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**There is no Other Monkey in the Mirror for Spider Monkeys (*Ateles geoffroyi*)**

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## 23 Abstract

24 Mirror self-recognition (MSR), usually considered a marker of self-awareness, occurs in several  
25 species and may reflect a capacity that has evolved in small incremental steps. In line with  
26 research on human development and building on previous research adopting a gradualist  
27 framework, we categorized the initial mirror responses of naïve spider monkeys (*Ateles*  
28 *geoffroyi*) according to four levels. We compared social, exploratory, contingent and self-  
29 exploratory responses to a mirror and faux mirror during three short trials. If spider monkeys  
30 respond as most monkey species, we predicted they would perform at level 0, mainly showing  
31 social behavior toward their mirror-image. However, because spider monkeys show  
32 enhancement of certain cognitive skills comparable to those of great ape species, we predicted  
33 that they would perform at level 1a (showing exploratory behavior) or 1b (showing contingent  
34 behavior). GLMMs revealed that monkeys looked behind and visually inspected the mirror  
35 significantly more in the mirror than the faux mirror condition. Although the monkeys engaged  
36 in contingent body movements at the mirror, this trend was not significant. Strikingly, they  
37 showed no social behaviors toward their mirror-image. We also measured self-scratching as an  
38 indicator of anxiety and found no differences in frequencies of self-scratching between  
39 conditions. Therefore, in contrast to most findings on other species, spider monkeys did not  
40 treat their image as another monkey during their initial exposure to the mirror. In fact, they  
41 reached at least level 1a within minutes of mirror exposure. These responses recommend spider  
42 monkeys as good candidates for further explorations into monkey self-recognition.

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44 *Keywords:* spider monkeys, mirror self-recognition, self-awareness, gradualist framework

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47           There is no Other Monkey in the Mirror for Spider Monkeys (*Ateles geoffroyi*)

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49           Several studies have investigated whether species recognize themselves in the mirror  
50 (reviewed in Anderson & Gallup, 2015; de Veer & van den Bos, 1999). The interest in mirror  
51 self-recognition (MSR) largely stems from the fact that MSR is usually considered a marker of  
52 self-awareness (e.g., Gallup, 1982; Anderson & Gallup, 2011), which implies ownership of a  
53 self-concept and the ability to distinguish between the self and others, and may be highly  
54 adaptive in group-living species (Bekoff & Sherman, 2003; Cenami Spada et al., 1995). To  
55 date, clear evidence of MSR occurs in relatively few species, including great apes (e.g.,  
56 Anderson, 1994; Anderson & Gallup, 1999; Gallup, 1970; Gallup et al., 2011), bottlenose  
57 dolphins (*Tursiops truncatus*: Reiss & Marino, 2001), Asian elephants (*Elephas maximus*:  
58 Plotnik et al., 2006), and Eurasian magpies (*Pica pica*: Prior et al., 2008), although often only in  
59 a limited number of individuals of those species. Other species, in contrast, show no evidence of  
60 MSR, failing to spontaneously recognize their image in a mirror (e.g., monkeys: see Anderson  
61 & Gallup, 2015 for a review; parrots: van Buuren et al., 2018).

62           When exposed to a mirror, monkeys typically persist in perceiving their mirror-image as  
63 an unfamiliar conspecific, even when given extended exposure and other facilitating cues such  
64 as paired exposure (Gallup et al., 1980). In an experiment with brown capuchin monkeys  
65 (*Sapajus apella*), de Waal et al., 2005) challenged the view that the monkeys were responding  
66 as they would to unfamiliar conspecifics. A similar response occurs in cichlid fish  
67 (*Astatotilapia burtoni*: Desjardins & Fernald, 2010).

68           A gradualist framework of the evolution of cognitive skills in small incremental steps  
69 has been proposed to explain the variety of behaviors displayed by different taxa during mirror  
70 exposure (e.g., de Waal, 2019; de Waal et al., 2005; de Waal & Ferrari, 2010; Murray, 2020).  
71 This gradualist framework can better explain behaviors toward a mirror, such as aggressive

72 responses in some bird and monkey species, to quick habituation in dogs and cats, to its  
73 instrumental use by some monkeys and parrots, and to self-exploration in great apes (see de  
74 Waal, 2019, for a review; Murray, 2020). This framework also explains why some species show  
75 some evidence of MSR after intensive training (e.g., Chang et al., 2015).

76 In line with research on human development (e.g., Rochat, 2001, 2003), in non-human  
77 species, naïve individuals' responses to mirror exposure can be categorized according to  
78 different levels. Here, we build on previous research (e.g., de Waal et al., 2005; Inoue-  
79 Nakamura, 1997; Murray, 2020; Plotnik et al., 2006) to define the following four levels. Level 0  
80 consists of individuals responding to their mirror image as they would to a conspecific, showing  
81 aggressive and/or affiliative behavior. Level 1a consists of individuals exploring the mirror  
82 without showing any aggressive and/or affiliative behavior. At level 1b, individuals start  
83 connecting their image with their own body, performing unusual and repetitive behaviors in  
84 front of the mirror, as if testing the contingencies between their body movements and those of  
85 the image in the mirror. Finally, at level 2, individuals show self-exploration of body parts  
86 which are not visible without a mirror. Individuals can also be tested for level 2 by marking  
87 them with paint on the forehead and examining whether they touch the paint in their altered  
88 image reflected in the mirror (e.g., Anderson & Gallup, 2011; Gallup, 1970).

89 We used the gradualist framework to evaluate spider monkeys' (*Ateles geoffroyi*) initial  
90 responses to their image in a mirror. Spider monkeys are an interesting species to test for levels  
91 higher than 0 because they show enhancement of certain cognitive skills comparable to great  
92 ape species (e.g., Amici et al., 2008, 2010; Amici et al., 2018; Deaner et al., 2006), including  
93 human-like holistic face processing (Taubert, 2010). Here, we assessed the response level of  
94 seven spider monkeys to a brief exposure to a mirror and a faux mirror, by comparing their  
95 social, exploratory, contingent and self-exploratory behaviors between the two conditions. We  
96 kept the mirror exposure brief (5 minutes for each trial, for a total of three trials) as we focused

97 on spider monkeys' response level to the initial mirror exposure. If spider monkeys respond as  
98 most monkey species, we predicted they would perform at level 0 by mainly showing social  
99 behavior toward their image in the mirror. However, if their responses to mirror exposure are  
100 related to the enhancement of cognitive skills, we predicted that they would perform at levels  
101 1a, 1b or 2 by showing exploratory, contingent and self-exploratory behaviors, respectively.

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## Method

### 104 Subjects and Study Site

105 We tested seven sexually mature spider monkeys (four females, three males) housed at  
106 the Centenario Zoo in Merida, Mexico. They were wild born but were raised as pets before  
107 being rescued and brought to the zoo. Spider monkeys were housed in well-established groups  
108 in enclosures with outdoor and indoor areas. All subjects were used to being temporarily  
109 isolated in the area of their enclosure where a familiar experimenter (FeA) individually tested  
110 them. They had all previously participated in experimental tasks, but none of them had  
111 previously been tested with a mirror, although we cannot exclude that they had been  
112 inadvertently exposed to mirrors while they were kept as pets. Subjects participated in the trials  
113 on a voluntary basis. Before and during testing, they were not deprived of food or water at any  
114 time. The experimental protocols provided spider monkeys with a form of enrichment and were  
115 approved by the Centenario Zoo and the University of Chester's School of Psychology Ethics  
116 Committee.

### 117 Materials

118 A Clark's 600 mm x 450 mm safety mirror was used; this had a stainless steel polished  
119 mirror quality surface on one side (used for the Mirror condition) and a non-reflecting brushed  
120 steel surface on the reverse side, in which it was not possible to see reflections of forms, shapes

121 or colors (used for the Faux mirror condition). Febreze odor neutralizing spray was applied  
122 between each trial to prevent olfactory cues.

### 123 **Procedure**

124 Subjects were tested alone in the familiar testing room. We used two rings to hang a  
125 mirror in the testing room, so that subjects could peer behind it, but not move it. Subjects  
126 received a small food reinforcement for entering the testing room and one at the end of the trial  
127 before being released into the home enclosure. We administered two different conditions each  
128 lasting 5 minutes. In the Mirror condition, the mirror was hanging in the testing room, with the  
129 reflecting stainless polished surface facing the subject. In the Faux mirror condition, the mirror  
130 was hung in the same position but with the non-reflecting brushed steel surface facing the  
131 subject. All individuals received 3 trials for the Mirror condition and 3 for the Faux mirror  
132 condition. The presentation of mirror type was counterbalanced, with some subjects starting  
133 with the Mirror and some with the Faux mirror condition.

### 134 **Coding**

135 All trials were video-recorded, and later coded from the videos by two observers (i.e.,  
136 CMS and LM). Cohen's weighted kappa tests were run to determine the level of agreement  
137 between coders. Sampling one subject across two conditions, perfect agreement was found for  
138 facial orientation ( $k = 1.000$ ;  $p < .0001$ ), and very high agreement was found for overall  
139 behavioral classification ( $k = 0.811$ ;  $p < .0001$ ). We coded affiliative and agonistic behaviors,  
140 indicative of level 0; exploratory behaviors, indicative of level 1a; contingent behaviors  
141 (defined as visual alternation from the body part to the mirror, including slowly waving the  
142 hand, moving slowly forward and backward, moving one leg slowly while standing on the other  
143 foot), indicative of level 1b; and self-exploratory behaviors, indicative of level 2 (Table 1).  
144 These behaviors were recorded when directed toward the mirror in the Mirror condition and  
145 toward the non-reflecting side of the mirror in the Faux mirror condition. In addition, we coded

146 self-scratching as a potential indicator of anxiety (see Maestripietri et al., 1992 and Schino et al.,  
147 1996 for evidence in other species; Table 1). All behaviors were coded as duration (i.e. total  
148 seconds spent in the behavior during the 5-minute trial), except for look behind and self-  
149 scratching, which were coded as frequency (i.e. total counts during the 5-minute trial).

150 (Insert Table 1 here)

## 151 **Statistical analyses**

152 Analyses were conducted using generalized linear mixed models (GLMMs: Baayen et  
153 al., 2008) with the lme4 package in R (version 3.5.0; Bates, 2010). In each GLMM the  
154 frequency or the time spent in one of the behavioral responses listed in Table 1 was the  
155 dependent variable (following a Gaussian distribution, with normally distributed and  
156 homogeneous residuals) and condition (Mirror or Faux mirror) was the predictor variable. In  
157 each model, we included the subject's sex (i.e. male or female) and trial number (i.e. 1 to 3) as  
158 control fixed factors, and the subject's identity as random factor. We compared full and null  
159 models using a likelihood ratio test (Chatfield et al., 2002). In case of a significant difference  
160 between full and null models, we conducted likelihood ratio tests to obtain the  $p$  values for each  
161 test predictor via single-term deletion (Barr et al., 2013). No convergence or stability issues  
162 were detected (except for some convergence issues in one model, see below).

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## **Results**

166 *Level 0 – Social behaviors.* Monkeys showed no social behaviors (i.e., agonistic  
167 behavior, affiliative behavior, fear) toward their image in the mirror, in any trial. No model was  
168 therefore run.

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170           *Level 1a – Exploration.* Six of the seven monkeys looked behind the mirror with a mean  
171 latency of 49 seconds in trial 1 (videos 1-3 in SM). The comparison between the full and null  
172 model for looking behind the mirror was significant (GLMM:  $\chi^2 = 6.30$ ,  $df = 1$ ,  $p = .012$ );  
173 monkeys looked behind the mirror more often than the faux mirror (Table 2; Figure 1). The  
174 comparison between the full and null model for physical inspection of the mirror was not  
175 significant (GLMM:  $\chi^2 = 0.58$ ,  $df = 1$ ,  $p = .445$ ; see Table 2), suggesting no differences in the  
176 physical inspection of either the mirror or the faux mirror between the two conditions. All seven  
177 monkeys engaged in visual inspection of the mirror, with a mean latency of 34 seconds in trial 1  
178 (videos 1-4 in SM). For visual inspection of the mirror, the comparison between the full and  
179 null model was significant (GLMM:  $\chi^2 = 4.21$ ,  $df = 1$ ,  $p = .040$ ); monkeys visually inspected the  
180 mirror more often than the faux mirror (Table 2; Figure 1). In all instances of look behind and  
181 visual inspection of the mirror, the monkeys did not do anything else than move around their  
182 enclosure prior to approaching the mirror.

183

184           (Insert Table 2 here)

185           (Insert Figure 1)

186           *Level 1b – Contingent behaviors.* Four of the seven monkeys showed contingent body  
187 movements in front of the mirror with a mean latency of 58 seconds in trial 1 (videos 1, 3 and 4  
188 in SM). The comparison between the full and null model did not reach significance (GLMM:  $\chi^2$   
189 = 3.33,  $df = 1$ ,  $p = .068$ ) but the tendency was for the subject to have a higher probability of  
190 performing contingent body movements in the Mirror condition than in the Faux mirror  
191 condition (Table 2; Figure 1, video 2 in SM). Monkeys showed no contingent facial movements  
192 in any trial, so no model was run for this variable.

193



219 behavior. Our result on social behaviors contrasts with research on other species, which failed to  
220 immediately differentiate their mirror image from that of a conspecific, and often showed social  
221 behaviors even after several hours of mirror exposure. Social behaviors during initial mirror  
222 exposure occur in other New World monkey species (e.g., cotton-top tamarins, *Saguinus*  
223 *oedipus*, and squirrel monkeys, *Saimiri sciureus*: Inoue-Nakamura, 1997; brown capuchin  
224 monkeys, *Sapajus apella*: Anderson & Roeder, 1989; de Waal et al, 2005), by several species of  
225 macaques (e.g., rhesus macaques, *Macaca mulatta*: Inoue-Nakamura, 1997; Rajala et al., 2010;  
226 Suarez & Gallup, 1986; long-tailed macaques, *M. fascicularis*: Gallup, 1977; stump-tailed  
227 macaques, *M. arctoides*; Anderson, 1983; bonnet macaques, *Macaca radiata*: Inoue-Nakamura,  
228 1997; but see Japanese macaques, *M. fuscata*: Inoue-Nakamura, 1997) and by gibbons  
229 (*Hylobates*, *Symphalangus* and *Nomascus spp.*; Inoue-Nakamura, 1997; Suddendorf & Collier-  
230 Baker, 2009; Ujhely et al, 2000). Remarkably, all four great apes exhibit some social behavior  
231 during initial mirror exposure (e.g., Inoue-Nakamura, 1997 for chimpanzees, *Pan troglodytes*,  
232 gorillas, *Gorilla gorilla*, and orangutans, *Pongo pygmaeus*; Walraven et al, 1995 for bonobos,  
233 *Pan paniscus*). Gallup (1970), for example, reported that chimpanzees repeatedly engaged in  
234 social behaviors towards their mirror image, with a substantial reduction only after around 20  
235 hours of mirror exposure.

236           Very few studies to date have shown a lack of social responses during initial mirror  
237 exposure: bottlenose dolphins (Reiss & Marino, 2001), Asian elephants (Plotnik et al., 2006),  
238 and Western gorillas (Posada & Colell, 2007). Therefore, the performance of spider monkeys in  
239 our study is remarkable. Although our study only provides a preliminary understanding of  
240 spider monkeys' reaction to mirrors, it is noteworthy given that spider monkeys already show  
241 cognitive skills comparable to those of great apes (e.g., Amici et al., 2008, 2010; Amici et al.,  
242 2018; Deaner et al., 2006).

243           Secondly, spider monkeys looked behind and visually inspected the mirror more often  
244 than they did the faux mirror. Our results suggest that spider monkeys reached level 1a in trial  
245 1, after less than a minute of mirror exposure. Although four of the seven monkeys engaged in  
246 some contingent body movements while facing the mirror within a minute of mirror exposure,  
247 we found no significant difference between the mirror and the faux mirror conditions. This is  
248 something requiring further investigation, considering that contingent behaviors have been  
249 taken as evidence of level 1b (e.g., de Waal et al., 2005; Inoue-Nakamura, 1997; Plotnik et al.,  
250 2006). The spider monkeys showed no evidence of self-exploration (i.e. level 2), which is  
251 unsurprising given the reduced exposure to the mirror. Importantly, the different responses  
252 shown by spider monkeys in the mirror condition compared to the faux mirror condition cannot  
253 be explained by differences in individuals' anxiety. Indeed, subjects did not differ in the self-  
254 scratching rate between conditions.

255           Our study provides a first assessment of spider monkeys' response to mirrors, which  
256 revealed that spider monkeys reach at least level 1a after only minutes of mirror exposure.  
257 Future studies should investigate spider monkeys' response to mirrors by focusing on the  
258 following aspects. Firstly, our findings of no occurrence of social behavior should be replicated  
259 with subjects that were not previous pets. Although in the Yucatan peninsula spider monkey  
260 pets are usually kept outdoors, where mirrors are typically absent, some experience with mirrors  
261 could have influenced our study subjects' performance. Secondly, future studies should include  
262 observation of spider monkeys' reactions to other monkeys to directly compare mirror  
263 responses with how monkeys typically interact with one another. Thirdly, subjects should be  
264 tested for a longer time, and with alternative stimuli such as video proxies of the mirror, to  
265 evaluate whether spider monkeys reach further levels of response to mirror exposure. Should  
266 spider monkeys perform like dolphins, elephants and great apes, there will be further support to

267 the view that spider monkeys show an enhancement of certain cognitive skills. Such discovery  
268 will also provide renewed impetus for a revised perspective on MSR.

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**Table 1**

*Behavioral responses (adapted from Povinelli et al., 1993) according to Self-Recognition (SR) continuum framework (Murray, 2020)*

Level	Behavioral responses	Description
L0 - No self-recognition	Agonistic behavior	Subject shows aggressive behaviors toward the mirror (e.g., threat faces, charging)
	Social behaviors	Fear Subject shows grimaces, escape behavior and/or squeals  Affiliative behavior Subject shows affiliative behaviors toward the mirror (e.g., face greeting, tee-tee vocalizations, play invitations, sexual presentations)
L1a – Differentiated responses to mirror	Look behind	Subject lifts the mirror to inspect its back or peers over its edge to view its reverse side
	Exploration	Mirror physical inspection Subject touches the mirror with hands, feet, mouth, nose or tail  Mirror visual inspection Subject explores the mirror by looking at it without touching it
L1b - Differentiated responses to video (or mirror) including contingency-checking	Contingent behaviors	Contingent body movements Subject makes purposeful or repetitious body movements, while facing the mirror (e.g., the subject's face is oriented toward its body, then to the mirror and back; hands or arms are slowly waved in front of the mirror; side to side or backward/forward body movements in front of the mirror)  Contingent facial movements Subject makes unusual face movements, while facing the mirror
	L2 – Self-exploratory behavior	Body self-exploration
Self-exploration		Face self-exploration Subject uses fingers, hand or tail to examine its face or mouth, while facing the mirror
Anxiety indicator	Self-scratching	Subject repeatedly rubs its body with the fingers

*Note.* All behaviors were coded as duration (in seconds), except for look behind and self-scratching, which were coded as counts. For self-scratching, a new event was scored after a pause of 5 seconds.

**Table 2**

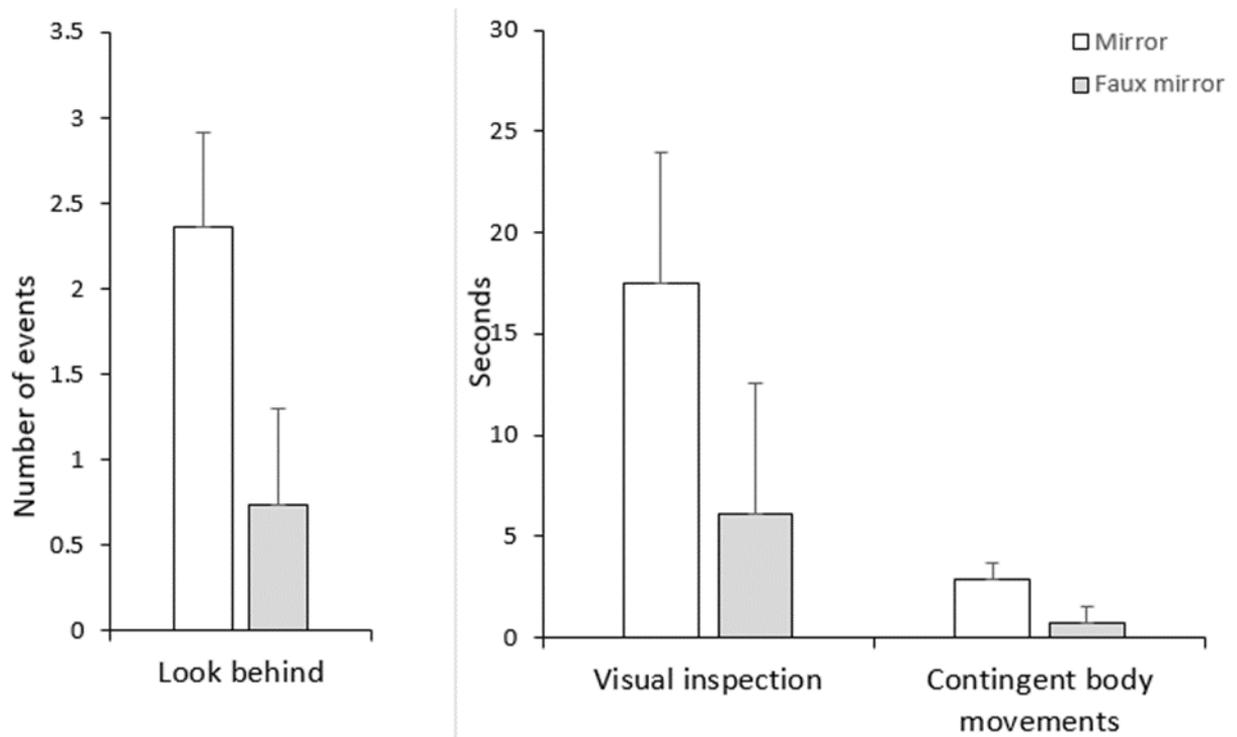
*Results of GLMM models, including estimates, standard errors (SE), confidence intervals (CIs), likelihood ratio tests (LRT), degrees of freedom (df) and P values*

	Estimate	SE	2.5% CI	97.5% CI	LRT	df	P
<b><u>Looking behind</u></b>							
Intercept	2.85	1.10	0.81	4.89	-	-	-
<b>Condition</b>	1.62	0.63	0.38	2.86	6.30	1	<b>0.001</b>
Trial number	-1.14	0.39	-1.90	-0.38	8.15	1	0.002
Sex	0.35	1.08	-1.71	2.40	0.14	1	0.704
<b><u>Physically inspecting</u></b>							
Intercept	8.40	3.88	1.03	15.77	-	-	-
Condition	-1.90	2.59	-6.89	3.08	0.58	1	0.445
Trial number	-2.54	1.58	-5.59	0.51	2.69	1	0.101
Sex	3.13	2.80	-1.91	8.16	1.50	1	0.220
<b><u>Visually inspecting</u></b>							
Intercept	16.07	10.52	-3.42	35.55	-	-	-
<b>Condition</b>	11.38	5.54	0.53	22.23	4.21	1	<b>0.040</b>
Trial number	-7.61	3.40	-14.25	-0.96	4.96	1	0.026
Sex	10.57	11.51	-11.44	32.58	1.09	1	0.296
<b><u>Contingent body movements</u></b>							
Intercept	3.99	1.79	0.58	7.40	-	-	-
Condition	2.14	1.21	-0.16	4.45	3.33	1	0.068
Trial number	-2.07	0.74	-3.48	-0.66	7.86	1	0.005
Sex	1.69	1.22	-0.64	4.03	2.07	1	0.150
<b><u>Self-scratching</u></b>							
Intercept	2.29	0.94	0.53	4.04	-	-	-
Condition	0.19	0.58	-0.94	1.32	0.12	1	0.734
Trial number	-0.86	0.35	-1.55	-0.16	5.73	1	0.017
Sex	0.56	0.83	-1.04	2.15	0.60	1	0.440

*Note.* Significant effects of test predictors are in bold.

**Figure 1**

*Estimated marginal means (+ SE) of the probability of looking behind the mirror/faux mirror, visually inspecting the mirror/faux mirror and performing contingent body movements in the Mirror condition and in the Faux mirror condition*



## Supplementary Materials

### Video 1

*Spider monkey engaged in Visual inspection, Contingent body movement, Look behind and Self-scratching in front of the mirror*

### Video 2

*Spider monkey engaged in Visual inspection, Look behind and Physical inspection of the mirror*

### Video 3

*Spider monkey engaged in Visual inspection, Look behind, Contingent body movement and Physical inspection of the mirror*

### Video 4

*Spider monkey engaged in Visual inspection and Contingent body movement in front of the mirror*