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Gorillas (*Gorilla gorilla*) and Orangutans (*Pongo pygmaeus*) Encode Relevant Problem Features in a Tool-Using Task

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Two important elements in problem solving are the abilities to encode relevant task features and to combine multiple actions to achieve the goal. The authors investigated these 2 elements in a task in which gorillas (*Gorilla gorilla*) and orangutans (*Pongo pygmaeus*) had to use a tool to retrieve an out-of-reach reward. Subjects were able to select tools of an appropriate length to reach the reward even when the position of the reward and tools were not simultaneously visible. When presented with tools that were too short to retrieve the reward, subjects were more likely to refuse to use them than when tools were the appropriate length. Subjects were proficient at using tools in sequence to retrieve the reward.

In recent years there has been a renewed interest in problem solving and tool use in a number of species, including chimpanzees, capuchins, cotton-top tamarins, and New Caledonian crows (Chappell & Kacelnik, 2002; Hauser, 1997; Povinelli, 2000; Visalberghi, Fragaszy, & Savage-Rumbaugh, 1995; Visalberghi & Limongelli, 1996). Most of these studies focused specifically on the mechanisms underlying tool use in these various species and, in particular, on the causal understanding that subjects have of the problems and the requirements that tools must meet to satisfactorily solve the problem.

Currently, there is much controversy about how much nonhuman primates understand of tool use and causality. Whereas some researchers argue that nonhuman primates have only a limited understanding of the critical features of various tasks (Povinelli, 2000), others argue that these primates can decide between relevant and irrelevant features of various problems (Hauser, 1997; Limongelli, Boysen, & Visalberghi, 1995). This controversy has arisen partly because (a) different studies have used different problems that contain multiple elements, (b) there is extensive training involved, and (c) in many cases choices are directly visible and there is nothing to be computed mentally. This creates a situation in which subjects are faced either with problems that are too hard, with training regimens that may potentially interfere with their performance, or with simpler problems that do not require any sort of encoding and mental manipulation. What is missing are studies that focus on a simple problem and investigate the basic elements underlying causal understanding in that problem. Two basic elements of problem solving involving tool use that remain largely unexplored are the use of mental representation to encode relevant tool features and the ability to chain discrete behaviors to achieve the goal. A detailed study of each of these two elements can throw some light on the type of causal understanding that subjects can attain in those situations, thus helping to resolve some of the controversy in the field. The ability to represent features of the problem is a central skill for mental problem solving, because imagining possible solutions and choosing the most appropriate one is based on keeping track of the relevant features of a problem. Thus, mental representation, not just direct perception, of certain relevant features of the problem is clearly important.

Similarly, chaining elements into a coherent sequence is fundamental for problem solving because even simple problems often involve more than one step. For instance, getting a grub from a hole involves getting a tool (which often also means making it), inserting the tool in the hole, and taking it out. If these two basic elements—representation and planning—are not in place, it may be pointless to argue about more complex topics or about some psychological (i.e., cognitive) understanding of the problem.

In this study we investigated these two basic elements in the tool use of orangutans and gorillas. We used the tool and out-of-reach problem, in which the subject had to use a tool to retrieve a reward on a platform. Various primates have succeeded at this problem and can use tools proficiently to get the reward within reach (see Tomasello & Call, 1997, for a review). However, much less is known about whether subjects can represent the length of the tool and whether they can use a tool to retrieve another tool. We chose this problem because of the simplicity of its elements and because it required no specific training and afforded the possibility to present the critical elements of the problem (tools and reward on the platform) separately. This permitted us to investigate the two issues in this study. First, we studied the representation issue by looking at whether subjects can encode the requirements that a tool should meet (in terms of its length) to be effective. We investigated whether subjects were able to select tools of an appropriate length to reach the reward when the position of the reward and the length of the tool were not simultaneously visible and whether subjects would refuse to attempt to use tools that were too short. Second, we studied the issue of planning by looking at whether subjects were able to select the correct sequence of tools to reach the reward—in particular, whether they could use a tool to retrieve another tool and whether upon getting a tool they could decide if

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they needed a longer tool or if they could directly reach the reward with the tool in their possession.

We selected gorillas and orangutans because we wanted to compare the representational and behavior-chaining skills of two apes that have seemingly different tendencies to use tools. In a recent review, Tomasello and Call (1997; see Table 3.2) found that 15 studies had reported tool use in orangutans, whereas only 8 studies had reported tool use in gorillas. Moreover, this compilation also showed that orangutans use a greater variety of tools than do gorillas, although both gorillas and orangutans can solve the tool and out-of-reach problem (e.g., Fontaine, Moisson, & Wickings, 1995; Lethmate, 1982). Research in the wild has also shown that some orangutan populations use tools regularly (van Schaik, Fox, & Sitompul, 1996), whereas this has not been described for any gorilla population yet. Thus, this study investigated whether cognitive differences can be a potential explanation of the different tendency of gorillas and orangutans to use tools.

Pilot Experiment

The aim of the pilot study was to investigate whether subjects could obtain and modify a stick from a tree branch, which then could be used as a tool to retrieve an out-of-reach food reward. We tested all gorillas and orangutans listed in Table 1 except Ndiki and Dokana. Subjects were housed at the Wolfgang Köhler Primate Research Center in Leipzig, Germany. All subjects were either adults or subadults and captive born, except Bebe and Ndiki, who were wild born (see Table 1 for additional details). The gorillas and orangutans lived in social groups consisting of 7 and 8 individuals, respectively. Subjects had access to indoor areas (gorillas, 264 m^2; orangutans, 230 m^2) and outdoor areas (gorillas, 2,300 m^2; orangutans, 1,680 m^2). The outdoor areas contained natural vegetation, trees, and various objects such as tires and climbing ropes. The animals were fed three times a day on a diet of vegetables, fruit, and monkey chow. In addition, food such as nuts was regularly hidden inside various locations of the enclosure to promote natural foraging activities. All subjects were individually tested in their indoor cages (25 m^2 and 3.15 m high). Water was available ad libitum and subjects were not food deprived at any time. Subjects had no prior experience with experiments involving tool use.

The food used in the pilot study and all following experiments was a flattened grape placed on a platform. Food was placed within the subject's reach on a wooden platform (60 × 30 cm), which was flushed against the metal mesh of the testing cage (see Figure 1). This allowed subjects to retrieve the food through the mesh with their fingers. Once subjects had obtained the food on five consecutive trials, the food was moved 20 cm out of the subject's reach. Each subject was then provided with a large tree branch on three separate occasions. The results of the pilot study showed that all subjects were able to break off and modify sticks from the branches and use them as tools to retrieve the food in all trials. Once it was established that the subjects could use sticks as tools, we provided subjects with tools (i.e., sticks cut from branches and stripped of leaves) that had been prepared by the experimenter. This allowed us to conduct the following series of experiments.

Table 1
Name, Gender, Age, and Rearing History of the Subjects Who Participated in This Study

Subject	Gender	Age (years)	Rearing history
Gorilla			
Gorgo	M	21	Nursery raised
Ndiki	F	24	Mother raised
Bebe	F	22	Mother raised
Vimoto	M	7	Mother raised
Viringika	F	7	Mother raised
Vizuri	F	7	Mother raised
Orangutan			
Bimbo	M	22	Nursery raised
Walter	M	13	Mother raised
Dunja	F	31	Nursery raised
Pini	F	14	Mother raised
Toba	F	8	Mother raised
Dokana	F	13	Mother raised

Note. M = male; F = female.

Experiment 1

This experiment investigated whether subjects could choose the tool with the appropriate length (out of two possible tools) that would allow successful retrieval of a piece of food that was placed out of the subject's reach. We presented three conditions that varied in the lengths of the tools and the distance of the reward in the platform.

Method

Subjects. We used all gorillas (*Gorilla gorilla*) and orangutans (*Pongo pygmaeus*) listed in Table 1 in this experiment.

Materials. Straight wooden sticks of 10, 15, and 30 cm in length and 0.5–0.8 cm in diameter were used as tools, and a flattened grape was used as a reward.

Procedure. The experimenter placed two tools on the platform perpendicular to the mesh, 30 cm apart. The platform itself was out of reach so that the subject was unable to get the tools at this time. Then the experimenter placed the reward on the platform out of reach of the subject and equidistant between the tools (see Figure 1). The following conditions were used in the experiment and varied in tool length and whether one or both tools were suitable to reach the reward:

> *Long tool only A:* The lengths of the tools were 30 cm and 10 cm, and the reward was placed 20 cm from the mesh. Therefore, only the longer tool was suitable to retrieve the reward.
>
> *Long tool only B:* The lengths of the tools were 30 cm and 15 cm, and the reward was placed 25 cm from the mesh. Therefore, only the longer tool was suitable to retrieve the reward.
>
> *Either tool:* The lengths of the tools were 30 cm and 15 cm, and the reward was placed 10 cm from the mesh. Therefore, both tools were suitable to retrieve the reward.

Once the food was placed on the platform, the experimenter waited 5 s before pushing the platform flush against the mesh so that the subject could choose one of the two tools. When the subject chose one tool, the other tool was immediately removed by the experimenter. In all experiments, subjects were permitted to use the tool until they retrieved the reward. If during the tool manipulation the subject accidentally pushed the reward out of reach, the experimenter waited 10 s and then picked up the grape and placed it back into the food container. Also, if subjects chose the incorrect tool, the trial was stopped after 10 s.

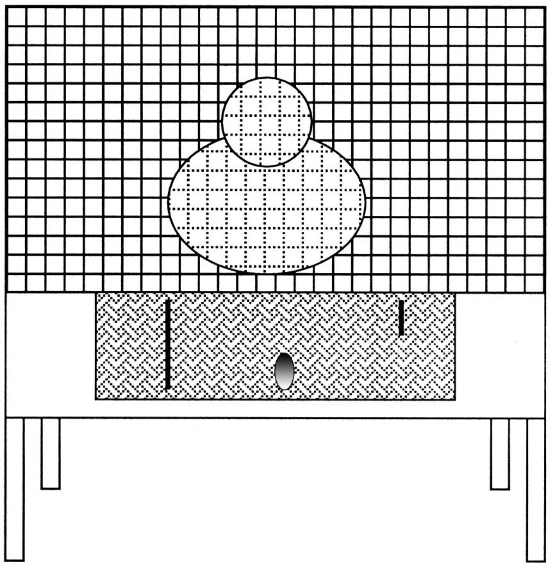

Figure 1. Setup of the experiment. The subject behind the metal mesh could choose between the two tools on each side of the sliding platform to rake in the reward depicted in the center of the platform of the testing room.

Each subject received a total 24 trials (three tool length conditions, replicated eight times). The three conditions were presented in succession with the position of the two tools counterbalanced for side distributed in three to six sessions, depending on how cooperative the subjects were. All trials were videotaped, and we scored which tool subjects targeted.

Results

Table 2 presents the number of trials in which subjects chose the longer tool across conditions. There were no significant differences between species for any of the conditions (long tool only A: Mann–Whitney $U = 11.5$, $p = .54$; long tool only B: $U = 12.5$, $p = .66$; either tool: $U = 5.5$, $p = .082$; $N = 11$, in all cases). Therefore, in subsequent analyses we collapsed the data across species.

There were significant differences across conditions, Friedman test(2) = 9.59, $p = .008$. Post hoc comparisons across conditions corrected with the Bonferroni–Holm procedure (Holm, 1979) revealed that subjects selected the longer tool significantly more often in the long tool only A condition compared with the long tool only B condition (Wilcoxon $T = 28$, $N = 7$, adjusted $p = .048$). The comparison between the long tool only A and either tool conditions approached significance ($T = 40.5$, $N = 9$, adjusted $p = .055$), whereas there were no significant differences between the long tool only B and either tool conditions ($T = 27$, $N = 8$, $p = .25$).

Overall, subjects selected the longer tool more often than would be expected by chance in the long tool only A ($T = 66$, $N = 11$, $p < .001$) and long tool only B conditions ($T = 55$, $N = 10$, $p < .01$) but not in the either tool condition ($T = 44.5$, $N = 10$, $p = .084$). Thus, subjects showed a preference for the longer tool only when it was needed to get the reward. Such a preference for the longer tool could even be identified in the first trial (see Table 2) for the long tool only A condition (binomial test: $p = .012$) but not for the long tool only B (binomial test: $p = .065$) or either tool conditions (binomial test: $p = .23$). Finally, there was no evidence that subjects changed their tool preference over trials when the first three trials were compared with the last three trials for each condition (long tool only A: $T = 8$, $N = 4$, $p = .38$; long tool only B: $T = 11$, $N = 6$, $p = 1$; either tool: $T = 9$, $N = 5$, $p = .81$).

Discussion

This experiment formally established that both species used tools effectively to get the reward on the platform. Subjects selected the longer tool preferentially when it was needed to retrieve the reward. This was particularly true for the condition in which the tools showed the largest difference in size and the reward could be reached with only the longer tool. Although this experiment formally established the use of tools in this task for gorillas and orangutans, it did not require that the subjects encode any particular feature of the task such as tool length or reward distance; these features could simply be perceived.

Experiment 2

In Experiment 1, when both tools were suitable to retrieve the reward, gorillas showed no preference for the longer tool and simply selected tools (either short or long) that were appropriate to get the reward. To increase the difficulty of the problem, we introduced tools with novel lengths and presented the food and tools sequentially rather than simultaneously. Therefore, subjects would have to also remember, rather than just perceive, the length requirements of the tools to get the reward.

Method

Subjects. All gorillas listed in Table 2, except Ndiki, were tested in this experiment.

Table 2
Number of Trials (out of 8 Possible) and Mean Percentage in Which Subjects Chose the Longer Tool Across Conditions

Subject	30 vs. 10 cm: Long tool only	30 vs. 15 cm: Long tool only	30 vs. 15 cm: Either tool
Gorilla			
Gorgo	6 (L)	4 (S)	3 (L)
Bebe	7 (L)	5 (L)	5 (L)
Vimoto	8 (L)	7 (L)	3 (S)
Viringika	8 (L)	8 (L)	3 (S)
Ndiki	5 (L)	5 (L)	8 (L)
Vizuri	8 (L)	7 (L)	4 (S)
Subtotal %	88	75	54
Orangutan			
Bimbo	8 (L)	8 (L)	5 (L)
Walter	8 (L)	5 (L)	8 (L)
Pini	7 (L)	6 (L)	6 (L)
Toba	8 (L)	6 (L)	5 (L)
Dokana	7 (S)	7 (L)	7 (L)
Subtotal %	95	80	78
Total %	91	77	64

Note. *Long tool only* and *either tool* indicate which tool was suitable to get the reward. The type of tool chosen on the first trial is indicated in parentheses. L = long; S = short.

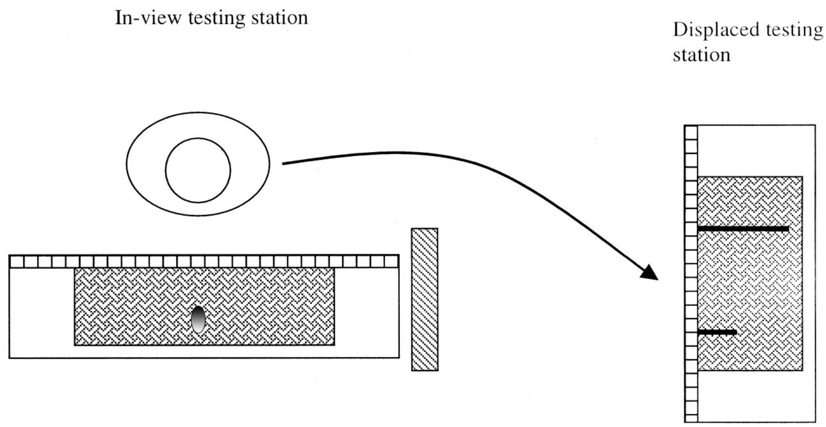

Figure 2. Bird's-eye view of the in-view and displaced testing stations, which allowed the food and the tools to be visibly displaced. The occluding panel is shown on the right side of the in-view testing station. This prevented the subject from seeing the food and tools simultaneously when the subject moved from the in-view station to the displaced station in order to choose a tool.

Materials. Straight wooden tools of 15, 25, and 35 cm in length and 0.5–0.8 cm in diameter were used as tools, and a flattened grape was used as a reward. Two testing stations, in view and out of view, located at right angles to each other, were used (see Figure 2). An opaque panel (85 × 32 cm) prevented subjects' simultaneous visual access of both testing stations. The occluding panel prevented simultaneous visual access only when the subject was at the sequential testing station as opposed to the in-view station (see Figure 2).

Procedure. The general procedure was the same as in Experiment 1, with some important differences. The experimenter placed the reward out of reach on the platform in Testing Station 1. After a delay of 5 s, the experimenter went to Testing Station 2 and placed two tools of different lengths on the platform perpendicular to the mesh and separated by 30 cm from each other. Once the subject arrived at Station 2, the experimenter waited 5 s before pushing the platform against the mesh so that the subject could select one of the tools available. In every trial, subjects retrieved one of the tools and moved to Station 1 to retrieve the reward.

There were two tool suitability conditions that varied in whether only the longer (long tool only condition) or both tools (either tool condition) were suitable to get the reward. To make the trials as varied and novel as possible, each condition was presented with three possible sets of tools: (a) 35 versus 25 cm, (b) 35 versus 15 cm, and (c) 25 versus 15 cm. The position of the reward on the platform depended on the condition and the set of tools presented. In the long tool only condition, the food was placed 25 or 35 cm from the mesh when the longer tool was 25 or 35 cm, respectively. In the either tool condition, the food was placed 15 or 25 cm from the mesh when the shorter tool was 15 or 25 cm, respectively.

Each subject was given a total of 24 trials (two tool suitability conditions, each with three sets of tools, replicated four times) in random order, with the type of tool counterbalanced for side. The number of testing sessions was one or two, depending on the subjects.

Results

Table 3 presents the number of trials in which subjects chose the longer tool in each condition. There were no significant differences between conditions ($T = 8$, $N = 5$, $p = 1$), and subjects tended to select the longer tool more often than expected by chance in both conditions ($T = 15$, $N = 5$, $p = .063$). Individual analyses indicated that 4 out of 5 subjects selected the longer tool significantly more often than expected by chance in each condition (binomial tests: $p < .05$). Thus, most subjects showed a preference for the longer tool regardless of whether the longer tool was necessary to get the reward.

Although this preference for the longer tool seems to have been present from the beginning of the experiment for the long tool only condition (all subjects selected the longer tool in the first trial), our small sample size did not allow us to draw any firm conclusions on the subjects' initial tool preferences (binomial test: $p = .063$). Nevertheless, a comparison between the first and the last three trials revealed no significant differences in tool preference for any of the two conditions (Wilcoxon test: $N < 3$, in both cases, *ns*).

Discussion

Unlike in the previous experiment, subjects appeared to prefer the longer tool to the shorter one irrespective of whether both tools or only the long one was suitable to get the reward. This means that selecting the longer tool cannot be explained as a result of directly comparing the tool length with the position of the reward. However, it is conceivable that subjects may have selected the longer tool by directly comparing it with the shorter one without necessarily encoding the length of each of them. We investigated

Table 3
Number of Trials (out of 12 Possible) and Mean Percentage in Which Subjects Chose the Longer Tool, Depending on Whether Either or Only the Longer Tool Was Suitable to Get the Reward

Gorilla	Either tool	Long tool only
Gorgo	9 (L)	10 (L)
Bebe	10 (S)	11 (L)
Vimoto	10 (S)	8 (L)
Viringka	10 (L)	12 (L)
Vizuri	12 (L)	10 (L)
Total %	85	85

Note. The type of tool chosen on the first trial is indicated in parentheses. L = long; S = short.

whether subjects were able to encode the length of the tool (and were not just perceiving it) in the next experiment in which each tool was presented separately. To select the longer one, subjects would have to mentally encode and compare the tools' respective lengths.

Experiment 3

This experiment investigated the ability of subjects to choose the correct tool for retrieving the out-of-reach reward after opaque boxes were placed over the tools. We included some conditions in which each tool and the reward were presented simultaneously and other conditions in which each tool and the reward were presented sequentially, thus preventing direct comparisons between the tools and the distance at which the reward was located. In the critical condition, subjects had to encode and mentally compare the length of the tools to select the appropriate one.

Method

Subjects. We tested all subjects listed in Table 1, with the exception of Ndiki, who refused to participate.

Materials. We used the same tools and rewards as in Experiment 2 and a single testing station with its corresponding platform. We also used an occluder, 60 × 30 cm, which was placed in front of the mesh, to prevent the subjects' visual access to the placing of the tools on the platform. Two white cardboard boxes (36 cm long × 9 cm wide × 5 cm deep) were used to cover the tools once they were on the platform.

Procedure. As in previous experiments, the experimenter placed two tools, separated by 30 cm, on opposite sides of the platform. However, unlike in previous tests, tool placement was conducted behind an occluding panel so that subjects were prevented visual access to the particular tools that were positioned on the platform. Before removing the occluding panel, the experimenter covered each tool with a box. As in the previous experiment, trials varied in the type of tool combinations used (there were three possible types: 35 vs. 25 cm, 35 vs. 15 cm, and 25 vs. 15 cm) and in tool suitability (i.e., whether either or only the longer tool was suitable to reach the reward). In addition, the current experiment also manipulated the way in which subjects were given visual access to the tools. In particular, the experimenter presented the tools in the three following ways after 5 s had elapsed since the removal of the occluding panel:

> *Simultaneous visible:* Each box was removed and not placed back over the tools. This corresponds to the presentation used in all previous experiments.
>
> *Simultaneous covered:* Each box was removed so that the subject could see both tools simultaneously; later the boxes were placed over the tools once again.
>
> *Sequential covered:* Each box was removed in turn, then placed back over the tool so that the subject never saw both tools simultaneously.

Once the experimenter had finished presenting the tools, a food reward was placed equidistant between the two tools or boxes. As in Experiment 2, the position of the food depended on the tool combination being used and whether both tools or just the longer one could be used to retrieve the reward. After the reward was deposited on the platform and 5 s elapsed, the platform was pushed against the mesh to allow the subject to select one of the two tools available. In those conditions in which the tools were covered by boxes, subjects indicated their choice by touching one of the two boxes and the experimenter offered the corresponding tool.

Each subject received a total of 72 trials (three types of tool combinations, each with two tool suitability conditions and three types of tool presentation, replicated four times) in random order. The number of sessions needed to complete all trials varied between 4 and 11, depending on the subjects. The position of the various tools was counterbalanced for side, whereas the box placed on the experimenter's right side of the platform was removed first during the tool presentation phase of the experiment.

Table 4
Number and Mean Percentage of Trials (out of 12 Possible) in Which Subjects Chose the Longer Tool, Depending on the Form of Presentation and Tool Suitability

Subject	Simultaneous visible		Simultaneous covered		Sequential covered	
	Either tool	Long tool	Either tool	Long tool	Either tool	Long tool
Gorilla						
Gorgo	6 (L)	10 (L)	8 (L)	8 (L)	9 (L)	6 (L)
Bebe	9 (L)	10 (L)	8 (L)	8 (L)	9 (S)	7 (L)
Vimoto	12 (L)	9 (L)	10 (L)	10 (L)	10 (S)	12 (L)
Viringika	9 (L)	11 (L)	7 (L)	8 (S)	10 (L)	8 (L)
Vizuri	11 (L)	9 (L)	8 (S)	10 (L)	10 (L)	10 (L)
Subtotal %	78	82	68	73	80	72
Orangutan						
Bimbo	10 (L)	12 (L)	10 (L)	11 (L)	8 (L)	7 (L)
Walter	11 (L)	12 (L)	8 (S)	9 (L)	8 (L)	7 (L)
Pini	12 (L)	12 (L)	11 (L)	12 (L)	10 (L)	10 (L)
Toba	11 (L)	12 (L)	11 (S)	12 (L)	11 (L)	11 (L)
Dokana	8 (S)	12 (L)	7 (S)	6 (L)	6 (L)	7 (L)
Subtotal %	87	100	78	83	72	70
Total %	82	91	73	78	76	71

Note. In the simultaneous visible presentation, each box was removed and not placed back over the tools. In the simultaneous uncovered presentation, both tools were uncovered simultaneously and then re-covered. In sequential covered, each box was removed in turn and then placed back over the tools. *Long tool* and *either tool* indicate tool suitability. The type of tool chosen on the first trial is indicated in parentheses. L = long; S = short.

Results

Table 4 presents the number of trials in which subjects chose the longer tool. There were no significant differences between species for any of the conditions except the simultaneous visible–long tool condition, in which orangutans selected the longer tool significantly more often than did gorillas ($U = 0$, $p = .008$; Us > 6.5, ps $> .30$, in all other conditions). Upon detecting this interspecies difference, we analyzed the data for gorillas and orangutans separately for those conditions involving the simultaneous visible–long tool condition. However, such a reduction in sample size seriously reduced the statistical power, making it impossible to find significant differences in any of the conditions, even in those cases in which all subjects selected the long tool in every trial (e.g., see simultaneous visible–long tool, in Table 4). Therefore, given that gorillas and orangutans only differed in one out of six conditions, we opted for collapsing the data across species.

First, we analyzed whether tool preference varied depending on tool suitability within each presentation condition. Subjects selected the longer tool equally often regardless of whether either tool or only the longer tool was suitable to get the reward in all presentation conditions (sequential covered: $T = 21$, $N = 7$, $p = .30$; simultaneous covered: $T = 25$, $N = 7$, $p = .08$; simultaneous visible: $T = 33$, $N = 9$, $p = .25$). Overall, subjects showed a marked preference for the longer tool in all conditions ($T = 45$,

$N = 9$, $p = .004$, or $T = 55$, $N = 10$, $p = .002$). This means that subjects showed a preference for the longer tool regardless of whether it was strictly needed to get the reward. This preference for the longer tool appeared in the first trial for all conditions (binomial test: $p < .05$) except the simultaneous covered–either tool (binomial test: *ns*) and the sequential covered–either tool (binomial test: $p = .11$). Moreover, a comparison between the first and the last three trials revealed no significant differences in tool preference for any condition (Wilcoxon test: all *p*s $> .5$).

Second, we collapsed across tool suitability conditions and analyzed whether the preference for the longer tool varied across presentation conditions. There were significant differences across presentation conditions, Friedman test(2) = 9.77, $p = .008$. Post hoc comparisons across conditions corrected with the Bonferroni–Holm procedure revealed that subjects selected the longer tool significantly more often in the simultaneous visible condition compared with the simultaneous covered ($T = 43$, $N = 9$, $p = .012$) and sequential covered conditions ($T = 36$, $N = 8$, $p = .008$). In contrast, there were no significant differences between the two covered conditions ($T = 21.5$, $N = 8$, $p = .64$). Thus, subjects showed a more marked preference for the longer tool when they could see both tools simultaneously at the time of choice. Nevertheless, recall that they still preferred the longer tool to the shorter one in the sequential covered condition, in which they could not see the tools simultaneously and only the long tool was suitable to reach the reward.

Discussion

Subjects showed a marked preference for the longer tool, particularly in the simultaneous visible condition. Nevertheless, subjects still showed such a preference when the tools were presented sequentially. This implies that subjects were capable of mentally comparing the length of the tools. The preference for the longer tool cannot be based on an absolute rule because in some trials (i.e., when paired with the short tool) the medium tool was appropriate, whereas in other trials (i.e., when paired with the long tool) it was not. Therefore, subjects had to make a relative judgment of the length of the tool to select the longer of the two options available. These results mirror previous research showing that orangutans and chimpanzees can mentally compare food quantities that have been presented separately and make relative judgments about the location of the larger one (Beran, 2001; Call, 2000).

The level of preference for the longer tool was dependent on tool presentation but not on suitability. Thus, apes selected the longer tool regardless of whether it was strictly needed to get the reward. In other words, they preferred the longer tool even when the shorter tool was good enough, and this preference was detected within each of the three presentation conditions. Because there was no cost for choosing the longer tool, it is difficult to know whether apes selected the longer tool because they preferred it or because it was more appropriate to get the reward. In the next experiments we addressed these questions by introducing a cost for retrieving the longer tool.

Experiment 4

This experiment investigated the subjects' ability to use a tool to get another tool, which could then be used to retrieve a food reward. Thus, this experiment investigated the ability to chain discrete responses to obtain a goal and also introduced a small cost (i.e., spending time to retrieve the longer tool) that may resolve the questions raised in Experiment 3.

Method

Subjects. We tested all subjects listed in Table 1 in this experiment.

Materials. We used straight wooden tools of 20 cm (short) and 35 cm (long) in length and 0.5–0.8 cm in diameter, the same rewards as in Experiment 2, and a single testing station with its corresponding platform.

Procedure. The experimenter placed the two tools on the platform. The short tool was placed on one side of the platform perpendicular to the mesh whereas the longer tool was placed on the other side of the platform parallel to the mesh, 10 cm away from the platform's edge. Thus, once the platform was flush against the mesh, the subject was able to directly reach the short tool but not the long one. Then, the experimenter placed the reward on the platform at one of two distances from the mesh corresponding to two different tests that we conducted in succession. First, we ran the distant reward test, in which the experimenter placed the reward 35 cm from the mesh so that only the long tool was suitable to get the reward. After 5 s had elapsed, the platform was pushed against the mesh, allowing the subject to grab the short tool and then make a choice between reaching for the reward or for the long tool. In this test, subjects had to use the small tool to retrieve the long tool, which could then be used to retrieve the food.

Upon completing the distant reward test, we conducted the close reward test in which the experimenter deposited the reward 15 cm from the mesh so that the short tool was long enough to get the reward and then, after 5 s had elapsed, pushed the platform against the mesh to let the subject get the short tool and make a choice between retrieving the reward or the long tool.

Each subject received a total of eight trials in each of the two tests with the type of tool counterbalanced for side. The number of sessions varied between one and four, depending on the subjects.

Results

Table 5 presents the number of trials in which subjects used the short tool provided by the experimenter to get either the reward or the (longer) tool in each condition. There were no significant differences between species for the distant reward ($U = 9.5$, $p = .33$) or close reward conditions ($U = 12.5$, $p = .33$). Therefore, we collapsed the data across species in subsequent analyses.

Subjects raked in the tool significantly more often in the distant reward compared with the close reward condition ($T = 66$, $N = 11$, $p = .001$). Moreover, subjects targeted the tool significantly more often than the reward in the distant reward condition ($T = 55$, $N = 10$, $p < .002$), whereas they targeted the reward significantly more than the tool in the close reward condition ($T = 66$, $N = 11$, $p = .001$). Thus, subjects only showed a preference for the tool when it was needed to get the reward. However, such a preference for the tool in the distant reward condition was not apparent in the first trial (only 7 out of 11 subjects chose the long tool; binomial test: $p = .55$). In fact, there was some indication that subjects tended to increase their choice toward the tool (as opposed to the reward) when the first three trials were compared with the last three trials ($T = 15$, $N = 5$, $p = .063$). In contrast, subjects showed a clear preference for targeting the reward in the close reward condition (binomial test: $p = .001$), which did not change over trials ($N = 1$, *ns*).

Table 5
Number and Mean Percentage of Trials in Which Subjects Chose to Rake in the Longer Tool (With the Shorter One) as Opposed to the Reward as a Function of Whether the Reward Was Within Reach of the Shorter Tool

Subject	Distant reward–long tool	Close reward–either tool
Gorilla		
Gorgo	7 (T)	0 (R)
Bebe	5 (T)	0 (R)
Vimoto	8 (T)	0 (R)
Viringika	8 (T)	0 (R)
Vizuri	8 (T)	1 (R)
Ndiki	7 (R)	0 (R)
Subtotal %	90	2
Orangutan		
Bimbo	4 (T)	0 (R)
Walter	7 (R)	0 (R)
Pini	7 (R)	0 (R)
Toba	8 (T)	0 (R)
Dokana	6 (T)	0 (R)
Subtotal %	80	0
Total %	85	1

Note. The choice on the first trial is indicated in parentheses. T = tool; R = reward.

Discussion

Subjects were able to use a short tool to get another longer tool, which could then be used to retrieve a food reward. This demonstrated the apes' ability to chain discrete responses to obtain a goal. Moreover, subjects also deployed their responses in an efficient manner because they retrieved the longer tool only when it was needed to reach the reward. Yet there was some indication that subjects did not deploy this strategy from the beginning but increased their responses toward the longer tool over trials. In contrast, when the reward was closer, thus making the shorter tool suitable, they simply used the shorter tool to retrieve the reward—and they did so from the beginning of the test.

Although subjects adjusted well to the distance of the reward and to the cost of getting the long tool, getting that only when it was necessary, it is unclear whether they would also be able to select the tool with the appropriate length when the distance to the reward and the available tools were not presented simultaneously. We investigated this issue in the next experiment.

Experiment 5

The results from Experiment 4 showed that subjects could use a tool to get another tool, which could be used to retrieve a reward. However, all information was available simultaneously. Therefore, as in Experiments 1–4, we decided to run the same experiment with the added condition of having the tools displaced from the food.

Method

Subjects. We tested all subjects listed in Table 1, with the exception of Ndiki, who refused to participate.

Materials. We used the same tools and rewards as those used in Experiment 4 and the same two testing stations as those used in Experiment 2.

Procedure. The general procedure was a combination of the procedures used in Experiments 2 and 4. We manipulated two variables: reward–tool presentation (simultaneous vs. sequential) and tool suitability (either tool vs. long tool only). The simultaneous presentation was identical to that of Experiment 4: The experimenter presented the reward and the tools on the same platform in the same configuration. After 5 s elapsed, the experimenter pushed the platform against the mesh, allowing the subjects access to the short tool so that they could choose between fishing for the long tool or the reward. The sequential presentation was identical to that described in Experiment 2: The experimenter placed the reward in Testing Station 1 and then moved to Station 2 to present the tools in the same configuration as in the previous condition. Once the subject arrived at Station 2, the experimenter waited 5 s before pushing the platform against the mesh so that the subject could retrieve the short tool and choose between moving back to Station 1 to get the reward or raking in the long tool and then returning to Station 1. In every trial, subjects retrieved one of the tools and moved to Station 1 to retrieve the reward.

As in previous experiments, we also manipulated the tool length needed to get the reward. There were trials in which the short tool was suitable to retrieve the reward (either tool condition; reward placed at 15 cm from mesh) and others in which only the long tool was suitable (long only condition; reward placed at 25 cm from mesh).

Each subject received a total of 48 trials (two reward–tool presentation conditions, with two tool suitability conditions, replicated 12 times) in a randomly presented fashion and counterbalanced for left and right side. The number of testing sessions varied between two and seven, depending on the subject.

Results

Table 6 presents the number of trials in which subjects used the short tool to get either the reward or the longer tool across conditions. There were no significant differences between species

Table 6
Number and Mean Percentage of Trials (out of 12 Possible) in Which Subjects Chose to Rake in the Longer Tool (With the Shorter One) as Opposed to the Reward, Depending on the Tool and Reward Presentation and Tool Suitability

	Simultaneous		Sequential	
Subject	Either tool	Long tool	Either tool	Long tool
Gorilla				
Gorgo	2 (R)	11 (R)	12 (T)	12 (T)
Bebe	0 (R)	7 (R)	2 (R)	2 (R)
Vimoto	0 (R)	11 (T)	6 (R)	5 (R)
Viringika	0 (R)	11 (T)	12 (T)	12 (T)
Vizuri	2 (R)	11 (T)	12 (T)	12 (T)
Subtotal %	7	85	73	72
Orangutan				
Bimbo	0 (R)	11 (T)	12 (T)	12 (T)
Walter	0 (R)	12 (T)	9 (T)	10 (T)
Pini	0 (R)	12 (T)	5 (R)	9 (T)
Toba	0 (R)	11 (T)	11 (T)	11 (T)
Dokana	1 (R)	10 (T)	2 (R)	3 (R)
Subtotal %	3	93	65	75
Total %	5	89	69	73

Note. The choice on the first trial is indicated in parentheses. R = reward; T = tool.

for any of the conditions (simultaneous–either tool: $U = 10$, $p = .69$; simultaneous–long tool: $U = 8$, $p = .42$; sequential–either tool: $U = 9$, $p = .55$; sequential–long tool: $U = 10.5$, $p = .69$). Therefore, we collapsed the data across species in subsequent analyses.

There were significant differences on the likelihood of selecting the tool across conditions, Friedman test(3) = 19.03, $p < .001$. An analysis within each of the presentation conditions revealed that in the simultaneous condition, subjects selected the tool more often in the long tool condition compared with the either tool condition ($T = 55$, $N = 10$, $p = .002$). Moreover, subjects significantly targeted the reward when it was within reach (i.e., either tool condition, $T = 55$, $N = 10$, $p = .002$), whereas they significantly targeted the tool when the reward was outside of reach (i.e., long tool condition, $T = 55$, $N = 10$, $p = .002$). This replicated the results of the previous experiment. Conversely, in the sequential condition, subjects targeted the tool equally often regardless of the position of the reward ($T = 8$, $N = 4$, $p = .38$). However, they still showed a significant preference for the tool when the reward was outside of reach ($T = 47$, $N = 10$, $p = .049$) but not when the reward was within reach ($T = 37$, $N = 9$, $p = .10$).

Subjects did not change their preferences in any of the four conditions when the first three trials were compared with the last three trials (sequential–either tool: $T = 15$, $N = 6$, $p = .44$; $N < 4$, in all other conditions, *ns*). Results of the first trial showed that subjects preferentially targeted the reward in the simultaneous–either tool condition (binomial test: $p = .002$), but no significant preference for the tool or the reward was detected in the other conditions (binomial tests: all *p*s $> .10$).

Discussion

In the simultaneous condition, subjects showed a preference for the long tool, thus incurring the cost to retrieve it, only when it was necessary to get this tool to get the reward. This result replicated the findings of the previous experiment. In contrast, subjects in the sequential condition showed a preference for the long tool regardless of whether it was needed to get the reward–although they still preferentially targeted the tool when that was needed to get the reward. In other words, when the reward and the tools were not simultaneously visually available, subjects often used the more costly but “safer” strategy of fishing for the long tool even when it was not strictly necessary. It is unclear whether this represents a conservative strategy or a failure to encode the exact distance at which the reward was located. We ran the next experiment to see whether when offered a tool that was too short, subjects would decline to make an attempt to get the reward.

Experiment 6

In Experiment 5, subjects chose the efficient strategy when the food and tools were presented simultaneously. That is, they fished for the long tool only when it was strictly needed, but not when the short tool was enough to get the reward. However, when the tools and the reward were presented sequentially, subjects often opted for retrieving the long tool regardless of whether it was needed to reach the reward. One possible interpretation is that when subjects could no longer see the position of the food, they could not remember its exact position. However, because getting the long tool is not strictly a mistake—it is just less efficient—we decided to run a further experiment in which only one tool was presented to the subject in both the simultaneous and sequential conditions. This single tool was suitable to get the reward in only half of the trials.

Method

Subjects. We tested the subjects listed in Table 1, with the exception of Gorgo, Ndiki, and Dokana, who refused to participate.

Materials. We used two straight wooden sticks, a short one (15 cm long) and a long one (45 cm long), with the rewards and the two testing stations used in Experiment 5.

Procedure. The general procedure and conditions were identical to those of Experiment 5 except that we used only one tool in each trial. Thus, we manipulated the same two variables as in the previous experiment: tool and reward presentation (simultaneous vs. sequential) and tool length required to get the reward (suitable vs. not suitable). Once subjects were given access to the single tool located on the platform perpendicular to the fence, we scored their behavior in one of the following categories representing an increasing level of effort directed toward the reward: (0) did not pick up the tool from the table; (1) picked up the tool but did not use it (this included eating it or breaking it); (2) picked up the tool and approached the sequential station but did not use it (separate condition only); (3) used the tool for something other than trying to retrieve the food; and (4) used the tool to attempt to retrieve the food. If during a given trial subjects had not taken the tool after 15 s elapsed, the experimenter withdrew the platform, scored a zero, and conducted the next trial. There were trials in which the tool length was suitable (suitable tool condition; reward placed at 15 cm from the mesh), whereas in others the tool was too short (unsuitable tool condition; reward placed at 45 cm from the mesh). Subjects received half of the trials with the short tool and the other half with the long tool.

Each subject received a total of 48 trials (two reward–tool presentation conditions, each with two tool length conditions, replicated 12 times) in a randomly presented fashion, counterbalanced for left and right side. Number of testing sessions varied between one and three, depending on the subjects.

Results

Table 7 presents the frequency of the various types of attempts across conditions. Because there were no significant differences between species for any of the conditions and measures (Mann–Whitney tests: all *p*s $> .34$), we collapsed the data across species in subsequent analyses.

First, we analyzed full attempts. There were significant differences in the percentage of full attempts across conditions, Friedman test(3) = 22.17, $p < .001$. Subjects performed full attempts significantly more often when the tool was suitable than when it was unsuitable in both the simultaneous and the sequential presentation conditions ($T = 36$, $N = 8$, $p = .008$, in both cases). Moreover, presentation did not have an effect on the percentage of full attempts. Subjects performed full attempts equally often in the simultaneous and sequential conditions both when the tool was suitable ($N = 2$, *ns*) and when it was unsuitable ($T = 19$, $N = 6$, $p = .094$).

Although the data on first trial performance suggested that most subjects made full attempts even in the unsuitable conditions (see Table 7), an analysis comparing the first and the last three trials revealed no significant differences between trials. Subjects did not significantly modify their number of full attempts in the tool

Table 7
Number (out of 12 Possible) of Types of Attempts as a Function of Reward Presentation and Tool Suitability

	Simultaneous–tool unsuitable			Simultaneous–tool suitable			Sequential–tool unsuitable			Sequential–tool suitable		
Subject	No	Partial	Full	No	Partial	Full	No	Partial	Full	No	Partial	Full
Gorilla												
Bebe	0	4[a]	8	0	0	12[a]	0	4	8[a]	0	0	12[a]
Vimoto	8	2	2[a]	0	0	12[a]	2	3	7[a]	0	0	12[a]
Viringika	4[a]	6	2	0	0	12[a]	2	10[a]	0	0	0	12[a]
Vizuri	6	3	3[a]	0	0	12[a]	1	4	7[a]	0	0	12[a]
Orangutan												
Bimbo[b]	6	3[a]	3	0	0	12[a]	4	3	4[a]	3	1[a]	8
Walter	8	2[a]	2	0	0	12[a]	1	2	9[a]	0	0	12[a]
Pini	1	5[a]	6	0	0	12[a]	3	3	6[a]	0	0	12[a]
Toba	5	0	7[a]	0	0	12[a]	1	1[a]	10	1	0	11[a]

Note. No = failed to pick up the tool or to approach the reward location; Partial = picked up the tool, approached the reward but did not attempt to retrieve it; Full = attempted to retrieve the reward with the tool.
[a] The subject performed the corresponding type of attempt on the first trial.
[b] Bimbo had only 11 trials in the sequential–tool unsuitable condition because as he picked up the tool, he immediately dropped it back onto the table and then it was out of his reach. Because the experimenter was not able to determine whether the subject dropped it intentionally or by accident, this trial was omitted from analyses.

suitable ($N = 1$, *ns*) and tool unsuitable conditions ($T = 24$, $N = 7$, $p = .11$).

Second, and more important, we also analyzed the refusals to use the tool to get the reward (*No* attempts in Table 7). There were significant differences in the percentage of refusals across conditions, Friedman test(3) = 18.80, $p < .001$. Subjects refused to use the tool significantly more often when the tool was unsuitable than when it was suitable in both the simultaneous ($T = 28$, $N = 7$, $p = .016$) and sequential presentation conditions ($T = 21$, $N = 6$, $p = .031$). Moreover, presentation condition did have an effect on the percentage of refusals but only when the tool was unsuitable. Thus, subjects refused to use the tool more often when the tool and the reward were presented simultaneously as opposed to sequentially ($T = 26$, $N = 7$, $p = .047$). In contrast, when the tool was suitable subjects refused tools equally often in both presentation conditions ($N = 2$, *ns*).

There was only 1 subject (Viringika; see Table 7) who refused to use the unsuitable tool on the first trial. However, additional analyses showed that subjects did not significantly modify their number of refusals between the first and the last three trials in the tool suitable ($N = 1$, *ns*) and tool unsuitable conditions ($T = 11$, $N = 5$, $p = .44$).

Discussion

Subjects refused more tools and carried out fewer attempts at getting the food when the tool was too short to reach the reward. This is even true for those conditions in which subjects were unable to see the tool and the reward simultaneously. The analysis across trials failed to provide evidence that this ability improved throughout testing. This may imply that subjects took notice of (and remembered) the relationship between the location of the reward and the length of the tool they were offered early in the testing session.

General Discussion

Gorillas and orangutans used straight tools to get an out-of-reach reward on a platform in a variety of situations. They fashioned tools, selected tools of the appropriate length, used a tool to get another tool and then get the reward, and refused to use tools that were too short to reach the reward. Several findings in this study suggest that subjects can encode two key features of the task: the relative length of the tools and the tool length in relation to the distance to the reward.

The results in the sequential condition of Experiment 3 support the idea that subjects were able to select the longer of two tools when they were presented sequentially. This implies that they had to encode and remember the length of two tools separately (because no direct comparison was possible) and then mentally compare them in order to select the longest one. This task was further complicated by the fact that there were three possible pairs of tools, and the medium tool was correct with the short tool but not with the long tool. In addition, Experiment 6 provides evidence indicating that individuals can also encode tool length in relation to the distance of the reward because they refused to fish for rewards that were too far away for the tools they were given. That they could do this when the reward and the tool were not presented simultaneously (and hence had to encode the reward distance and decide whether the tool available was suitable to reach the reward) was particularly remarkable.

However, the evidence for encoding these two task features (tool length and its relation to the distance of the reward) appeared at different stages during testing. Initially, apes showed a preference for the longer tool regardless of whether the short tool could also be used to get the reward. This preference, however, was not a fixed one but involved degrees of flexibility. First, because we used a variety of tools of different lengths, the preference for the longer tool cannot be easily explained by the suggestion that subjects always picked a tool with a certain length (e.g., 25 cm).

The reason for this is that in some experiments, 25 cm may be appropriate, but in other experiments it is not. Moreover, in some experiments (e.g., Experiment 3), a 25-cm tool is appropriate in some trials and inappropriate in others, depending on the other tools with which it is paired.

The only case in which subjects preferred to use the short tool to get the reward was when both the tools and the reward were simultaneously visible, the reward was within reach of the short tool, and there was a cost to getting the longer tool. Because the longer tool could always be used to retrieve the reward in Experiments 1–5 (whereas the use of the short tool was effective in only half of the trials), it is likely that subjects focused on encoding and comparing the tool length rather than on the distance of the reward. This would explain why in the tool-out-of reach experiment subjects chose the safe but costly strategy of retrieving the longer tool in the sequential condition, but not when the tools and reward were placed together. Furthermore, this could also explain why apes showed a preference for the longer tool. It is possible that the gorillas and orangutans were failing to encode the distance of the reward and therefore opting more often for the safe strategy of choosing the longer tool.

Obviously, having a preference for the longer tool does not rule out the possibility that gorillas and orangutans were unable to mentally represent the exact distance of the reward in the sequential conditions. But this issue was not directly addressed until our last experiment, in which subjects were offered a single tool and they had to decide whether they would attempt to fish for the reward. We found that subjects were most likely to refuse to use a tool when it was unsuitable to retrieve the reward. Although the statistical analysis comparing the first and the last three trials revealed no significant learning effect, the performance choices on the first trial in the suitable and unsuitable tool conditions were quite comparable. This, however, was unsurprising. It would not have been expected that subjects would immediately become attentive to the position of the reward. After all, in previous experiments it was not essential for subjects to encode the distance of the reward because they could use the safe strategy of choosing the longer tool. Subjects, therefore, became attentive to the position of the reward in relation to the length of the tool as an important task feature after they experienced that a failure to encode the position of the reward before retrieving the tool offered by the experimenter also failed to produce positive results.

Besides the information about encoding task features, this study also showed that gorillas and orangutans can use two tools in sequence: a shorter tool to retrieve a longer tool with which to then retrieve the reward. This is analogous to some of the abilities previously described in chimpanzees (Köhler, 1927). Moreover, the subjects used such a strategy only when the long tool was strictly necessary to get the reward in those trials in which the reward and the tools were simultaneously visible (e.g., Experiment 4). In those trials in which the longer tool was unnecessary, they simply used the short tool that was within reach.

We found hardly any interspecific differences, although our sample size may explain this to some extent. We only detected a significant interspecies difference in one out of the six conditions of Experiment 3. The gorillas' skillful performance may be a bit surprising given the very limited evidence for gorillas using tools (McGrew, 1989; but see Fontaine et al., 1995). Unlike orangutans who regularly use tools in captivity (and one population has been reported to do so in the wild; see van Schaik et al., 1996), reports of gorillas using tools are fewer than those on orangutans (see Tomasello & Call, 1997, for a review). Therefore, we found no evidence of interspecies differences in the encoding of tool features and the sequential use of tools to retrieve a reward. Both gorillas and orangutans were able to encode critical task features and to use tools in sequence.

In conclusion, these results show that gorillas and orangutans can encode and mentally compare two important features of the platform test: tool length and distance to the reward. Moreover, they can also use tools in sequence to get other tools that are appropriate to get the reward. Clearly, these two aspects, although important, represent only a relatively simple cognitive dimension. Future studies are needed to ascertain other features that gorillas and orangutans find relevant and how these features interact with problems of increasing complexity.

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