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1 **Mirror self-recognition: A review and critique of attempts to promote and**
2 **engineer self-recognition in primates**

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26

27 **Abstract**

28

29 We review research on reactions to mirrors and self-recognition in nonhuman
30 primates, focusing on methodological issues. Starting with the initial demonstration in
31 chimpanzees in 1970 and subsequent attempts to extend this to other species, self-
32 recognition in great apes is discussed with emphasis on spontaneous manifestations of
33 mirror-guided self-exploration as well as spontaneous use of the mirror to investigate
34 foreign marks on otherwise nonvisible body parts – the mark test. Attempts to show
35 self-recognition in other primates are examined with particular reference to the lack of
36 convincing examples of spontaneous mirror-guided self-exploration, and efforts to
37 engineer positive mark test responses by modifying the test or using conditioning
38 techniques. Despite intensive efforts to demonstrate self-recognition in other primates,
39 we conclude that to date there is no compelling evidence that prosimians, monkeys, or
40 lesser apes – gibbons and siamangs – are capable of mirror self-recognition.

41

42 **Keywords:** Great apes, lesser apes, monkeys, self-recognition, awareness, mirror-
43 guided behavior, mark test

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51 **Introduction**

52 The demonstration of visual self-recognition in chimpanzees (Gallup 1970) prompted
53 sustained interest and controversy in the field of comparative psychology. The
54 knowledge that humans' nearest evolutionary relatives are sufficiently self-aware to
55 be able to understand how they look from another visual perspective (i.e., their
56 reflection in a mirror) helped pave the way for important empirical and theoretical
57 developments, including experimental approaches for assessing theory of mind in
58 great apes (Premack and Woodruff 1978). Like theory of mind, however, self-
59 recognition continues to be a contentious issue among anthropologists, biologists,
60 philosophers and psychologists. Some authors resist the idea that the capacity for self-
61 recognition is not uniquely human, raising methodological issues (e.g., Heyes 1994).
62 However, methodological refinements along with empirical and theoretical advances
63 have led to repeated replication and confirmation of the capacity for self-recognition
64 in great apes (Gallup et al. 1995; Povinelli et al. 1997). Gallup (1970) also reported
65 that, unlike chimpanzees, macaque monkeys showed no evidence of self-recognition;
66 he concluded that: "the capacity for self-recognition may not extend below man and
67 the great apes" (p. 87). This proposal has stimulated many attempts to find self-
68 recognition in other species; indeed some authors have gone to extraordinary lengths
69 in an effort to marshal support for continuity in cognitive capacities among species.
70 The alternative view -- that fundamental qualitative differences in cognition might
71 have evolved within the Primate order, including self-awareness, has been repeatedly
72 challenged. Here, we review the history of research on responses to mirrors and self-
73 recognition in nonhuman primates, with special reference to recent claims for mirror
74 self-recognition in non-great ape species.

75 Perhaps just as significant as the evidence for self-recognition in chimpanzees
76 in Gallup's (1970) original study was the absence of such evidence in macaque
77 monkeys tested under identical conditions. When first confronted with their
78 reflections, both chimpanzees and macaques reacted as if they were in the presence of
79 an unfamiliar conspecific – a reaction that is typical of most visually capable
80 organisms (Gallup 1968; Anderson 1994). But whereas chimpanzees soon started to
81 use the reflection to carefully explore parts of their body that they could not normally
82 see, such as looking inside their mouth, removing mucous from the corner of an eye,
83 or investigating their ano-genital area (Fig. 1), similar spontaneous mirror-guided
84 self-exploration was never observed in macaques; the latter continued to direct social
85 responses towards the reflection, or simply ignored it as they habituated to the
86 presence of the “other monkey.”

87 After 10 days of mirror exposure, the chimpanzees and monkeys were
88 anesthetized and marked on their forehead and an ear using a nonirritant, odorless dye.
89 Upon recovery from anesthesia, in the absence of the mirror neither apes nor monkeys
90 made any effort to touch the marks, which confirmed that they were unaware of their
91 presence. When the mirror was reinstated, however, chimpanzees but not macaques
92 used the reflection to guide their fingers to the marks, which they then investigated.
93 This behavioral difference confirmed that the apes, but not the monkeys, understood
94 that the source of the individuals reflected in the mirror was themselves, corroborating
95 self-recognition seen in the apes' spontaneous mirror-guided self-exploration. In
96 addition, after touching the marks, the apes often examined and sniffed their fingers,
97 in an apparent attempt to gain further information about the strange marks that could
98 only be seen in the mirror.

Following Gallup's (1970) report, two lines of primate research on the broad topic of "mirror-image stimulation and self-recognition" emerged. One aimed to extend knowledge about self-recognition in great apes - its ontogenetic and phylogenetic distributions, its relationship to other manifestations of self-awareness, and factors influencing its expression. The other approach was was characterized by many investigations of the responses of other primate species to mirrors, often including tests for self-recognition. Below we review both lines of research.

Self-recognition in chimpanzees and orangutans

To test the hypothesis that visual self-recognition would be shared with another species of primates, Lethmate and Dürcker (1973) presented a mirror to two zoo-housed orangutans as well as six chimpanzees, and found little difference in their self-recognition: individuals of both species showed spontaneous mirror-guided self-exploration of otherwise nonvisible body regions, and both used the mirror to investigate otherwise visually inaccessible marks on their bodies. In contrast, four gibbons from two species, two tufted capuchin and two spider monkeys, two lion-tailed macaques, a Hamadryas baboon, and three mandrills all failed to show any signs of self-recognition; instead they showed only social responses to their reflection. Suarez and Gallup (1981) confirmed self-recognition in chimpanzees and an orangutan, and reported that one chimpanzee showed self-recognition after only four days of mirror exposure. This study also used an important control procedure originally introduced by Gallup, Wallnau and Suarez (1980) in a study of rhesus monkeys: in addition to a mark applied to a normally unseen body part such as the head, a similar mark was made on a directly visible area, such as the wrist. This procedure provided a logical means to discount a lack of curiosity and motivation to

124 touch unusual marks on their body as an explanation for the lack of any evidence for
125 self-recognition in the third species of great ape tested by Suarez and Gallup: lowland
126 gorillas (see below).

127 Several studies have investigated factors that might influence self-recognition
128 in great apes. Early social experience appears to be one such factor. Whereas wild-
129 born, group-raised chimpanzees responded to their reflection in the same fashion as in
130 Gallup's (1970) study, laboratory-born chimpanzees raised in isolation from an early
131 age failed to show any signs of self-recognition (Gallup et al. 1971). This work lent
132 support to Mead's (1934) view that the sense of self is shaped through social
133 experiences and interactions. Concerning the onset of self-recognition in human
134 infants, there is general agreement that the evidence becomes clear at around 16-24
135 months of age (Amsterdam 1972; Anderson 1984; Nielsen and Dissanayake 2004). A
136 sign-language-trained orangutan first showed convincing signs of mirror self-
137 recognition at the age of 3 years (Miles 1994), whereas non-sign-language trained
138 chimpanzees did so at around 2.5 years of age (Lin et al. 1992). Bard et al. (2006)
139 claim that chimpanzees may even show mirror-guided self-directed behaviors
140 suggestive of self-recognition by 24 months of age; these studies suggest a slightly
141 later ontogenetic emergence of self-recognition in great apes compared to typically
142 developing human infants. It should be noted, however, that the age 24 months
143 applied only when the definition of self-recognition was relaxed to include "any
144 mirror-guided self-touches." (Bard et al. 2006, p. 201); mark-directed responses
145 suggested a later emergence, at 28 months. But in the largest cross-sectional study to
146 date – testing 92 captive chimpanzees - Povinelli et al. (1993) found that the capacity
147 was far more developmentally delayed, with only one chimpanzee out of 46 who
148 ranged from 2 to 6 years of age showing mirror self-recognition. Signs of self-

149 recognition, consisting of either spontaneous mirror-guided self-exploration or
150 positive mark tests, were most commonly seen by Povinelli et al. (1993) among
151 adolescents and young adults (8-15 years), with chimpanzees in middle to later
152 adulthood showing fewer signs and less interest in their reflections. Until this
153 apparent age-related decline in cognitive ability starts to impair the capacity for self-
154 recognition, however, it appears to be a stable, enduring trait, as shown by a study of
155 two juvenile chimpanzees re-tested after a period of 1 year with no access to mirrors
156 (Calhoun and Thompson, 1988), and a re-test of 12 chimpanzees 8 years after an
157 initial assessment of their self-recognition ability (de Veer et al 2003). Using the same
158 criteria to measure self-recognition, the latter study found that 67% of the
159 chimpanzees showed the same reactions as when previously tested 8 years earlier.
160 The ability of chimpanzees to recognize themselves under different conditions of
161 mirror-image stimulation was reported by Kitchen et al. (1996). Six captive female
162 chimpanzees aged 7 to 14 years were presented with regular, convex, concave and
163 triptych (producing three images) mirrors. After confirming that all six apes passed
164 the mark test, the authors observed mirror-guided self-referenced behaviors during the
165 first exposure to all three kinds of distorting mirrors, which they concluded was
166 evidence of “a level of abstractional ability” with regard to their self-awareness.

167 It should be noted that, just as in humans, not all chimpanzees show evidence
168 of self-recognition (Gallup 1997; Gallup et al 2011). It is conceivable that intellectual
169 and/or personality-related factors might influence the initial responses shown toward
170 the reflection (e.g., aggression, submission, affiliation) in all species of great apes,
171 and also contribute to individual differences in whether the transition from social to
172 self-directed behavior eventually emerges.

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Insert Fig. 1 about here

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178 **Self-recognition in bonobos**

179 Responses to mirror-image stimulation by bonobos – the great ape species most
180 closely related to chimpanzees - were first described in 1994 (Hyatt and Hopkins
181 1994; Westergaard and Hyatt 1994). The majority of the bonobos tested showed
182 considerable interest in their reflection, and performed many more self-directed
183 behaviors in mirror-present than mirror-absent sessions; their behaviors were largely
184 indistinguishable from chimpanzees tested in similar conditions. In another study,
185 several members of a group of zoo-housed bonobos engaged in spontaneous mirror-
186 guided self-directed behaviors such as picking their nose and eye region, i.e., using
187 the reflection to investigate normally unseen body parts, and these behaviors were
188 shown on the first exposure to the mirror (Walraven et al. 1995). Although no mark
189 tests were conducted in these studies, it seems clear that like chimpanzees, bonobos
190 readily used the mirror to examine and inspect otherwise unobservable body parts,
191 and thus showed that they recognize themselves on the basis of “compelling instances”
192 of self-exploration as set out by Povinelli et al. (1993, p. 351).

193

194 **The gorilla enigma**

195 Given their phylogenetic closeness to chimpanzees and humans, the absence of
196 evidence for self-recognition in gorillas reported by Suarez and Gallup (1981) was
197 unexpected. Like other great apes tested by Suarez and Gallup, the gorillas initially
198 directed social responses to their reflection, a tendency that decreased across exposure

199 days. However, unlike chimpanzees and orangutans, none of the gorillas showed
200 spontaneous mirror-guided self-exploration. Despite an additional six days of
201 exposure to the mirror, during the mark test the gorillas showed avid interest in the
202 control mark on their wrist, but none of them investigated the mark on their brow that
203 could only be seen in the mirror.

204 Another failure to find evidence of self-recognition in zoo-housed gorillas was
205 reported by Ledbetter and Basen (1982), who gave each of a 10-year-old adult male
206 and an 11-year-old female almost 400 hours of mirror exposure. The male in
207 particular showed social responses - notably aggression - toward his reflection.
208 Although both individuals habituated to the mirror, no signs of self-recognition were
209 observed either in the form of spontaneous mirror-guided self-exploration or during a
210 formal mark test. Another two laboratory-housed gorillas showed very few social
211 responses toward their reflection and no mark-directed touching in a mark test
212 (Swartz & Evans, 1994).

213 In an attempt to facilitate the emergence of self-recognition in two adult zoo-
214 housed gorillas, Shillito et al. (1999) presented each ape with an angled-mirror
215 apparatus inspired by Anderson and Roeder (1989) that prevented them from making
216 direct eye contact with the reflection. It had been suggested that due to gorillas'
217 natural aversion to direct gaze, insufficient exploration of the reflected face could
218 account for their failure to learn that they themselves were the source of the reflection.
219 However, the gorillas never showed mirror-guided self-exploration during the angled
220 mirror exposure period (approximately 45 min per day for 33 days), nor did they
221 touch the mark on their head during a mark test. In contrast, both gorillas showed
222 extensive interest in marks on their wrists, indicating that their failure to investigate
223 the mark on their head in was not due to a general lack of interest in such marks.

Replacing angled mirrors with a flat mirror and eliminating possible interference due to the presence of human observers by conducting observations via video cameras made no difference: neither gorilla showed convincing signs of self-recognition.

Do the above studies show that, despite belonging to the primate family that is genetically closest to humans, gorillas are incapable of recognizing themselves in a mirror? There are claims for self-recognition in some individual gorillas. The American Sign Language-trained gorilla Koko was reported to groom her face, pick at her teeth and adorn herself in front of mirrors from the age of 3.5 years. When marked at 19 years of age, Koko almost never touched a target area of her head during sham-mark sessions, but did so almost 50 times when she was marked and could see herself in the mirror (Patterson and Cohn 1994). Those authors also described a 22-year-old zoo-housed male gorilla showing mirror-guided self-directed responses especially when his caretaker held the mirror, and Swartz and Evans (1994) claim that he responded positively on a mark test. Members of a zoo-housed group of gorillas were described as showing mirror-guided self-directed behaviors, and two individuals with marks on their face wiped the mark when looking in the mirror; (Parker, 1994) concluded that there were striking similarities in the responses of gorillas and chimpanzees to their reflections. A more strictly controlled marking procedure conducted on a 17-year-old male zoo-housed gorilla (“Xebo”) revealed significantly more mark-directed responses in the presence of the mirror than when there was no mirror present. As this positive outcome was obtained following an instance of manipulating his face while looking in the mirror, the authors concluded that gorillas are indeed capable of self-recognition (Posada and Colell 2007).

In another case study using a sham-marking control procedure, a 45-year-old male gorilla (Otto) showed the highest frequency mark-directed behaviors when the

mirror was present (Allen and Schwartz 2008), although he showed no mirror-guided self-explorations. Interestingly, neither Xebo nor Otto directed social responses toward their reflection when the mirror was first introduced. Another adult male gorilla (“Mopie”), who had failed to show any sign of self-recognition when tested by Shillito et al. (1999), was given additional exposure to his reflection and then tested using variants of the mark test (Shumaker and Swartz, 2002). Following training to peel colored stickers off the walls of his enclosure or his own body in exchange for a food reward, Mopie discovered a sticker on his head after looking in the mirror; he removed this sticker and exchanged it for food. When stickers were replaced by a beam from a laser pointer, Mopie soon learned to touch laser spots to receive rewards, and he touched one spot that appeared below his chin and that was visible only in the mirror; however, he did not respond to a laser spot on his head.

Training was also used in a study of a 26-year-old female gorilla who learned how to use a mirror to solve a discrimination task. She then reportedly passed a version of the mark test, though few details were given (Nicholson and Gould 1995). Finally, in a study consisting of a single mirror presentation to members of 12 nonhuman primate species, mirror-guided self-directed responses were reported in all four great apes species (chimpanzees, bonobos, gorillas and orangutans) (Inoue-Nakamura, 1997), but the report is short on details and no mark tests were conducted. In summary, although the evidence for self-recognition is mixed and less compelling for gorillas than for other great apes, the basic underlying capacity may be present in some individuals. It is possible that gorillas may be more susceptible to experiential and/or personality constraints on the spontaneous and unambiguous expression of self-recognition. Interestingly, in a cross-cultural study of toddlers living in four different sociocultural contexts, Kärtner et al. (2012) found that cross-cultural

differences in children's self-recognition behaviors was largely related to caretakers' emphasis on individuality and autonomy of the child. Although some researchers have assessed the role of maternal style in great apes on the behavioral development of offspring (e.g., Hemelrijk and de Kogel 1989; De Lathouwers M, Van Elsacker L 2004), potential effects on self-recognition have not yet been addressed. Povinelli (1994) suggested that unusual interventions such as enculturation and sign-language training might facilitate the emergence of otherwise dormant cognitive structures supporting the capacity for self-recognition in gorillas. It has also been argued that the capacity for self-recognition in gorillas may be in the process of being lost due to evolutionary changes in gorilla socioecology that no longer put a premium on mental state attribution in the context of competition for reproductive opportunities (Gallup, 1997). In concluding the review of the literature on gorillas, we note that in contrast to the situation for chimpanzees and orangutans, there is a marked lack of video evidence showing compelling self-recognition in gorillas. In view of its importance we urge those in possession of such material to make it publically available.

The search for self-recognition in other primates

Gallup (1970) assessed mirror-image reactions not only in chimpanzees but also in members of two Old World monkey species, rhesus and stump-tailed macaques. Upon initial exposure to their reflection the monkeys behaved much like the chimpanzees, showing strong but diminishing interest across days and initially frequent but declining social responses. Unlike chimpanzees, however, the monkeys never used the mirror to inspect normally unseen parts of their body, and none tried to touch the mark on their head when they saw their reflection during the mark test. These striking

ape-monkey differences in mirror-guided self-directed behavior led other researchers to begin searching for self-recognition in non-great ape primates. Multiple interventions and manipulations have been tried in attempts to obtain evidence that monkeys are capable of realizing that their behavior is the source of the behavior depicted in the mirror. In a previous review of “challenges” in self-recognition research on primates we summarized the various interventions and manipulations used in the first three decades of the field (Anderson & Gallup 1999). Procedures have included starting exposure to mirrors at a very early age (from birth or shortly thereafter), prolonging exposure to months or even years, allowing monkeys physical access instead of just visual access to mirrors, providing portable mirrors, using multiple fixed and/or angled mirrors, and allowing monkeys to see not only their own reflections but also those of other members of their group. Various combinations of these procedures have been used with bushbabies, lemurs, marmosets and tamarins, squirrel monkeys, capuchin monkeys, talapoin monkeys, baboons and several species of macaques, but none has resulted in any prosimian or monkey showing compelling and reproducible evidence that it recognized its own reflection.

Gibbons and siamangs

Primates of the family Hylobatidae (gibbons and siamangs) are estimated to have diverged from the great ape lineage 16-18 million years ago, and from macaques 29 million years ago (Carbone et al. 2014). From a cognitive evolutionary perspective these so-called lesser apes are often seen as a crucial intermediate case between Old World monkeys and great apes. Lethmate and Dückler (1973) reported only social responses to a mirror, and no self-directed responses in four zoo-housed gibbons belonging to two species. Inoue-Nakamura (1997) also reported no self-directed

responses in a pair of white-handed gibbons. In a study of mirror-image reactions in nine white-handed gibbons and one gibbon-siamang hybrid, Hyatt (1998) found no mark-directed behaviors during a mark-test, despite four of the gibbons receiving an additional 400 hours of mirror-image stimulation before the test. Ujhelyi et al. (2000) exposed three gibbons of three different species to a mirror in intermittent periods for up to a total of 10 days. Upon initial exposure the three individuals showed a range of reactions including some social behaviors. However, none of the gibbons responded to marks on their head in modified mark tests.

There has been one claim that siamangs show self-recognition (Heschl and Fuchsbichler, 2009). Following a negative mark test, the behavior of two 7-year-old siamangs toward a mirror was studied over a 90-day period. The authors reported a total of seven and five “truly self-referring behaviors in front of the mirror” for the male and female, respectively (p. 224). However, these behaviors were merely self-referenced behaviors that often occur in the absence of a mirror (e.g., scratching the head or face); the authors labeled them as “truly self-referring” simply because the siamangs were looking at the mirror for longer than 3 sec when they were performed. It is noteworthy that most of the instances consisted of self-scratching, which is widely accepted to be an indicator of increased tension or anxiety (Maestripieri et al. 1992) and often occurs in non-self-recognizing primates when they see their reflection, which can be perceived as an oddly behaving conspecific (Anderson, 1994). It is also unfortunate that the authors did not report similar occurrences of self-scratching of other body regions while the gibbons stared at the mirror; in any case there was nothing like the prolonged, careful mirror-mediated inspection of otherwise nonvisible regions that is typical of chimpanzees’ spontaneous self-exploration. In contrast to Heschl and Fuchsbichler’s claim, following an extensive series of

experiments with three species of hylobatids including siamangs, Suddendorf and Collier-Baker (2009) reached a quite different conclusion. Despite elaborate attempts to create incentives for passing the mark test, including the use of highly preferred cake icing as marks, all of the subjects failed the mark test, with none showing any evidence of being able to correctly decipher mirrored information about themselves. On the basis of these studies we conclude that there is no strong evidence that gibbons or siamangs are capable of self-recognition.

Attempts to engineer positive performance on the mark test

Many investigators overlook the fact that some of the strongest evidence for self-recognition in humans and great apes is their use of mirrors to engage in spontaneous, close inspection of normally unseen body parts. Instead, they focus their efforts into getting their subjects to perform what looks like a positive mark test response. Anderson and Gallup (1999) reviewed studies that included more direct manipulations of monkeys' experience with their reflections with this objective in mind. In this category are attempts to explicitly train monkeys to learn the correspondence between the reflected environment and the real one (for example, using reflections to find otherwise hidden objects), marking the subject on different parts of the body over several days, progressing from directly visible body marks to marks visible only via the mirror, rewarding the subject for touching marks, and increasing the saliency of the marks used during mark tests. In the remainder of this review we focus on some of these recent attempts to engineer self-recognition in monkeys.

One earlier claim for self-recognition in a small South American monkey, the cotton-top tamarin, deserves comment because it was the first such claim and as such

374 it received considerable publicity. Hauser et al. (1995) incorrectly asserted that
375 previous studies of self-recognition in monkeys had neglected the issue of whether
376 they would be interested in any marks on their bodies, and conducted mark tests with
377 tamarins in which the monkeys' natural crest of white hair on the head was dyed a
378 different color. A total of 13 mark-directed responses were reported in 5 tamarins thus
379 marked; however, serious doubts were raised about that study's conclusions based on
380 inadequate information about inter-observer reliability, whether the monkeys also
381 touched their dyed crest when the mirror was absent, and whether they repeatedly
382 investigated their dyed crest (testing was halted as soon as any mark-directed
383 response was noted (Anderson and Gallup 1997, 1999). An attempt by the same
384 laboratory to replicate their finding of self-recognition in cotton-top tamarins resulted
385 in failure (Hauser et al. 2001), and since then there have been no further claims that
386 monkeys of the family Callithrichidae are capable of self-recognition. Indeed in one
387 modification of the mark test, a chocolate-flavored cream was used to increase
388 marmoset monkeys' motivation to locate the mark on their head, but no marmosets
389 used their reflection to investigate the mark; in fact some individuals tried to lick the
390 chocolate mark in the mirror (Heschl and Burkart 2006). If there is a lesson to be
391 learned from the case of the cotton top tamarins, it is that studies of visual self-
392 recognition need to be especially careful about procedural aspects such as inter-
393 observer reliability, comparing behaviors in the presence and absence of mirrors,
394 comparing behaviors while looking at the mirror versus looking elsewhere, and the
395 validity of the behavioral parameters recorded, including frequency and durations.

396 In the most recent attempt to engineer self-recognition in monkeys, Chang et
397 al. (2015) used a training procedure with rhesus monkeys that they claim resulted in
398 "mirror-induced self-directed behaviors resembling mirror self-recognition" (p. 1).

Other authors have been quick to conclude from Chang et al.'s report that rhesus monkeys appear to show the same level of self-awareness as some great apes (Toda and Platt, 2015). As this study represents the newest challenge to the view that the capacity for self-recognition in primates may be limited to the great apes and humans, it requires close scrutiny.

Compared with previous attempts to train mirror self-recognition in monkeys, the procedures used by Chang et al. (2015) were especially elaborate, long-drawn-out, and painstaking. Training lasted for up to 38 days with literally thousands of trials, and initially required that monkeys be chair-restrained and forced to confront their reflection for extended periods of time. As the monkeys looked at the mirror they received short bursts of laser beams focused on their faces in an attempt to produce irritation. Coupled with the application of the laser beams, the monkeys were also given food rewards for touching the points of irritation on their faces. As might be expected from principles of conditioning, this training resulted in the monkeys eventually learning this simple association and reacting to marks they saw in the mirror by touching their faces and looking at their fingers – much as they would when encountering other learned sources of irritation or injury.

It is important to recall that in designing the mark test, Gallup (1970) took careful and detailed steps to ensure that the chimpanzees would not know they had been marked and would be unable to detect the marks without a mirror. First, the chimpanzees were anesthetized and rendered unconscious prior to the application of the marks so they would have no information about having been marked. Second, the marks were strategically placed on the top of an eyebrow ridge and the opposite ear in such a way that the marks could not be seen without a mirror. Finally, the dye was chosen to be free from any telltale tactile or olfactory cues, so that once the dye had

dried and the chimpanzees recovered from anesthesia in the absence of a mirror there would be no way for them to know about the existence of the strange red marks on their faces. Similar to other authors who have tried to engineer self-recognition in monkeys (Heschl and Burkart 2006; Roma et al. 2007; Rajala et al. 2010), Chang et al. (2015) did just the opposite. Their monkeys were given extensive and focused experience with the marks and underwent prolonged periods of explicit training with reinforcement to touch these and other marks before being tested for self-recognition. Our view is that what Chang et al. (2015) accomplished as a consequence is a trained simulation of self-recognition, rather than self-recognition itself, analogous to somebody being taught the correct responses to questions on an intelligence test and thereby receiving a higher score, but without any fundamental change in their underlying intelligence. As we pointed out in a critique of a previous paper claiming to demonstrate self-recognition in rhesus monkeys based on a different source of irritation (Anderson and Gallup, 2011), to be a valid test of self-recognition the mark must not only be previously unseen and unfelt, it must be unknown (but see Bard et al. 2006 for an alternative view).

It is noteworthy that following their training with lasers and extensive reinforcement, Chang et al.'s (2015) monkeys failed to distinguish between laser marks projected to the wall of their cage and to parts of their body that they could see directly: they similarly touched both, suggesting that they had not learned to distinguish one from the other and were only doing what they had been trained to do. Rather than showing the monkeys understood they were seeing themselves in the mirror, these observations imply that their bodies were simply being treated as another part of the environment, to be responded to for reward as dictated by their training history. By contrast, with no coaxing or training whatsoever chimpanzees

often come to spontaneously use mirrors to investigate and manipulate features of their body they have not seen before; they make faces at the mirror, inspect the inside of their mouth, and/or use the reflection to investigate their ano-genital area. It is notable that none of Chang et al.'s rhesus monkeys showed similar patterns of spontaneous self-exploration, nor have any other monkeys.

It is interesting to compare the videotaped instances of ostensible mirror-induced self-directed behavior presented by Chang et al. (2015) and readily available video clips of chimpanzees responding to mirrors. The behaviors are quite different. Unlike the rich, impromptu series of attempts by chimpanzees to manipulate and investigate things about themselves discovered in the mirror, the instances described as self-directed in the rhesus monkeys are simpler and stereotyped, including “checking their own bodies or pulling their own face or head hair” (p. 215). In addition, in Chang et al.'s videos the dye marks appear very fresh and are probably visible even without a mirror and as such may have inadvertently provided the monkeys with visual and tactile cues that could be used to detect the presence of these marks in the absence of a mirror; this invalidates these demonstrations and is clearly at variance with most of the work done with apes.

It would be of interest to follow the behavior of Chang et al.'s (2015) trained rhesus monkeys over an extended period of time. One question that might be asked is how they would react toward their reflection after some time with no mirror present. Studies have shown that in macaques although the tendency to treat the reflection as another animal eventually habituates, simply removing the mirror for several days or even moving it from one side of the cage to the other can trigger a dramatic reinstatement of social responses toward the reflection; this even occurs in rhesus monkeys reared in front of mirrors all their lives (Gallup and Suarez 1991). If Chang

et al.'s monkeys also show a resurgence of social responses, the case for self-recognition would be substantially weakened. As noted earlier, the capacity for spontaneous self-recognition is stable in chimpanzees even after years with no intervening exposure to their reflection.

Trying to engineer self-recognition through extensive training is not fundamentally different from attempts to program robots in the presence of mirrors to superficially go through some of the same movements involved in self-recognition (Gold & Scassellati, 2009). Whatever engineers and computer scientists get robots to do, they are clearly doing it while circumventing what it is that underpins this evolved, natural capacity in humans and great apes. Merely simulating certain features of self-recognition through training/programming does not mean that the underlying mechanisms are the same, similar, or even remotely related (Gallup et al. 2011).

Neuropsychological considerations

Another interesting difference in self-awareness between chimpanzees and monkeys was described by Menzel et al. (1985). Mirror-experienced chimpanzees and rhesus monkeys were given the task of finding hidden food on the other side of an opaque barrier by monitoring the reflection of their own hand in a mirror. Unlike the chimpanzees, who solved the problem with ease, the rhesus monkeys failed. Indeed, they vocalized and threatened their hand when they saw it approach the food in the mirror – as if it were the hand of another monkey. Studies with humans show that when the right cortical hemisphere is temporarily deactivated with sodium amobarbital, people often mistake their hand as belonging to someone else (Meador et al. 2000), reminiscent of rhesus monkeys. Furthermore, humans whose faces were morphed in a 50/50 ratio with the face of a famous person report seeing the famous

person's face when their right hemisphere is anesthetized, but see their own face when the left hemisphere is anesthetized (Keenan et al. 2001). The same is true for schizophrenic patients who also cannot distinguish images of their hand from another person's hand, and people with premorbid schizophrenic traits who exhibit right hemisphere deficits for recognizing their faces and deficits for picking self-descriptive adjectives (Platek et al. 2002; 2003). Damage to the right hemisphere has also been implicated in mental state attribution deficits and impaired autobiographical memory (see Gallup et al. 2003). Right hemisphere damage likewise leads to deficits in ownership and agency of body parts (Feinberg & Keenan, 2005). Data such as these implicate the existence of self-processing mechanisms in the right side of the human brain. The extent to which homologous mechanisms exist in the brains of self-recognizing great apes compared to non-self-recognizing monkeys remains to be clarified.

Two recent comprehensive reviews exemplify the growing interest in the neuropsychological basis for self-recognition. One consists of a thorough and detailed account of evidence showing specific neural anatomical features that distinguish primate species that can recognize themselves in mirrors from those that cannot (Butler and Suddendorf, 2014). The other involves an ALE meta-analysis of fMRI studies of self-recognition and theory of mind in humans (van Veluw and Chance, 2014), which identifies specific areas of the brain that are especially active under conditions of self-face identification. Consistent with predictions made long ago based on the hypothesis that self-awareness is what makes mental state attribution possible (Gallup, 1982), there is mounting evidence for considerable overlap between brain areas linked to self-recognition and those that have been implicated in the

capacity to take into account what other people know, want or intend to do; i.e.,
theory of mind.

Finally, we could use Menzel's paradigm to make another testable
prediction. If Chang et al.'s (2015) trained monkeys have achieved an integrated
sense of self-awareness as a consequence of extensive somatosensory training, then
they ought to be able solve Menzel's problem with ease or at least much faster than
macaques with no such training (Anderson, 1986; Itakura, 1987).

Conclusions

In the final analysis, the results of any study must be independently replicated by
other scientists in order for the findings to be considered reliable. The demonstration
of mirror self-recognition in chimpanzees, orangutans and humans has been replicated
many times by different investigators all over the world (for a review see Gallup et al.
2011). In contrast, the track record for claims of self-recognition in other species has
not been encouraging. Single published reports of mirror self-recognition in one
elephant that failed on a re-test (Plotnik et al. 2006), one dolphin (Reiss & Marino
2001), and two magpies (Prior et al. 2008) have yet to be replicated. Indeed, recent
evidence with other corvids suggests that apparent instances of mirror self-recognition
by magpies may be an artifact of tactile cues (Soler et al. 2014). And in the case of
cotton-top tamarins (Hauser et al. 1995) an attempt to replicate the original positive
results completely failed (Hauser et al. 2001).

In conclusion, it is important to stress that without strong corroborating
evidence, training-induced performances that merely mimic or resemble behavior
spontaneously seen in other species tell us little about the cognitive abilities
underlying such behaviors. While interesting, the results presented by Chang et al.

(2015) are not compelling evidence that rhesus monkeys are capable of self-recognition. It is important to recall that mirror self-recognition per se was not selected for in evolutionary history. Instead, mirror self-recognition is an expression of an underlying sense of self that allows individuals to engage in other cognitive and emotional acts such as empathy, reconciliation, consolation, and perspective-taking. It is therefore reasonable to ask, for example, whether monkeys trained to show behaviors that resemble passing the mark test also then show any of those other signs of social intelligence that are characteristic of naturally self-recognizing species. If they do not, it remains unclear what theoretical advances emerge from efforts to train “mirror-induced self-directed behaviors resembling mirror self-recognition” (p. 1). Of equal importance is whether claims of finding self-recognition in species hitherto considered incapable can be replicated by other investigators.

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764

765 **Figure legend:**

766

767 **Fig. 1** Examples of spontaneous mirror-guided exploration of normally unseen body
768 parts in chimpanzees (photos by D J Povinelli)
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