Navigating a tool end in a specific direction: stick-tool use in kea (Nestor notabilis)

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This study depicts how captive kea, New Zealand parrots, which are not known to use tools in the wild, employ a stick-tool to retrieve a food reward after receiving demonstration trials. Four out of six animals succeeded in doing so despite physical (beak curvature) and ecological (no stick-like materials used during nest construction) constraints when handling elongated objects. We further demonstrate that the same animals can thereafter direct the functional end of a stick-tool into a desired direction, aiming at a positive option while avoiding a negative one.

**Keywords:** birds; tool use; physical cognition

1. INTRODUCTION

Jane Goodall defined stick-tool use as ‘the use of an external object as a functional extension of mouth or beak, hand or claw, in the attainment of an immediate goal’ [1]. Later definitions of tool use incorporated other, more compact agents as tools (e.g. [2–4]). The usage of stick-like objects as tools is, however, rarely observed in non-human animals. Despite some non-reoccurring observations of other songbirds [5], there are merely two avian species universally acknowledged as regularly employing stick-tools in a foraging context in the wild: woodpecker finches use cactus spines [6] and New Caledonian crows use and manufacture numerous kinds of elongated tools from various materials to dislodge grubs from tree bark [7,8]. The potential use of stick-tools in both species is genetically determined [6,9]. Bird & Emery [10] demonstrated that captive rooks, which are not known to employ tools in the wild, were able to use sticks and elongated stones to push against a collapsible platform inside a Plexiglas tube, which was holding a food reward. There is, however, no empirical evidence to date that these animals can ascertain the precise direction of the functional tool end as natural tool users can.

The kea, a New Zealand mountain parrot, has shown great competence in physical problem solving tasks, including the use of compact objects as tools [11,12].


In an experiment featuring a box from which food could be attained by operating different openings, one male kea (Kermit) succeeded in poking a reward off a small platform by inserting a rod-shaped tool into a hole in a vertical transparent wall of the box [13]. Lacking the appropriate technique, five remaining subjects failed after six trials of 10 min including one trial after Kermit had demonstrated stick-tool use, although they all attempted to insert the tool into the opening.

Owing to the curvature of the kea’s beak, the stick-tool could not easily be handled. Surprisingly, Kermit quickly developed a sophisticated technique, allowing him to succeed despite this disadvantage: he took one tool end laterally into his beak and held it against the opening. He thereafter exchanged his bill with his foot, still pressing the tool end against the opening. Meanwhile, he took the other tool end into his beak tip and pushed it through the hole, manoeuvring it until it hit the reward [13]. Although the coordination of different body parts (beak and foot relative to body weight) indicates complex body control and coordination, it is still unclear whether Kermit operated the stick as a functional extension of his beak towards the reward or whether he learned to insert the tool and to wave it about inside the box until the reward appeared.

The following study investigates whether kea can navigate the stick towards the appropriate one of two options. To attain more stick-tool using subjects without shaping [14], we exposed the same birds that failed to succeed using the stick in the previous study to further demonstration trials by Kermit (although testing for social learning is not the goal of this study).

2. MATERIAL AND METHODS

(a) Subjects

Six adult male kea: Luke, Bruce, Kermit, Frowin, Pick and Tammy, participated in this study. All were bred in captivity and kept in an enriched outdoor aviary (10 m and 4 m high) at the Konrad Lorenz Institute for Ethology in Vienna. Food was spread every day at noon; fresh drinking water was available ad libitum. An experimental compartment (10 × 5 m) could be visually isolated from the remaining enclosure using opaque sliding doors. All subjects had participated in studies involving the use of compact-shaped objects as tools [11,12] as well as in an experimental series involving stick-tool option [13]. Testing was conducted in accordance with the Austrian Animal Experiments Act (§2, Federal Law Gazette no. 501/1989).

(b) Demonstration phase

The basic apparatus we used was a wooden box with a transparent Plexiglas front (for dimensions see figure 1). The front left a gap at the lower end and contained a small round hole (diameter 3.5 cm) in its centre. A slanted aluminium wall with a small platform placed in its centre was situated inside the box. The upper end of the platform was 10 cm from the hole in the Plexiglas front (figure 1). A food reward (a quarter of a peanut) was placed inside a wooden box onto the platform inside the apparatus. The content of the box was shown to the subject before the start of each trial. Two rod-shaped tools were provided (length 20 cm; 2 and 1 cm diameter) in front of the box. Two different tool diameters were used so that the birds could choose which was easier for them to handle. To retrieve the reward, one of the two stick-tools had to be inserted into the hole and manoeuvred until it hit the reward box, releasing the food (inside the box) through the gap at the lower end of the Plexiglas front. Each subject was allowed to observe Kermit retrieve the reward from a distance of 1 m in three demonstration trials. This was followed by a self-trial. If subjects did not retrieve the reward within 10 min by themselves, the same procedure was repeated the next day. If they retrieved the reward, they received nine additional self-trials. Each successful subject received two additional sessions of
10 trials without prior demonstrations over the following days in order to improve their technique.

Subjects received a maximum of five demonstration sessions (three demonstrations and one self-trial each). Animals that did not master the task within this time did not receive further testing.

(c) **Discrimination phase**
We used the same apparatus as in the demonstration phase except that there were two reward boxes differing in colour, red or green. For half of the subjects green was baited, for the other half red. Subjects received five sessions of 10 trials. Within each session, the green box was on the platform for half of the trials and the red box for the other half in random order. A trial was scored as correct when the subjects retrieved the reward when the positive stimulus was offered and did not combine the tool with the opening when the negative stimulus was on the platform for 1 min.

(d) **Test phase**
We used the same basic apparatus as in the previous phases but this time there were two platforms placed next to each other on the slanted wall. Subjects received five sessions of 10 trials in which both the red and the green boxes were placed on the two platforms. The positive stimulus could be on the right-hand side and further away from the opening than the negative (positive far right; PFR), on the left-hand side and further away from the hole (PFL), on the right-hand side and closer to the hole (PCR) or on the left-hand side and closer to the hole (PCL). Each session comprised each side condition (PSR/L; PCR/L; PSR/L) at least once and conditions for the remaining trials were randomly selected. A trial was scored as correct if the positive stimulus was poked off its platform first.

### 3. RESULTS

Pick successfully operated the stick after one demonstration session. Frowin required three and Luke five sessions. Bruce and Tammy attempted to combine the tool with the opening but failed to insert it within the time given and were therefore eliminated from further testing. Pick and Frowin used the same technique as the demonstrator (see the electronic supplementary material, video). Luke, supporting the tool on the rim of the opening, pushed it through the opening by

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Table 1. Individual performance in each phase: session number of first success (demonstration phase); session number in which subjects ceased to hit the negative stimulus (discrimination training); number correct out of 10 trials per session 1–5.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>demo phase succeeded in session</th>
<th>colour discrimination positive learned</th>
<th>testing phase session 1 correct/10</th>
<th>session 2 correct/10</th>
<th>session 3 correct/10</th>
<th>session 4 correct/10</th>
<th>session 5 correct/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce</td>
<td>red</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Tammy</td>
<td>red</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Kermit</td>
<td>green</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Luke</td>
<td>green</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Pick</td>
<td>green</td>
<td>7</td>
<td>6.75</td>
<td>7.5</td>
<td>7</td>
<td>6.75</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.4</td>
<td>0.25</td>
<td>0.64</td>
<td>0.4</td>
<td>0.94</td>
<td></td>
</tr>
</tbody>
</table>

10 trials without prior demonstrations over the following days in order to improve their technique.

Subjects received a maximum of five demonstration sessions (three demonstrations and one self-trial each). Animals that did not master the task within this time did not receive further testing.
Table 2. Mean percentage correct for the testing conditions: positive stimulus closer (PC), further (PF) or at the same
distance (PS) to the opening than the negative stimulus. PCL–PSR depict the mean percentage correct depending on
whether the left or right-hand side was positive (e.g. PCL, positive close left; PCR, positive close right). Two-tailed
Binominal tests were conducted for each of the conditions (p-values).

<table>
<thead>
<tr>
<th>subjects</th>
<th>positive close (%)</th>
<th>positive far (%)</th>
<th>positive same (%)</th>
<th>PCL (%)</th>
<th>PCR (%)</th>
<th>PFL (%)</th>
<th>PFR (%)</th>
<th>PSL (%)</th>
<th>PSR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frowin</td>
<td>69</td>
<td>58</td>
<td>73</td>
<td>60</td>
<td>75</td>
<td>60</td>
<td>57</td>
<td>87</td>
<td>57</td>
</tr>
<tr>
<td>Kermit</td>
<td>75</td>
<td>80</td>
<td>60</td>
<td>80</td>
<td>83</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Luke</td>
<td>77</td>
<td>54</td>
<td>81</td>
<td>77</td>
<td>75</td>
<td>40</td>
<td>67</td>
<td>62</td>
<td>100</td>
</tr>
<tr>
<td>Pick</td>
<td>59</td>
<td>61</td>
<td>65</td>
<td>70</td>
<td>42</td>
<td>50</td>
<td>71</td>
<td>53</td>
<td>85</td>
</tr>
<tr>
<td>total</td>
<td>69.99</td>
<td>63.6</td>
<td>69.89</td>
<td>71.94</td>
<td>69.04</td>
<td>50</td>
<td>73.8</td>
<td>75.88</td>
<td>70.71</td>
</tr>
<tr>
<td>s.e.</td>
<td>4.52</td>
<td>8.94</td>
<td>4.08</td>
<td>9.22</td>
<td>10.76</td>
<td>13.57</td>
<td>4.06</td>
<td>5.65</td>
<td>4.67</td>
</tr>
<tr>
<td>binominal test</td>
<td>p = 0.006a</td>
<td>p = 0.04a</td>
<td>p = 0.001a</td>
<td>p = 0.02a</td>
<td>p = 0.16</td>
<td>p = 1</td>
<td>p = 0.008a</td>
<td>p = 0.035a</td>
<td>p = 0.035a</td>
</tr>
</tbody>
</table>

*Above chance level.

repeatedly shifting his grip of the beak backwards until he reached the end of the tool.

During the discrimination phase, red was positive for Kermit and Frowin; green for Luke and Pick. Initially, all animals hit the negative stimulus as readily as the positive. Frowin stopped doing so in session 2, Kermit and Pick in session 3 and Luke in session 5.

Once testing started, Pick and Frowin hit the correct option on their first trial. In each of the five testing sessions, the group hit the positive stimulus more often than the negative (two-tailed binominal test; n = 40; p1 = 0.016; p2 = 0.038; p3 = 0.002; p4 = 0.016; p5 = 0.038, table 1). There was no difference in performance between the first and the fifth sessions (McNemar test; n = 40; p = 1.00; see electronic supplementary material, figure S2).

Kermit hit the positive option significantly more often than the negative one after two sessions, Pick after three (he did decrease in performance later; see table 1) and Luke and Frowin after three sessions (two-tailed binominal test for correct first choice cumulated over sessions: pKer = 0.041; pLu = 0.042; pFr = 0.016; pPi = 0.038; for more details see table 1). The performance of all subjects except Pick remained above chance after five sessions (pPi = 0.11; pKer = 0.0003; pLu = 0.002; pFr = 0.006; see table 1).

There was no significant difference in performance between the positive close (PC), the positive same (PS) and the positive far (PF) conditions (Friedmann’s ANOVA; n = 4; χ² = 1.5; p = 0.43; see table 2 and the electronic supplementary material).

4. DISCUSSION

Owing to their strong beak curvature, kea are physically not privileged to handle stick-like objects. Furthermore, unlike naturally stick-tool-using birds, kea do not use twigs for nest construction but breed in burrows [15]. We can therefore presume that they additionally lack an ecological predisposition to direct elongated objects [13]. Despite these circumstances, after receiving demonstrations, three out of five observers mastered the complex motor challenge of handling a stick-tool within the short time frame of this study.

Two subjects used the same multi-step technique as the demonstrator. Mastering this technique required a high level of body motor control: successful performance entailed actively controlling concerted foot and bill actions and simultaneously anticipating their effects. During the discrimination training, all subjects became reluctant to combine the stick-tool with the opening once the negative stimulus was displayed, suggesting that the reward was their primary motivation.

When two stimuli were accessible, subjects did not simply manoeuvre the tool arbitrarily inside the apparatus but aimed at the baited box, swiftly translating the movement of their beaks to that of the functional tool end, navigating it into the desired direction. Although all individuals reached significance levels after a few sessions, the average percentage of correct trials per session tended to stand at around 70 per cent in each of the five sessions. This indicates that once the two-choice paradigm was introduced, subjects quickly grasped the essential characteristics of the stick as a tool but had difficulties with certain properties of the task. One reason may be the technical impracticality of holding the stick-tool firmly inside a curved beak: the tool was jiggling between the tips of the maxilla and mandible while the birds were pushing it. Possibly, mistakes occurred because animals inadvertently hit the negative stimulus while aiming at the positive one.

This is to our knowledge the first evidence of a bird species, lacking a socio-ecological predisposition for using stick-like objects, designating the direction of a stick-tool as a functional extension of a body part (beak).

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