effectively when they did not remember the answer for the tests. Throughout the experiments, there are three lines of evidence supporting the possibility that at least some of the orangutans appeared to judge their own memory. First, in Experiment 1, one female orangutan, Bonnie escaped the memory test significantly more often when the baiting of the preferred reward was visually blocked as compared to when it was visible, and she discriminated the two testing conditions from the beginning of trials. Second, the orangutans as a group were significantly more likely to escape the memory test when they could not see the experimenter hiding the preferred reward than when they could see the hiding process in Experiment 2, and their effective use of the escape response was transferred to Experiment 3, in which the apes used the escape response significantly more often when the two hiding locations were switched than when they remained the same. Third, in Experiment 4, one adult female, Lucy, performed significantly better in the memory test when the escape response was available than when it was unavailable, selectively avoiding the memory test in which she would perform poorly, and she showed her successful use of the escape response from the beginning of trials.

Although the above findings are consistent with the metacognition account, there are alternative explanations for the apes' successful performance. The current study therefore attempted to eliminate such alternative possibilities. As for experiments 1–3, for instance, it is possible that the orangutans learned an association between certain perceptual cues and mistakes in the memory test. That is, the apes might have gradually found out that they were prone to mistakes in the memory test when the barrier had been presented or when the hiding locations had been switched, only to learn to escape the test according to such perceptual

information. At first glance, this might be sound especially given that the orangutans came to be proficient in escaping the test in Experiment 2 but after failing to do so in experiment 1 and the pilot test. However, as mentioned above, the orangutans were able to transfer their appropriate use of the escape response to Experiment 3, which was a different experimental setting than the first three experiments. Also, the group analyses failed to detect any clear evidence for trial-and-error learning within Experiment 3. No clear effect of learning was found in Experiment 2, either. Considering that the orangutans suddenly became skillful in using the escape response in Experiment 2, the lack of significant group results in Experiment 1 and the pilot test rather seems to be due to confounding effects such as the apes' food preference, their limited understanding of the escape response contingency, and the infrequent use of the safe choice. Most importantly, associative learning seems to be insufficient for explaining Bonnie's performance in Experiment 1, because she needed little experience before demonstrating her skillful escape use. In addition, she had not had experienced a barrier of any kind in previous experimental settings. Therefore, although associative learning cannot be totally ruled out for the group results in Experiments 2 and 3, Bonnie's performance in Experiment 1 does not really fit this explanation.

Another alternative explanation for the orangutans' performance is that the apes escaped the memory test based on their direct perception of task difficulty. Namely, the orangutans might have avoided taking the memory test when their attempt to point at the baited blue cup failed and they felt uneasy. This explanation cannot be refuted in experiments 1–3 because the orangutans were given an opportunity of choosing whether to take the memory test *after* the test reached the final stage (i.e., after the blue cups were moved to their final destinations). Experiment 4 was designed to eliminate this possibility. In this experiment, the orangutans had to decide whether they would proceed to take the memory test *before* the final presentation of the memory test. When the apes were making a decision on whether to take or quit the test, the two hiding locations were still lined up in front of the center hole of the Plexiglas panel, and the orangutans could not tell where the baited blue cup would end up. Hence, it was impossible for the subjects to avoid the test only after they failed to pick up a blue cup that they thought was baited with two grapes. Instead, the subjects had to predict their future performance in the memory test based on their current memory about the location of the preferred reward. In experiment 4, Lucy was the only subject who performed significantly better in the memory test when the escape response was available than when it was unavailable, by selectively escaping the memory test in which she would perform poorly. Therefore, the account of direct difficulty perception cannot be applied to

at least Lucy's performance in this experiment. Likewise, the associative learning is insufficient for explaining her successful performance because there were no obvious perceptual cues available that were correlated with her memory performance (e.g., the presence of the barrier). In addition, she demonstrated her effective use of the escape response from the beginning of trials, which makes it unlikely that any kind of trial-and-error learning occurred.

Although the other subjects did not show any evidence for appropriate escape use in Experiment 4, one should be cautious about interpreting their performance. In all the experiments in the current study, the possibility of receiving two grapes by chance was set to 50%, which the orangutans might have found pretty high. In other words, it is possible that some of the subjects merely preferred to receive two grapes with a 50% probability rather than receiving one grape with certainty on some trials, which might have resulted in their apparent random use of the escape response. Further studies should be conducted to investigate whether decreasing the chance probability of receiving the preferred reward could encourage orangutans to make the safe choice appropriately.

Also related to this issue, one might argue that the orangutans in the current study assessed the risk of losing the preferred reward or calculated the likelihood of their own success in the memory tasks as did the rhesus monkeys in Kornel et al.'s (2007) and Shields et al.'s (2005) studies. For example, by taking the chance probability of success into account, the subjects might have estimated that they would successfully complete the memory test with an about 80% probability on a certain trial, and consequently decided to take the memory test. Although this might be the case, note that such risk assessment would be impossible without aforementioned judgment on things like perceptual cues, task difficulty, or memory. And as discussed above, for at least some of the orangutans (Bonnie and especially Lucy), the basis of their judgment appeared to lie in their own memory trace.

Another issue involved in the current study, particularly in Experiment 4, is delayed gratification. In this experiment, the subjects could either receive an immediate but less preferred reward with certainty or wait for a desirable reward with a risk of losing it. Considering that the frequency of their escape use in experiment 4 was relatively high as compared to the other experiments, it is likely that the subjects were in fact encouraged to make the safe choice because they preferred the immediate gratification over the delayed one to some extent. However, such a confounding effect should not be a major obstacle for examining their metacognitive ability, because each of the orangutans did decide to take the memory test in a considerable percentage of trials, demonstrating their competence in delayed gratification. Previous studies have also reported

that an orangutan and chimpanzees successfully (if not perfectly) self-imposed a long delay in order to increase the amount of their reward gain (Beran 2002; Beran et al. 1999). In any case, the fact remains that Lucy showed her effective use of the escape response in experiment 4 despite her some preference for the immediate reward, if any.

With regard to individual performance, one interesting question is why the two prominent subjects, Bonnie and Lucy, employed metacognitive strategies rather inconsistently across the experiments. It is true that each of these subjects failed to show their significantly efficient escape use in some of the experiments, but there seem to be sound explanations for that. Bonnie successfully used the escape response at the significant level in Experiments 1 and 2. Her escape performance did not reach the significant level in the pilot test and Experiment 3, but she still used the escape response in the predicted directions. It is possible that her limited understanding of escape response contingency (in the pilot test) and the relative easiness of the Switch conditions (in Experiment 3) discouraged her from using the escape response frequently, which became an obstacle to the detection of possible significant results. In Experiment 4, Bonnie used the escape response in a random manner. This was not surprising considering that her memory performance in the Forced condition did not differ from the chance level (i.e., she was always guessing the location of preferred reward in the primary task). Consequently, she could not selectively avoid trials in which she would more likely make a mistake. As for Lucy, her escape use was significantly effective in Experiments 2 and 4. She used the escape response in the predicted directions in the pilot test and Experiment 3, but failed to reach the significant level. Again, this could be due to her limited understanding of escape response contingency and the relative easiness of the Switch conditions. In Experiment 1, Lucy chose the escape response once in the Visible condition and never used it in the Hidden condition. It is likely that her food preference interfered with her performance. Given that she chose dog food in 8.3% of preference trials, she might have preferred dog food by chance on this particular testing trial. Overall, both of the subjects produced some evidence for the competence in using metacognitive strategies.

Finally, although the present study was admittedly explorative, one can speculate implications of the current findings. The ability to monitor their own memory would be a great advantage for nonhuman great apes in general. For instance, if individuals can assess the strength of their own memory trace about different locations of important resources such as food or potential mates, they can selectively travel to those which they surely remember without wasting energy and time. Likewise, if subjects can tell the absence of a critical piece of information about a novel task, they can actively seek for it by observing other skillful

individuals without using a trial-and-error strategy (cf. Sabiaul et al. [in press](#)). It would not be therefore surprising that other great ape species possess such a metacognitive ability as some of the orangutans in the current study appeared to demonstrate. More research similar to the current experiments should be conducted on all species of great apes in order to reveal similarities and perhaps differences among species.

In conclusion, the current study is the first to document metacognitive judgments in nonhuman primates without conducting thousands of training trials. The orangutans were tested whether they were able to escape various kinds of spatial memory tests when they lacked a critical piece of information for the tests and when their memory about the location of preferred reward was poor. The results suggest that at least some orangutans appear to monitor their own memory, which was comparable with a growing body of evidence that great apes have sophisticated understanding of what others see and know (Hare et al. 2000, 2001; Kaminski et al. 2004; Melis et al. 2006; Shillito et al. 2005; Tomasello et al. 1999). The study of apes' understanding of their own minds has been rather neglected as compared to that of their understanding of other minds. Further studies are necessary to investigate to what extent great apes can monitor their own cognitive activities in various kinds of situations. Such research would contribute to establish a theoretical framework linking a gap between self and others in the great ape's mind.

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References

- Barth J, Call J (2006) Tracking the displacement of objects: a series of tasks with great apes (*Pan troglodytes*, *Pan paniscus*, *Gorilla gorilla*, and *Pongo pygmaeus*) and young children (*Homo sapiens*). *J Exp Psychol Anim Behav Proc* 32:239–252
- Beran MJ (2002) Maintenance of self-imposed delay of gratification by four chimpanzees (*Pan troglodytes*) and an orangutan (*Pongo pygmaeus*). *J Gen Psychol* 129:49–66
- Beran MJ, Pate JL, Rumbaugh DM (1999) Delay of gratification in chimpanzees (*Pan troglodytes*). *Dev Psychol* 34:119–127
- Beran MJ, Smith JD, Redford JS, Washburn DA (2006) Rhesus macaques (*Macaca mulatta*) monitor uncertainty during numerosity judgments. *J Exp Psychol Anim Behav Proc* 32:111–119
- Bräuer J, Call J, Tomasello M (2004) Visual perspective-taking in dogs (*Canis familiaris*) in the presence of barriers. *Appl Anim Behav Sci* 88:299–317
- Call (2001) Object permanence in orangutans (*Pongo pygmaeus*), chimpanzees (*Pan troglodytes*), and children (*Homo sapiens*). *J Comp Psychol* 115:159–171

- Call (2003) Spatial rotations and transpositions in orangutans (*Pongo pygmaeus*) and chimpanzee (*Pan troglodytes*). *Primates* 44:347–357
- Call J (2005) The self and other: a missing link in comparative social cognition. In: Terrace HS, Metcalfe J (eds) *The missing link in cognition: origins of self-reflective consciousness*. Oxford University Press, New York, pp 321–341
- Call J, Carpenter M (2001) Do apes and children know what they have seen?. *Anim Cogn* 4:207–220
- de Blois ST, Novak MA, Bond M (1998) Object permanence in orangutans (*Pongo pygmaeus*) and squirrel monkeys (*Saimiri sciureus*). *J Comp Psychol* 112:137–152
- de Blois ST, Novak MA, Bond M (1999) Can memory requirements account for species' differences in invisible displacement tasks?. *J Exp Psychol Anim Behav Proc* 25:168–176
- Hampton RR (2001) Rhesus monkeys know when they remember. *Proc Natl Acad Sci* 98:5359–5362
- Hampton RR, Zivin A, Murray EA (2004) Rhesus monkeys (*Macaca mulatta*) discriminate between knowing and not knowing and collect information as needed before acting. *Anim Cogn* 7:239–246
- Hare B, Call J, Tomasello M (2001) Do chimpanzees know what conspecifics know?. *Anim Behav* 61:139–151
- Hare B, Call J, Agnetta B, Tomasello M (2000) Chimpanzees know what conspecifics do and do not see. *Anim Behav* 59:771–785
- Inman A, Shettleworth SJ (1999) Detecting metamemory in nonverbal subjects: a test with pigeons. *J Exp Psychol Anim Behav Proc* 25:389–395
- Kaminski J, Call J, Masello M (2004) Body orientation and face orientation: two factors controlling apes' begging behavior from humans. *Anim Cogn* 7:216–223
- Kornell N, Son LK, Terrace HS (2007) Transfer of metacognitive skills and hint seeking in monkeys. *Psychol Sci* 18:64–71
- MacDonald SE, Agnes MM (1999) Orangutan (*Pongo pygmaeus abelii*) spatial memory and behavior in a foraging task. *J Comp Psychol* 113:213–217
- Melis AP, Call J, Tomasello M (2006) Chimpanzees conceal visual and auditory information from others. *J Comp Psychol* 120:154–162
- Nelson TO, Narens L (1990) Metamemory: a theoretical framework and new findings. In: Bower GH (ed) *The psychology of learning and motivation*, vol. 26. Academic Press, New York, pp 125–141
- Nelson TO, Narens L (1994) Why investigate metacognition? In: Metcalfe J, Shimamura AP (eds) *Metacognition: knowing about knowing*. MIT Press, Cambridge, pp 1–25
- Paukner A, Anderson JR, Fujita K (2006) Redundant food searches by capuchin monkeys (*Cebus apella*): a failure of metacognition? *Anim Cogn* 9:110–117
- Sabial F, Romansky K, Cantlon JF, Klein T, Terrace H (in press) Cognitive imitation in 2-year-old human children (*Homo sapiens*): a comparison with rhesus monkeys (*Macaca mulatta*). *Anim Cogn*. doi:10.1007/s10071-006-0070-3
- Shields WE, Smith JD, Guttmannova K, Washburn DA (2005) Confidence judgments by humans and rhesus monkeys. *J Gen Psychol* 132:165–186
- Shields WE, Smith JD, Washburn DA (1997) Uncertain responses by humans and rhesus monkeys (*Macaca mulatta*) in a psychophysical same-different task. *J Exp Psychol Gen* 126:147–164
- Shillito DJ, Shumaker RW, Gallup GG, Beck BB (2005) Understanding visual barriers: evidence for level 1 perspective taking in an orang-utan, *Pongo pygmaeus*. *Anim Behav* 69:679–687
- Shumaker RW and Swartz KB (2004) Cognition: mirror self-recognition. In: Bekoff M (ed) *Encyclopedia of Animal Behavior*, Vol. 1, A-C. Greenwood Press, Westport CT London, pp 308–312
- Smith JD, Schull J, Strote J, McGee K, Egnor R, Erb L (1995) The uncertain response in the bottlenosed dolphin (*Tursiops truncatus*). *J Exp Psychol Gen* 124:391–408
- Smith JD, Shields WE, Allendoerfer KR, Washburn DA (1998) Memory monitoring by animals and humans. *J Exp Psychol Gen* 127:227–250
- Smith JD, Shields WE, Schull J, Washburn DA (1997) The uncertain response in humans and animals. *Cognition* 62:75–97
- Smith JD, Shields WE, Washburn DA (2003a) The comparative psychology of uncertainty monitoring and metacognition. *Behav Brain Sci* 26:317–339
- Smith JD, Shields WE, Washburn DA (2003b) Inaugurating a new area of comparative cognition research. *Behav Brain Sci* 26:358–373
- Son LK, Kornell N (2005) Metacognitive judgments in rhesus macaques: explicit versus implicit mechanisms. In: Terrace HS, Metcalfe J (eds) *The missing link in cognition: origins of self-reflective consciousness*. Oxford University Press, New York, pp 296–320
- Swartz KB, Himmanen SA (2006) Individual response strategies in list learning by orangutans. *Int J Psychol Psychol Therapy* 6:233–248
- Tomasello M, Hare B, Agnetta B (1999) Chimpanzees, *Pan troglodytes*, follow gaze direction geometrically. *Anim Behav* 58:769–777
- Washburn DA, Smith JD, Shields WE (2006) Rhesus monkeys (*Macaca mulatta*) immediately generalize the uncertain response. *J Exp Psychol Anim Behav Proc* 32:185–189