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## Limited spread of innovation in a wild parrot, the kea (*Nestor notabilis*)

Received: 3 August 2005 / Revised: 14 February 2006 / Accepted: 15 February 2006  
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**Abstract** In the local population of kea in Mount Cook Village, New Zealand, some keas open the lids of rubbish bins with their bill to obtain food scraps within. We investigated the extent to which this innovation has spread in the local population, and what factors limit the acquisition of bin opening. Only five males of 36 individually recognised birds were observed to have performed successful bin opening. With one exception there were always other keas present, watching successful bin opening. Seventeen additional individuals were seen to have benefitted from lid opening. Their foraging success was less than that of the bin openers. Social status of bin openers did not differ from scrounging males. Among the individuals that were regularly seen at the site of the bins but were not successful in bin opening, social status and the ratio of feeding directly from open bins correlated with the amount of opening attempts. We conclude that scrounging facilitated certain behavioural aspects of bin opening rather than inhibiting them. The fact that only 9% of opening attempts were successful, and the long period of time required to increase efficiency in lid opening shows that mainly individual experience, and to a lesser extent insight and social learning, play key roles in acquisition of the opening technique. The results indicate that the spread of innovative solutions of challenging mechanical problems in animals may be restricted to only a few individuals.

**Keywords** Innovation · Physical cognition · Social learning · Scrounging

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### Introduction

Innovative behaviour recorded by ornithologists in the field has become one of the standard parameters for comparative studies of bird cognition (Lefebvre and Bolhuis 2003). Lefebvre and his co-workers, after scanning avian behaviour journals, found positive correlations between the number of records of innovative behaviour per parvorder for: the size of neurological structures (Lefebvre et al. 1998; Timmermans et al. 2000), tool use (Lefebvre et al. 2002), individual learning (Gossette 1968; Sasvãri 1985), problem solving and an inverse degree of neophobia (Webster and Lefebvre 2001; 'cognitive' traits reviewed in Lefebvre and Bolhuis 2003 considered here only). Whereas similar analyses on data of primates showed an additional correlation of innovation rate and social learning reports (Reader and Laland 2002), so far there is no clear relationship between innovation and social learning in birds (Lefebvre 2000; Lefebvre and Bolhuis 2003). The impact of this difference on behavioural innovation as a driving force in the evolution of primates and birds is not clear, but 'the ability to invent new behaviour may have played a pivotal role in primate and avian-brain evolution' (Reader and Laland 2003, p. 22).

The aim of this paper was to provide a case study to which extent an innovation was spread in a local population of wild kea (an endemic mountain parrot) in Mount Cook National Park, New Zealand, in 2003, and to evaluate the behavioural mechanisms involved in acquisition of this behaviour. The innovation considered here is lid opening of rubbish bins. It is regarded as being innovative because we know that only two out of seven local populations of keas topple over the lids of wheely bins for the food scraps within and wheely bins provide a phylogenetically very recent source of food. (The type of bins provided during the time of our study was introduced in Mount Cook Village in the early 90s.) Keas do turn over stones of more than 1 kg of weight in order to obtain access to larvae of insects in the alpine grassland (personal observation). Thus, it is not uncommon for a kea to

move heavy objects and this is necessary in opening bin lids. In this respect, bin opening refers to Lee's (1991) definition of innovation: Introduction of a novel mode of coping with the environment by performing new behaviour or by applying an existing behaviour in a novel context.

According to the correlative findings of Lefebvre and his co-workers summarized earlier, and due to the kea's neophilia (Keller 1975; Kubat 1992) and problem-solving ability (Johnston 1999; Huber et al. 2001), this parrot species should provide a good model for innovative behaviour in birds. Parrots have a relatively large brain and they are represented in Lefebvre et al.'s (1998) analysis as innovative birds in general. In spite of these facts and although keas are well known in New Zealand for their innovative problem-solving abilities, there are very few scientific reports about innovative behaviour in this species from the field (Marriner 1908; Beggs and Mankelov 2002).

Keas open the lids of rubbish bins outside the kitchen of a large multi-storey hotel in Mount Cook Village where they regularly gather during night and in the early morning. Hotel staff have encountered keas attempting to open bins for several years. However, none of the hotel kitchen staff that we talked to has observed the birds in the process of opening a bin lid completely. Although the start of bin opening in the local population was not witnessed by us, we focus on aspects of bin opening as innovation *sensu* process (i.e. the origin of a new skill in a particular individual; Wyles et al. 1983; cited in Reader and Laland 2003) by analysing the behaviour of opening attempts and considering alternative hypotheses as to why only a small part of the local population is performing successful bin opening. If the frequency of successful bin openers is small, even though other birds observe successful lid opening, it has to be evaluated whether scrounging opportunities prevent other birds from learning how to open the bins (see Laland 2004 for a review): It may not be worthwhile for scroungers to open bins themselves if the payoff for scrounging and bin opening is equal. We call those individuals scroungers that use the behavioural investment of other keas in lid opening to obtain food (Bernard and Sibly 1981) but are never observed to open bins successfully themselves. Bin openers in the present case opened bins on their own but also consumed food from bins opened by other keas. Thus, we call bin openers opportunists (Vickery et al. 1991). Scroungers may also not open lids because they have no opportunity to do so due to asymmetries in competition for access to bins, or asymmetries in the physical strength required to open the bins. Finally, the analyses of unsuccessful lid-opening attempts gives an indication whether the 'idea' (Rogers 1995; cited in Reader and Laland 2003) of lid opening seems novel to the individual and whether lid opening provides a challenging mechanical problem for which the birds may have an inappropriate physical cognition that prevents them from opening the bins successfully.

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## Methods

### Study animals

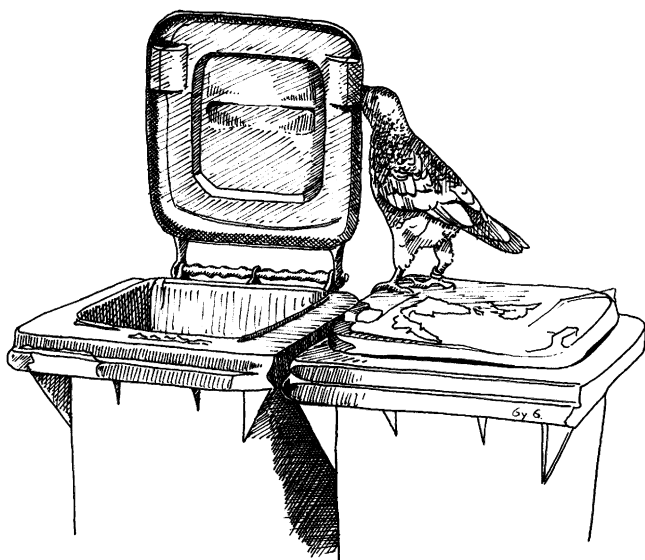
Free-ranging keas regularly frequent a large multi-stored hotel in Mount Cook Village in South Island, New Zealand (elevation 725 m, annual rainfall approximately 5000 mm). In March 2002, we began banding the birds with colour bands as a means of individual identification. Age class and sex were determined according to phenotype (Mallet, cited in Bond et al. 1991; Higgins 1999). We made no mistakes with sexing according to the phenotype, when compared with the DNA sex determination technique through blood samples we collected from birds in the field (G. K. Gajdon, N. Fijn and B. Robertson, unpublished data).

### Description of rubbish bins

Observations were conducted outside the kitchen of a hotel where approximately a dozen bins were wheeled out and placed close together near the kitchen entrance. The bins were of standard type used worldwide in industrial countries for automatic disposal with rubbish trucks. There were two bin sizes: small bins of 120 l, bin height 90 cm; and large bins of 240 l, bin height 107 cm. Bins of both sizes were successfully opened by keas. The dimensions of the lid from front to hinge was 51 cm (large bins: 68 cm) and 43 cm from side to side (large bins: 55 cm). About 400 g (measured on several bins with a spring weight) had to be lifted in order to open the lid at its front edge (large bins: 800 g), and 500–600 g (large bins: 900–1000 g) in order to open it where the handles were located, about 15 cm away from the front corner of the lid. Median body weight of keas measured during the period of observation was 730 g for females (quartiles: 675–760 g,  $N = 8$ ) and 945 g for males (quartiles: 875–1000 g,  $N = 16$ ). The distance between the front edge of a lid in vertical position and the front edge of the open bin was 70 cm (large bins: 90 cm). The maximum height a kea can reach with its bill in standing position is 40–45 cm. There was only a thin rim around a closed lid measuring 1–3 cm at its thinnest location and 6–7 cm at its largest dimension at the front corner of the bin. Wooden logs (approx. 3 kg) were placed on top of the bins by the kitchen staff as an attempted preventative measure against keas opening the bins. The kitchen staff also cleaned food scraps from the concreted ground on a daily basis. Figure 1 shows relative dimensions of a kea engaged in bin opening.

### Observational method

Bin-opening behaviour was systematically recorded between 18 December 2002 and 30 January 2003. Bin opening was performed regularly during that period. Keas stopped frequenting the area outside the kitchen on a regular basis after that period and no further bin opening occurred



**Fig. 1** Kea engaged in bin opening (drawn from a photo)

during that season. We conducted observation sessions in the early morning, from dawn (when there was adequate light to positively identify individual colour bands on the birds), until the birds left the kitchen area (partially due to disturbance from increasing activity of kitchen staff in the vicinity). Keas were present at the kitchen area during 35 morning sessions for a median duration of 1:21 h (quartiles: 1:02–2:05 h).

Nine additional sessions of night observations were performed from dusk until dawn. In contrast to the morning sessions, where we stood near the kitchen area when recording data, we were seated in a campervan, using it as a bird hide, during night sessions. We parked the campervan in a car park adjacent to the kitchen area. The bins were illuminated for most of the night by outdoor lights, or by a strong torch run from a car battery. The torch pointed to the ground and was switched on when we failed to identify the colour bands of birds present due to insufficient illumination.

At the start of each observation session, we scanned for all individuals that were present at the kitchen area and recorded their main activity. Identity of further individuals landing at the kitchen area or flying away were continuously recorded, as well as identity of all individuals that were observed to exhibit successful (toppling over lids in a way to keep the bins open) and unsuccessful opening attempts at bin lids (seizing lids without opening success or dropping them so that the bins remain closed). Furthermore, all feeding events of individuals from inside and around the bins were recorded. Food scattered on the floor was removed by the birds from the bins and was left outside the bins after eating the most nutritious parts (meat and butter) whilst leaving bones, butter containers or bread. Since keas chew all food into tiny pieces before consuming it, feeding events were enduring, easily detectable events. Unsuccessful attempts at lifting lids that were blocked in some way (e.g. because the bird was standing on the same lid) were recorded separately. Moving and pushing off wooden logs

from the top of the bins was also recorded, but this was not considered as an opening attempt. From the end of December onwards, we also recorded the degree of lid opening during unsuccessful attempts (categorised as lid remaining closed, being opened less than half way, about half way and more than half way).

Since the start of our observations in Mount Cook National Park in March 2002, we continuously recorded social interactions, including displacements in agonistic interactions. Individual colour combinations of bands were identified with binoculars, if needed. All data was spoken onto dictaphones during observation in the field.

## Data analyses

Clutton-Brock-indexes (Clutton-Brock et al. 1979; 'dominance index' in the following) for individuals' overall success in agonistic interactions was calculated on data collected from 20 March 2002 until 30 January 2003 (1594 agonistic interactions in total). The numerator of the index for any individual  $i$  contains the number of other birds  $i$  displaced plus the number that those other birds displaced plus 1. The denominator is the number of other birds that displaced  $i$  plus the number that displaced them plus 1. Non-parametric two-tailed statistical tests (Mann–Whitney  $U$  test, Fisher's exact test and Spearman rank correlation of SPSS 10.0.7 for Windows) and a 0.05 level of significance were used if not stated otherwise. The results are presented as median and quartiles  $Q1$  and  $Q3$ .

## Results

### Birds observed

A total of 36 individually banded keas were recognized in the vicinity of the kitchen area during 44 observation sessions (21 individuals during nine night sessions and 34 individuals during 35 morning sessions. Two individuals were seen in night sessions only). Due to our banding efforts, we only rarely failed to individually identify the birds present: median total number of keas seen per morning session was 13 (quartiles 9–15) and two (quartiles 1–3) for unbanded birds; for night sessions the median total number of keas seen was eight (quartiles 3–12) and zero (quartiles 0–0.5) for unbanded birds.

Twelve of the individually banded birds were classified as females and 23 as males (sex of one banded kea was unknown). This male-biased sex ratio is consistent with male sex biases found for kea at the rubbish dump at Arthur's Pass, New Zealand (Jarret and Wilson 1999; Diamond and Bond 1991). Six birds were fledglings (two males, four females), nine birds were juveniles (seven males, two females), three birds were subadults (two males, one female) and 18 birds were adults (12 males, five females, one of unknown sex). The number of sessions in which individual birds were present at the kitchen area was not statistically different between juveniles and adults or between

females and males (fledglings and subadults were not considered because fledglings just started to visit the village during the period of observation and only three individuals were subadults. (Statistics: median (quartiles): juveniles: 16 (2.5–32); adults: 9 (1–15.75); Mann–Whitney  $U$  test:  $U = 54$ ,  $N_1 = 9$ ,  $N_2 = 18$ ,  $P = 0.126$ ; males: 11 (3–25); females: 5 (1.25–17.25); Mann–Whitney  $U$  test:  $U = 112$ ,  $N_1 = 23$ ,  $N_2 = 12$ ,  $P = 0.364$ ; fledglings: 3.5 (1.75–10.5); subadults: 3 (1–25).

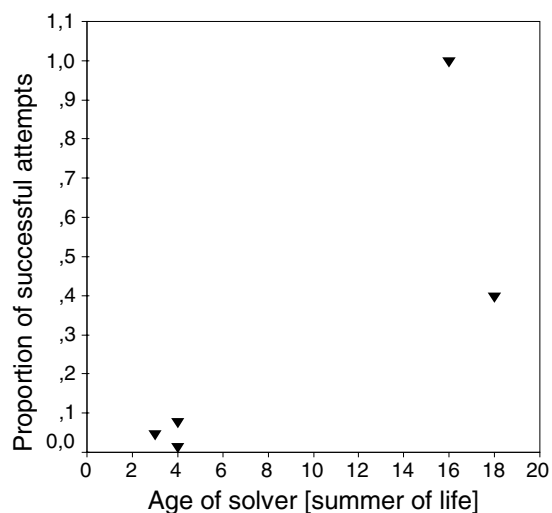
Dominance indexes (see ‘Methods’) were different between females and males (Mann–Whitney  $U$  test:  $U = 48$ ,  $N_1 = 10$ ,  $N_2 = 23$ ,  $P = 0.009$ ; for two females no index could be calculated because they were never observed in an agonistic interaction). Ranked index of different age classes of males or females did not differ. (Statistics: median (quartiles) of index rank: fledgling males: 10.25 (3–17.5),  $N = 2$ ; juvenile males: 11 (7–19),  $N = 7$ ; subadult males: 17 (14–20),  $N = 2$ ; adult males: 14 (6.5–22.75),  $N = 12$ ; Mann–Whitney  $U$  test for juvenile versus adult males:  $U = 39$ ,  $N_1 = 7$ ,  $N_2 = 12$ ,  $P = 0.800$ ; fledgling females: 25.5, 25–26,  $N = 2$ , no index for two female fledglings; juvenile females: 23.5, 15–32,  $N = 2$ ; subadult female: 21,  $N = 1$ ; adult females: 29 (14–30.5),  $N = 5$ ).

### General opening attempts

We observed a total of 478 opening attempts performed in 22 morning (median 8.5, quartiles 2.75–22.5) and eight night sessions (median 28.5, quartiles 8–40). Fifteen known individuals were involved in all opening attempts (median attempt per individual: 8; quartiles 5–40; unidentified individuals performed 15 attempts in total). All these individuals were seen feeding at the bin area. Ninety-one attempts were performed by five individually known juveniles (median 8, quartiles 3.5–38), 29 attempts by two subadults (4 and 25 attempts) and 343 attempts by eight adult keas (median 13, quartiles 5–49.75). There is no statistical difference in the number of individual opening attempts between juveniles and adults (Mann–Whitney  $U$  test:  $U = 74$ ,  $N_1 = 9$ ,  $N_2 = 18$ ,  $P = 0.698$ ). Four hundred and fifty-seven attempts were performed by 13 individually known males that were older than fledglings (median 20, quartiles 5–46) and six attempts were performed by two females. This difference in number of opening attempts between males and females is not significant (Mann–Whitney  $U$  test:  $U = 42$ ,  $N_1 = 21$ ,  $N_2 = 8$ ,  $P = 0.03$ ,  $\alpha^* = 0.025$ ;  $\alpha^*$ : Bonferroni-corrected  $\alpha$  level for testing once on age and once on sex differences).

### Successful bin opening

We recorded a total of 41 successful bin openings (9% of all attempts) performed in 11 morning sessions (median 1, quartiles 1–3) and six night sessions (median 3.5, quartiles 1.75–5). Successful bin opening was performed by five individuals only: 17 times by a 4-year-old male, 16 and 5 times by two males aged at least 20 and 17 years, respectively, and once each by another 4-year-old and a



**Fig. 2** Bin-opening efficiency (proportion of successful openings from all opening attempts) of the five opportunists in relation to age. The two older keas were banded by staff from the Department of Conservation as juvenile and adult keas in 1988. Thus, for the latter bird the age indicated represents minimal age

3-year-old male. We failed to recognise the bands of a bird that opened a lid on one occasion during a night watch (there were indications that it was the 20-year-old male reported above that had 16 successful opening attempts). Thus, bin opening was performed only by males, never by juveniles and just three individuals performed almost all successful occurrences of bin opening. Birds that opened bins were also observed to consume food from bins opened by other keas and thus are called opportunists. Dominance indexes were not different between males that were observed to open bins successfully and males that did not (median (quartiles) of opportunists: 14 (5–28); scroungers: 12.5 (6.75–19.75); Mann–Whitney  $U$  test:  $U = 40$ ,  $N_1 = 5$ ,  $N_2 = 18$ ,  $P = 0.709$ ). Within the small sample size of the five opportunists, there is no significant correlation between proportions of number of completely successful opening attempts from all opening attempts and age of opportunists (Spearman rank correlation:  $r_s = 0.718$ ,  $N = 5$ ,  $P = 0.172$ ), but the two oldest opportunists were clearly the most efficient bin openers (Fig. 2).

### Payoff for bin opening and scrounging

In order to check whether only a few individuals performed successful bin opening due to other birds’ easy access to food from scavenging at bins already opened, we examined how often opportunists and scroungers were seen feeding to give an indication of the payoff of these two foraging strategies. If scrounging birds were seen feeding at least as often as the opportunists then this is an indication that there is no advantage for scroungers to open bins themselves.

Opportunists were seen feeding more often than scroungers (median (quartiles) of opportunists: 25 (12.5–28),  $N_1 = 5$ ; scroungers: 9 (4–13),  $N_2 = 17$ ). The somewhat trivial effect of individuals that were only very rarely present and therefore not having the opportunity to

perform many opening attempts (or feeding events), can be removed by considering only individuals that were present during at least 10 sessions. With this restriction, as well as the exclusion of fledglings because they were never seen attempting to open the bin lids, no significant correlation between number of sessions present and opening attempts was found (Spearman rank correlation:  $r_s = 0.411$ ,  $N = 15$ ,  $P = 0.128$ ). The number of observed feeding events but not the dominance index was significantly different between four opportunists and 11 scroungers of this subset of individuals. (Statistics: median (quartiles): feeding events of opportunists: 26 (20.5–28.5); scroungers: 12 (8–18);  $U = 1.5$ ,  $P = 0.007$ ;  $\alpha^* = 0.025$ ; dominance index of opportunists: 18.5 (4.25–30.5); scroungers: 13 (7–22);  $U = 1.5$ ,  $P = 0.602$ .  $\alpha^*$ : Bonferroni-corrected  $\alpha$  level for testing once on number of feeding events and once on dominance index).

Among this group of 11 scroungers that were frequently present at the bin area, there were significant correlations between the dominance index and the number of opening attempts ( $r_s = 0.934$ ,  $P < 0.001$ ,  $\alpha^* = 0.017$ ), and the bin-foraging ratio ( $r_s = 0.773$ ,  $P = 0.005$ ,  $\alpha^* = 0.017$ ) but not the number of total feeding events ( $r_s = 0.624$ ,  $P = 0.04$ ,  $\alpha^* = 0.017$ ;  $\alpha^*$ : Bonferroni-corrected  $\alpha$  level for triple testing). The bin-foraging ratio is the event-ratio of taking food out of a bin versus feeding on food scraps that were left by other birds outside the bins after feeding on it.

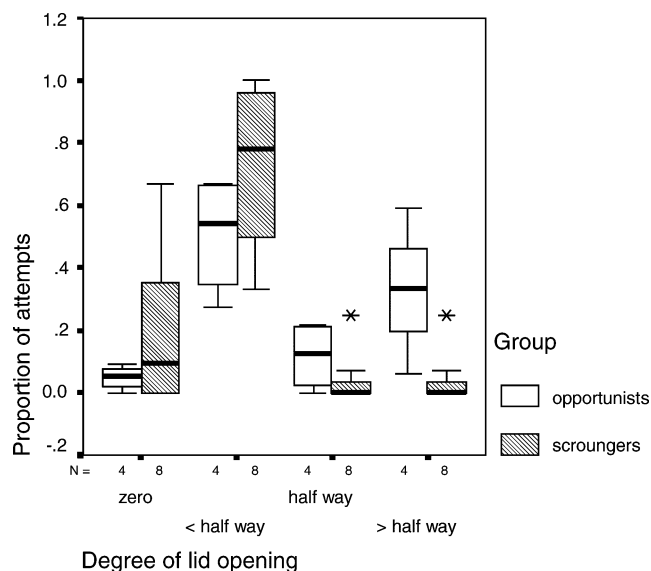
### Opening behaviour

When successfully opening a lid, a bird grasped the lid at its front edge with the bill while often standing on an adjacent bin. They lifted the lid above their breast and made a few small steps toward the hinge until the lid was in a position where it started to drop backwards. Keas did not attempt to open the bin from the inappropriate location close to the lid's hinge. Only in three events did we observe simultaneous opening attempts of two birds at the same lid. Bin lids were opened less than half way in these cooperative-like attempts.

In order to prevent the kea opening the lids, the kitchen staff put wooden logs on bin lids (see section 'Dimension of Rubbish Bins' in 'Methods'). A lid with a log on top is too heavy for a kea to open. Indeed, we recorded only three times that a kea attempted to open a bin with a log on top. We did not record the availability of bins with or without a log on top, but the kitchen staff took care to place logs on most of the lids in the evenings and many logs were lying on the ground in the mornings. The keas were strong enough to push the logs off with their head and bill. We observed four opportunists and six scroungers pushing logs off (median (quartiles) number of logs pushed off by opportunists: 3.5 (2.25–10.75); by scroungers: 3.5 (1–9.25)). However, only in 11 of the 52 observed events of pushing a log off, was there an opening attempt immediately afterwards at the same bin. This indicates that the kea just pushed a lot of logs off and this decreased the likelihood that they would try to open a lid with a log on it.

There were other inappropriate opening attempts performed, such as opening attempts while standing on the lid of the same bin (25 attempts) or while another bird was standing on the bin (two attempts). On seven occasions we observed repeated opening attempts at a lid that was blocked by a neighbouring bin in an obvious way to the human observer. Sometimes the lid of an opened bin was held in an upright position by a taller adjacent bin or wall. On 12 occasions, we saw a bird moving an already opened lid and in six additional cases the lid was closed again by a bird. Thus, about every 10th unsuccessful opening attempt consisted of one of the inappropriate attempts described earlier. Scroungers that unsuccessfully attempted to open lids as well as opportunists made these mistakes and there was no statistical difference in the proportion of such inappropriate attempts between these birds (Mann-Whitney  $U$  test:  $U = 22$ ,  $N_1 = 10$ ,  $N_2 = 5$ ,  $P = 0.708$ ; median (quartiles) of unsuccessful attempters: 0.08 (0–0.26); opportunists: 0.07 (0.04–0.12)).

Thus, the majority of unsuccessful opening attempts were not due to bins that were blocked in some way. The weight of the lids may have provided a challenge to birds, but they seem to be not too heavy for males at least. Keas are known to be able to move stones of several kilograms of weight. Furthermore, after we started to record the degree of bin opening, we were able to collect data of eight scroungers that manipulated the lids but were never observed to open a bin completely. From all opening attempts at unblocked lids the proportion of manipulations that led to no lifting of the lid was low in all birds (Fig. 3). In most attempts, scroungers and opportunists lifted the lid less than half way. Only the proportion of attempts with the lid being opened



**Fig. 3** Relative number of opening attempts at unblocked lids for four different degrees of lid opening, dissected separately for scroungers and opportunists. Note: Only data of four opportunist and eight scroungers were available because recording of degree of lid opening started later in the field season. The boxes indicate the interquartile ranges with the medians, whiskers indicate the range of data without outliers

more than half way was significantly larger in opportunists than scroungers (median (quartiles) of opportunists: 0.33 (0.13–0.53); scroungers: 0 (0–0.05), Mann–Whitney  $U$  test:  $U = 2.0$ ,  $N_1 = 4$ ,  $N_2 = 8$ ,  $P = 0.022$ ).

### Birds watching bin opening

With one exception there were always scroungers present at the kitchen area at the time of the 41 successful bin openings we observed (median number of scroungers present: 4, quartiles 2–8). In 17 of these openings, we saw clear signs that other keas watched the successful performance: in six events one other opportunist was watching, in 11 events one scrounger, and in two events, each, two and three scroungers. With 186 bird counts for scroungers, calculated from the data earlier, and 49 bird counts for additional opportunists present at the kitchen area at time of successful bin opening, this gives a very similar proportion of counts for opportunists (0.122) and scroungers (0.113) watching successful bin opening.

It was not systematically recorded which birds watched unsuccessful opening attempts, but it happened frequently. Beside the three events reported earlier when two birds attempted to lift the same lid at the same time, there were another 12 events when a watching bird approached and attempted to lift the same lid after the first bird had released it. On four other occasions, watching birds approached and attempted to lift the lid of an adjacent bin rather than the same lid.

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## Discussion

We found that only 14% (5/36) of the observed individuals in Mount Cook Village successfully opened the lids of rubbish bins. Another 47% (17/36) of the observed individuals were seen to scrounge from bins opened by the opportunists or from food scraps taken out of the bins. Thus, in total 61% of the individuals had some profit from bin opening. In the following, we discuss possible reasons for the low frequency of opportunists.

### Implications of scrounging opportunities

The question of whether scrounging opportunity inhibits or facilitates other birds to learn new behaviour is of crucial relevance for the spread of innovations (Giraldeau and Lefebvre 1987; Caldwell and Whiten 2003; Laland 2004). In contrast to other foraging tasks in which producer and scrounger tactics are not fully compatible (Barnard and Sibly 1981), such a constraint is unlikely for bin opening as no split attention is required to detect opportunity for either of the two tactics. Thus in terms of the model of Vickery et al. (1991), the sum of relative abilities for the two tactics fully overcompensate each single relative ability; a condition in which a population of pure opportunists

is favoured by the model. Yet this was not the case in bin opening performed by the kea.

Also, the small frequency of successful bin openers in the local population was unlikely to be simply the result of scrounging opportunity. Opportunists had a higher payoff than scroungers in terms of both the number of observed feeding events at the kitchen area, and the proportion of feeding food from the bins rather than of the food scattered around the bins. Because food was left outside the bins after taking the preferred energy-rich parts like fat and meat, it is reasonable to assume that food left outside the bins was less nutritious for keas than food chosen and taken out of a bin. Thus, it would have been advantageous for scroungers to open the bins themselves. This is also demonstrated by the fact that 59% (10/17) of the scrounging individuals were seen to attempt to open the bin lids.

It may be that a scrounger's payoff being considerably smaller than the opportunists' payoff is still profitable because by scrounging only, the bird does not have to pay the energetic costs of acquiring the technique how to open bins. According to this argument, less successful scroungers would be expected to do more opening attempts than more successful scroungers because, in comparison to more successful scroungers, their gain is more likely to outweigh their costs. Our finding is contrary to this: unsuccessful individuals who were regularly seen at the kitchen area (during 10 sessions at least), who had a low dominance index and were seen less often to scrounge directly from open bins were seen less often to perform opening attempts than unsuccessful individuals with a high dominance index and high foraging in bin ratio. Given the fact that dominance indexes do not differ between scroungers and opportunists, it is unlikely that the low frequency of opportunists is the result of a simple asymmetry in competition for access to closed bins.

In summary, increased scrounging opportunity can facilitate certain aspects of finding solutions as it was found in ravens (Fritz and Kotrschal 1999) and marmosets (Caldwell and Whiten 2003), for example to manipulate bin lids rather than to prevent such attempts (Giraldeau and Lefebvre 1987).

### Lid opening as mechanical problem

Pfeffer et al. (2002) found a similar independency of social status from innovator status in an operant task for free-ranging graylag geese as we did in lid opening. In contrast, the study of Kothbauer-Hellman (1990) showed an impact of the social status of titmice that opened milk bottles in a flock. This difference may be explained by the fact that bin opening provides a more challenging mechanical problem than opening of milk bottles with one strike of the beak. The fact that only 9% of all opening attempts resulted in complete lid opening demonstrates that the invention of bin opening is new for most individuals and that it is not easily solved by applying the bird's usual behavioural repertoire of foraging techniques. Keas performed inappropriate opening attempts at bin lids that were blocked in some

way. We know only of one study to date that investigated how animals push off a large object that covers a reward. Similar to our findings, there was little evidence for cooperative turning over heavy stones in Petit et al.'s (1992) study with macaques. Capuchins, like keas, tried to lift a cover while sitting on it (E. Visalberghi, 27 August 2003, personal communication). Since the keas often pushed a log off a bin without attempting to open that bin afterwards, it is not clear whether the birds have a functional understanding of logs as an object preventing lid opening.

However, the relatively small proportion of unsuccessful opening attempts at lids that were blocked in some way (about one out of 10 unsuccessful attempts) shows that blocked bin lids were not the main reason for unsuccessful opening attempts. Also, the low proportion of lid manipulations performed by unsuccessful birds during which the lid remained completely closed (Fig. 3) indicates that the opportunists were unlikely to be the only birds strong enough to cope with the weight of the bin lids.

Instead, we assume that the unsuccessful keas did not consider that they have to move the lid towards the hinge in order to bring it into an upright position where it starts to drop over backwards. Because the keas are too small in order to open a bin completely by lifting the lid with the bill at the front part of the bin (see Fig. 1), they needed to make a few small steps toward the hinge when the lid is about half way up. In fact, only the proportion of attempts with the lid being opened more than half way was significantly larger in opportunists than scroungers. Such a failure to consider the relative position of an object in space or in relation to other objects is not surprising as it requires similar problem-solving abilities to tool-use behaviour, e.g., the trap-tube paradigm—a cognitively challenging task (Visalberghi and Limongelli 1994; Povinelli 2000; D. M. Frigaszy, 27 August 2003, personal communication, see also Funk 1996 for failure of Golden-crowned parakeet to spatially relate objects to one another). Similarly, but in some contrast to captive keas, the keas at Mount Cook Village had difficulties in solving a task where they had to remove a tube by pushing it to the end of an upright pole (Gajdon et al. 2004). The kea's natural foraging technique to turn over stones in the alpine grassland might explain their impressive persistence in attempting to open bin lids (see also Winkler and Leisler 1999). However, stones that kea turn over do not have the dimensions of bin lids with hinges. Keas just have to move stones in order to turn them over.

### Impact of social learning

The bin-opening efficiency of the oldest opportunists was much greater than the efficiency of considerably younger adult opportunists. This suggests the need for an extended period of individual trial-and-error learning to master the mechanical problem. Thus, asocial learning of bin opening is costly and social learning can be assumed to be advantageous (Laland 2004). Contrary to this assumption, the same result indicates that individual experience rather than social learning may have played a pivotal role in the acqui-

sition of the bin-opening technique. There was also lack of evidence that the birds used social information for solving a task of removing a tube from an upright pole (Gajdon et al. 2004), even though there were other birds watching in proximity. Both techniques are conspicuous and easily seen in the field, even from a great distance.

Nevertheless, we should not classify keas as being incapable of social learning. Enhancement effects (Spence 1937; Thorpe 1956) are not considered here. It is one of the key features of keas to involve objects in social interactions (Diamond and Bond 2004) and the kea's reliance on the parts of an object that were manipulated by a conspecific was already demonstrated with captive keas (Huber et al. 2001). Rather it seems that stimulus or local enhancement did not considerably increase the likelihood of solving the task of bin opening because the opening requires a special technique. Huber et al. (2001) also found that the keas did not copy the behaviour of their respective models but rather paid attention to the affordances of the objects manipulated, providing evidence for the capacity of a very intelligent form of social learning (emulation; Tomasello 1990, 1998; Klein and Zentall 2003). The keas' focus on affordances is in accordance with Diamond and Bond's (1999) conclusions from their survey of kea biology where they integrated the findings of their field studies. The low-success performance of kea in bin opening or removing a tube from an upright pole indicates that at least wild keas do not depict from observation the information of relative object position for solving a task. This was not required in the study of Huber et al. (2001) because parts of the locks were close together and the locks could be opened by learning that they can be 'demolished' somehow. Also, the extended period required for acquiring an efficient bin-opening technique is no indication for impoverished cognition in keas because even chimpanzees need a long time to improve in nut cracking (Matsuzawa et al. 2001).

The keas observed probably many more unsuccessful opening attempts than successful ones because of the small proportion of successful lid openings. This might have interfered with learning socially the technique how to open the lids. However, in the test phase of the field experiment where the birds had to remove a tube from a pole (Gajdon et al. 2004), the keas watched successful attempts in the majority of cases and, nevertheless, there was no indication for social learning.

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### General conclusions

Contrary to the hypothesis that a 'time of plenty' favours innovations (Kummer and Goodall 1985), we assume that food deprivation was a driving factor for the invention of bin opening. We do so because the season of bin opening starts during wintertime, a period of food scarcity (Jackson 1969). During this season, reproducing kea males have the additional foraging pressure to provide a breeding female and chicks with food. Thus, the fact that only males opened bin lids might be in accordance with the explanation for general sex differences in foraging innovation due to

differential parental investment (Reader and Laland 2003). The keas' natural foraging technique of turning over stones, opportunity to scrounge and enhancement effects when observing other birds opening bin lids may provide the motivational and behavioural basics for birds to attempt to move the lids of rubbish bins. By persistently doing opening attempts for a long period and by random success when doing so, the birds slowly learn to increase their efficiency in bin opening. Birds of island populations are regarded to be less neophobic than birds of the mainland because they suffer from predation pressure less and benefit in detecting new food sources that are more likely to become rare on islands (Haemig 1989). This scenario seems to fit for kea (Diamond and Bond 1999).

The finding that juveniles did not successfully open bin lids is in accordance with Diamond and Bond's (1991, 1999) finding that adult keas are the most capable scavengers that engaged more in excavating foraging activities than other age classes in a refuse dump. However, not only juveniles but also the majority of older males failed to open the bin lids successfully. For the reasons described earlier, we do not think that this is a matter of differing strength in different males and that this indicates the mechanical challenge bin opening provides even for attempting adult males.

The data of failed opening attempts indicates that it is unlikely that scroungers would be able to substitute missing bin openers within a short time (for producer replacement in pigeons see Giraldeau and Lefebvre 1986). This may happen in the future. But due to park management reasons, the bin system was changed later in 2003 in order to prevent keas from opening the bins. Nevertheless, our data indicate that the spread of innovations in animals may be restricted to a few individuals when innovations concern challenging mechanical problems.

**Acknowledgements** We are grateful for the assistance and support of the Department of Conservation of New Zealand, especially Ray Bellringer, Phil Crutchley and Kerry Weston from the Mount Cook Area Office and Andy Grant from the Christchurch Conservancy Office. We also thank DOC volunteers from the Mount Cook Visitor Centre, and Rachel Johnston and Miriam Studer for their help in the field, Hans Winkler for comments on the manuscript, Miriam Locher and Jonathan Daisley for improving the English. This study was financed by the Austrian Science Fund (BIO P15027). Banding permission was received from the Department of Conservation of New Zealand (CHH 12/129 and CA/282/FAU).

## References

- Barnard CJ, Sibly RM (1981) Producer and scroungers: a general model and its application to captive flocks of house sparrows. *Anim Behav* 29:543–550
- Beggs W, Mankelov S (2002) Kea (*Nestor notabilis*) make meals of mice (*Mus musculus*). *Notornis* 49, 50
- Bond AB, Wilson KJ, Diamond J (1991) Sexual dimorphism in the kea (*Nestor notabilis*). *Emu* 91:12–19
- Caldwell CA, Whiten A (2003) Scrounging facilitates social learning in common marmosets, *Callithrix jacchus*. *Anim Behav* 65:1085–1092
- Clutton-Brock TH, Albon SD, Gibson RM, Guinness FE (1979) The logical stag: adaptive aspects of fighting in red deer (*Cervus elaphus* L.). *Anim Behav* 27:211–225
- Diamond J, Bond AB (1991) Social behavior and the ontogeny of foraging in the kea (*Nestor notabilis*). *Ethology* 88:128–144
- Diamond J, Bond AB (1999) Kea, bird of paradox: the evolution and behavior of a New Zealand parrot. University of California Press, Berkeley, Los Angeles, London
- Diamond J, Bond AB (2004) Social play in kea (*Nestor meridionalis*) with comparison to kea (*Nestor notabilis*). *Behaviour* 141:777–798
- Fritz J, Kotrschal K (1999) Social learning in common ravens, *Corvus corax*. *Anim Behav* 57:785–793
- Funk MS (1996) Spatial skill development in Golden-crowned parakeets (*Cyanoramphus auriceps*): a Piagetian assessment. *Bird Behav* 11:91–104
- Gajdon GK, Fijn N, Huber L (2004) Testing social learning in a wild mountain parrot, the kea (*Nestor notabilis*). *Learn Behav* 32:62–71
- Giraldeau L-A, Lefebvre L (1986) Exchangeable producer and scrounger roles in a captive flock of pigeons: a case of the skill pool effect. *Anim Behav* 34:797–803
- Giraldeau L-A, Lefebvre L (1987) Scrounging prevents cultural transmission in food-finding behaviour in pigeons. *Anim Behav* 35:387–394
- Gossette RL (1968) Examination of retention decrement explanation of comparative successive discrimination reversal learning by birds and mammals. *Percept Mot Skills* 27:1147–1152
- Haemig PD (1989) A comparative experimental study of exploratory behavior in Santa Cruz Island and mainland California scrub jays *Aphelocoma coerulescens*. *Bird Behav* 8:32–42
- Higgins PJ (1999) Handbook of Australian, New Zealand and Antarctic birds. Oxford University Press, Oxford
- Huber L, Taborsky M, Rechberger S (2001) Social effects on object-exploration in keas. *Anim Behav* 62:945–954
- Jackson JR (1969) What do keas die of? *Notornis* 16:33–44
- Jarret M, Wilson K-J (1999) Seasonal and diurnal attendance of kea (*Nestor notabilis*) at Halpin Creek rubbish dump, Arthur's Pass, New Zealand. *Notornis* 46:273–286
- Johnston R (1999) The Kea (*Nestor notabilis*): A New Zealand problem or problem solver? M.Sc. thesis, University of Canterbury, Christchurch, New Zealand
- Keller R (1975) Das Spielverhalten der Keas (*Nestor notabilis* Gould) des Züricher Zoos. *Zeitschrift für Tierpsychologie* 38:393–408
- Klein ED, Zentall TR (2003) Imitation and affordance learning by pigeons (*Columbia livia*). *J Comp Psychol* 117:414–419
- Kothbauer-Hellman R (1990) On the origin of a tradition: milk bottle opening by titmice (*Aves, Paridae*). *Zool Anz* 255:353–361
- Kubat S (1992) Die Rolle von Neugier, Andersartigkeit und sozialer Struktur für die Exploration von Objekten beim Kea (*Nestor notabilis*). PhD thesis, University of Vienna, Vienna, Austria
- Kummer H, Goodall J (1985) Conditions of innovative behaviour in primates. *Philos Trans Royal Soc Lond* 308:203–214
- Laland KN (2004) Social learning strategies. *Learn Behav* 32:4–14
- Lee P (1991) Adaptations to environmental change: an evolutionary perspective. In: Box HO (ed) Primate responses to environmental change. Chapman & Hall, London, pp 39–57
- Lefebvre L (2000) Feeding innovations and their cultural transmission in bird populations. In: Heyes CM, Huber L (eds) The evolution of cognition. MIT Press, Cambridge, pp 311–328
- Lefebvre L, Bolhuis J (2003) Positive and negative correlates of feeding innovation in birds. In: Reader SM, Laland KN (eds) Animal innovation. Oxford University Press, Oxford, pp 39–61
- Lefebvre L, Gaxiola A, Dawson S, Timmermans S, Rozsa L, Kabai P (1998) Feeding innovations and forebrain size in Australasian birds. *Behaviour* 134:1003–1017
- Lefebvre L, Nikolakakis N, Boire D (2002) Tools and brains in birds. *Behaviour* 139:939–973
- Marriner GB (1908) The kea: a New Zealand problem. Marriner Brothers, Christchurch
- Matsuzawa T, Biro D, Humle T, Inoue-Nakamura N, Tonooka R, Yamokoshi G (2001) Emergence of culture in wild chimpanzees: education by master-apprenticeship. In: Matsuzawa T (ed) Primate origins of human cognition and behavior. Springer-Verlag, Tokyo, pp 557–574

- Petite O, Desportes C, Thierry B (1992) Differential probability of "coproduction" in two species of macaques (*Macaca tonkeana*, *M. mulatta*). *Ethology* 90:107–120
- Pfeffer K, Fritz J, Kotrschal K (2002) Hormonal correlates of being an innovative graylag goose, *Anser anser*. *Anim Behav* 63:687–695
- Povinelli DJ (2000) *Folk physics for apes*. Oxford University Press, New York
- Reader SM, Laland KN (2002) Social intelligence, innovation and enhanced brain size in primates. *Proc Natl Acad Sci USA* 99:4436–4441
- Reader SM, Laland KN (2003) Animal innovation: An introduction. In: Reader SM, Laland KN (eds) *Animal innovation*. Oxford University Press, Oxford, pp 3–35
- Rogers EM (1995) *Diffusion of innovations*. Free Press, New York
- Sasvári L (1985) Keypeck conditioning with reinforcement in two different locations in thrush, tit, and sparrow species. *Behav Proc* 11:245–252
- Spence KW (1937) Experimental studies of learning and higher mental processes in infra-human primates. *Psychol Bul* 34:806–850
- Timmermans S, Lefebvre L, Boire D, Basu P (2000) Relative size of the hyperstriatum ventrale is the best predictor of feeding innovation rate in birds. *Brain Behav Evol* 56:196–203
- Thorpe WH (1956) *Learning and instincts in animals*. Methuen, London
- Tomasello M (1990) Cultural transmission in the tool use and communicatory signalling of chimpanzees? In: Parker ST, Gibson KR (eds) *Language and intelligence in monkeys and apes: comparative developmental perspectives*. Cambridge University Press, Cambridge, pp 271–311
- Tomasello M (1998) Emulation learning and cultural learning. *Behav Brain Sci* 21:703–704
- Vickery WL, Giraldeau L-A, Templeton JJ, Kramer DL, Chapman CA (1991) Producer, scroungers, and group foraging. *Am Nat* 137:847–863
- Visalberghi E, Limongelli L (1994) Lack of comprehension of cause-effect relation in tool-using capuchin monkeys: *Cebus apella* *J Comp Physiol* 108:15–22
- Webster SJ, Lefebvre L (2001) Problem solving and neophobia in a Passeriforme-Columbiforme assemblage in Barbados. *Anim Behav* 62:23–32
- Winkler H, Leisler B (1999) Exploration and curiosity in birds: functions and mechanisms. In: 22nd international ornithological congress, Birdlife South Africa, Durban, Johannesburg, pp 915–932
- Wyles JS, Kunkel JG, Wilson AC (1983) Birds, behaviour, and anatomical evolution. *Proc Natl Acad Sci USA* 80:4394–4397