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3 **Naïve chicks prefer hollow objects**

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6

7 **Abstract**

8 Cognitive predispositions can influence approaching and avoid responses since the early
9 stages of life. Young individuals of species that require parental care (e.g. human babies
10 and chicks of the domestic fowl) are attracted by stimuli that contain features present in
11 social partners such as face-like configurations, biological motion and self-propulsion.
12 Studies on human infants showed that 8-month-old babies might possess expectations
13 about the biological properties of animate entities. It is not clear though whether
14 previous experience with animate entities had generated those expectations, or whether
15 they arose spontaneously. We reasoned that naïve chicks of the domestic fowl (*Gallus*
16 *gallus*) might be a convenient subject to investigate whether the mere property of being
17 filled vs. hollow triggers unlearned preferences. To this aim we tested preferences of
18 naïve and imprinted chicks for hollow and closed cylinders of the size and colour that
19 elicit affiliative responses. We documented an unlearned attraction for hollow stimuli,
20 showing that the property of being filled is not sufficient to elicit affiliative responses in
21 chicks. The preference for hollow stimuli could be decreased through filial imprinting, by
22 exposing naïve chicks to filled stimuli. When chicks were imprinted on stimuli that could
23 be either filled or hollow, the preference for hollow stimuli emerged again. Further
24 experiments revealed that hollow objects were mainly attractive by means of depth cues
25 such as darker innards, more than as places to hide or as objects with high contrast.

26

27 **Introduction**

28 Sensory and cognitive predispositions can help living beings to cope with their environment
29 by influencing approach and avoid responses (Vallortigara 2012a; Rosa Salva et al. 2015;
30 Versace and Vallortigara 2015). It is not surprising, hence, to observe in different species
31 unlearned preferences for specific colours (Schaefer and Hess 1951; Giurfa et al. 1995; Raine
32 and Chittka 2007; Ham and Osorio 2007), shapes and sizes (Fabricius and Boyd; Schulman et
33 al. 1970; Ham and Osorio 2007), configurations (Rosa-Salva et al. 2010), dynamics

34 (Vallortigara et al. 2005; Mascalzoni et al. 2010), and odours (Knaden et al. 2012; Dekker et al.
35 2015; Keeseey et al. 2015; Versace and Reisenberger 2015).

36 Precocial species – in which individuals are mobile from the moment of birth, and can be tested
37 with little if any experience with their environment– are very convenient to investigate the
38 unlearned predispositions that can orient living beings since their early stages of life (Versace
39 and Vallortigara 2015). Soon after hatching, chicks of the domestic fowl (*Gallus gallus*), which
40 is a nidifugal species, possess some unlearned preferences to approach stimuli that are more
41 similar to animate social partners (Vallortigara 2012b).

42 Evolved mechanisms to approach objects that possess the features of animate partners would
43 provide a critical advantage for survival in species that rely on parental care. In line with this,
44 when given a choice between a stuffed hen vs. a stuffed scrambled hen, chicks prefer to
45 approach the hen (Johnson and Horn 1988). Behavioural studies have found that this
46 preference is driven by an unlearned attraction towards the face configuration contained in
47 the stuffed hen (Johnson and Horn 1988; Rosa-Salva et al. 2010). Moreover, between the
48 biological movement of a hen or a cat and the rigid motion of a hen rotated on its vertical axis,
49 chicks prefer to approach the biologically moving object (Vallortigara et al. 2005; Miura and
50 Matsushima 2016); and between a self-propelled object and an object propelled by another
51 one, naïve chicks prefer the self-propelled object (Mascalzoni et al. 2010). Overall, chicks
52 prefer to approach objects which are endowed with more animate features (Rosa Salva et al.
53 2015; Versace and Vallortigara 2015).

54 Observations on infants (Gelman 1990) suggest that 3-year-old children have a
55 representation of the insides of animate beings as more likely to be filled than those of
56 inanimate objects. Studies on human infants (Setoh et al. 2013) have shown that 8-month-old
57 babies might possess expectations about the biological properties of animate and agentic
58 entities. In this study infants were more surprised to see that self-propelled and agentic
59 objects were hollow than when there was no evidence that those objects were hollow. It is not
60 clear though whether previous experience with animate entities with innards (e.g. the
61 parents) had generated infants' expectations, or whether they arose spontaneously. We
62 reasoned that chicks of the domestic fowl (*Gallus gallus*), who are spontaneously attracted by
63 entities which show cues associated with animacy in the absence of previous experience
64 (Rosa Salva et al. 2015; Versace and Vallortigara 2015), might be a convenient subject to
65 identify whether the property of being filled/hollow triggers unlearned preferences.

66 To this aim we tested preferences of naïve chicks (**Experiment 1**) maintained in darkness
67 (Experiment 1a) or exposed to light (Experiment 1b) for hollow and closed cylinders of the

68 size and colour that elicit filial responses. Moreover, since chicks rapidly learn features of
69 their social partners by mere exposure through filial imprinting (Horn 1985; McCabe 2013)
70 (Horn 1985; McCabe 2013), they are a valuable model to study the role of experience in
71 modifying spontaneous preferences. To this aim we investigated how imprinting modified
72 unlearned preferences for hollow and filled objects (**Experiment 2**) after imprinting on
73 hollow objects (Experiment 2a), filled objects (Experiment 2b) and objects who could not be
74 perceived hollow or filled because their sides were occluded (Experiment 2c).
75 Since we noticed an overall preference for hollow objects, we investigated whether this
76 behaviour was elicited by a preference for the stimulus that could better hide the chick
77 (chicks could enter the hollow stimulus). In **Experiment 3** we checked whether the
78 preference for hollow stimuli was still present when the stimuli were too small to host and
79 hide chicks. We tested both dark-reared chicks and chicks exposed to light that had never
80 seen the test stimuli or any other object of similar size, shape and colour. We observed a
81 preference for hollow objects. In **Experiment 4** we checked whether the size of the hollow
82 object was important in determining the preference for hollow objects comparing the
83 preference for the large and the narrow hollow objects. In **Experiment 5** we checked whether
84 the darker colour of the shadows present in the innards of hollow objects has a role in driving
85 preferences for hollow stimuli by comparing preferences for filled objects with a white vs. a
86 black stopper (Experiment 5a). Since chicks preferred the object with the black stopper, we
87 tested whether the preference for a hollow stimulus was stronger or weaker than the
88 preference for a black cap (Experiment 5b). The observed preference for the black cap
89 stimulus could be explained both by brightness (chicks preferred lower brightness) and by
90 contrast (chicks preferred greater contrast). To clarify the importance of contrast and
91 brightness in determining the preference for hollow objects, in **Experiment 6** we used two-
92 dimensional stimuli with different colour and identical contrast, i.e. a white disk on a black
93 background vs. a black disk on a white background. If the preference of chicks for hollow vs.
94 Filled and for Black vs. Hollow was driven by the darker colour (innards or cap), in this
95 contrast chicks should have chosen the white disk on a black background. If the preference
96 was driven by contrast, chicks were expected to have no preference. A preference for the
97 black disk on a white background would be consistent with a preference for darker
98 objects/innards, possibly a cue of depth.

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100

101 **MATERIALS AND METHODS**

102 **Ethical note**

103 This study was approved by the ethical committee of the University of Trento (Organismo
104 preposto al benessere degli Animali) prot. N. 14-2015 and was licensed by the Ministero della
105 Salute, authorization n. 1138/2015. The research adhered to the ASAB/ABS Guidelines for the
106 Use of Animals in Research.

107
108 **Subjects**

109 The subjects were 24-hour old chicks of the domestic fowl (*Gallus gallus*) of the Hybro strain
110 (a local hybrid variety of the White Leghorn breed). This breed is sexually dimorphic at the
111 moment of hatching. The eggs were obtained from a commercial hatchery (Agricola Berica,
112 Montegalda, Italy), then incubated in complete darkness at 37.7 °C until hatching. Three days
113 before hatching humidity was increased from 40% to 60%. Eggs hatched in individual boxes
114 (11 x 8.5 x 14 cm) and chicks could hear their conspecifics but had no visual or tactile contact
115 with conspecifics until the moment of test. The exact number of chicks used in each
116 experiment, divided by Sex, is presented in Table 1.

117

Experiment	Experience	Test stimuli	Females	Males
Experiment 1a	Naïve: Dark-reared	Hollow – Filled (large)	57	52
Experiment 1b	Naïve: Light-reared	Hollow – Filled (large)	27	26
Experiment 2a	Imprinted: Occluded	Hollow – Filled (large)	37	27
Experiment 2b	Imprinted: Filled	Hollow – Filled (large)	59	64
Experiment 2c	Imprinted: Hollow	Hollow – Filled (large)	57	67
Experiment 3	Naïve: Light-reared	Hollow – Filled (narrow)	17	14
Experiment 4	Naïve: Dark-reared	Large – Narrow (hollow)	47	36
Experiment 5a	Naïve: Dark-reared	White – Black (large filled)	11	16
Experiment 5b	Naïve: Light-reared	Hollow – Black filled (large)	19	21
Experiment 6	Naïve: Dark-reared	White disk – Black disk	19	17

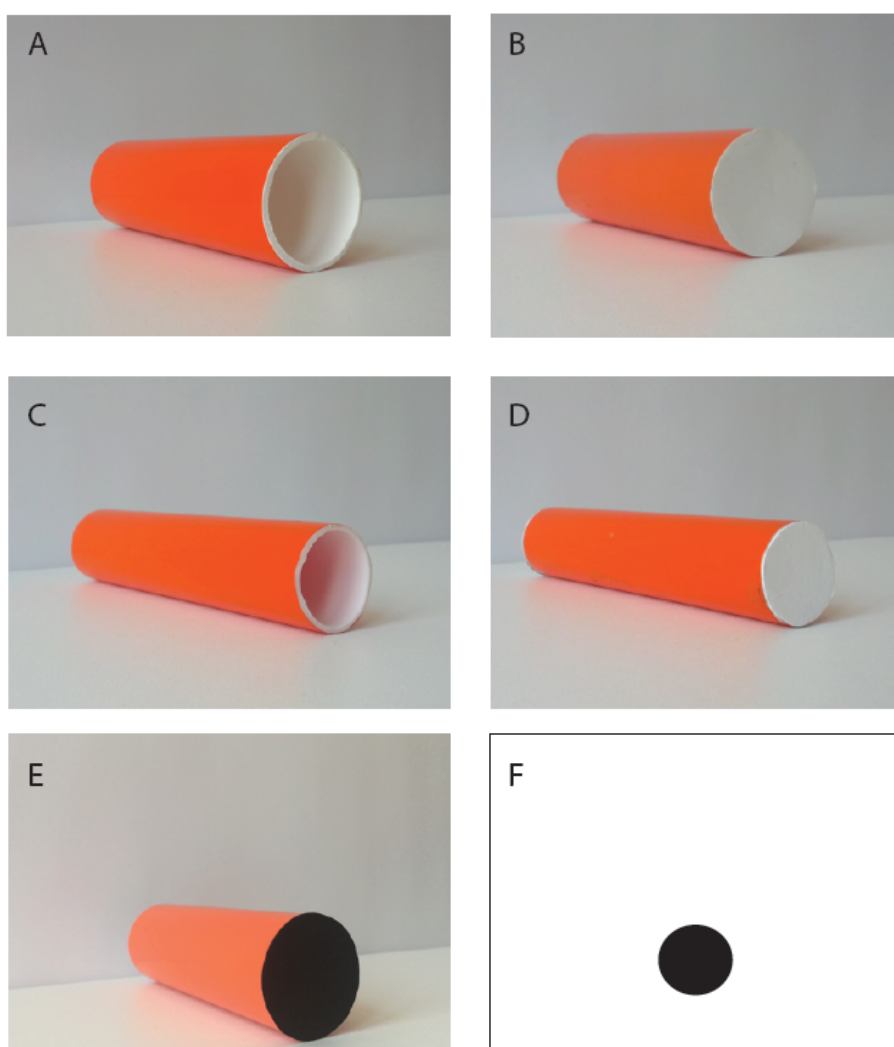
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120 **Test stimuli**

121 Test stimuli are shown in Figure 1. In Experiment 1 and 2 test stimuli were large plastic tubes
122 (12 cm, \varnothing 4 cm) left open (Hollow, Fig. 1A) or closed with a white cap (Filled, Fig. 1B), with an
123 orange external surface and a white internal surface. In Experiment 3 we used the same
124 stimuli with the only difference that the diameter was 2.5 cm (Narrow stimuli are shown in
125 Fig. 1C and 1D). In Experiment 4 we used Large and Narrow hollow stimuli (Fig. 1A and 1C).
126 In Experiment 5 we used stimuli similar to those used in Experiments 1 and 2 with the only
127 difference that one cap was black (Fig. 1E). In Experiment 6 we used a white disk on a black
128 background, and a black disk on a white background (Fig. 1F) with a diameter of 4 cm located
129 at 4.5 cm from the ground.

130



131

132 Figure 1. Stimuli used in Experiment 1 and 2 (A and B), Experiment 3 (C and D), Experiment 4 (A and C),
133 Experiment 5 (A and E), and Experiment 6 (Panel F shows the Black disk on the white background. The other
134 stimulus was a White disk on a black background).

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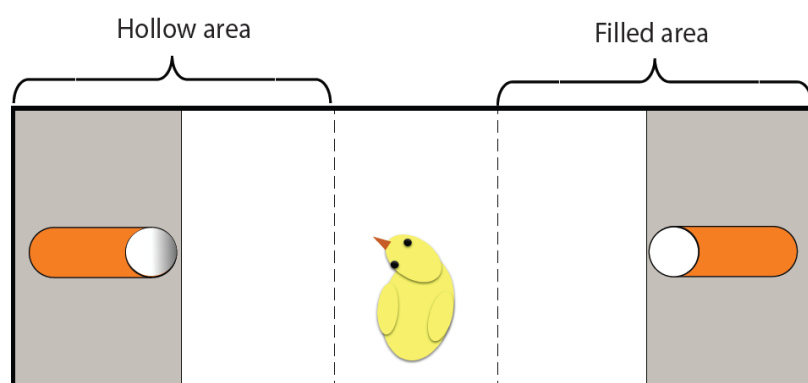
136 **Imprinting stimuli**

137 In experiment 2 chicks were individually imprinted to orange cylinders (12 cm, \varnothing 4 cm), that
138 were presented through a 7.5 x 10 cm transparent plastic window. Imprinting lasted 24 ± 3
139 and was immediately followed by the test. Chicks had no direct interaction with the stimulus
140 during imprinting and the only interaction with conspecifics was auditory. In the Occluded
141 condition the cylinder was presented horizontally and the chicks could not see whether it was
142 hollow or filled because the edges were covered. In the Hollow and Filled condition the hollow
143 and or filled cylinder were presented perpendicular to the transparent window and the chick
144 could see whether it was hollow or not.

145

146 **Test apparatus**

147 The experiment took place in a 100 x 30 x 31 cm white arena open on the top (see Figure 2).
148 Test stimuli were located in the middle of each short side on a white plastic platform that was
149 4.5 cm high. The box was virtually divided into three areas: a left area (41 cm), a central area
150 (18 cm) and a right area (41 cm). The white platforms occupied 15 cm in each side area. In
151 Experiment 4, the platforms were removed and the stimuli were placed directly on the walls
152 of the apparatus.



153

154

155 Figure 2. Illustration of the testing apparatus.

156

157 **PROCEDURE**

158 **Imprinting**

159 Soon after hatching, in the imprinting experiments chicks were individually exposed to the
160 imprinting stimulus for 24 hours before testing under constant light. Imprinting cages were
161 28 x 38 x 32 cm and the stimulus was presented through a transparent partition (7.5 x 10 cm).
162 In this way chicks had no direct interaction with the stimuli before testing, similarly to naïve
163 chicks that had never experienced stimuli like those used during the test.

164 **Test**

165 **Procedure and data analysis**

166 We followed the same procedure in all experiments. Each chick was individually located in the
167 centre area facing the long side of the box opposite to the experimenter and video recorded
168 for 360 seconds. We recorded which side area was entered first (First choice) and the seconds
169 spent in each side area. The chick was considered to have entered a new sector as soon as it
170 crossed the borderline with both feet. After the testing phase chicks were not used in any
171 other experiment.

172 We checked whether the first choice was significantly different from the 0.5 chance level
173 using a Chi-squared test, with alpha = 0.05.

174 For each chick that left the central area we calculated an index of preference for the Hollow
175 stimulus (Experiments 1, 2 and 3) or an index of preference for the Narrow (Experiment 4) or
176 Black stimulus (5) in this way:

177

178 *Hollow preference* = (seconds in the Hollow stimulus area) / (seconds in the Hollow stimulus area+seconds in the
179 Filled stimulus area)

180

181 *Narrow preference* = (seconds in the Narrow stimulus area) / (seconds in the Narrow stimulus area+seconds in
182 the Large stimulus area)

183

184 *Black preference* = (seconds in the Black stimulus area) / (seconds in the Black stimulus area+seconds in the
185 White stimulus area)

186

187 For all indices, 1 indicates a full preference for the respective stimulus (Hollow, Narrow,
188 Black), 0.5 no preference and 0 a full preference for the opposite stimulus (Filled, Large,
189 White). Since all data had a bimodal distribution with peaks on the extremes (0 and 1) we
190 used non-parametric statistics to test for significance: the Kruskal-Wallis test to test for
191 differences between conditions and sexes, and the Mann-Whitney-Wilcoxon one-sample test
192 vs. the 0.5 chance level.

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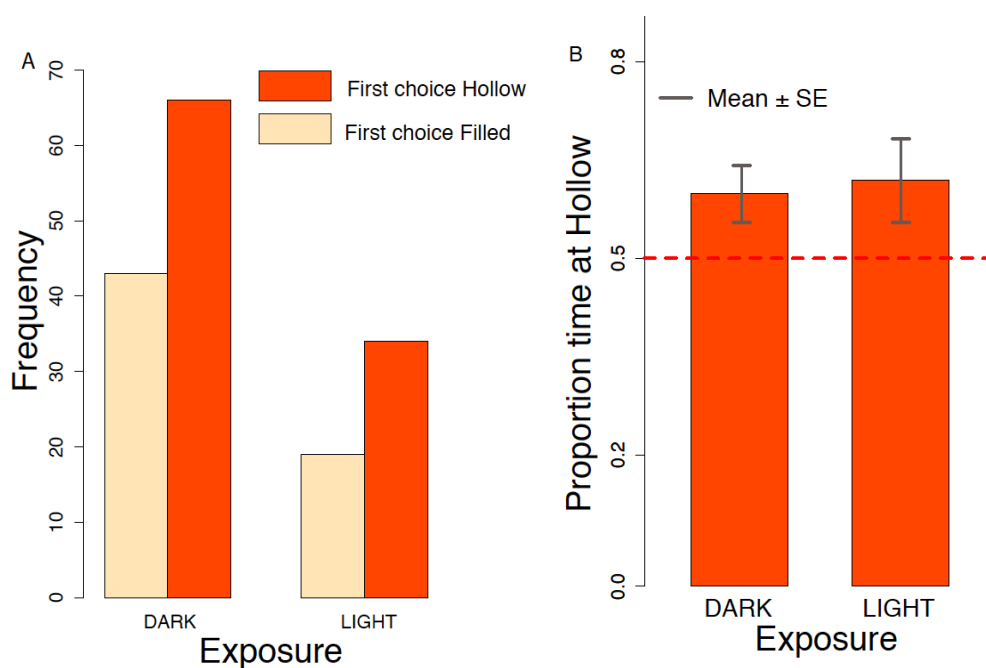
195 **RESULTS**

196 **Experiment 1: naïve chicks (dark-reared and light-reared) chicks tested with Hollow vs.**
197 **Filled stimuli.**

198 We assessed the preference for the hollow/filled object in naïve chicks, namely dark-reared
199 and light-reared chicks that had never experiences any of the test stimuli before the test.

200 **First choice.** There was no significant difference between dark- and light-reared chicks (Chi-
201 square test: $\chi = 0.073$, $df = 1$, $P = 0.79$), and in both conditions chicks had the same trend,
202 therefore we collapsed the two naïve conditions for further analyses. The number of chicks
203 that approached the Hollow vs. Filled stimulus was significantly different from chance (Chi-
204 square test: $\chi = 8.91$, $df = 1$, $P = 0.003$) with an overall preference for the Hollow stimulus
205 (Figure 3A).

206 **Hollow preference.** Considering the Hollow preference index we did not observe any
207 significant Sex difference (Kruskal-Wallis test: $H = 0.32$, $df = 1$, $P = 0.57$) or Exposure (dark- vs.
208 light-rearing) difference (Kruskal-Wallis test: $H = 0.07$, $df = 1$, $P = 0.79$), therefore we
209 collapsed the two naïve conditions for further analyses. We documented a significant
210 preference for the Hollow stimulus (Mann-Whitney test: $V = 8053$, $df = 1$, $P = 0.01$), see Figure
211 3B.



212
213
214 Figure 3. **A.** Number of naïve chicks that first approached the Hollow or Filled stimulus in the dark-reared and
215 light-reared condition. **B.** Proportion of time spent at the Hollow stimulus by dark-reared and light-reared
216 chicks.

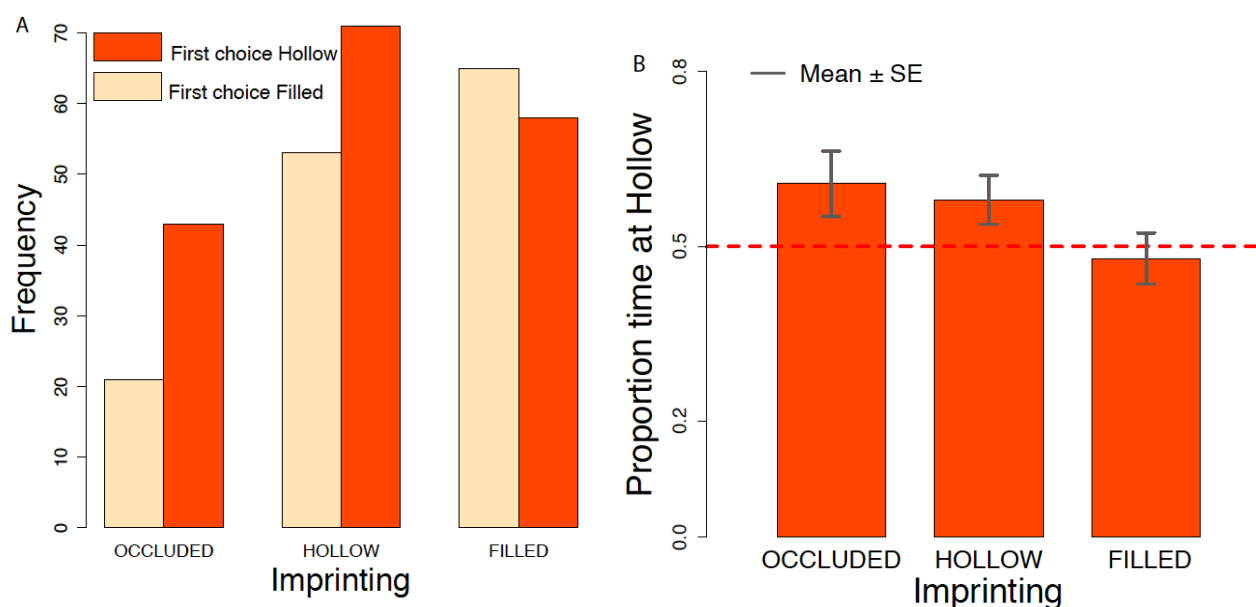
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218 **Experiment 2: chicks imprinted with Hollow, Filled or Occluded and tested with Hollow**
219 **vs. Filled stimuli.**

220 To investigate the role of experience in determining the preferences for hollow objects we
221 investigated the preference for the hollow/filled object in imprinted chicks, namely chicks
222 that had been exposed to the filled or hollow object, or to an object located horizontally the
223 sides of which were occluded, so that it did not show whether it was filled or hollow.

224 **First choice.** The number of chicks that approached the Hollow vs. Filled stimulus was
225 significantly different between imprinting conditions (Chi-square test: $\chi = 7.15$, $df = 2$, $P =$
226 0.028). Chicks imprinted on the Occluded object showed a significant preference for the
227 hollow object (Chi-square test: $\chi = 7.56$, $df = 1$, $P = 0.006$), whereas chicks imprinted on the
228 Filled (Chi-square test: $\chi = 0.40$, $df = 1$, $P = 0.53$) and Hollow object (Chi-square test: $\chi = 2.61$,
229 $df = 1$, $P = 0.11$) did not. While the first choice of chicks imprinted on the Occluded object did
230 not differ from the first choice of chicks imprinted on the Hollow object (Chi-square test: $\chi =$
231 1.35 , $df = 1$, $P = 0.24$), there was a significant difference between the first choice of chicks
232 imprinted on the Occluded object and the first choice of chicks imprinted on the Filled object
233 (Chi-square test: $\chi = 6.02$, $df = 1$, $P = 0.014$). Only chicks imprinted on the Filled object had a
234 tendency to choose the Filled object (Figure 4A).

235



236

237 Figure 4. **A.** Number of imprinted chicks that first approached the Hollow or Filled stimulus after being exposed
238 to Occluded, Hollow or Filled imprinting stimuli. **B.** Proportion of time spent at the Hollow stimulus for chicks
239 exposed to Occluded, Hollow or Filled imprinting stimuli.

240

241 **Hollow preference.** Considering the Hollow preference index we did not observe any
242 significant Sex difference (Kruskal-Wallis test: $H = 1.60$, $df = 1$, $P = 0.21$) or Exposure
243 difference (Kruskal-Wallis test: $H = 3.66$, $df = 2$, $P = 0.161$). We observed an overall trend for
244 preferring the the Hollow stimulus (Mann-Whitney test: $V = 27016.5$, $df = 1$, $P = 0.063$), that
245 turned out highly significant when considering only the chicks imprinted on the occluded and
246 hollow objects (Mann-Whitney test: $V = 10721.5$, $df = 1$, $P = 0.009$), see Figure 4B.

247

248 **Experiment 3: naïve chicks tested with narrow Hollow vs. narrow Filled stimuli.**

249 To investigate the extent and consistency of the hollow preference, we tested the preference
250 for the hollow/filled object in naïve chicks, using smaller stimuli than those used in
251 Experiment 1.

252 **First choice.** Chicks confirmed the preference for hollow stimuli (Chi-square test: $\chi = 17.06$, df
253 $= 1$, $P < 0.001$).

254 **Hollow preference.** Considering the Hollow preference index we did not observe any
255 significant Sex difference (Kruskal-Wallis test: $H = 1.46$, $df = 1$, $P = 0.23$) but an overall
256 preference for the Hollow stimulus (Mann-Whitney test: $V = 461$, $df = 1$, $P < 0.001$).

257

258 **Experiment 4: naïve chicks tested with Large hollow vs. Narrow hollow stimuli.**

259 To investigate whether the preference of young chicks for hollow objects was driven by the
260 possibility to hide inside hollow objects, we presented naïve dark-reared chicks with a choice
261 between Large (4 cm in diameter, large enough to hide a chick) and Narrow hollow stimuli
262 (2.5 cm in diameter, too small to hide a chick).

263 **First choice.** The number of chicks that approached the Large vs. Narrow stimulus was not
264 significantly different between Sexes (Chi-square test: $\chi = 0.14$, $df = 1$, $P = 0.71$), therefore we
265 collapsed the data from males and females together. There was no significant preference for
266 the Large or Narrow stimulus (Chi-square test: $\chi = 0.108$, $df = 1$, $P = 0.74$), suggesting that the
267 possibility to hide inside the Large hollow stimuli is not the main drive of the preference for
268 hollow stimuli.

269 **Narrow preference.** Considering the Narrow preference index we did not observe any
270 significant Sex difference (Kruskal-Wallis test: $H = 0.11$, $df = 1$, $P = 0.74$). Overall we observed
271 no significant preference for Large or narrow stimuli (Mann-Whitney test: $V = 1583.5$, $df = 1$, P
272 $= 0.56$).

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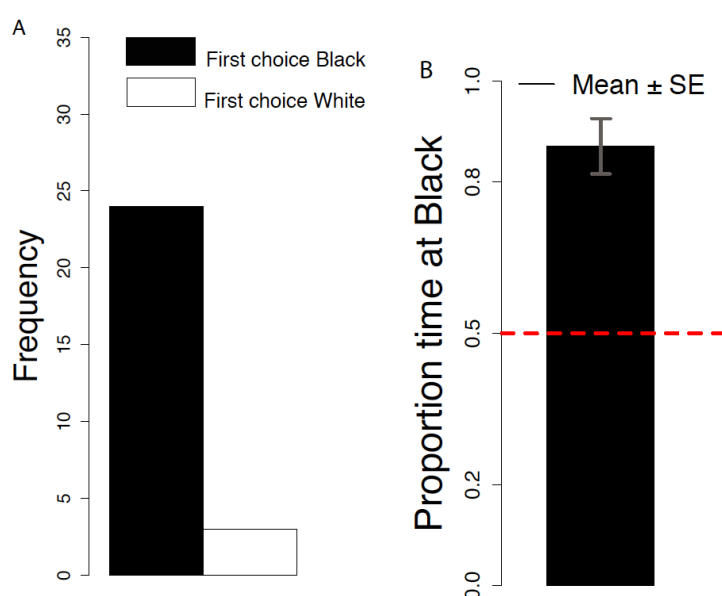
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275 **Experiment 5a: naïve chicks tested with filled White vs. filled Black stimuli.**

276 **First choice.** The number of chicks that approached the White vs. Black stimulus was not
277 significantly different between Sexes (Chi-squared test: $\chi = 0.12$, $df = 1$, $P = 0.73$), therefore we
278 collapsed the data from males and females together. We observed a significant preference for
279 the Black stimulus (Chi-squared test: $\chi = 16.33$, $df = 1$, $P < 0.001$), see Figure 5A.

280 **Black preference.** Considering the Black preference index, we did not observe any significant
281 Sex difference (Kruskal-Wallis test: $H = 0.066$, $df = 1$, $P = 0.80$). Overall we observed a
282 significant preference for the Black stimulus (Mann-Whitney test: $V = 354$, $df = 1$, $P < 0.001$),
283 see Figure 5B.

284



285

286 Figure 5. **A.** Number of chicks that first approached the Black or White stimulus. **B.** Proportion of time spent at
287 the Black stimulus.

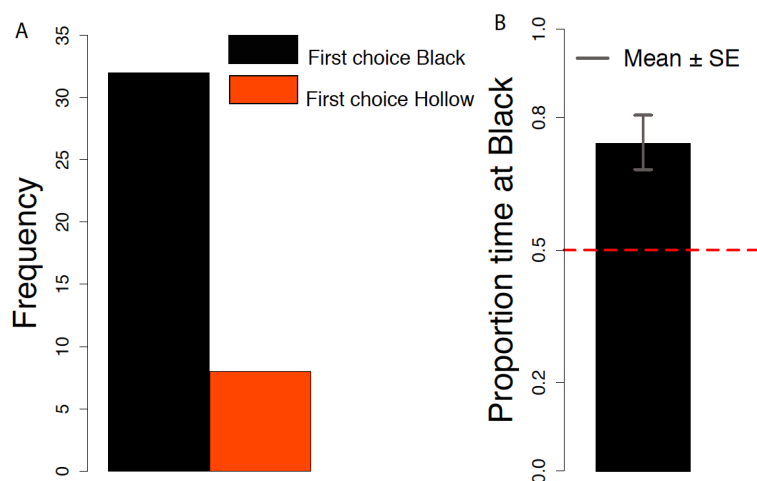
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289 **Experiment 5b: naïve chicks tested with filled Black vs. Hollow stimuli.**

290 **First choice.** The number of chicks that approached the Hollow vs. Black stimulus was not
291 significantly different between Sexes (Chi-squared test: $\chi = 0.307$, $df = 1$, $P = 0.58$), therefore
292 we collapsed the data from males and females together. We observed a significant preference
293 for the Black stimulus (Chi-squared test: $\chi = 14.4$, $df = 1$, $P < 0.001$), see Figure 6A.

294 **Black preference.** Considering the Black preference index we did not observe any significant
295 Sex difference (Chi-squared test: $\chi = 0.818$, $df = 1$, $P = 0.366$). Overall we observed a
296 significant preference for the Black stimulus (Mann-Whitney test: $V = 174$, $P < 0.001$), see
297 Figure 6B.

298



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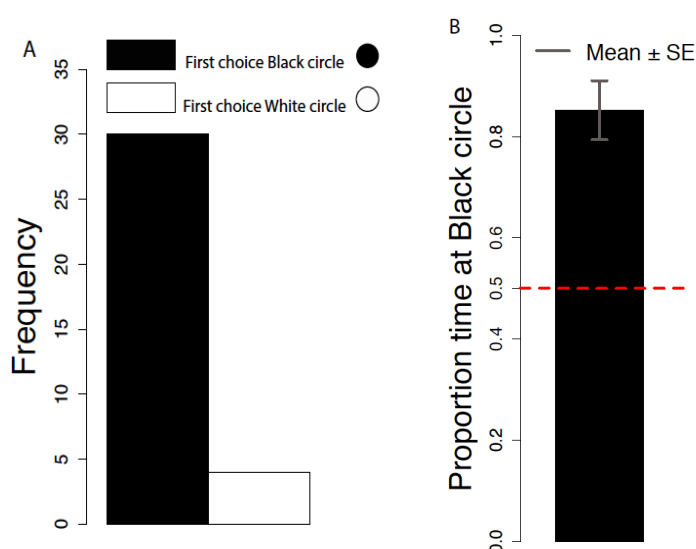
300 Figure 6. **A.** Number of chicks that first approached the Black or Hollow stimulus. **B.** Proportion of time spent at
301 the Black stimulus.

302

303 **Experiment 6: naïve chicks tested with a White disk on a black background vs. a Black**
304 **disk on a white background.**

305 **First choice.** The number of chicks that approached the White vs. Black disk was not
306 significantly different between Sexes (Chi-squared test: $\chi = 0.166$, $df = 1$, $P = 0.68$). Overall we
307 observed a significant preference for the Black stimulus (Chi-squared test: $\chi = 19.882$, $df = 1$, P
308 < 0.001), see Figure 7A.

309 **Black preference.** Considering the Black preference index we did not observe any significant
310 Sex difference (Kruskal-Wallis $\chi^2 = 0.65$, $df = 1$, $P = 0.42$). Overall we observed a significant
311 preference for the Black stimulus (Mann-Whitney test: $V = 519$, $df = 1$, $P < 0.001$), see Figure
312 7B.



313

314 Figure 7. **A.** Number of chicks that first approached the Black disk on a white background or the White disk on a
315 black background. **B.** Proportion of time spent at the Black disk on a white background.

316 **Discussion**

317 Sensory and cognitive predispositions can help naïve individuals in deciding whether to
318 approach or avoid novel objects (Versace and Vallortigara 2015). Chicks of the domestic fowl,
319 which belong to a precocial social species, appear to be endowed with predispositions to
320 approach animate social partners (Rosa Salva et al. 2015), given that in the absence of
321 previous experience, young individuals prefer to approach face-like configurations (Rosa-
322 Salva et al. 2010), self-propelled objects (Mascalzoni et al. 2010) and biologically-moving
323 objects (Vallortigara et al. 2005). For young chicks, approaching choices are particularly
324 important as they can influence imprinting. Filial imprinting is a process through which young
325 chicks develop a strong social attachment, including following responses, to the first
326 conspicuous objects they encounter in their life (for general reviews on chick's development
327 and imprinting see Rogers (1995), Bolhuis (1991) and McCabe (2013)). Although chicks can
328 imprint on a variety of objects – including both natural and artificial objects –, specific colours,
329 shapes, size and motion types induce stronger imprinting (see Introduction). Chicks'
330 predispositions produce a bias in favour of naturalistic objects compared to artificial objects,
331 as shown by the fact that once imprinted on a naturalistic object chicks cannot reverse their
332 preference for an artificial object (Boakes and Panter 1985; Bolhuis and Trooster 1988) or
333 have a delayed reversal (de Vos and van Kampen 1993), although the opposite seems to be
334 easier.

335 Little is known though on the spontaneous preferences of chicks for approaching hollow or
336 filled objects. This property can be particularly relevant to orient filial responses, because the
337 presence of innards is associated with animate objects (Gelman 1990), that in the wild include
338 social partners. Moreover, it has been observed that preschool children can reason about
339 inside and outside features of objects (Gelman and Wellman 1991), 14-month-old babies
340 associate an object's behaviour more with internal than with external features (Newman et al.
341 2008), and preverbal infants (8-month-old) expect animate objects to possess insides (Setoh
342 et al. 2013). In the case of human babies, spontaneous preferences in the absence of previous
343 experience with hollow or filled objects have not been assayed. We wondered whether the
344 mere presence/absence of visible innards might trigger spontaneous approach preferences of
345 young chicks for the first conspicuous objects encountered in their life, or whether experience
346 might bias chicks preferences about the innards of social partners. To this aim we tested naïve
347 and imprinted chicks using as hollow or filled objects orange cylinders of the size that can
348 elicit filial responses.

349 In our experiments we consistently observed a preference of naïve chicks for approaching
350 hollow objects. The same preference held for chicks that during imprinting had been exposed
351 to objects occluded on their sides, that therefore were not explicitly filled or hollow, but were
352 clearly approached. The preference for hollow objects was reduced when chicks were
353 imprinted for 24 hours on filled objects, suggesting that chicks are sensitive to this feature of
354 social partners, and that even a brief experience can modify preferences for hollow/filled
355 objects. Yet, we did not observe an increase of the preference for hollow objects after
356 imprinting on hollow objects, and difference in performance between chicks imprinted on
357 hollow and filled objects was not strong. This suggests that after imprinting takes place, the
358 difference between hollow and filled imprinting objects is less salient, namely that objects
359 that differ only for the property of being filled or hollow are not categorized as markedly
360 different.

361 To establish which property of hollow objects was attracting chicks we ran a series of
362 subsequent experiments to investigate whether chicks were attracted by hollow objects as
363 hiding cavities, and/or whether the brightness and contrast of hollow objects were attractive
364 cues that triggered exploration. Although inexperienced chicks spontaneously recognize the
365 properties of occluding objects, and search objects behind barriers that completely occlude
366 them (Chiandetti and Vallortigara 2011), in our experiments chicks did not prefer larger
367 hollow objects, in which they could more easily hide, to smaller hollow objects. This suggests
368 that the preference for hollow objects is not mainly driven by the possibility to hide into them.
369 On the contrary, chicks were more attracted by darker insides or darker “caps”. The attractive
370 feature of hollow objects could be either the darker part inside the object (its shadows, which
371 are a depth cue), or the higher contrast introduced by the presence of shadows. If the contrast
372 but not the lower brightness was attracting the chicks, we expected them to have no
373 preference when facing a choice between two scenes with the same (but opposite) contrast: a
374 white disk on a black background and a black disk on a white background. Instead, in this
375 setting chicks strongly preferred the black disk on a white background, suggesting that lower
376 brightness of an object but not the contrast per se is attractive for chicks.

377 To sum up, naïve chicks exhibited a consistent preference for hollow objects, which was
378 mainly mediated by the lower brightness on the insides, probably interpreted as a depth cue.
379 This preference could be modified by imprinting experience, simply by exposing chicks to a
380 filled object for 24 hours. At least for still objects such as the stimuli used in our experiments,
381 the property of being “filled” does not make objects more attractive as social partners for
382 chicks of the domestic fowl. Further experiments should clarify whether the preference for

383 hollow vs. filled objects is modified introducing cues of animacy, such as the presence of
384 movement or face configurations in the presented objects.

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386 REFERENCES

- 387 Boakes R, Panter D (1985) Secondary imprinting in the domestic chick blocked by previous
388 exposure to a live hen. *Anim Behav* 33:353–365. doi: 10.1016/S0003-3472(85)80059-2
- 389 Bolhuis JJ (1991) Mechanisms of avian imprinting: a review. *Biol Rev* 66:303–345. doi:
390 10.1111/j.1469-185X.1991.tb01145.x
- 391 Bolhuis JJ, Trooster WJ (1988) Reversibility revisited: stimulus-dependent stability of filial
392 preference in the chick. *Anim Behav* 36:668–674. doi: 10.1016/S0003-3472(88)80149-0
- 393 Chiandetti C, Vallortigara G (2011) Intuitive physical reasoning about occluded objects by
394 inexperienced chicks. *Proc R Soc B Biol Sci* 278:2621–7. doi: 10.1098/rspb.2010.2381
- 395 de Vos GJ, van Kampen HS (1993) Effects of primary imprinting on the subsequent
396 development of secondary filial attachments in the chick. *Behaviour* 3-4:245–263. doi:
397 10.1017/CBO9781107415324.004
- 398 Dekker T, Revadi S, Mansourian S, et al (2015) Loss of *Drosophila* pheromone reverses its role
399 in sexual communication in *Drosophila sukukii*. *Proc Biol Sci* 282:20143018. doi:
400 10.1098/rspb.2014.3018
- 401 Fabricius E, Boyd H Experiments on the following-reaction of ducklings. *Wildfowl Trust Annu*
402 *Rep* 84–89.
- 403 Gelman R (1990) First principles organize attention to and learning about relevant data:
404 Number and the animate-inanimate distinction as examples. *Cogn Sci* 14:79–106. doi:
405 10.1016/0364-0213(90)90027-T
- 406 Gelman SA, Wellman HM (1991) Insides and essences: Early understandings of the non-
407 obvious. *Cognition* 38:213–244.
- 408 Giurfa M, Nunez J, Chittka L, Menzel R (1995) Colour preferences of flower-naive honeybees. *J*
409 *Comp Physiol A*. doi: 10.1007/BF00192415
- 410 Ham AD, Osorio D (2007) Colour preferences and colour vision in poultry chicks. *Proc R Soc B*
411 *Biol Sci* 274:1941–8. doi: 10.1098/rspb.2007.0538
- 412 Horn G (1985) *Memory, imprinting, and the brain an inquiry into mechanisms*. Clarendon
413 *Press, Oxford*
- 414 Johnson MH, Horn G (1988) Development of filial preferences in dark-reared chicks. *Anim*
415 *Behav* 36:675–683. doi: 10.1016/S0003-3472(88)80150-7
- 416 Keesey IW, Knaden M, Hansson BS (2015) Olfactory Specialization in *Drosophila sukukii*

- 417 Supports an Ecological Shift in Host Preference from Rotten to Fresh Fruit. *J Chem Ecol*.
418 doi: 10.1007/s10886-015-0544-3
- 419 Knaden M, Strutz A, Ahsan J, et al (2012) Spatial Representation of Odorant Valence in an
420 Insect Brain. *Cell Rep* 1:392–399. doi: 10.1016/j.celrep.2012.03.002
- 421 Mascalzoni E, Regolin L, Vallortigara G (2010) Innate sensitivity for self-propelled causal
422 agency in newly hatched chicks. *Proc Natl Acad Sci U S A* 107:4483–5. doi:
423 10.1073/pnas.0908792107
- 424 McCabe BJ (2013) Imprinting. *Wiley Interdiscip Rev Cogn Sci* 4:375–390. doi:
425 10.1002/wcs.1231
- 426 Miura M, Matsushima T (2016) Biological motion facilitates imprinting.
- 427 Newman GE, Herrmann P, Wynn K, Keil FC (2008) Biases towards internal features in infants’
428 reasoning about objects. *Cognition* 107:420–32. doi: 10.1016/j.cognition.2007.10.006
- 429 Raine NE, Chittka L (2007) The Adaptive Significance of Sensory Bias in a Foraging Context:
430 Floral Colour Preferences in the Bumblebee *Bombus terrestris*. *PLoS One* 2:e556. doi:
431 10.1371/journal.pone.0000556
- 432 Rogers LJ (1995) *The Development of Brain and Behaviour in the Chicken*. CAD International,
433 Wallingford
- 434 Rosa Salva O, Mayer U, Vallortigara G (2015) Roots of a social brain: Developmental models of
435 emerging animacy-detection mechanisms. *Neurosci Biobehav Rev* 50:150–168. doi:
436 10.1016/j.neubiorev.2014.12.015
- 437 Rosa-Salva O, Regolin L, Vallortigara G (2010) Faces are special for newly hatched chicks:
438 evidence for inborn domain-specific mechanisms underlying spontaneous preferences
439 for face-like stimuli. *Dev Sci* 13:565–77. doi: 10.1111/j.1467-7687.2009.00914.x
- 440 Schaefer H, Hess H (1951) Color Preferences in Imprinting Objects. *Z Tierpsychol* 16:161–172.
- 441 Schulman AH, Hale BE, Graves H. (1970) Visual stimulus characteristics for initial approach
442 response in chicks (*Gallus domesticus*). *Anim Behav* 18:461–466.
- 443 Setoh P, Wu D, Baillargeon R, Gelman R (2013) Young infants have biological expectations
444 about animals. *Proc Natl Acad Sci U S A* 110:15937–42. doi: 10.1073/pnas.1314075110
- 445 Vallortigara G (2012a) Core knowledge of object, number, and geometry: A comparative and
446 neural approach. *Cogn Neuropsychol* 29:213–236. doi: 10.1080/02643294.2012.654772
- 447 Vallortigara G (2012b) Aristotle and the chicken: Animacy and the origins of beliefs. In: Fasolo
448 A (ed) *The Theory of Evolution and its Impact*. Springer International Publishing, New
449 York, pp 189–200
- 450 Vallortigara G, Regolin L, Marconato F (2005) Visually inexperienced chicks exhibit

451 spontaneous preference for biological motion patterns. PLoS Biol 3:e208. doi:
452 10.1371/journal.pbio.0030208

453 Versace E, Reisenberger J (2015) Large-scale assessment of olfactory preferences and
454 learning in *Drosophila melanogaster*: behavioural and genetic components. PeerJ
455 3:e1214. doi: 10.7717/peerj.1214

456 Versace E, Vallortigara G (2015) Origins of knowledge: Insights from precocial species. Front
457 Behav Neurosci 9:338. doi: 10.3389/fnbeh.2015.00338

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