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RESEARCH ARTICLE

# Apes Produce Tools for Future Use

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There is now growing evidence that some animal species are able to plan for the future. For example great apes save and exchange tools for future use. Here we raise the question whether chimpanzees, orangutans, and bonobos would produce tools for future use. Subjects only had access to a baited apparatus for a limited duration and therefore should use the time preceding this access to create the appropriate tools in order to get the rewards. The apes were tested in three conditions depending on the need for pre-prepared tools. Either eight tools, one tool or no tools were needed to retrieve the reward. The apes prepared tools in advance for future use and they produced them mainly in conditions when they were really needed. The fact that apes were able to solve this new task indicates that their planning skills are flexible. However, for the condition in which eight tools were needed, apes produced less than two tools per trial in advance. However, they used their chance to produce additional tools in the tool use phase—thus often obtaining most of the reward from the apparatus. Increased pressure to prepare more tools in advance did not have an effect on their performance. Am. J. Primatol. 77:254–263, 2015.


**Key words: future planning; tool use; primates; mental time travel**

## INTRODUCTION

There is ample evidence showing that several species of animals can plan their actions immediately before executing them. For instance, New Caledonian crows, rooks, and apes select appropriate tools prior to using them [Bird and Emery, 2009; Chappell and Kacelnik, 2002; Martin-Ordas et al., 2012; Sanz et al., 2004; Wimpenny et al., 2009], chimpanzees, monkeys, and pigeons show motor anticipation in sequential responding tasks [Beran et al., 2004; Beran et al., 2012; Beran and Parrish, 2012; Biro and Matsuzawa, 1999; Pan et al., 2011; Scarf and Colombo, 2010; Scarf et al., 2011], and apes choose the direction for moving a reward away from a trap without having to correct the initial displacement [Martin-Ordas et al., 2008; Seed et al., 2009]. Despite the short interval between planning, execution, and the consequences of the action, planning of this kind is crucially important and adaptive as it allows individuals to respond more efficiently (faster reaction times and fewer errors) in a variety of situations.

In recent years, studies on planning have begun to extend the temporal horizon between planning and executing an action and the consequences it produces (so-called future planning). This ability allows one to foresee novel situations and behave anticipatorily in a very flexible way [Suddendorf and Busby, 2005; Suddendorf and Corballis, 1997]. Scrub jays, several ape species, and dolphins have been shown to be capable of executing responses that will be crucial for the consequences that they will have not immediately but minutes or hours later [Beran et al., 2012; Clayton et al., 2005; Dufour and Sterck, 2008; Kuczaj et al., 2010; Mulcahy and Call, 2006; Osvath and Osvath, 2008; Raby and Clayton, 2009].

Raby et al. [2007] found that scrub jays made provisions for a future need. The birds were shut in either compartment A or B for 2 hr during alternate mornings. In compartment A there was food, in compartment B, there was no food. In the evening before scrub jays cached food mainly in compartment B, indicating they anticipated their hunger in the next morning. Moreover, birds did not just cache food in places associated with hunger. When birds had access to only one of the two compartments on alternate mornings and food A was always in compartment A

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and food B in compartment B, they cached food that they would not have access to in the morning. In other words they preferentially cached food B in compartment A and food A in compartment B.

Mulcahy and Call [2006] presented bonobos and orangutans with an apparatus that required the use of a special tool to release the food. This tool, however, could only be used when the apparatus was in an open position. At the beginning of each trial the apparatus was locked and subjects were presented with four different tools including the tool needed to get the food. After 5 min had elapsed, the subject was sent into a waiting room and all the tools left in the room were removed. An hour later the subject returned to the test room after the apparatus had been unlocked. Thus, in order to get the food apes had to (1) select the appropriate tool; (2) transport it to the waiting room; and (3) transport the tool back to the testing room to use it there. Subjects were able to save the appropriate tool to use one hour later. In some cases, the apes even selected the correct tool to use it after a delay of 14 hr. Control conditions ruled out that they merely learned the association between grapes, apparatus, and tools as it was necessary for the subject to see the apparatus while they selected the tool. Moreover, in the absence of a future task apes did not transport the appropriate tool even when they were rewarded for it.

Other studies have replicated and extended these findings. Osvath and Osvath [2008] have tested chimpanzees and orangutans using a similar set-up as Mulcahy and Call [2006]. They found that these apes could override immediate drives in favour of future needs, and they did not merely rely on associative learning or semantic prospection in that task. Dufour and Sterck [2008] tested whether chimpanzees would save tokens to use them one hour later in an exchange task. Chimpanzees did not collect and save the correct tokens in order to exchange them later for food. However, chimpanzees had the experience of many training sessions in which the tokens were available, this might have led to less flexible behaviour in the test sessions in which suddenly tokens were no longer present. The authors suggested chimpanzees' planning behaviour is limited to the situation where the action to obtain the future benefit only depended on a chimpanzee's own behaviour as in a tool use task. However, Roberts and Feeney [2009] have argued these studies do not prove the animals are able to project themselves into possible future scenarios. The apes might have chosen the appropriate tool because they understand its functional value without anticipating its use an hour later (but see Mulcahy and Call, 2006, Experiment 4).

Despite the differences between the bird and ape studies, they have in common that individuals select an item (food or a tool) and save it for later consumption or use. There is one notable exception to this general pattern. Osvath and Karvonen [2012] reported a male chimpanzee who often threw stones at zoo visitors also manufactured some of his projectiles prior to the arrival of the visitors by dislodging pieces of cement from various parts of his enclosure. According to Osvath and Karvonen [2012], this chimpanzee placed his newly produced projectiles in stone caches and concealed them under hay prior to the arrival of the visitors. Apparently, he hid the projectiles in an attempt to conceal them from the caretakers who tried to remove them [see also Osvath, 2009].

The Osvath and Karvonen [2012] finding is remarkable because the chimpanzee was not merely saving an item but also producing it, which means it had an idea of what to do. Moreover, this finding has potentially important implications for human evolution because paleoanthropologists have used the transportation of raw materials and manufacture of Acheulean tools as one of the first indications of planning behaviour [e.g., Bar-Yosef, 2002; Harmand, 2009; Mellars, 2005; Spinapolice, 2012], something which has been dated between 2.5 and 1.6 million years ago. Particularly important with regards to future planning is the discovery of tool caches made of materials transported from distant sources [up to 10 km, Goren-Inbar et al., 2000] since they may indicate multiple tools were prepared in advance of their use.

The aim of this study was to investigate whether apes were capable of producing multiple tools in anticipation of its future use. There were two reasons for doing this. One reason was to attempt to replicate Osvath and Karvonen [2012] results with additional chimpanzees and extend it to bonobos and orangutans as this would help us to evaluate the distribution of making tools for future use in the ape clade. Additionally, Osvath and Karvonen [2012] were not able to test the observed behaviour under controlled experimental conditions.

The second reason for carrying out this study is to further address the alternative explanation raised by Roberts and Feeney [2009] mentioned above with regard to future planning. If apes were selecting tools for their functional features and not for the task they would encounter at a later time, they should fail a tool making task because the raw materials provided were non-functional. Unless, of course, the apes modified the tools to make them functional, and more importantly, they did so in a way that met the requirements of the task they would be confronting. More specifically, if they prepared multiple tools only when needed, this would suggest that apes were anticipating their future needs. This is especially true given that Osvath and Osvath [2008] demonstrated that multiple identical functional tools were not more valuable than a single functional tool when all that was needed to solve the task was a single tool.

We presented a baited apparatus for a short period of time, which forced subjects to use multiple tools as quickly as possible to obtain all the available food. The apparatus was such that each tool could only be used once (and each produced one piece of food). Prior to the exposure to the baited apparatus, however, subjects were not given tools but the raw material with which they could manufacture them. In order to maximize the food obtained when the apparatus became accessible, subjects needed to prepare multiple tools during the period when the apparatus was non-accessible so that when they had access to the apparatus they would not waste any time manufacturing tools. In the experimental condition eight tools were needed, whereas in two control conditions either one or no tool was needed. If apes only selected tools based solely on the functional value without anticipating their later use they should either not produce any tools or produce the same amount of tools in all three conditions. If apes planned for their future needs they should only produce tools in advance when they were really needed.

## METHODS

### Participants

Twenty-five apes (14 chimpanzees, 4 bonobos, 7 orangutans) of various ages (ranging from 6 to 37 years) were tested (see Table I). All subjects lived in stable groups with their conspecifics at the Wolfgang Köhler Primate Research Center in Leipzig Zoo. They had access to an outdoor area and an indoor area with natural vegetation and sleeping rooms for the night. The apes were fed a diet of various fruits, vegetables, and cereals several times per day. Throughout testing, subjects were never deprived of food and water was always available. They were tested individually (or with their dependent off-spring) in familiar testing cages by one of three familiar experimenters (henceforth E) from 2009 to 2011.

Subjects were divided into two groups (see below). They were included in the analysis of a testing period when they produced and used at least one tool within one block. For one chimpanzee (Annett) the test was cancelled in her second testing period because she repeatedly destroyed the apparatus, but her available data were included into the analysis.

The research reported here adhered to the American Society of Primatologists (ASP) Principles for the Ethical Treatment of Non-Human Primates and were reviewed and approved by the ethics commission of the department of Psychology of the Max Planck Institute for Evolutionary Anthropology and the Leipzig Zoo. Furthermore, this research complied with the legal requirements of Germany.

**TABLE I. Name, Species, Gender and Age of the Subjects Included in the Study**

| Subject | Species | Gender | Age (years) | Group |
|---|---|---|---|---|
| Joey | Bonobo | M | 28 | 2–50 sec |
| Kuno | Bonobo | M | 14 | 2–50;sec |
| Ulindi | Bonobo | F | 17 | 2–50 sec |
| Yasa | Bonobo | F | 13 | 2–50 sec |
| Alex[a] | Chimpanzee | F | 9 | 1–120 sec & 1–50 sec |
| Alexandra | Chimpanzee | F | 11 | 1–120 sec & 1–50 sec |
| Annett | Chimpanzee | M | 11 | 1–120 sec & 1–50 sec |
| Fifi | Chimpanzee | F | 17 | 1–120 sec & 1–50 sec, |
| Jahaga | Chimpanzee | F | 17 | 1–120 sec & 1–50 sec |
| Karah | Chimpanzee | F | 6 | 2–50 sec |
| Lobo | Chimpanzee | M | 7 | 2–50 sec |
| Lome | Chimpanzee | M | 10 | 2–50 sec |
| Patrick | Chimpanzee | M | 14 | 2–50 sec |
| Pia | Chimpanzee | F | 12 | 2–50 sec |
| Riet[a] | Chimpanzee | F | 34 | 2–50 sec |
| Sandra | Chimpanzee | F | 18 | 2–50 sec |
| Tai | Chimpanzee | F | 9 | 2–50 sec |
| Trudi | Chimpanzee | F | 17 | 1–120 sec & 1–50 sec |
| Bimbo | Orangutan | M | 30 | 1–120 sec |
| Dokana | Orangutan | F | 21 | 1–120 sec & 1–50 sec |
| Dunja | Orangutan | F | 37 | 1–120 sec |
| Kila | Orangutan | F | 10 | 1–120 sec & 1–50 sec |
| Padana | Orangutan | F | 13 | 1–120 sec & 1–50 sec |
| Pini | Orangutan | F | 22 | 1–120 sec |
| Raaja | Orangutan | F | 7 | 1–120 sec & 1–5 sec |

[a]= neutered.

### Materials

Apes were tested in a room divided into an ape area and a human area. On one side of the room there was a large window so that zoo visitors could see the testing room. Testing took place in one of the cages (2.5 m × 2.2 m) of the ape area. The apparatus was fixed on a mesh panel (50 cm × 70 cm) on E's side of the room. There was a table (85 cm × 32 cm) under the apparatus, perpendicular to the mesh panel.

The apparatus consisted of eight Plexiglas tubes (25 cm × 3.5 cm diameter) mounted next to each other in battery and perpendicular to the mesh (see Fig. 1). Each tube was open on the ape's side and had a hole on the bottom part (3 cm). When a grape was placed inside a tube, the ape could insert a stick into the tube and push it forward with her finger so that the stick in turn displaced the grape into the hole in the bottom of the tube. Then the grape fell down into a slanted tray that directed the grape towards the mesh where the ape could grab it. After the stick was inserted into the tube and pushed forward, it could no longer be retrieved by the ape. Thus, each stick could only be used once. The access to the apparatus could be blocked with a small Plexiglas board (45 cm × 10 cm) and the access to the table could be blocked with a large Plexiglas barrier that was fixed on the mesh.

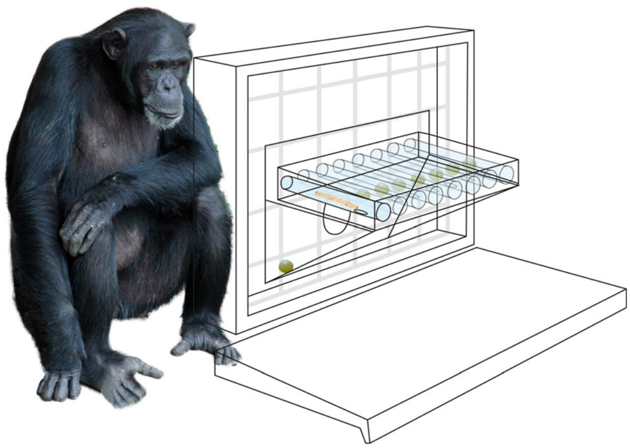

Fig. 1. Set-up.

Apes received two boards made of soft wood in each trial. They were approximately 12 cm wide and 8–10 cm long (depending on the length of the finger of a given subject.) To prepare the tools subjects needed to split the boards into small sticks. The boards and therefore the tools had a length requiring subjects to push them into the tubes to dislodge the grapes but the tools were too short for subjects to be retrieved and reused.

### Procedure

Training: Subjects had to learn to produce tools and how the apparatus worked. The training started when the ape approached the mesh panel with the apparatus. E then put one grape in one tube of the apparatus. She gave one wooden board to the subject, who had no previous experience with these boards. When the subject performed the anticipated actions (i.e., breaking the board into pieces and inserting the pieces into the tube with the grape) E praised her verbally. After the subject had made the tool (usually by biting pieces off the board), inserted the tool, making the grape fall down and eating it, the trial was over and the subject was sent out of the cage. E removed the wooden pieces then a second trial began. To participate in the test, a subject had to produce a tool and obtain the grape in two training trials. Subjects passed these criteria in 10 min on average within one session.

Test: Prior to each trial E baited the apparatus or the table according to the conditions (see below). The apparatus was present in all conditions, and its tubes were blocked so that the subject did not have access to them. Each trial consisted of two phases: tool preparation and tool use.

### Tool Preparation Phase (8 Min)

It started when the subject received the two boards (usually E placed them into the cage when the subject was there, but in some cases the boards were already present in front of the apparatus when the subject entered the cage). Then E left the testing room for 8 min. After 8 min had elapsed, E entered the testing room again and unblocked the apparatus or the table (empty apparatus condition).

### Tool Use Phase (120 or 50 Sec)

This phase started as soon as subjects could insert the prepared tools, making the grapes fall down and the subjects were able to grab them. E did not react to what the ape was doing and only interfered in the few cases when the grape got stuck or when there was the possibility that the subject could pull the tool out and use it again. After 120 or 50 sec E blocked the apparatus with the Plexiglas board or the table with the Plexiglas panel (empty apparatus condition). Note that only the tubes were blocked but not the slant from which the apes could grab the grapes so that the subject could potentially insert all tools in the tool use phase and eat the grapes after that phase. The trial was over after the subject had eaten all grapes he or she had access to.

After each trial the subject was moved into another cage. In case the subject took boards, leftovers of the board, or prepared tools into the other cage, they were retrieved, usually by the keeper. E then entered the cage, removed the board, leftovers and useable tools. She then counted the number of all usable tools from inside the cage, inside the apparatus, from outside the cage (on E's side of the mesh—in the few cases when tools fell out or were thrown out) and from the leftovers the subject had exchanged. Then the subject was moved inside the testing cage for the next trial.

There were three different conditions depending on where and how many grapes were baited.

*All grape condition*

Each tube was baited with one grape so that subjects needed to prepare eight tools to get all grapes.

*One grape condition*

One single tube was baited with one grape, (all other seven tubes remained empty), so that subjects needed to prepare only one tool to get the grape.

*Empty apparatus condition*

Eight grapes were placed on the table under the apparatus within reach of the subject so that subjects needed to prepare no tool to get the grapes (when the Plexiglas barrier was removed).

### Design

Each subject received all three conditions. Subjects were tested in one or two testing periods (see below). Each period consisted of 45 trials (15 trials per condition) divided into three 15-trial blocks. Each block consisted of three sub-blocks of five trials per condition, which were presented in randomized order so that subjects started with different conditions in each sub-block. Subjects usually received 2–3 trials of the same condition per day. In a few cases when the subject was no longer motivated to continue (i.e., did not approach the apparatus when E called her while showing a grape) or when testing time was over, subjects received only one trial per day. This means that a sub-block of one condition (five trials) was finished within two testing days, that a block (15 trials) was finished in about 6 days of testing, and that the whole period (45 trials) required about 18 days of testing. Subjects were usually tested 2–3 times a week.

Subjects were divided into two groups. Group 1 was tested in two periods. In the first period it was tested with the tool use phase lasting 120 sec (group 1–120 sec) and in the second period it was tested with the tool use phase lasting 50 sec (group 1–50 sec). Group 2 only received one test period in which the tool use phase lasted 50 sec (group 2–50 sec).

### Scoring, Reliability and Analysis

All trials were video-recorded with two cameras. We measured *success* defined as the number of grapes apes obtained in each trial in the all grape condition, which was unambiguous. As our question was whether and how many tools apes produced in advance, our main measure was the number of *prepared tools* in each trial. This measure was determined following three steps.

First, we counted the number of *all tools* that were useable. Therefore E counted the number of *all* usable *tools* from inside the cage, inside the apparatus, and from outside the cage after each trial. A part of the board was defined as a useable tool when it had the length of the board, when it was thick enough that it would not break when a grape was moved with it (diameter >30 mm) and thin enough to be inserted in a tube (diameter <4 mm). This was unambiguous.

Second, we coded the number of *late tools* from the videotapes. These were the useable tools subjects produced in the tool use phase. (Some very skilful subjects were able to produce a tool within 5–10 sec). When this was not clearly visible indirect indications were also used. These included clicking noises (when subjects split the board) and the fact whether the tool could be used successfully (i.e., subject could retrieve the grape with the tool). An independent and naïve observer scored a randomly selected sample of 20% of the trials to assess inter-observer reliability. Reliability for the number of *late tools* was excellent (Pearson $=0.90$, $N=315$).

Third, we calculated the number of *prepared tools*. These were the useable tools subjects produced in the tool preparation phase. Therefore the number of *late tools* was subtracted from the number of *all tools*. (We used the indirect approach to calculate the number of *prepared tools* by using the number of *late tools* as it was easier to code the 120/50 sec lasting tool use phase in which subjects usually sat in front of the apparatus than the 8 min lasting tool preparation phase. In the few cases in which it was not possible to code the number of *late tools*, the number of *prepared tools* subjects produced in the tool preparation phase was coded directly. If that was also not possible, we used the data that was coded live by E during the test).

As stated above, our main measure was the number of *prepared tools*. For the analysis we used the per cent of trials in which subjects prepared tools and the mean number of tools prepared in each of the three conditions. In addition we analyzed whether *success* depended on whether subject had *prepared tools* in advance. Finally, we analyzed whether the number of late tools produced in the tool use phase varied depending on the duration of the tool use phase. The periods (group 1- 120 sec, group 1- 50 sec, and group 2- 50 sec) were first analyzed separately using Friedman and Wilcoxon test (exact) and later compared with each other using Mann–Whitney U test.

## RESULTS

### a) 120 sec (Group 1)

Figure 2 presents the mean percentage of trials in which subjects prepared tools in advance. There was a significant difference between conditions (Friedman $=10.98$, $N=13$, df $=2$, $P=0.004$). Subjects prepared tools in most trials of the all grape compared to the two other conditions (all grape vs. empty apparatus Wilcoxon $T=60.5$, $N=11$, $P=0.011$, all grape vs. one grape Wilcoxon $T=47.5$, $N=10$, $P=0.039$). There was no significant difference between one grape and empty apparatus condition (Wilcoxon $T=53.5$, $N=11$, $P=0.072$). When subjects prepared tools in advance in the all grape condition they obtained more grapes than when they did not prepare tools in advance (Wilcoxon $T=17.0$, $N=13$, $P=0.048$).

Figure 3 presents the mean number of *prepared tools* in the three conditions. There was a significant difference between conditions (Friedman $=10.08$, $N=13$, df $=2$, $P=0.006$). Subjects prepared significant more tools in the all grape than in the empty apparatus condition (Wilcoxon $T=58.00$, $N=11$, $P=0.022$), the other comparisons were non-significant (all grape vs. one grape Wilcoxon $T=65.5$, $N=13$, $P=0.177$, empty apparatus vs. one grape Wilcoxon $T=59.00$, $N=12$, $P=0.123$).

### b) 50 sec (Group 1 and 2)

Since there were no significant differences between Group 1 and Group 2 in any of the three conditions for either the mean per cent of trials with

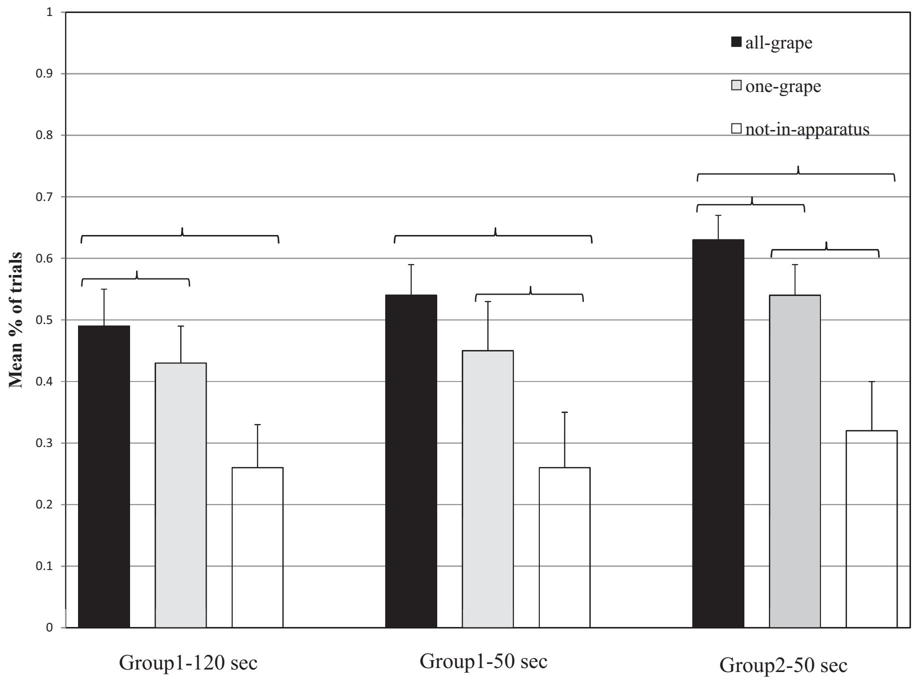


Fig. 2. Proportion of trials (+SE) in which subjects prepared tools for the two groups in the three testing periods.

*prepared tools* (Mann–Whitney tests: all grape condition: $U = 75.5$, $P = 0.341$; one grape condition: $U = 73.5$, $P = 0.381$; empty apparatus condition: $U = 64.0$, $P = 0.821$, $n1 = 10$, $n2 = 12$ in all cases) or the mean number of *prepared tools* (Mann–Whitney tests: all grape: $U = 84.5$, $P = 0.107$; one grape condition: $U = 78.0$, $P = 0.254$; empty apparatus condition: $U = 69.5$, $P = 0.539$, $n1 = 10$, $n2 = 12$ in all cases), we pooled together the data from both groups for subsequent analyses.

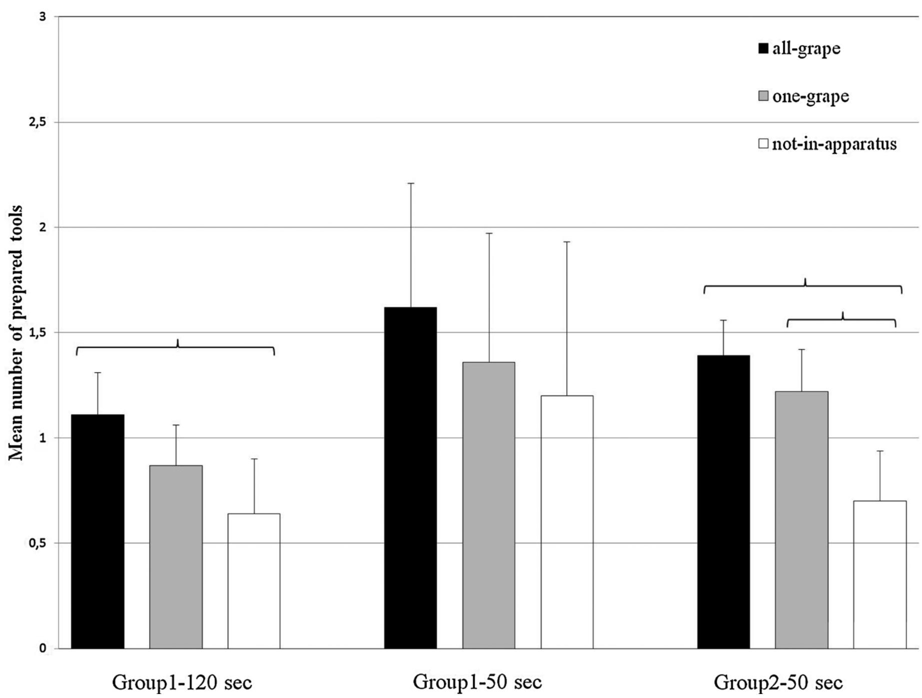


Fig. 3. Mean number of tools (+SE) prepared for the two groups in the three testing periods.

There was a significant difference between conditions for the per cent of trials with *prepared tools* (Friedman $= 20.80$, $N = 22$, df $= 2$, $P < 0.001$). Pairwise comparisons revealed subjects produced tools in a higher percentage of trials in the all grape compared to the empty apparatus (Wilcoxon $T = 188.0$, $N = 19$, $P < 0.001$) and the one grape conditions (Wilcoxon $T = 138.5$, $N = 18$, $P = 0.018$). Additionally, subjects produced tools in a higher percentage of trials in the empty apparatus than the one grape condition (Wilcoxon $T = 186.0$, $i = 20$, $P = 0.001$).

Similarly there was a significant difference between conditions for the mean number of *prepared tools* (Friedman $= 12.64$, $N = 22$, df $= 2$, $P = 0.002$). Pairwise comparisons revealed subjects produced significantly more tools in the all grape compared to the empty apparatus (Wilcoxon $T = 214.0$, $N = 22$, $P = 0.003$) and the one grape conditions (Wilcoxon $T = 189.5$, $N = 22$, $P = 0.040$). Additionally, subjects produced significantly more tools in the empty apparatus than the one grape condition (Wilcoxon $T = 188.0$, $N = 22$, $P = 0.045$).

### c) 120 sec vs. 50 sec (Within Group 1)

We increased the pressure to prepare tools in advance in Group 1 by reducing the time allocated to the tool use phase from the first to the second period. Note, however, that learning and decreased motivation could have also affected subjects' responses. Three subjects could not be tested in the second period, either because they were not motivated to participate (two orangutans) or had died (one orangutan). We therefore just compared the performance of the 10 subjects who were tested in both periods.

There were no differences between periods for the mean number of trials in which subject prepared tools in advance (All-grape condition: Wilcoxon $T = 24.5$, $N = 10$, $P = 0.759$; One-grape condition: Wilcoxon $T = 17.5$, $N = 10$, $P = 0.552$; Not-in-apparatus condition: Wilcoxon $T = 19.0$, $N = 10$, $P = 0.349$) and for the mean number of *prepared tools* (All-grape condition: Wilcoxon $T = 31.0$, $N = 10$, $P = 0.720$; One-grape condition Wilcoxon $T = 28.0$, $N = 10$, $P = 0.959$; Not-in-apparatus condition: Wilcoxon $T = 24.0$, $N = 10$, $P = 0.090$). Thus increased pressure did not increase the number of tools subjects prepared in advance.

We also compared the number of *late tools* in the three conditions (see Fig. 4). Interestingly, the number of *late* produced *tools* did not decrease—even though we reduced the duration of the tool use phase. For the one-grape condition subjects even produced more *late tools* in 50 sec than in 120 sec (Wilcoxon $T = 55.00$, $N = 10$, $P = 0.005$).

## DISCUSSION

Chimpanzees, orangutans, and bonobos produced tools for future use. Crucially, they prepared tools more often (and in slightly larger quantities) in those conditions requiring them. Since the apparatus and the grapes were present in all conditions, we can

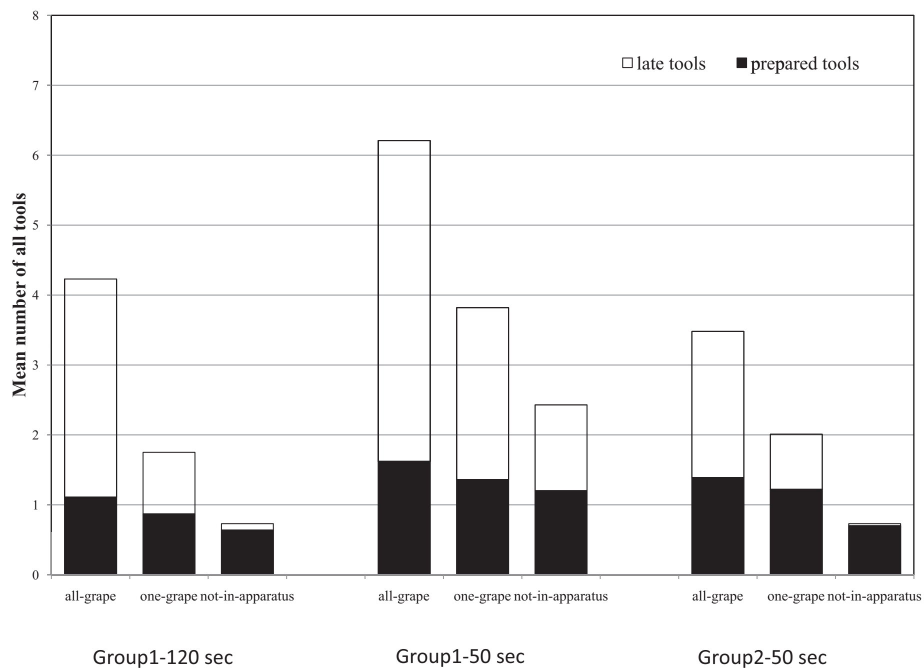


Fig. 4. Mean number of *all* tools (*prepared* tools and *late* tools) (+SE) for the two groups in the three testing periods. Dark bars correspond to the results depicted in Figure 3.

exclude that their mere presence led to differential tool production. Instead these results indicate that apes took into account both, the location of the grapes and (to a much lesser extent) their number when they decided whether to produce tools in advance.

Apes not only modified the boards to make functional tools out of them, but they did so mainly in the situation when tools were needed. This result is inconsistent with Roberts and Feeney [2009] explanation that apes select tools only for their functional features and not for the task they would encounter at a later time. As the apes prepared multiple tools when needed, our results suggest that apes were really anticipating their future needs. Indeed, apes did not try to use the tools in the Tool preparation phase when the apparatus was closed, but they used those same tools as soon as the apparatus was open.

The current study adds another piece of evidence to the idea that apes are able to plan for future needs. It shows that similar to early humans, chimpanzees, bonobos, and orangutans are able to prepare multiple tools from raw material in advance of their use [see also Osvath, 2009; Osvath and Karvonen, 2012]. We did not find differences in the performance of the three ape species. Previous studies have also shown that all the three species transport and save tools for future use [Dufour and Sterck, 2008; Mulcahy and Call, 2006; Osvath and Osvath, 2008]. Thus, the transportation of raw materials and manufacture of tools of early humans between 2.5 and 1.6 million years ago is probably not the first indication of future oriented planning behaviour as some paleoanthropologists have suggested [e.g., Bar-Yosef, 2002; Harmand, 2009; Mellars, 2005; Spinapolice, 2012]. Based on the great ape findings, it is more likely that the common ancestor of humans and apes was already able to prepare and transport tools for future use. It is even possible that the future planning skills are more widespread in mammals and birds, or—more likely—that they have evolved independently in a convergent cognitive evolution [Clayton et al., 2003; Emery and Clayton, 2004] as there is strong evidence that corvids also make provision for a future need by saving food for later consumption [Raby and Clayton, 2009, see also Introduction).

However, one could argue that in the current study apes only planned for the very near future as the tool use phase followed immediately 8 min after the raw material was provided in the same room. It is true that the interval between planning, execution, and the consequences of the action was rather short. However, the interval per se may not be a major limiting factor because other studies have shown that apes are capable of executing responses for the consequences that they will have hours or days later [Dufour and Sterck, 2008; Mulcahy and Call, 2006; Osvath and Osvath, 2008]. Future studies are required to elucidate how far the temporal and also the spatial horizon of tool-making can be extended.

Surprisingly, apes also prepared tools in advance when there was only one grape in the apparatus. However, they did so less than in the experimental condition when the apparatus was baited with eight grapes. Moreover, it is not a mistake to prepare one or two tools in advance when there is one grape in the apparatus just to be on the safe side. In fact in a few cases one tool got stuck when inserted.

Apes produced most tools in the condition in which eight tools were needed, but they produced less than two tools per trial in advance in that condition. Surprisingly, increasing the pressure by reducing the latency of the tool use phase did *not* change the performance of the apes. We expected subjects to produce more tools in advance when the tool use phase was shorter, as they had less time to produce *late* tools. However, subjects prepared the same number of *late tools*, regardless how long the tool use phase was. There are at least two potential explanations for this puzzling finding. One possibility is that apes did not need to produce additional tools because they were able to manufacture tools during the tool use phase—something that often resulted in them getting most of the rewards from the apparatus. Indeed, they seemed to increase their ability to produce tools quickly during this period as testing progressed. Moreover, subjects who had experience with the task produced more *late tools* in the 50 sec tool use phase compared to naïve subjects. Another more speculative possibility is that failing to match the number of pre-prepared tools to the potential rewards that one could obtain represents a limitation in apes' planning abilities. In other words, apes might know that they need to prepare a tool in advance but anticipating how many tools are needed might be too taxing, particularly for species that do not spontaneously enumerate objects. Future studies are needed to investigate this possibility.

More surprisingly, when the tool use phase was short (50 sec), subjects did *not* manage to get significantly more grapes when they had prepared tools in advance when the apparatus was filled with eight grapes. The reason for this was that they could potentially prepare tools during the tool use phase—thus, producing tools in advance did *not* automatically lead to a greater success. In that respect it is remarkable that apes produced tools in advance at all and did so more in the all grape than in the other conditions. In other words, apes produced tools in advance even though they did not receive more rewards. This means the appearance of the future task rather than the amount of reinforcement dictated apes tool production. This may indicate that apes used their future planning abilities although it was not absolutely necessary in order to get as much grapes as possible.

One could argue that it would have been better to leave only the useable tools -and to remove the boards from the cage—when the tool use phase began so that subjects could not produce late tools. But this might not solve the problem as even useable tools could be split during the tool use phase, and the two parts were still useable. However, giving subjects no opportunity to solve the problem in the future without having something prepared in advance should be investigated further in future studies. In the current study we wanted to keep the procedure as simple as possible. We therefore used a task in which intense training was not needed. All subjects learned within one session how the apparatus worked and they had no problem discovering that they had to split the board in order to get a stick that could be inserted. Additionally, our task afforded the possibility of self-correction after an initial failure due to poor planning as it often happens during daily activities. One can imagine a situation in which a chimpanzee fails to bring a hammer tool to the location where nuts are available. Although costly, the chimpanzee could potentially return and get the tool.

Many authors have emphasized that planning behaviour involves anticipation of future needs and therefore has to be independent from current motivations [Clayton et al., 2003; Suddendorf and Busby, 2003; Suddendorf and Corballis, 1997]. Preparing tools in advance in the current study was not independent from the current motivational state as apes were probably highly motivated to get the grapes while they produced the tools. However, other studies have shown evidence that animals are capable of preparing for the future independent from the current motivational state. For example, this is the case in the above mentioned study by Raby and Clayton [2009]—when scrub jays cached one kind of food in a place in which it would not be available in the next morning. As scrub jays in the evening cached the food instead of eating it, they were obviously not hungry [however, see Suddendorf and Corballis, 2008].

Also squirrel monkeys—but not rhesus monkeys and rats—seem to anticipate future needs independent from current motivational states [Naqshbandi and Roberts, 2006; Paxton and Hampton, 2009]. In a study by Naqshbandi and Roberts [2006] a non-thirsty animal had its water bottle removed and could then choose between a smaller and larger quantity of food. Consumption of the food induced thirst. When subjects selected the smaller quantity the water bottle was returned sooner than when they selected the larger quantity. Monkeys reversed their baseline preference for the larger quantity of food when the experimental contingencies were introduced. The authors could exclude that monkeys' behaviour was controlled by a food aversion induced by thirst that followed of large amounts of food as subjects preferred the large quantity again when water was available [Naqshbandi and Roberts, 2006]. However, this paradigm has been criticized because trial and error learning cannot be ruled out [Shettleworth, 2007; Suddendorf and Corballis , 2008].

In conclusion, this study added another piece of evidence to the idea that great apes plan for the future by using a new task. Apes do not only transport and save tools for future use but they also produce tools in advance to use them later, but it does not provide compelling evidence that apes tailor their tool productivity to the potential number of rewards to be obtained. Future studies should address the question how independent this behaviour is from the current motivational state of the subjects.

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