Western scrub-jays do not appear to attend to functionality in Aesop's Fable experiments

Corina J Logan, Brigit Harvey, Barney A Schlinger, Michelle Rensel

Western scrub-jays are known for their highly discriminatory and flexible behaviors in a caching (food storing) context. However, it is unknown whether their cognitive abilities are restricted to a caching context. To explore this question, we tested scrub-jays in a non-caching context using the Aesop's Fable paradigm, where a partially filled tube of water contains a floating food reward and objects must be inserted to displace the water and bring the food within reach. We found that scrub-jays did not attend to the functional properties of objects or tubes, and were not motivated to participate in these experiments, suggesting that either this paradigm was ecologically irrelevant or perhaps their flexibility is restricted to a caching context.

1 **Western scrub-jays do not appear to attend to functionality in Aesop's Fable experiments**

2 Corina Logan[1]*~, Brigit Harvey[2], Barney A. Schlinger[2,3,4], Michelle Rensel[2]

4 [1]SAGE Center for the Study of the Mind, University of California Santa Barbara, Santa Barbara,

5 CA USA

6 [2]Department of Integrative Biology and Physiology, University of California Los Angeles, Los

7 Angeles, CA USA

8 [3]Department of Ecology and Evolutionary Biology, UCLA, Los Angeles, CA USA

9 [4]Laboratory of Neuroendocrinology, Brain Research Institute, UCLA, Los Angeles, CA USA

10 ~Current address: Department of Zoology, University of Cambridge, Downing Street,

11 Cambridge CB2 3EJ UK

13 *Corresponding author:

14 Corina Logan

15 Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ UK

16 cl417@cam.ac.uk

17 **ABSTRACT**

18 Western scrub-jays are known for their highly discriminatory and flexible behaviors in a caching

19 (food storing) context. However, it is unknown whether their cognitive abilities are restricted to a

20 caching context. To explore this question, we tested scrub-jays in a non-caching context using

21 the Aesop's Fable paradigm, where a partially filled tube of water contains a floating food

22 reward and objects must be inserted to displace the water and bring the food within reach. We

23 found that scrub-jays did not attend to the functional properties of objects or tubes, and were not

24 motivated to participate in these experiments, suggesting that either this paradigm was

25 ecologically irrelevant or perhaps their flexibility is restricted to a caching context.

26

27 **INTRODUCTION**

28 Western scrub-jays (*Aphelocoma californica*; hereafter referred to as scrub-jays) are known for

29 their highly discriminatory and flexible behaviors in a caching (food storing) context. For

30 example, scrub-jays prefer to recover perishable food items sooner than non-perishable items

31 (Clayton et al. 2001), they plan what they want for breakfast the next morning (Raby et al. 2007),

32 and jays with prior experience stealing other's caches use cache protection strategies (Dally et al.

33 2006, see review in Grodzinski & Clayton 2010). However, it is unknown whether such abilities

34 are restricted to a caching context - the context in which these abilities evolved (Grodzinski &

35 Clayton 2010). To begin to answer this question, we tested scrub-jays in a non-caching context

36 using the Aesop's Fable paradigm. In this paradigm, clear tubes that are partially filled with

37 water contain a floating food reward that can only be reached by inserting objects into the tube to

38 raise the water. In all other corvid species tested (the family including jays, magpies, and crows),

39 some to all individuals tested using the Aesop's Fable paradigm were successful: they were

40   sensitive to the functional properties of objects and tubes, preferring the more functional option

41   to gain a food reward (3-4 out of 4 rooks [*Corvus frugilegus*] solved 3 experiments: Bird &

42   Emery 2009a; 0-2 out of 5 Eurasian jays [*Garrulus glandarius*] solved 7 experiments: Cheke et

43   al. 2011; New Caledonian crows [*Corvus moneduloides*]: 1 out of 4 crows succeeded at water vs.

44   sand and 4 out of 4 crows succeeded on the rest of the experiments according to group averages

45   in 5 experiments in Taylor et al. 2011, 0-6 out of 6 crows were successful in 6 experiments in

46   Jelbert et al. 2015, 0-6 out of 6 crows were successful in 7 experiments in Logan et al. 2014).

47   The only non-corvid bird tested so far, the great-tailed grackle (*Quiscalus mexicanus*), was also

48   successful (0-6 out of 6 grackles in 3 experiments) and two individuals changed their preferences

49   when circumstances changed, indicating behavioral flexibility (Logan 2015a). Of these species,

50   the Eurasian jay is the only other caching specialist and it exhibited flexibility outside of a

51   caching context (Brodin & Lundborg 2003, Pravosudov & de Kort 2006). This leaves an open

52   question of whether scrub-jays can apply their flexibility outside of a caching context.

53   We gave scrub-jays five Aesop's Fable experiments that have been conducted on other

54   bird species to make their performance comparable. In Experiment 1 (Water vs. Sand), one tube

55   was partially filled with water and the other with sand; stones were available to solve the task by

56   dropping them into the water tube (Bird & Emery 2009, Taylor et al. 2011, Jelbert et al. 2014,

57   Logan et al. 2014). Experiment 2 (Heavy vs. Light) consisted of one water tube with more

58   functional heavy objects and less functional light objects, while Experiment 3 (Heavy vs. Light

59   Magic) was the same except the heavy objects became non-functional because they stuck to a

60   magnet while the light objects became the functional option because they fell past the magnet

61   (Logan 2015a). Behavioral flexibility, the ability to change preferences when the task changes,

62   would be demonstrated if individuals that preferred heavy objects or had no object preference in

Experiment 2 changed their preference to either no preference or to preferring light objects in Experiment 3. Experiment 4 (Colored U-tube) consisted of two differently colored apparatuses, each with a small tube containing food, but too small to insert stones, and a large tube that could accommodate stones (Logan et al. 2014). One apparatus had a connector tube under the lid, therefore to succeed the bird must associate color with function to complete the task. This experiment was modified from its previous version (in Logan et al. 2014) by making each apparatus more visually distinct through expanding the color cues and shapes to include the whole apparatus and both tubes; this should facilitate the perception that both tubes belonged to one apparatus rather than being separate. Additionally, the water in the large tubes was tinted with food coloring such that when stones were dropped into the connected apparatus, water in the connected small tube would change color, therefore allowing the hidden mechanism (the connector tube) to be inferred (using the concept of water flow). Experiment 5 (Uncovered U-tube) was the same as Experiment 4 except all color cues were removed and the connector tube exposed so the bird could see how the apparatus worked (Logan et al. 2014).

If scrub-jays attend to the functional properties of objects and tubes and flexibly change their preferences when the task changes, as has been found in non-caching specialists and in one caching specialist bird, this would indicate that their highly discriminatory and flexible behavior generalizes to conditions outside of the context in which their cognitive abilities evolved.

METHODS

Animal Ethics

This research was carried out in accordance with the University of California, Los Angeles' (UCLA) Institutional Animal Care and Use Committee (protocol # 1995-026-63).

86

Subjects

Three wild adult male Western scrub-jays (*Aphelocoma californica*) were caught using Potter

traps baited with peanuts in southern California (July-August 2013), and one female nestling

(BB) was taken from the nest in the summer of 2012 and hand-raised (all captures were

authorized under appropriate federal and state collecting permits). Birds were sexed genetically,

and the validity of this measure was confirmed via inspection of gonads in another study (see

Griffiths et al. 1998, Rensel et al. 2015). For these experiments, jays were housed singly, in

visual but not auditory isolation of other birds, in aviaries measuring 5.3x1.2x1.9m. Jays had *ad*

libitum access to water and access to food (Roudybush Daily Maintenance Diet, fruit,

mealworms, and peanuts) for a minimum of 20 hours everyday, which was removed before and

during testing when testing occurred. Birds were tested in two batches: BB and GG were tested

from August 2014 to January 2015, and PA and H from June to November 2015.

99

Experimental Set Up

For each experiment, testing apparatuses were placed on a paper-covered table (0.3x1.1x0.6m)

inside the aviary with perches placed above the table to allow easier access to the apparatuses.

Testing lasted up to five hours per day between 0700 and 1600. If testing occurred in the

morning, food was removed from the aviaries the night before (between 1800 and dusk). For

afternoon test sessions, food was removed at 0700. Testing sessions lasted up to approximately

20 minutes. If a bird did not interact with the task after 4 minutes, the apparatus was removed

from the testing aviary for at least 10 minutes before resuming the session. Water tubes were

baited with peanut pieces attached to cork using a tie wrap to allow the food to float.

109 Experiments 1-5 consisted of 20 trials per bird. All experiments were recorded with a Sony

110 Handycam HD camera on a tripod.

111

112 **Color Learning for Side Bias Prevention**

113 To prevent side bias during the water tube experiments involving two tubes, jays were required

114 to learn to associate food with color, forcing them to attend to color rather than location (see

115 Logan et al. 2014). A gold tube always contained food (small peanut fragments), while a silver

116 tube never did. One gold and one silver tube were placed on the table, one on the left and one on

117 the right (left side first, pseudorandomized for side) with the open ends of the tubes facing the

118 side walls such that birds could not see which tube contained the food. Birds were habituated to

119 the task using a blue tube (all tubes measured 50x50x67mm, outer diameter=26mm, inner

120 diameter=19mm) until they learned to search for food even if it was not visible. After

121 habituation, the color learning test began and jays got one choice per trial, marked as the first

122 tube they look into, and proficiency was reached when an individual chose the gold tube at least

123 17 out of the most recent 20 trials (having achieved at least 8 out of 10 on each set of 10

124 contributing to the passing score). Pseudorandomization consisted of alternating sides for the

125 first two trials and then allowing each tube to remain on the same side for a maximum of two

126 consecutive trials. Between 20 and 80 trials were required for three birds to reach proficiency

127 (Table 1), similar to grackles (Logan 2015a), Darwin's finches (Tebbich et al. 2010), and

128 pigeons (Lissek et al. 2002), and faster than pinyon jays, Clark's nutcrackers, and previously

129 tested Western scrub-jays (Bond et al. 2007). GG did not complete this training due to his lack of

130 motivation. During two-tube water tube experiments (Experiments 1, 4, and 5), a side bias was

131 considered to have developed if a bird approached the same side three or more times. At this

132   point, the experiment was suspended and the subject was given the color learning test. If they

133   chose gold at least 8 out of 10 trials, the experiment resumed. However, if they no longer had a

134   color preference, they were tested until they chose gold at least 17 out of the most recent 20 trials

135   (per the criteria above), and then the experiment resumed.

136

137   **Stone Dropping Training**

138   Birds were trained to lift stones off of the testing table, carry them to the perch, and drop them

139   down the tube of an apparatus with a collapsible platform. The apparatus was a clear cast acrylic

140   box (185x110x85mm) with a 90 mm tube (outer diameter: 51mm, inner diameter: 43mm) on top

141   of the box and a platform inside that was held up by a magnet (Figure 1A; as in Bird & Emery

142   2009). Magnetic contact was broken upon impact from the stone dropped into the tube, allowing

143   the platform to fall down and release food onto the table. Birds were first encouraged to

144   accidentally push the stone into the tube by placing a small piece of peanut under the stone

145   balanced on the edge of the rim, then they progressed to picking up and dropping the stone into

146   the tube from anywhere on the table. Birds accessed the top of the tube by standing on a perch

147   placed near the top of the tube rather than by standing on the ground because they were more

148   willing to participate in this context. Proficient stone drops were defined as those in which the

149   bird picked up the stone from the table and directly dropped it into the tube. Once proficiency

150   was reached, 30 more trials were conducted to ensure their expertise on the task. BB and GG

151   required 72 and 255 trials to pass this training, respectively, while PA and H never passed (we

152   stopped their training at 536 and 507 trials, respectively; Table 1).

153

154   **Multi-stone Dropping Training**

155   After reaching proficiency on stone dropping training, birds received multi-stone dropping

156   training to learn that solving a task might require dropping more than one object into the tube.

157   The multi-stone apparatus was similar to the stone dropping training apparatus, but had a larger

158   box (box: 200x180x150mm; tube: 95mm tall, 50mm outer diameter, 44mm inner diameter;

159   Figure 1B; design in Logan et al. 2014) and the platform was balanced on a circular rod rather

160   than being held up by a magnet. Counterweights placed at the rear of the platform ensured that 2-

161   4 stones needed to drop down the tube, which then slid down a ramp to land on the front of the

162   platform, before the platform would fall open, thus releasing the food. Individuals passed this

163   training once they successfully solved 10 consecutive trials. BB and GG were immediately

164   proficient, thus they completed all 10 trials proficiently.

165

166   **Reachable Distance**

167   The height at which a bird could reach the food in the tube was determined in advance to

168   establish how high to set the water level in the experiments. This was necessary so that the food

169   would be out of reach and require the desired number of objects to bring it within reach. The

170   reachable distance was the distance from the bottom of the tube to the top of the food, which sat

171   on top of a plastic sandwich bag stuffed with cotton in a standard tube used in the water

172   experiments (a clear cast acrylic tube measuring 170mm tall, 50mm outer diameter, 43mm inner

173   diameter and attached using super glue to a clear cast acrylic base measuring 300x300x3mm).

174   Birds were allowed to access the food, initially well within reach, and then the distance was

175   decreased until it was out of reach.

176

177   **Experiment 1: Water vs. Sand**

178   This experiment consisted of two standard tubes: one partially filled with sand and the other with

179   water to the same height in each tube, to determine whether birds preferred to drop stones into

180   the functional water tube rather than the non-functional sand tube (Figure 2; similar to Logan et

181   al. 2014). First, birds were given a 10-trial training period in which any initial tube preferences

182   were discouraged by heavily baiting the non-preferred tube. Tubes contained water and sand

183   (and were pseudorandomized for side), but no floating food and the tops were taped over with

184   bait (peanuts) placed on top and at the base of each tube. The tube the bird ate from first was

185   recorded to determine whether a preference emerged. After these training trials, the experiment

186   began and the sand and water tubes continued to be pseudorandomized for side. Four stones

187   (weighing 14-21g and displacing 6-8mm water) were located between the two apparatuses: two

188   on the base of one apparatus and two on the other.

189

190   **Experiment 2: Heavy vs. Light**

191   One standard water tube was given with 4 heavy (a steel rod encased in fimo clay, each weighing

192   10g and displacing 2-3mm of water) and 4 light (black plastic tube partially filled with fimo clay,

193   each weighing 2g and displacing 1-1.5mm water) objects (Figure 3A; see Logan 2015a). Heavy

194   objects displaced more water than light objects and therefore were more functional, however

195   light objects were also functional if enough were inserted. First, birds were given a 3-trial

196   training period in which any initial object preferences were discouraged0 by heavily baiting the

197   non-preferred object. A heavy and a light object were placed next to each other on the table and

198   bait was placed underneath and on top of both objects. The object the bird ate from first was

199   recorded to determine whether a preference emerged, and the trial ended when the bird had

200 interacted with both objects. After these trials, the experiment began and pairs of heavy and light

201 objects were pseudorandomized for location.

202

Experiment 3: Heavy vs. Light Magic

204 This experiment was the same as Experiment 2, except here the heavy objects became non-

205 functional to determine whether birds could change their preference from the previous

206 experiment. A magnet was attached to the inside of the tube above the water level so that the

207 heavy (metal) objects became non-functional (they stuck to the magnet if inserted into the tube),

208 thus making the light (non-metal) objects the only functional option because they could fall past

209 the magnet and into the water (Figure 3B). Three heavy and 3 light objects were placed in

210 pseudorandomized pairs at the base of the tube because 4 heavy objects would not fit on the

211 magnet.

212

Experiment 4: Colored U-tube

214 This experiment consisted of two apparatuses made of clear cast acrylic, each containing a

215 standard tube and a small-diameter tube (small tube outer diameter=25.4mm, inner

216 diameter=19mm) 25mm apart, with 160mm of tube above and 90mm below a clear cast acrylic

217 lid (300x400x3mm) on a wooden box (Figure 4A). The small tubes contained out of reach

218 floating peanuts (the reachable distance for each bird was obtained for the small tube prior to

219 beginning the experiment), but were too small for stone insertion. On one apparatus, a tube under

220 the lid connected the two water tubes such that inserting the stone into the standard tube resulted

221 in the food rising in the small tube. The connected apparatus was indicated by a particular color

222 (counterbalanced across birds) and was pseudorandomized for side. The apparatuses were the

223   same as in Logan et al. (2014) with modifications to make the two tubes on each apparatus

224   appear as part of the same apparatus and to distinguish the two apparatuses from each other.

225   Instead of both apparatuses having a white paper background with differently colored shapes at

226   the base of the standard tube as in a previous study (Logan et al. 2014), here each apparatus had

227   a distinct background color (blue or brown). On top of these backgrounds, each apparatus had a

228   different color and shape (pink triangle or yellow square) that extended around the base of the

229   two tubes to further unify the tubes of each apparatus by making them appear more as a single

230   unit, instead of only extending around the base of the standard tube. One white strip of electrical

231   tape was placed on each apparatus to indicate that these are the same apparatuses in the next

232   experiment. Any initial apparatus preferences were discouraged by heavily baiting the non-

233   preferred object over the course of 10 trials as in Experiment 1. During the experiment, 20-30

234   drops of red (for pink) or yellow food coloring (the same as the colored paper on the connected

235   tube) were placed into each wide tube such that when a stone was dropped into the connected

236   apparatus, the flow of tint from the standard to the small tube would visibly indicate water flow.

237   Four stones were placed between the apparatuses as in Experiment 1.

238

239   **Experiment 5: Uncovered U-tube**

240   This experiment was the same as Experiment 4 except all paper and color cues were removed

241   and the boxes around the bases were removed on both apparatuses, thus exposing the connector

242   tube under the lid of the connected apparatus (Figure 4B). Food coloring (the same color as that

243   used for the connected color in Experiment 4) was used in the same way as before to show the

244   water flow through the connector tube.

245

246 **Statistical Analyses**

247 Binomial tests were carried out in R v3.2.1 (R Core Team 2015), and, when there were multiple

248 p-values per experiment, they were corrected using the Bonferroni-Holm method.

249

250 **RESULTS**

251 All choices per trial per bird are shown in Figure S1 (Supplemental Material) and a video

252 showing the experiments is available online at: https://youtu.be/RCNENBwsbA8.

253

254 **Experiment 1: Water vs. Sand**

255 GG had no preference for which tube to drop the stones into (Table 1). BB did not complete this

256 experiment: her motivation to participate declined because she received few food rewards (she

257 primarily chose the sand tube). To prevent her from giving up on dropping objects down tubes

258 entirely, she was given alternating sessions with a water tube and the multiple stone dropping

259 apparatus and stones for four days until she regained motivation and began to participate again.

260

261 **Experiment 2: Heavy vs. Light**

262 BB and GG consistently successfully obtained the food using both heavy and light objects

263 without a preference for the more functional heavy objects (Table 1).

264

265 **Experiment 3: Heavy vs. Light Magic**

266 BB had no preference for heavy or light objects, though it appeared that she was developing a

267 preference for light objects near the end of her experiment so it is possible that the preference

268 would have been significant given more trials (Table 1). GG stopped participating in experiments

269   at this time at first because he was afraid of the magnet, but even after a successful magnet

270   habituation period, his motivation for participating in tests did not recover.

271

272   **Experiment 4: Colored U-tube**

273   BB had no preference for dropping stones into the standard tube on the brown apparatus, which

274   indicated the connected apparatus (Table 1).

275

276   **Experiment 5: Uncovered U-tube**

277   BB had no preference for dropping stones into the connected apparatus (Table 1).

278

279   **DISCUSSION**

280   Two scrub-jays successfully obtained the food in the Heavy vs. Light experiment because both

281   objects were functional, however no scrub-jays attended to the functional differences between

282   objects or tubes or changed their preference when the task changed. In every other species tested

283   so far, including a caching specialist (Eurasian jay), at least some individuals attended to the

284   functional differences between objects and/or tubes, thus making the scrub-jays the first species

285   tested to lack such attention to function (Bird & Emery 2009a, Cheke et al. 2011, Taylor et al.

286   2011, Jelbert et al. 2014, Logan et al. 2014). While it appeared that BB was learning to prefer

287   light objects in Heavy vs. Light Magic, she did not learn to significantly prefer this object type

288   within the 20 trials that are standard for these experiments. In contrast, within 20 trials, 4 out of 6

289   great-tailed grackles preferred to drop heavy objects in Heavy vs. Light and two grackles

290   changed their preference in Heavy vs. Light Magic (Logan 2015a). The color and water flow

291   modifications to the Colored U-tube and Uncovered U-tube experiments did not appear to

292   facilitate learning to prefer the connected apparatus.

293   The two scrub-jays that became proficient at stone dropping required a similar amount of

294   training as required by grackles (6 grackles learned in 135-362 trials and 2 grackles never

295   learned; Logan 2015a) and New Caledonian crows (12 crows learned in 1-116 trials and others

296   never became proficient, unpublished data from Jelbert et al. 2014 and Logan et al. 2014). Using

297   the same platform apparatus, Eurasian jays and rooks needed much less training to learn the task

298   (4 Eurasian jays learned in 11-33 trials and 1 never became proficient, Cheke et al. 2011;

299   whereas all 4 rooks learned in 5 trials, Bird & Emery 2009b). Two out of four scrub-jays never

300   became proficient at stone dropping, and thus did not participate in stone dropping experiments,

301   and both jays that participated in experiments did not participate in every experiment. It appeared

302   that their lack of motivation for participating in these kinds of tasks slowed their learning and

303   could have caused them to give up; alternatively they could have lacked motivation due to

304   cognitive limitations preventing them from solving the tasks. The exception was BB who showed

305   more motivation than the others and participated in more experiments, perhaps due to her being

306   the only hand raised jay in this group – a developmental experience that has been shown to

307   improve cognitive performance in other species (see Thornton & Lukas 2012).

308   The scrub-jays' lack of motivation combined with their lack of a preference for the

309   functional options suggests that either the Aesop's Fable paradigm is too ecologically irrelevant

310   for this species or that their highly discriminatory and flexible behaviors do not transfer to a non-

311   caching context. Future studies using different non-caching paradigms are needed to determine

312   which conclusion is correct.

313

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319

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324

325 **COMPETING INTERESTS**

326 The authors declare that there are no competing interests.

327

328 **DATA DEPOSITION**

329 Data are available at the KNB Data Repository:

330 https://knb.ecoinformatics.org/#view/corina_logan.20.3 (Logan 2015b).

331

332 **SUPPLEMENTAL INFORMATION**

333 All choices per trial per bird are shown in Figure S1 (Supplemental Material) and a video

334 showing the experiments is available online at: https://youtu.be/RCNENBwsbA8.

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1

Single stone dropping apparatus (A) and multi-stone dropping apparatus (B)

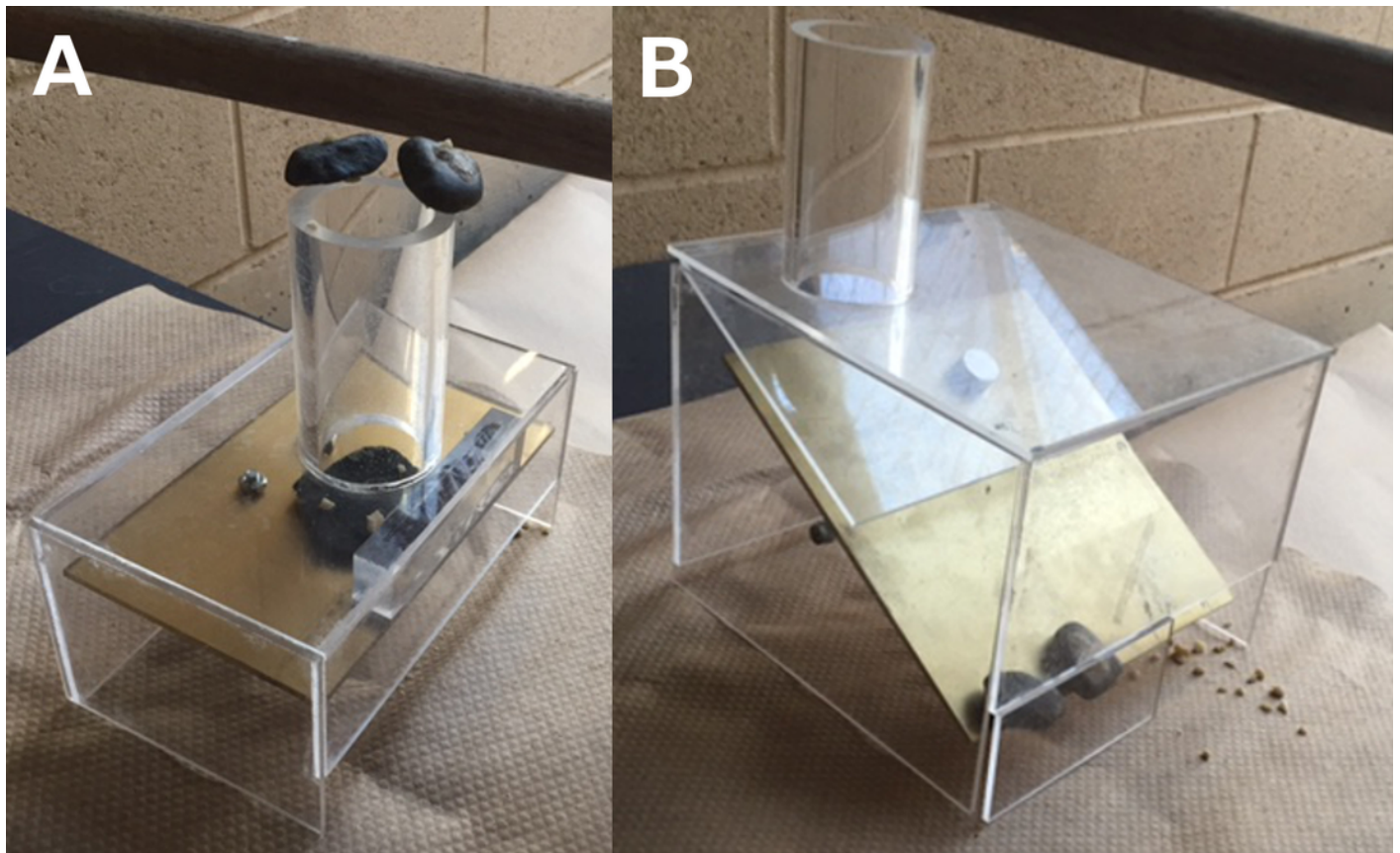
Photo credit: Brigit Harvey.

Water vs. sand experimental set up.

Photo credit: Brigit Harvey.

Heavy vs. light (A) and heavy vs. light magic (B) experimental set up. Notice the heavy object stuck to the magnet in B.

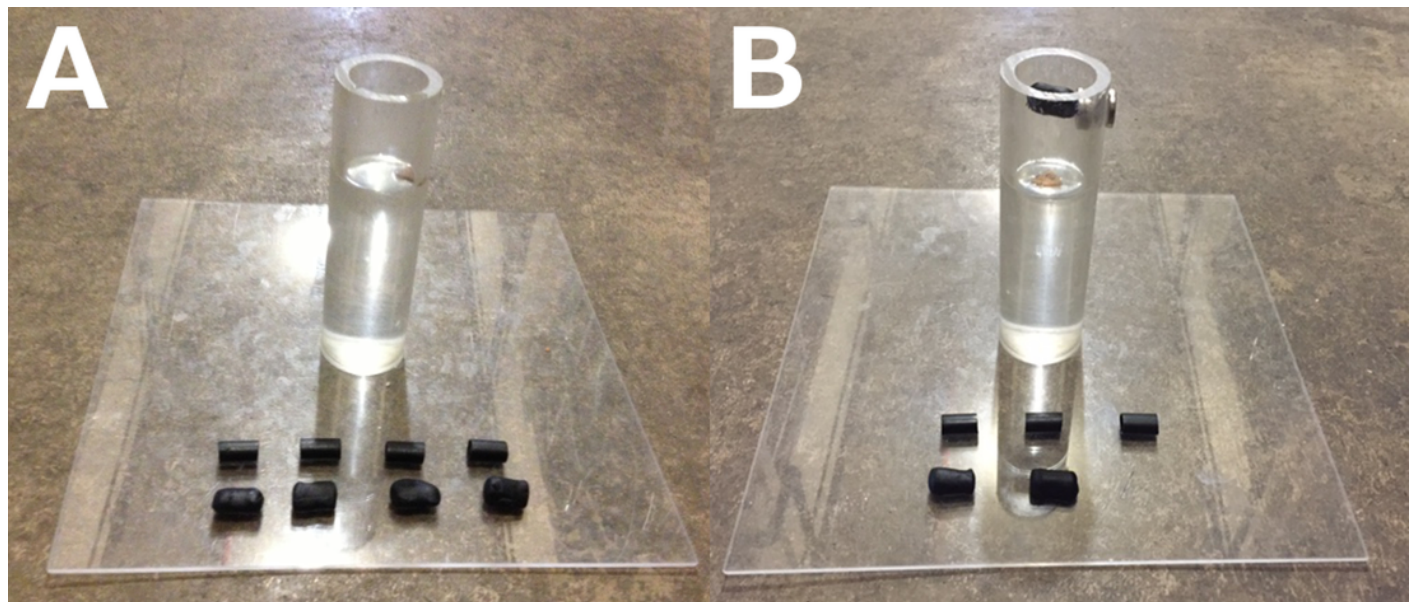
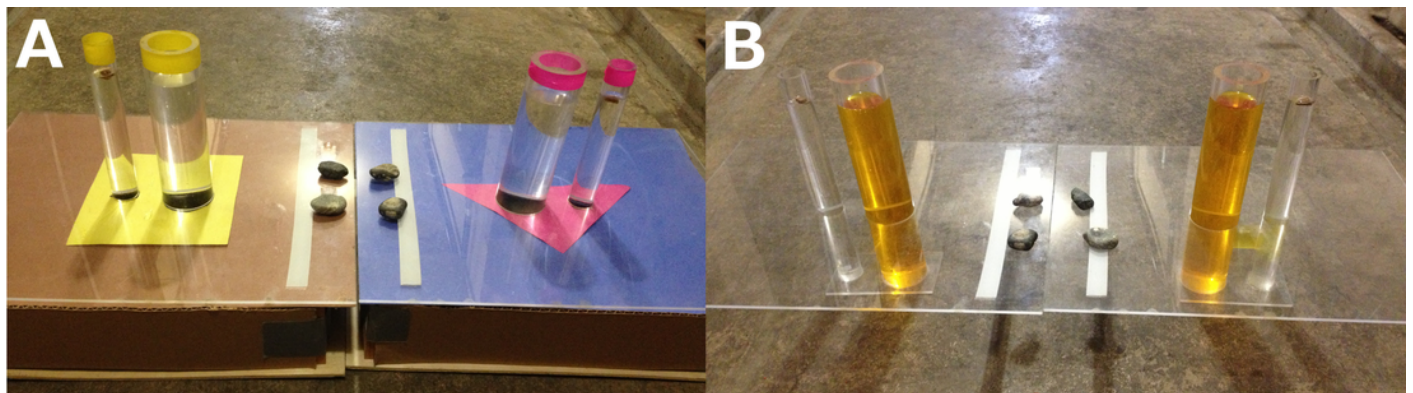
Photo credit: Brigit Harvey.

Colored u-tube (A) and uncovered u-tube (B) experimental set up. The connector tube is visible on the apparatus on the right in B.

Photo credit: Brigit Harvey.

Summary of results

The number of trials required to learn to associate food with the gold tube (color learning; min. 17 out of 20 trials correct) and to become proficient at dropping stones down the platform apparatus (stone drop training; number of non-proficient stone falls plus 30 proficient stone drops); p-values from binomial tests for experiments 1-5 (the Bonferroni-Holm correction was applied to Experiment 2). X=bird did not complete this experiment, -=bird did not participate in this experiment.

1 Table 1. Summary of results: The number of trials required to learn to associate food with the

2 gold tube (color learning; min. 17 out of 20 trials correct) and to become proficient at dropping

3 stones down the platform apparatus (stone drop training; number of non-proficient stone falls

4 plus 30 proficient stone drops); p-values from binomial tests for experiments 1-5 (the

5 Bonferroni-Holm correction was applied to Experiment 2). X=bird did not complete this

6 experiment, -=bird did not participate in this experiment.

Bird ID	Sex	Color learning	Stone drop training	Exp 1: Sand vs Water	Exp 2: Heavy vs light	Exp 3: Heavy vs light magic	Exp 4: Colored u-tube	Exp 5: Uncovered u-tube
BB	F	80	76	X	0.46	0.06	0.33	0.17
GG	M	X (28)	255	0.40	0.46	-	-	-
H	M	20	X (507)	-	-	-	-	-
PA	M	50	X (536)	-	-	-	-	-