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Self-recognition in primates: Phylogeny and the salience of species-typical features

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ABSTRACT **Self-recognition has been explored in nonlinguistic organisms by recording whether individuals touch a dye-marked area on visually inaccessible parts of their face while looking in a mirror or inspect parts of their body while using the mirror's reflection. Only chimpanzees, gorillas, orangutans, and humans over the age of approximately 2 years consistently evidence self-directed mirror-guided behavior without experimenter training. To evaluate the inferred phylogenetic gap between hominoids and other animals, a modified dye-mark test was conducted with cotton-top tamarins (*Saguinus oedipus*), a New World monkey species. The white hair on the tamarins' head was color-dyed, thereby significantly altering a visually distinctive species-typical feature. Only individuals with dyed hair and prior mirror exposure touched their head while looking in the mirror. They looked longer in the mirror than controls, and some individuals used the mirror to observe visually inaccessible body parts. Prior failures to pass the mirror test may have been due to methodological problems, rather than to phylogenetic differences in the capacity for self-recognition. Specifically, an individual's sensitivity to experimentally modified parts of its body may depend crucially on the relative saliency of the modified part (e.g., face versus hair). Moreover, and in contrast to previous claims, we suggest that the mirror test may not be sufficient for assessing the concept of self or mental state attribution in nonlinguistic organisms.**

Twenty-five years ago Gallup (1) asked how we might find out if nonhuman animals are self-aware. Having observed chimpanzees use a mirror for self-directed behavior, he developed an experimental procedure to test formally for self-recognition. The test involved three steps. First, a chimpanzee with prior mirror exposure was anesthetized. Second, a dye mark (lacking olfactory and tactile cues perceptible to humans) was applied to the anesthetized chimpanzee's eyebrow and ear. Last, following recovery, the chimpanzee's response to a mirror was recorded. Dye-marked chimpanzees looked in the mirror and touched the marks; the mirror was also used to inspect visually inaccessible body parts (e.g., inside the mouth). These behaviors were not observed in chimpanzees lacking prior mirror exposure.

To date, humans over the age of approximately 2 years old, chimpanzees, gorillas, and orangutans consistently show self-directed behavior when tested by Gallup's procedure, whereas other species do not (2–8). This phylogenetic pattern has been interpreted by some researchers as evidence that there are fundamental differences in the cognitive capacities of hominoids and all other species, and it has been used to predict further differences in cognitive capacity (4, 5, 7).

Comparative studies of cognition are often plagued by an inability to distinguish between differences in performance and differences in ability (9, 10). One solution to this problem is to design different methods that require different performances but test for comparable abilities. To this end, we carried out a modified version of the dye-mark test, using cotton-top tamarins (*Saguinus oedipus*). We reasoned that at least some failures to formally show self-directed mirror-guided behavior may have resulted because the traditional dye-mark test lacks saliency (either perceptual or motivational) for species other than humans and the apes (for further methodological critiques, see refs. 8, 11, and 12). If a more salient change is imposed, sensitive to species-typical morphological characteristics, other species may also show evidence of self-recognition, at least as defined by the original tests. In our experiments, therefore, we altered the color of the tamarin's naturally white hair, a trait that is species-typical and highly distinctive.

For two cotton-top tamarin groups, mirrors (19 × 21 cm) were mounted on the outside of their home cages [two on the small cage (4 × 4 × 6 feet; 1 foot = 30.5 cm) and three on the large cage (8 × 4 × 6 feet)], adjacent to perching areas; mirrors were withheld from a third group. During a baseline period, 5-min focal animal samples (n = 476) were recorded from all individuals. During these sampling periods, one to three trained observers were in the tamarins' home room and recorded all mirror-directed behavior as well as head, face, and upper and lower torso touching. Tamarins with access to mirrors showed initial interest, evidenced by brief stares, visual and manual searches behind the mirror, and occasional threats; we observed 27 cases of individuals touching the hair on their head, but only once while looking in the mirror. Moreover, mirror stares appeared generally nonaggressive, with no accompanying vocalizations and only five threat displays. Just prior to the start of our experiments, the only mirror-directed behavior observed was infrequent, brief staring.

The experimental procedure is summarized in Table 1. To test the effect of prior mirror exposure on recognition of hair color change, six individuals were given long mirror exposure (3 or 4 weeks) prior to experimental treatment (hereafter, LME subjects). In contrast, two subjects were given short mirror exposure (20 min) and one subject, no mirror exposure (hereafter SME subjects). Control treatments were designed to rule out the possible effects of the anesthesia, tactile and olfactory cues associated with the dye, and novelty of the color on self-directed mirror behavior.

Except for the hair-dye condition of L and F, the procedure for all subjects in every condition was as follows. Twenty minutes of pretest behavioral data were recorded immediately prior to testing, with the subject alone in the home cage. Next, the individual was moved to a holding cage in a separate room where it would be anesthetized. Ten minutes of behavioral data were recorded prior to anesthetization. Then the experimental manipulation was carried out, described for each condition below.

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Abbreviations: LME, long mirror exposure; SME, short (or no) mirror exposure.

Table 1. Testing procedures for cotton-top tamarins

Subject	Age	Sex	Baseline mirror exposure	Test conditions, in order				
				1	2	3	4	5
L	A	M	3 wk (long)	Hair dye	White hair dye			
F	A	F	3 wk (long)	Hair dye				
H	J	F	4 wk (long)	Hair dye				
N	J	M	4 wk (long)	Anesthesia	Colored mirror	White hair dye	Hair dye	
M	A	F	4 wk (long)	Anesthesia	Colored mirror	White hair dye	Gallup mark	Hair dye
Q	A	M	4 wk (long)	Anesthesia	Colored mirror	White hair dye	Gallup mark	Hair dye
C	A	M	None	Hair dye				
P	J	M	20 min (short)	Hair dye				
B	A	F	20 min (short)	Hair dye				

See text for details. A, adult; J, juvenile; M, male; F, female.

Animals were anesthetized by injecting them with 0.05–0.075 ml of ketamine, depending upon body weight; subjects took 45–90 min to recover completely from the anesthesia. After the animal appeared fully recovered, we again recorded 10 min of data in the holding cage. Thus, for every test condition we were able to check the effects of the anesthetizing procedure by comparing the holding cage data before and after the procedure. Next, the subject was returned to its home cage, again with no other group members present. Behavioral data were recorded for the next 20 min. Thus, for every condition, we were also able to compare the behavior of the 20-min test period to that of the initial 20-min pretest period. As a result, dyed hair-touching in a given condition was unlikely to be due to the particular day or time of testing. For the next and final 20 min of data recording, the other group members were returned to the home cage, and the behavior of all animals was recorded. In the hair-dye condition of L and F, each was immediately removed from its home cage, and the hair was dyed according to the hair-dye condition described below. Each subject was then returned to the home cage alone, where 20 min of behavioral data were recorded.

The hair dye (Manic Panic) consisted of 95% nontoxic hair conditioner and 5% vegetable dye. All subjects received different hair colors, including pink, blue, purple, green, or some combination of these colors. The hair dye was administered and allowed to sit for 15 min, and then the excess was washed out. With the exception of individual L, who received a broad blue streak down the middle of his white hair, all of the white hair was changed to a different color for all of the individuals; we were, however, careful to avoid coloring parts of their hair that could be sèen directly in the absence of the mirror. In case our subjects were at all aware of our head-directed actions, we took the precautionary measure of washing the rest of their bodies. All subjects were then thoroughly dried.

The justification for and details of each experimental manipulation were as follows: *Anesthesia*. To test for the effects of anesthesia and removal from the home cage, some subjects were removed, anesthetized, washed down with water, dried off, and then released back into the home cage upon recovery. *Colored mirror*. To determine whether the novelty of the color, independent of the subject's hair, might cause increased hair touching and staring, we placed a splotch of dye on the mirror, at approximately head level; the color applied was the one we administered to the subject in the subsequent hair-dye condition. *White hair dye*. In the original dye-mark test (*Gallup mark*), it is assumed that the dye itself causes no olfactory or tactile changes. To directly test this assumption in our own procedure, we applied white dye to the subject's hair. This dye presumably causes a change in hair texture, and perhaps even odor, equivalent to the changes produced by the colored dye, but does not cause a change in color. *Gallup mark*. To be certain increased saliency was necessary for the tamarins, we also conducted the traditional dye-mark test, applying marks on the right eyebrow and left ear; the colors were those we subsequently applied to each subject's hair.

During each test, one person videotaped the session while two additional observers recorded focal observations onto a checksheet; the latter was provided because subjects occasionally moved into positions within the cage that prohibited clear video records. The person responsible for the video record moved during the test session to capture the best possible angle on the test subject; the other two observers remained relatively stationary, approximately 5 feet from the front of the cage. Three observers were then responsible for transcribing the video records, using the following procedure. First, each video session was acquired onto a Macintosh Quadra 950 by using a Radius VideoVision acquisition board and the Adobe Premier software. Before each test session was formally scored, inter-observer reliabilities were obtained, focusing on all self-directed behavior and mirror stares; reliability scores exceeded 0.85. Second, one observer scored 10 test sessions blind with regard to condition by turning the color on the video monitor to black and white. This provided a blind test of the condition, since it was not possible to determine whether individuals were hair dyed. The correlation between these tests and those conducted with knowledge of condition was 0.92. Third, mirror-guided behavior was defined as an individual touching its body while looking in the mirror.

Results (Fig. 1) indicate that for hair-dyed individuals in the LME group (LME-D group), 5 of 6 touched their dyed hair while looking in the mirror (n = 13 dyed-hair touches in six 20-min samples). In no other experimental condition did individuals touch their head while looking in the mirror. Furthermore, all LME-D tamarins stared in the mirror longer

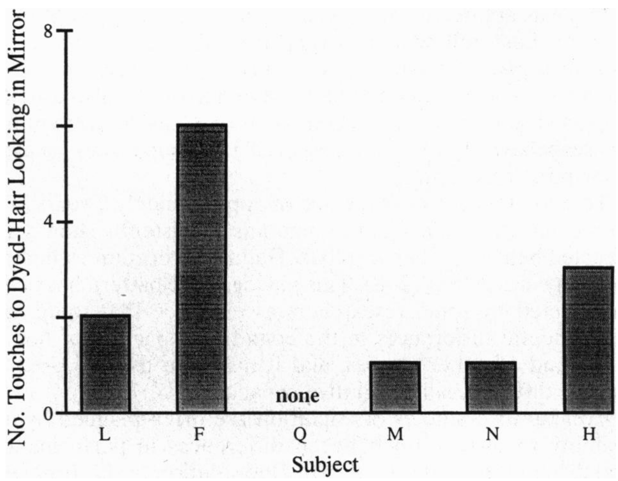

FIG. 1. Mirror-directed dyed-hair touching by tamarins with long mirror exposure (LME-D). Depicted are the dyed-hair touches while looking in the mirror during the 20-min post-dye test condition, while subjects were alone in their home cage.

and with individual stares of longer duration than in all control conditions combined (Fig. 2); all of these stares were nonaggressive. Thus, mirror-directed hair touching and the extended mirror staring in the hair-dye condition cannot be due to the anesthesia, removal from the home cage, novelty of the color independent of the subject's hair, or the nonvisual properties of the dye; and the traditional dye-mark test was insufficient to elicit self-directed, mirror-guided behavior.

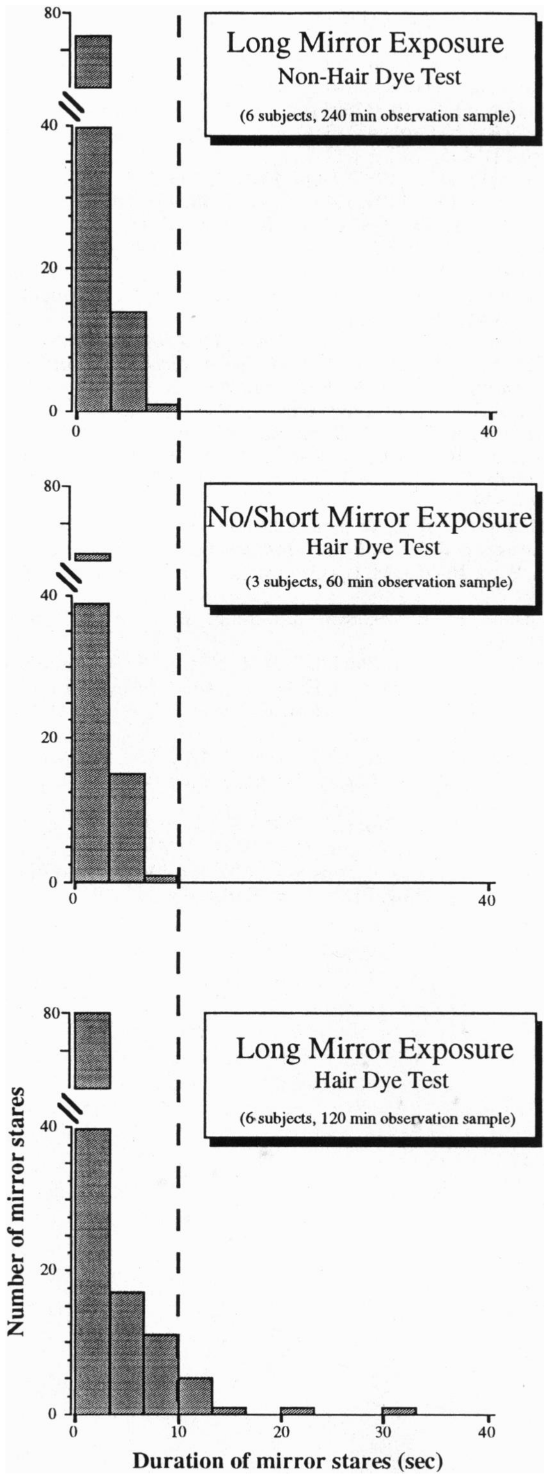

FIG. 2. Distribution of mirror stare durations as a function of test condition and prior mirror exposure. Data on stare duration were obtained only from the 20-min postmanipulation period, when individuals were alone in their home cage. (*Top*) Stare duration for subjects with LME during all non-hair-dye test conditions. (*Middle*) Stare duration for SME subjects that had their hair dyed. (*Bottom*) Stare duration for LME-D subjects. All stare duration values to the right of the dashed line are observed only among LME-D tamarins. All of these individuals exhibited both short and long stares, as evidenced by the following data [values indicate range of stare durations in frames (30 frames per sec) for each subject; see Table 1 for identifications]: L = 15–310, F = 18–990, N = 11–340, H = 8–442, M = 12–670, and Q = 20–470.

SME subjects never touched their dyed hair in front of the mirror and their stares were, on average, of short duration (<8.0 sec; Fig. 2). Thus, more than 20 min of prior mirror exposure is needed by the tamarins for mirror-guided dyed-hair touching and long stares. The absence of dyed-hair touching in this condition further suggests that none of the control variables can explain the observed dyed-hair touching among LME-D individuals.

Dyed-hair touching and staring by LME-D tamarins may not indicate that they see themselves in the mirror. Rather, they might see someone else with a dyed head and touch these areas to assess whether they also have such characteristics. If this were the case, we would expect individuals to touch their own hair and stare for long periods when they observed a hair-dyed individual. However, group members never touched their own hair after they observed a hair-dyed individual; and attention to a dyed individual's hair, as evidenced by grooming, was observed only twice. Thus, other group members detected the change in hair color, but this apparently did not affect their self-directed behavior and rarely affected their staring.

For all monkey species, including tamarins, staring is typically an aggressive threat (13, 14). In fact, most monkeys tested with the dye-mark procedure initially responded to a mirror by threatening the image, and some continued to do so for several months to years after (5, 15, 16). This suggests that in such species, the mirror image is seen as a competitor who is staring back and thus threatening. LME-D tamarins stared into the mirror peacefully and for long durations, but did not vocalize or act aggressively. Such prolonged staring (>10 sec) was not observed under any other condition for either of these subjects or the SME tamarins (Fig. 2). This suggests that the LME-D tamarins did not perceive the image as a competitor (i.e., as someone else).

Weeks after our experiments, we recorded several cases of LME-D individuals using the mirror to observe visually inaccessible body parts. In one instance, H turned and rolled sideways, and looked at her back in the mirror. In a second, M stared in the mirror through her legs with her head upside down, then stood up, and looked directly at her rear and tail. Although these observations are clearly not as dramatic as some of the cases described for chimpanzees where, for example, individuals will make faces at the mirror, we might not expect as much from tamarins, given their impoverished repertoire of facial expressions (13, 14). Similarly, given that head touching was generally uncommon in the tamarins (27 of 476 5-min baseline samples), it is not unexpected to see infrequent head touching in front of the mirror during the dye condition (11, 12).

We conclude by making three points. First, although we did not obtain as much self-directed mirror behavior throughout the experiment as typically seen with chimpanzees, gorillas, orangutans, and humans over the age of approximately 2 years, hair-dyed cotton-top tamarins with extensive mirror exposure do exhibit such behavior without any explicit shaping by the experimenter (17). At this level, our results are comparable to those obtained for the hominoids, and therefore conflict with the inferred phylogenetic gap. Second, we suggest that an important difference between our results and those of experiments conducted on other monkey species, and perhaps other species as well, is methodological (5, 8, 11, 12, 18). Specifically, and in contrast to the hominoids, looking into a mirror is likely to be aversive for all monkey species, since the image is potentially perceived as a competitor. Given that monkeys stare only briefly at mirrors, the traditional dye mark may not be sufficient to recruit the kind of attention that is necessary for animals to learn the correspondence between their body and its mirror image. To elicit significant mirror staring, one may need to impose more radical changes to the individual's body such that the alteration is highly salient and draws the animal's attention to the mirror image. Considering the role of evolutionary pressures and perceptual saliency in visual recognition, we significantly altered a highly visible species-typical feature of the cotton-top tamarin, and this resulted in self-directed mirror behavior. Third, our experiment raises problems for the claim that passing the mirror test provides evidence of a self concept and mental state awareness (1–8, 11). Though our modified mirror test elicited self-directed behavior from the tamarins, we suggest that formal tests will fail to show that members of this species are aware of either their own mental states or those of other conspecifics. This prediction is based on experiments with primates that are socially more complex than tamarins and, thus, are more likely to exhibit sophisticated cognitive abilities to support the intricacies of their social relationships. Although such tests are only in their infancy, they have consistently failed to provide evidence of mental state attribution (19–21). Given current testing procedures, we would also expect the tamarins to fail.

In conclusion, and as others have realized (e.g., refs. 8, 11, and 22), it is now necessary to provide a more precise specification of the cognitive mechanisms required to pass the mirror test. Until this occurs, the relevance of the mirror test for understanding the concept of self and the mental states of nonhumans and preverbal humans will remain ambiguous.

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