

Investigating animal cognition with the Aesop's Fable paradigm: Current understanding and future directions

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The Aesop's Fable paradigm – in which subjects drop stones into tubes of water to obtain floating out-of-reach rewards – has been used to assess causal understanding in rooks, crows, jays and human children. To date, the performance of corvids suggests that they can recognize the functional properties of a variety of objects including size, weight and solidity, and they seem to be more capable of learning from causal information than arbitrary information. However, 2 alternative explanations for their performance have yet to be ruled out. The perceptual-motor feedback hypothesis suggests that subjects may attend solely to the movement of the reward, repeating actions which bring the reward closer, while the object-bias hypothesis suggests that subjects could pass certain tasks by preferring to handle objects that resemble natural stones. Here we review our current understanding of performance on the Aesop's Fable tasks, and suggest that studies controlling for feedback and object preferences will help us determine exactly what animals understand about the cause and effect of water displacement.

In Aesop's classic fable, a thirsty crow comes across a pitcher of water. Finding the water level too low to drink, the quick-witted crow gathers together some nearby stones and drops them into the pitcher, raising the water level enough to quench his thirst. Two and half thousand years later the Aesop's fable paradigm has been used to investigate causal understanding in 3 species of corvids: rooks,¹ Eurasian jays,² and New Caledonian (NC) crows,³⁻⁵ as well as in human children,⁶ and is providing insight into the mechanisms animals use to learn about the world.

A Test of Insight?

In the classic fable, Aesop's clever crow insightfully recognized that stones would displace water and raise the water level in the pitcher. To examine whether corvids could indeed find such ingenious solutions to problems, Bird and Emery¹ provided rooks with a pile of stones and a tube of water containing a floating worm; examining whether they would spontaneously drop stones into the tube to bring the worm within reach. In line with the fable, and seemingly insightfully,¹ the rooks picked up the stones and dropped them into the tube, some of them on the

very first trial. However, it was unclear whether their success was comparable to the insight demonstrated by Aesop's crow.⁷⁻⁹ Importantly, these rooks already had experience of dropping stones into tubes to collapse a platform and obtain a reward, as part of a series of tool-use tasks.¹⁰ The behavior of dropping stones into tubes was therefore highly familiar to them, and the rooks could have merely generalized this previous behavior to the task at hand.^{8,9}

In a later study Taylor et al.³ provided a group of 6 NC crows with a baited tube and a pile of stones and found that none of the birds spontaneously dropped the stones into water to obtain the floating reward. Unlike rooks, these crows had no prior experience of handling stones and dropping them into tubes. The key difference in prior experience between rooks and NC crows seems to have been the factor that enabled rooks to spontaneously solve Aesop's fable, and since then, all other Aesop's fable experiments have deliberately trained subjects to manipulate and drop stones into tubes before running experimental tasks. To do this, subjects dropped stones into either a plastic training apparatus^{2,4,5} or directly into water.³

It remains plausible that corvids could spontaneously solve Aesop's Fable, without being trained to handle stones, if they were able to learn about the functional properties of water-filled

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tubes before the task began. In a different paradigm, von Bayern and colleagues¹¹ found that 2 out of 4 captive NC crows, trained to collapse a platform in a perspex apparatus with their beak, were able to spontaneously pick up and drop stones into the apparatus when a tube was attached (making it impossible to reach the platform by beak). This task demonstrated that some corvids can innovate the behavior of stone dropping without being explicitly trained, if they first have the opportunity to interact with the apparatus and learn its functional affordances (see also ref.¹²). Whether this is the case for the Aesop's fable task remains to be seen.

Causal Understanding

While success on this task is unlikely to represent an insightful solution, the Aesop's fable paradigm does provide a useful avenue to explore causal reasoning and physical cognition in animals. Several studies have demonstrated that stone dropping behaviors are goal-directed. Rooks and NC crows dropped only enough stones to bring the reward within reach, stopping once they had obtained the reward,^{1,3} and Eurasian jays preferentially dropped stones into baited rather than empty tubes.² Thus, we can use stone-dropping behaviors to investigate whether subjects understand the causal properties which enable them to obtain the reward. Do corvids understand anything about the causal nature of water displacement?

To investigate this, subjects are given a choice of 2 different tubes or 2 types of objects to drop into the tube, one of which is more functional and will enable them to obtain the reward from the tube faster (or at all).¹⁻⁶ To date, a range of different experiments have indicated that corvids are capable of rapidly learning some, but not all causal discriminations involving water displacement. A full summary of the tasks that have been attempted, and passed, by each species is provided in **Table 1** (with diagrams in **Fig. 1**). When given small or large stones both rooks and NC crows will prefer the larger stones which displace more water, bringing the reward within reach with fewer stone drops.^{1,3} Eurasian jays and NC crows can discriminate between objects that sink (and are therefore functional) and similarly looking objects that float (and therefore have no effect on the water level).²⁻⁵ NC crows also discriminate between objects that are solid which displace a lot of water, and objects of the same size and weight made of hollow wire that displace only a small amount of water.^{4,5} All 3 species discriminate between different tubes, dropping objects into tubes containing water instead of tubes containing sand or sawdust (for photo see **Fig. 2**),¹⁻⁵ and Eurasian jays and NC crows drop more objects into tubes containing water instead of tubes that are empty with a reward taped to the side ('air-filled' tubes).^{2,3} Finally, although NC crows fail to discriminate between wide and narrow tubes when they have access to lots of stones⁴, some NC crows choose efficiently when they have only a few stones, preferring to drop them into the narrow tube where each stone increases the water level by more than in the

wide tube.⁵ These birds can also switch their preference to the wide tube when the water level in the narrow tube is decreased.

Across all these tasks corvids were able to rapidly learn the most functional option, indicating that they appear to understand aspects of the causal nature of water displacement. The majority of subjects behaved comparably on each task, and there were no clear differences in performance across the different species (see **Table 1**). Subjects did not, however, typically succeed from the very first trial. This suggests that their success reflects a rapid ability to learn from causal cues, but does indicate an *a priori* understanding of displacement.

Non-causal Tasks

The suggestion that corvids have an increased propensity to learn from causal information is supported by their performance on tasks involving arbitrary or counter-intuitive cues. Taylor et al.³ set up a searching task where a reward was consistently hidden next to previously rewarded Aesop's fable stimuli (e.g. the reward was hidden next to a water-filled tube as opposed to a sand-filled tube, and next to a large stone as opposed to a small stone). NC crows did not learn to use these stimuli to find the hidden rewards over 20 trials, even though the searching tasks were given *after* the Aesop's Fable experiments, and all of them had already been associated with reward. This suggests that a simple associative rule – where any stimulus is preferred if it is paired with a reward – cannot account for the crows' successes.

Cheke et al.² gave Eurasian jays a series of Aesop's Fable tasks that involved non-causal as well as causal cues (**Table 1**). The first task involved the experimenter rewarding the subject once a specified number of stones had been dropped into one of 2 tubes (containing red or blue sawdust), which all birds failed. For the second task the jays received an L-shaped apparatus, where a reward was pushed along the horizontal base of the tube each time a stone was dropped, mimicking the approach of the reward in the water-based tasks, but without a causal relationship between the birds' actions and the movement of the reward (**Fig. 1D**). One of the 2 birds tested did succeed on this task, but the other failed. A third task involved a U-tube apparatus, which comprised 3 tubes: a narrow central tube containing the reward and 2 wider outer tubes into which stones could be dropped. The outer tubes were color coded and one had a concealed connection to the narrow tube, meaning that stones dropped into this tube would raise the water level in both this and the narrow tube, bringing the reward within reach. Here, the causal mechanism was counter-intuitive: stones dropped into an adjacent tube would raise the water level in the narrow baited tube. Yet, the actions and reward schedule were identical to other Aesop's Fable tasks. Neither of the Eurasian jays tested passed this counter-intuitive task.

Twelve New Caledonian crows, across 2 experiments^{4,5} were also given the U-tube task. One group with the same type of apparatus as the jays, the second with a modified version where 2 pairs of narrow and wide tubes were presented, separated by a 30

Table 1 Summary of performance on the different Aesop's fable tasks used to investigate causal understanding in corvids and children

Reference	Species	Goal directed?	Tube/Substrate Discriminations			Object Discriminations			Counter-Intuitive Discriminations				
			Water vs Sand	Water vs Air	Narrow vs Wide: equal	Narrow vs Wide: unequal	Large vs Small	Sinking vs Floating	Solid vs Hollow	Red vs Blue	L-shape	U-tube	Uncovered U-tube
Bird & Emery (2009) ¹	Rooks	Yes 3/3	Yes 3/3	x	x	x	Yes 3/3	x	x	x	x	x	x
Cheke et al (2011) ²	Eurasian jays	Yes 2/2	Yes 2/4	x	x	x	Yes 2/2	x	No 0/2	Yes 1/2	No 0/2	x	x
Taylor et al (2011) ³	NC crows	Yes 4/4	Yes 4/4	x	x	Yes 4/4	Yes 4/4	x	x	x	x	x	x
Jelbert et al (2014) ⁴	NC crows	x	Yes 6/6	No 0/5*	Yes 4/4	x	Yes 6/6	Yes 5/5	x	x	No 0/4	x	x
Logan et al (2014) ⁵	NC crows	x	Yes 3/5	Yes 4/6*	Yes 3/4	x	Yes 6/6	Yes 6/6	x	x	Yes 1/5	No 0/5	x
Cheke et al (2012) ⁶	Children	x	4–7 years	x	x	x	5–7 years	x	x	x	7+ years	x	x

Note: Table indicates the number of subjects that passed each test/total subjects, 'x' indicates a test was not given. Not all subjects participated in each task. For children, the age at which they learn to pass the task over 5 trials is provided; all tasks were passed by children aged 8+ on the first trial. Stone dropping in rooks and NC crows was considered goal-directed if they matched their stone drops to the water level and did not drop stones after obtaining the reward. Stone dropping in Eurasian jays was considered goal directed if they preferred baited to non-baited tubes. Counter-intuitive discriminations were designed to mimic the movement cues or reward schedule of standard Aesop's fable tasks, but without a clear causal mechanism.

*On the narrow and wide tubes task with equal water levels NC crows failed when provided with 12 objects, but the majority passed when restricted to 4 objects.

cm gap, which more closely matched the other tube discriminations. Here, one pair of narrow and wide tubes had a hidden connection between the 2 tubes, but the other pair did not (Fig. 1D). Eleven of the crows failed. However, one crow from the second experiment, Kitty, learnt to choose the connected tube over 20 trials. Kitty failed a follow-up *uncovered* version of the U-tube,⁵ where the connection between 2 of the tubes was visible; thus, she had not inferred the presence of a connection between the tubes, but unlike the other subjects had passed the task despite it involving counter-intuitive cues.

Overall, the corvids' performance on counter-intuitive tasks is in stark contrast to their performance on causal tasks. Either one or no subjects succeeded on each task, whereas the majority or all of the subjects passed the casual tasks (Table 1). Thus, to date, the evidence indicates that corvids are more capable of attending to causal information than arbitrary information, and using this information to guide their choices. These choices do not suggest that the birds had an understanding of the task from the very first trial, but they do appear to demonstrate that corvids can rapidly learn causal relationships, and thus, may well be able to reason causally. However, at present, there is still reason to question this conclusion. Two additional competing hypotheses, which could account for aspects of these birds' performances, have yet to be ruled out.

Alternative Explanations

The object-bias hypothesis

One plausible explanation for some of the birds' success is that subjects could pass the object-choice tasks if they had a preference for certain functional objects before the tasks began. Such a preference is plausible as all birds were initially trained to drop stones into tubes. This experience may have influenced their later choices: biasing the birds to find solid, heavy objects – most similar to normal stones – more appealing to drop into tubes than their alternatives. Although several studies found no signs that birds preferred to *approach* certain objects, either in searching tasks³ or during habituation,⁵ it is possible that birds preferred to *drop* certain objects into tubes. An object-bias could account for success on both the sinking vs. floating and solid vs hollow object tasks, but not on discriminations between different substrate-tube combinations.

To address this possibility, Logan and colleagues⁵ gave NC crows 2 tests with solid and hollow objects. One group first received the water-tube task, where solid objects displaced more water than hollow objects. They then received a task where they had to drop objects into the perspex training apparatus to collapse a baited platform (Fig. 1A). The only relevant property here was weight, and both objects (each weighing 10 g) were equally functional. However, all birds significantly preferred to drop the solid object on both tasks, regardless of functionality. A second group was given the platform task first, followed by the water-tube task, with the same result. Object-biases were therefore present in at least these subjects. With this in mind, it is unclear whether or not the subjects understood anything about

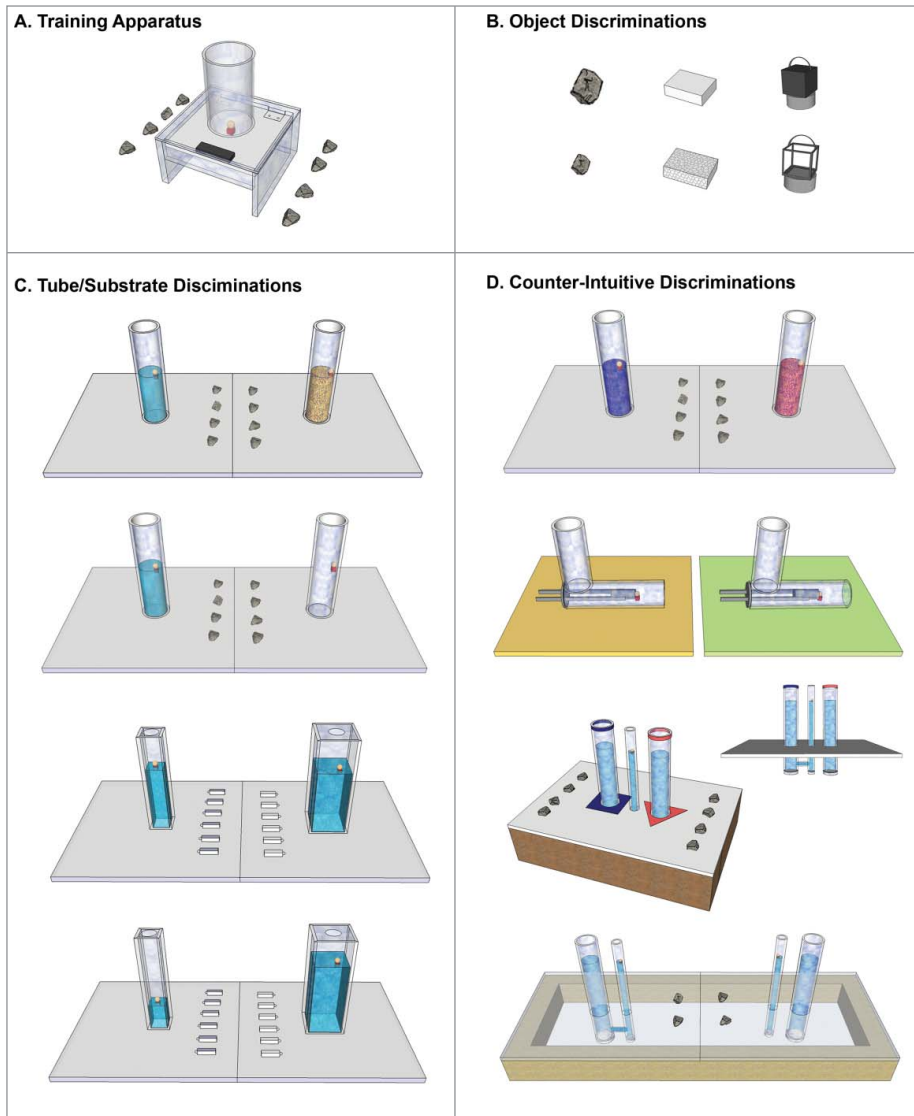


Figure 1. Diagrams of the experimental apparatus used for different Aesop's Fable tasks listed in **Table 1.** (A) *Training apparatus*, used in:^{2,4,5} stones dropped into the tube would collapse the central baited platform. (B) (l-r) *large vs small stones*; *sinking vs floating objects*: made of rubber and polystyrene, respectively; and *solid vs hollow objects*. (C) (top-bottom) *water vs sand*; *water vs air*; *narrow vs wide tubes*: with equal water levels; and *narrow vs wide tubes*: with unequal water levels. (D) (top-bottom) *blue vs red woodchips*: the reward was provided by the experimenter after a certain number of stones were dropped into one tube; *L-shape apparatus*: the reward was moved incrementally closer each time a stone was dropped into one apparatus; *U-tube apparatus*: stones dropped into the connected tube would also raise the water level in the central baited tube, but the connection was concealed; *Uncovered U-tube*: as before, but the connection between 2 of the tubes was visible. Logan et al.⁵ used pairs of narrow and wide tubes for the covered U-tube, as well as the uncovered U-tube (pictured), instead of a U-tube with 3 tubes (as used in^{2,4,6}). Some diagrams are reproduced from Jelbert et al.⁴

the effects of solidity on water displacement, and at present we must assume that they did not.

These results indicate that to overcome object-biases we need to go further than providing simple object preference tests before the experiments begin (although this remains an important starting point). Ideally, birds should be tested with pairs of tasks where each object is functional on one task only. However, the

difficulty in finding tasks where light or hollow objects have functional advantages limits this approach. One alternative to this would be to rule out any such biases before the experiment begins. Repeated experience of dropping both kinds of object into tubes to obtain arbitrary rewards could be provided, and subjects would only proceed to the experiment when they demonstrated an equal likelihood of choosing both objects. With this training, any preference the subjects had in the experiment would be more likely to reflect an ability to learn or understand which option is more functional, than to reflect a general bias toward one type of object.

The feedback hypothesis

A second explanation, which could account for the birds' performance on all tasks, is perceptual-motor feedback: repeating actions which bring the reward incrementally closer.^{7,13-15} Unlike an account which relies on insight or mental scenario building (imagining to some degree the effect that stones will have on the water level of the tube, before acting) the perceptual-motor feedback hypothesis proposes that a bird first recognizes the effect that dropping a stone has on the position of the reward after each stone has been dropped, then repeats those actions which bring the reward closer. In this case, birds do not need to understand any aspect of water displacement. They merely need to repeat actions which bring the reward closer, and prefer those objects and tubes which enable the largest movement of the reward.

Perceptual-motor feedback is a highly plausible account for the behavior of corvids on the Aesop's Fable tasks. However, the key question here is to what *extent* does feedback account for the birds' success? Perceptual-motor feedback is thought to account for the ability, found in several bird species, to spontaneously pull up lengths of string to retrieve an attached reward. Long strings cannot be pulled up all in one go, and the bird has to perform a series of 'pull-steps' to obtain the reward, holding loops of string under their feet while they pull more string up with their beaks. Often regarded as an example of insightful problem solving,¹⁶ Taylor and colleagues found that New Caledonian crows are unable to solve the string-pulling task



Figure 2. New Caledonian crow attempting the water vs. sand task. (in Jelbert et al.,⁴ photo credit SJ).

if they are denied visual feedback of the reward moving incrementally closer with each pull-step.¹⁴ Furthermore, 11 NC crows all failed to solve a horizontal string pulling problem, using a coiled string, where their pulling efforts did not immediately bring the reward closer.¹³ The requirement for visual feedback has also been found in primates, as apes could solve a ‘crank’ task when they had visual access to the incremental movement of the reward, but all subjects failed when this movement was concealed.¹⁵

To date, it is unclear whether or not birds rely on perceptual-motor feedback to solve the Aesop’s fable tasks, as this has not been explicitly controlled for. Cheke and colleagues found that neither of 2 Eurasian jays succeeded when they received no feedback for their actions in an arbitrary task (where the experimenter rewarded birds by hand for dropping a specified number of stones into tubes of red or blue sawdust). However, birds also performed relatively poorly on non-causal tasks which *did* provide feedback cues, such as the L-shaped apparatus and the U-tube tasks (Table 1). Therefore, there is reason to believe that birds are not *solely* responding to perceptual feedback, as the presence of feedback is not sufficient to enable their success.

To test the perceptual-motor feedback hypothesis explicitly, experiments could be run which control for feedback by blocking visual access to the reward’s movement (as in the string-pulling¹⁴ and crank¹⁵ tasks). Experiments could also require that the subject makes their choice before any feedback is provided, by selecting one *type* of object at the start of a trial, rather than selecting each object one at a time. Such controls would allow us to determine the extent to which their physical cognition can be explained by perceptual-motor feedback. If birds are successful *without* access to feedback, a stronger case could be made that corvids are capable of mental scenario building.

Comparisons with Other Species

To date, birds within the corvid family are the only non-human animals that have been tested on the Aesop’s Fable task. However, several primates have attempted a comparable task – the floating peanut task – where subjects spit water into a tube,

to bring a peanut within reach,¹⁷⁻¹⁹ making it highly plausible that they would be able to attempt the stone dropping experiments. Three of the Aesop’s Fable tasks⁶ – Sand vs Water, Sinking vs. Floating objects and the U-tube – have been conducted with 4–10 year-old children (Table 1). Eight year old children passed all tasks on the first trial, indicating that they immediately understood the tasks. However, younger children behaved more similarly to corvids, learning which option was correct over the course of 5 trials. Children passed the sand vs. water task between 4–7 years, and sinking vs. floating between 5–7 years, but only passed the U-tube task at age 7 or over. This mirrors the pattern found in corvids that individuals could readily learn to solve the causal tasks, but struggled with the counter-intuitive U-tube task.

There are differences in the way that performance was assessed for children and corvids which means we must be cautious of direct comparisons. In corvids success was primarily determined for each bird individually, using binomial tests to assess whether each subject chose the most functional option more often than chance over 20 trials. In contrast, children were given a maximum of 5 trials each, and success was evaluated at the age-group level for each trial separately, determining whether or not children of a certain age passed on their first trial, or on their second trial, and so on. This criterion is stricter for children as each child has fewer opportunities to learn the functionality of the task. This could mean that the success of corvids has been exaggerated in comparisons with humans. To examine this possibility we reanalysed some of the corvid data according to the criteria used for children, taking the experiment with the most subjects as our comparison group.⁴ As a group, NC crows passed the sand vs. water task on their 4th and 5th trials (n = 6) and the sinking vs. floating task on their 3rd, 4th and 5th trials (n = 6), but they did not pass the U-tube on any trial (n = 4). Thus, overall these results do appear to be in-line with human 5-year-olds (who passed sand vs. water on their 4th and 5th trials, sinking vs. floating on their 2nd and 5th trials, and the U-tube on no trials). Furthermore, NC crows surpass human 4-year-olds (who passed sand vs. water on their 5th trial only, and did not pass any other tasks). Results were not calculated for 6-year-olds in the original study due to small sample sizes, but by 7 y of age children perform differently from corvids and from those in younger age groups (passing sand vs. water on their 3rd and 5th trials, sinking vs. floating on their 2nd, 3rd, 4th and 5th trials, and the U-tube on their 1st, 3rd and 5th trials). This suggests that, over the course of development, differences may emerge in the learning and reasoning mechanisms that children apply to the Aesop’s Fable tasks.

Conclusions

Overall, the results from multiple experiments with corvids and children have demonstrated that several species of corvid are capable of rapidly learning which option is the most functional on causal Aesop’s Fable tasks. Our current results suggest that corvids are more able to attend to, or learn from, causal information than arbitrary information. Thus, they may be capable of

causal reasoning. However, alternative explanations for these results have not been fully ruled out. To understand the cognitive mechanisms that seemingly enable corvids to learn causal rules more effectively than arbitrary rules, future studies controlling for the object-bias hypothesis, and the perceptual-motor feedback hypothesis, will be highly informative. Furthermore, future studies dissecting the strategies that children use on these tasks, and whether these strategies vary during development, will help us to identify whether corvids share any of the signatures of human causal cognition.²⁰

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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