Raising the level: orangutans use water as a tool

Natacha Mendes*, **Daniel Hanus** and **Josep Call**

Max-Planck-Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany
*Author and address for correspondence: Department of Developmental and Comparative Psychology, Max-Planck-Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany (mendes@eva.mpg.de).

We investigated the use of water as a tool by presenting five orangutans (*Pongo abelii*) with an out-of-reach peanut floating inside a vertical transparent tube. All orangutans collected water from a drinker and spat it inside the tube to get access to the peanut. Subjects required an average of three mouthfuls of water to get the peanut. This solution occurred in the first trial and all subjects continued using this successful strategy in subsequent trials. The latency to retrieve the reward drastically decreased after the first trial. Moreover, the latency between mouthfuls also decreased dramatically from the first mouthful in the first trial to any subsequent ones in the same trial or subsequent trials. Additional control conditions suggested that this response was not due to the mere presence of the tube, to the existence of water inside, or frustration at not getting the reward. The sudden acquisition of the behaviour, the timing of the actions and the differences with the control conditions make this behaviour a likely candidate for insightful problem solving.

Keywords: orangutan; tool-use; water tool; insight; problem solving

1. INTRODUCTION

Great apes have been traditionally considered as the most insightful non-human problem solvers (e.g. Köhler 1925; Byrne 1995; Tomasello & Call 1997). New data on corvids, however, have challenged apes' hegemony in several aspects of problem solving, including causal knowledge and tool-use (Henrich 2000; Weir *et al.* 2002; Seed *et al.* 2006). The propensity to spontaneously use tools to extract embedded foods has been used to investigate their causal knowledge for avoiding obstacles, selecting and manufacturing tools. Tested with similar tasks, corvids and great apes perform in similar ways (Chappell & Kacelnik 2002; Mulcahy *et al.* 2005; Helme *et al.* 2006*a*,*b*), thus lending some credence to the hypothesis that they may have undergone convergent cognitive evolution (Emery & Clayton 2004).

However, in virtually all existing tasks, reward accessibility is gained by transferring force from a solid tool to the reward. Here, we investigated the use of

water as a tool to alter the reward's accessibility. A tube quarter-filled with water and baited with a floating peanut was presented to orangutans (*Pongo abelii*). The solution to this problem required orangutans to repeatedly collect water from a drinker and spit it inside the tube, thus raising the water level until subjects could extract the reward. Note that this problem is analogous to the one portrayed in Aesop's fable in which a thirsty crow threw stones into a pitcher to raise and drink the otherwise inaccessible water.

We investigated the type of actions used by orangutans (*Pongo abelii*) and their latency of occurrence within and across trials. Additionally, three follow-up control conditions were run in which the position of the reward regarding the empty tube differed: (i) it could be located out-of-reach on a table placed outside of the tube, to assess whether frustration at not getting the reward triggered the orangutans' behaviour (table condition), (ii) at the bottom of the tube, to assess whether the presence of water influenced the behaviour (dry condition) or (iii) attached to the top part of the tube, easily reachable, to assess whether orangutans indiscriminately added water inside tubes, independently of the position of the reward inside it (top condition). If subjects understood the problem, they should add more water in the dry than in the table or top conditions. Moreover, the latency to spit water inside the tube should be lower in the dry when compared with the table and top conditions.

2. MATERIAL AND METHODS

Five female orangutans of 7, 11, 16, 17 and 32 years of age participated in this study. Subjects were socially housed at the Wolfgang Köhler Primate Research Center, Leipzig zoo, Germany. Both inside and outside enclosures were equipped with climbing elements, trees, living vegetation, water sources and an environmental enrichment programme was daily provided. Subjects were neither food- nor water-deprived.

During the experimental condition, subjects were presented with a shelled peanut floating inside a vertical Plexiglas tube (26 cm long×5 cm wide). The tube was quarter-filled with water so that the peanut could not be reached directly and no tools were available. The drinker, situated 0.75 m away and below the tube, has always been in the testing room since its construction. Subjects received 10 trials except for one subject which received 5 trials and which had the drinker located out-of-sight, 3.5 m above the tube. We conducted one trial per session that could last 1200 s or until the subject got the peanut.

Upon completing the experimental condition, subjects were presented with the control conditions (electronic supplementary material, figure 1). Subjects received four blocks of trials with each block containing three different control conditions (table, dry and top). Order of presentation within and between blocks was counterbalanced. In the table condition, the peanut rested on a platform 31 cm in front of the tube out-of-reach from the subject. In the dry condition, the peanut was located on the bottom of the tube. In the top condition, the peanut was attached to the top of the tube and easily reachable for the subject. We scored whether and when the subjects obtained the reward and the frequency of three types of actions directed at the tube: hand actions (pulling, lifting and banging), mouth actions (biting, licking) and spitting water inside it. Additionally, we scored the time elapsed between successive mouthfuls of water within a trial. All statistics were two tailed.

3. RESULTS

During the experimental condition, all orangutans solved the problem in the first trial and continued to do so in the remaining trials. In the first trial, subjects collected water from the drinker and added it to the tube until they could reach for the peanut (see the electronic supplementary material, movie). The time
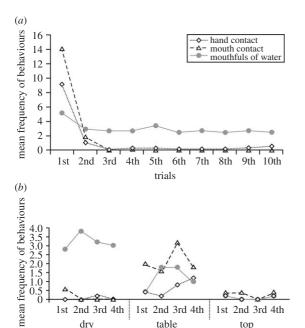
Figure 1. Mean frequency of behaviours performed by the orangutans across the (*a*) experimental condition and (*b*) control conditions.

required to solve the problem decreased exponentially across sessions, $\hat{y} = e^{(3.03/\text{session\#})+3.21}$, $R^2 = 0.95$, $F_8 = 163.0$, $p < 0.001$. On an average, subjects required 540 s (s.e.m. = 101) to solve the task in the first trial, but only 31 s (s.e.m. = 3) in the last trial. The actions directed towards the tube changed over time (figure 1*a*). Hand and mouth actions were common in the first trial (prior to solution) but were replaced by spitting in subsequent trials. Subjects needed an average of five mouthfuls of water in the first trial and approximately three mouthfuls per trial in subsequent trials. The latency to spit water into the tube also decreased dramatically within the first trial but remained constant (and low) in subsequent mouthfuls and trials (figure 2).

During the control condition, the orangutans added water in significantly more trials in the dry compared with the top condition, $t_4 = 9.0$, $p < 0.001$, but not in the table condition, $t_4 = 2.39$, $p = 0.076$ (mean (s.e.m.), dry = 4 (0); top = 0.4 (0.4); table = 2 (0.8)). However, within a trial, orangutans added more mouthfuls in the dry compared with table $t_4 = 4.55$, $p = 0.01$ and top conditions, $t_4 = 12.04$, $p < 0.001$, figure 1*b*. Moreover, orangutans added the first mouthful of water faster in the dry compared with top, $t_4 = 14.0$, $p < 0.001$, and table conditions, $t_4 = 3.28$, $p = 0.03$ (mean latencies: dry = 17 s, top = 112 s, table = 77 s). In the dry condition, the time required to solve the problem, the behaviours displayed (figure 1*b*) and the latency between mouthfuls (figure 2) closely resembled the data from the experimental condition, except the first trial.

4. DISCUSSION

All orangutans repeatedly added water to a tube to get access to a floating peanut. The solution appeared suddenly in the first trial after other behaviours failed to produce a positive outcome. Once spitting water into the tube appeared, subjects continued to use it

(right away) until they got the peanut even though a single mouthful did not produce the reward. Subjects persisted in spitting water although initially they were not rewarded for such actions. Since the temporal distribution of successive mouthfuls was not random during a session, this suggested that orangutans added water to the tube to get the peanut. Additionally, control conditions suggested that this response was not due to the presence of the tube, or that the water inside the tube triggered the response, or that it represented a frustration response at not getting the reward. The sudden acquisition of the behaviour, the timing of the actions and the differences with the control conditions make this behaviour a likely candidate for insightful problem solving (Köhler 1925; Lethmate 1982).

It is still unclear whether subjects fully formed a solution to the problem prior to spitting the first mouthful in the first session or that once they added the first mouthful they realized its potential beneficial effects. Further experimentation using an opaque tube that prevents subjects from seeing the effects of their actions could tease these two alternatives apart. One alternative to an insightful solution is that subjects previously solved this problem and here they simply remembered the solution. Although we cannot rule this out, we think that it is unlikely. Subjects had never received this task in the past and water was never required as a solution for a problem.

Unlike previous studies on animal tool-use, here orangutans used liquid (not a solid object) to alter the position of the reward. Although other animals such as archer fish (*Toxotes jaculatrix*) use water to affect the position of prey (Lüling 1963), there are two important differences with the current results. First, the water was not perceptually available but orangutans had to get it from a drinker and for one orangutan the drinker was not even within sight. Köhler (1925) described many of the examples of insight as a *perceptual* apprehension and recombination of the different parts of a problem, for instance two tools that need to be combined. Here, orangutans produced a solution without seeing the tool (water was inside the drinker), suggesting that they had to think at a more abstract level. Since subjects also solved the dry control condition, this means that the sight of the water was not strictly necessary to continue solving the problem. Moreover, unlike other studies in which animals must fetch tools that were initially out-of-sight (e.g. Chappell & Kacelnik 2002; Mulcahy *et al.* 2005), subjects in the current study could not use a search image of the tool, just a place where water could be obtained.

Second, spitting water in archer fish, but not in orangutans, is a pre-programmed response. In fact, orangutans can deploy multiple strategies to solve the same problem including reaching for the reward, breaking the tube or using tools to fish for the reward. It is precisely this flexible deployment of multiple strategies that has yet to be documented in tool-using corvids. New Caledonian crows (*Corvus moneduloides*) can use a hook to get rewards in a variety of tasks, but all of them fall within the category of extracting
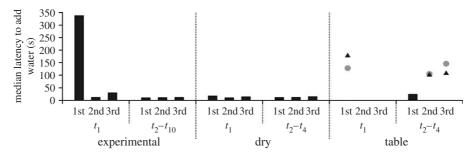
Figure 2. Median latency elapsed between the first three successive mouthfuls of water within a trial of the experimental condition and the dry and table control conditions. t_1 represents the first trial, t_2–t_{10} represent the combined scores from trial 2 to trial 10 of the experimental condition and t_2–t_4 the combined scores from trial 2 to trial 4 of the dry and table control conditions. Bars represent combined scores for four to five subjects, while symbols represent individual scores (triangle, padana; circle, pini).

embedded food from holes or crevices. It is yet unknown whether this species or other corvids are able to invent alternative strategies, particularly those involving unusual methods for unusual problems. Our working hypothesis is that whereas corvid tool-use is a cognitive specialization, great ape tool-use arises from cognitive generalization. This is why primates, and great apes in particular, can solve a variety of tasks in a variety of ways. However, some rooks (*Corvus frugilegus*) can solve certain problems involving obstacles (Seed *et al.* 2006), a New Caledonian crow fashioned tools out of an unusual material (Weir *et al.* 2002), and western scrub-jays (*Aphelocoma californica*) can deploy multiple strategies to protect their caches (Dally *et al.* 2005). This suggests that corvids possess considerable cognitive flexibility, but only future research can establish this in the tool-use domain. For now, what we can say is that orangutans can insight-fully solve an analogous version of the problem faced by the crow in Aesop's fable. It is yet to be seen if scientific evidence will show that crows can also behave as in the fable.

Byrne, R. W. 1995 *The thinking ape. Evolutionary origins of intelligence*. Oxford, UK: Oxford University Press.

Chappell, J. & Kacelnik, A. 2002 Tool selectivity in a non-primate, the New Caledonian crow (*Corvus moneduloides*). *Anim. Cogn.* **5**, 71–78. (doi:10.1007/s10071-002-0130-2)

Dally, J. M., Emery, N. J. & Clayton, N. S. 2005 Cache protection strategies by western scrub-jays, *Aphelocoma californica*: implications for social cognition. *Anim. Behav.* **70**, 1251–1263. (doi:10.1016/j.anbehav.2005.02.009)

Emery, N. J. & Clayton, N. S. 2004 The mentality of crows: Convergent evolution of intelligence in corvids and apes. *Science* **306**, 1903–1907. (doi:10.1126/science.1098410)

Helme, A. E., Call, J., Clayton, N. S. & Emery, N. J. 2006a What do bonobos (*Pan paniscus*) understand about physical contact? *J. Comp. Psychol.* **120**, 294–302. (doi:10.1037/0735-7036.120.3.294)

Helme, A. E., Clayton, N. S. & Emery, N. J. 2006b What do rooks (*Corvus frugilegus*) understand about physical contact? *J. Comp. Psychol.* **120**, 288–293. (doi:10.1037/0735-7036.120.3.288)

Henrich, B. 2000 Testing insight in ravens. In *The evolution of cognition* (eds C. Heyes & L. Huber), pp. 289–305. Cambridge, MA: MIT Press.

Köhler, W. 1925 *The mentality of apes*. New York, NY: Harcourt, Brace and World.

Lethmate, J. 1982 Tool-using skills of orangutans. *J. Hum. Evol.* **11**, 49–64. (doi:10.1016/S0047-2484(82)80031-6)

Lüling, K. H. 1963 The archerfish. *Sci. Am.* **209**, 100–108.

Mulcahy, N. J., Call, J. & Dunbar, R. I. M. 2005 Gorillas (*Gorilla gorilla*) and orangutans (*Pongo pygmaeus*) encode relevant problem features in a tool-using task. *J. Comp. Psychol.* **119**, 23–32. (doi:10.1037/0735-7036.119.1.23)

Seed, A. M., Tebbich, S., Emery, N. J. & Clayton, N. S. 2006 Investigating physical cognition in rooks (*Corvus frugilegus*). *Curr. Biol.* **16**, 697–701. (doi:10.1016/j.cub.2006.02.066)

Tomasello, M. & Call, J. 1997 *Primate cognition*. New York, NY: Oxford University Press.

Weir, A. A. S., Chappell, J. & Kacelnik, A. 2002 Shaping of hooks in New Caledonian crows. *Science* **297**, 981. (doi:10.1126/science.1073433)