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Mirror behavior and "self-hood" among primates

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MIRROR BEHAVIOR AND "SELF-HOOD" AMONG PRIMATES

BY

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Abstract

Mirror Behavior and "Self-hood" among Primates

by

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Some of the great apes (e.g., chimpanzees and orangutans) have been reported to exhibit mirror self-recognition (Gallup, 1970; Lethmate & Ducker, 1973) as mirror-mediated touching of dye marks located on the brow or ear (areas of the head which cannot be viewed directly). Successful tests for mirror self-recognition typically involve a period of familiarization to a reflective surface during which "social" responding (e.g., facial displaying) toward the mirror is said to decrease in frequency to be replaced by "self-directed" behavior (e.g., "making faces" toward the mirror, or inspection of the anal-genital area using the mirror). Prior to the research presented here, monkeys have consistently failed tests for mirror self-recognition. Recent evidence (Swartz & Evans, 1992) suggests that mirror self-recognition is less prevalent among chimpanzees than previous reports indicated and that "self-directed" behavior may not be entirely predictive of positive performance during mark tests. The aim of the present work was to investigate further the phenomenon of mirror self-recognition among chimpanzees, as well as its absence among

monkeys. In Experiment 1, an attempt was made to replicate previous research with chimpanzees (e.g., Gallup, 1970) using repeated mark tests for self-recognition among individual subjects (e.g., Swartz & Evans, 1992). Of three chimpanzees tested, only one subject exhibited unequivocal evidence of self-recognition and did so during only two of three mark tests. The behavior of monkeys (*Macaca nemestrina*) was then examined in the presence of mirror self-images. Mirror-looking by monkeys was increased both through schedule induction techniques (Experiment 2) and direct reinforcement (Experiment 3). In general, schedule induced mirror-looking was a transient phenomenon, involving brief (1-2 s duration) looks toward the mirror self-reflection. Sustained looks (up to 20 s duration) toward the self-reflection were then reinforced directly for two of these monkeys (Experiment 3). Given increased levels of mirror experience, the same monkeys were tested for mirror self-recognition using the Gallup mark test and a single monkey was judged to exhibit the phenomenon (Experiment 4). These data appear to be the first demonstration of self-recognition by a monkey. Self-recognition is discussed based upon research with human and non-human primates with emphasis on factors relevant to previous failures to demonstrate self-recognition among monkeys.

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Finally, a researcher must thank her research subjects and my girls (Roberta, Bibi, and Pavlova) taught me much through the years. I am indebted to these monkeys as we all are to the many primates used in experimentation. One

cannot explain to an animal why it is undergoing procedures which cause it discomfort and even if this were possible, I'm not sure that the animal would then accept the circumstances or justifications any more than a normal human would do so. As a researcher, I can only remember my debt to these particular animals and hope to find some way to help preserve the natural habitat for other members of their species. Closer to home, Seth and I will both work to improve the conditions in which laboratory and zoo animals are maintained.

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MIRROR BEHAVIOR AND "SELF-HOOD" AMONG PRIMATES

This introduction examines the phenomenon spoken of as mirror or visual "self-recognition." Once made familiar with mirrors, most humans and some of the great apes[1] exhibit mirror-mediated reaching to otherwise undetectable targets located on the head, a performance from which self-recognition is inferred. Prior to the research described here, researchers have failed to demonstrate comparable behavior among monkeys, although some 14 species have been tested (e.g., Gallup, 1977a; see also Gallup, 1982; Anderson, 1984a; and Povinelli, 1987 for reviews). Table 1 provides a brief survey of this literature.

This discussion will begin with a description of the procedures through which self-recognition is said to be demonstrated among humans and non-humans. The status of the phenomenon among chimpanzees (*Pan troglodytes*) is then examined since these animals are frequently studied in this

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1 While chimpanzees and orangutans have been shown to demonstrate mirror self-recognition (e.g., Lethmate & Ducker, 1973; Suarez & Gallup, 1981), gorillas have failed empirical tests (e.g., Ledbetter & Basen, 1982; Suarez & Gallup, 1981). Patterson (1984), however, described occurrences of mirror-oriented, mark-directed responding for her gorilla, "Koko." The latter demonstration is difficult to interpret, however, due to possible effects of unintentional prompting, the unspecified reinforcement history of the animal in the presence of its mirror reflection, and the application of marks with the animal neither anesthetized, tranquilized, nor sedated.

PRIMATE SPECIES TESTED FOR MIRROR IMAGE SELF RECOGNITION

Species	Author	Social Responses	Self-Directed Responses	Dye Test
Homo sapiens	Amsterdam, 1972	+	+	+
Pongo pygmaeus	Lethmate & Ducker, 1973, Suarez & Gallup, 1981	+	+	+
Pan troglodytes	Gallup, 1970, 71; Lethmate & Ducker, 1973; Calhoun-Radano & Thompson, 1979	+	+	+
Gorilla gorilla	Ledbetter & Basen, 1981; Suarez & Gallup, 1981	+	-	-
Hylobatus lar	Lethmate & Ducker, 1973	+	-	-
Hylobates agillis	Lethmate & Ducker, 1973	+	-	-
Cebus apella	Lethmate & Ducker, 1973	+	-	not tested (nt)
Ateles spec.	Lethmate & Ducker, 1973	+	-	nt
Papio hamdryas	Lethmate & Ducker, 1973	+	-	nt
Mandrillus aphinx	Lethmate & Ducker, 1973	+	-	nt
Macaca silenus	Lethmate & Ducker, 1973	+	-	nt
Papio anubis	Benhar, Carlton & Samuel, 1974	+	-	-
Macaca nemestrina	Calhoun-Radano & Thompson, 1978	+	-	-
Macaca arctoides	Gallup, 1970, Anderson, 1981	+	-	-
Macaca mulatta	Gallup, 1970, 1980	+	-	-
Macaca fascicularis	Gallup, 1970, 1976	+	-	-

(+ means positive or behavior shown, - mean negative or behavior not seen)

Table 1. Species of primates tested by means of the Gallup mark test for self-recognition. From The Question of Contingent Image Self-recognition in Apes and Monkeys (p.131) by S. Calhoun, 1983, Unpublished Doctoral Dissertation, The Graduate School of the City University of New York, Reprinted by permission.

context and according to several researchers (e.g., Gallup, 1970; Suarez & Gallup, 1981), chimpanzees readily exhibit self-recognition. There then follows an examination of the status of the phenomenon among monkeys, a group of primates which has consistently failed to exhibit criterion responses indicative of self-recognition, but which to according some reports (Platt & Thompson, 1985; Eglash & Snowden, 1983), can exhibit behavior which may be a precursor or component of self-recognition. In an effort to understand this apparent dichotomy in the cognitive capacities of chimpanzees and monkeys, a functional analysis of the reflective properties of mirrors is presented with speculations regarding the ontogeny of visual self-recognition among non-human primates, followed by a description of the various efforts among researchers to demonstrate monkey mirror self-recognition. In this, the aim is to provide a critical analysis of the relevant properties of mirrors which can be demonstrated to affect monkey responding.

Studies with humans are then discussed with special interest in the behavior of individuals (retarded persons, people diagnosed as schizophrenic, young children, some elderly persons, etc.) who reportedly fail tests for self-recognition or who exhibit abnormalities with respect to self-image. Next, suggestions by numerous researchers are

presented which attempt to account for the apparent absence of self-recognition among monkeys. In the final section of this introduction to the topic of mirror self-recognition, behavior is described which would seem to be required for the phenomenon of self-recognition to occur among non-human primates.

Experiments are then reported which attempted to: 1) replicate the basic phenomenon with chimpanzees in order to measure properties of mirror-looking among self-recognizing animals, 2) assess baseline levels of mirror-looking among pigtailed monkeys, 3) attempt to increase mirror-looking among monkeys to levels comparable to that of a self-recognizing chimpanzee (both through schedule induction and direct reinforcement), and 4) perform Gallup mark tests for self-recognition with these same monkeys.

Researchers who have demonstrated self-recognition among the great apes exposed subjects to a mirror (usually one which reflects the animal's entire body) for varying amounts of time daily. During the first four or more days of mirror exposure, mirror-directed "social" responding is typically reported. Later, "social" responses are reduced or no longer evident and mirror-mediated, "self-directed" responding is observed (e.g., "making faces" at the mirror, or using the mirror to inspect otherwise unviewable body parts). Then, while the animal is anesthetized, areas of

the head which it cannot view directly are marked with an odorless dye believed to produce no tactile cues, but having an appearance (blood red) assumed to be salient. After the animal is fully recovered from the anesthetic, the absence of mark-directed responding is confirmed with the mirror covered. Finally, mark-directed activity associated with mirror-looking in the mirror-uncovered condition indicates self-recognition. This procedure, introduced by Gallup (1970), will be referred to as the Gallup mark test. Typical modifications of the Gallup mark test may involve less systematic or less controlled exposure to mirrors or other reflective surfaces, an unknown history of mirror exposure (particularly in the case of human subjects), surreptitious application of the marking substance without anesthetization of the subject, marking other than one brow and the opposite ear, and/or marking with some substance other than a red rhodamine-B dye (e.g., Amsterdam 1972; Calhoun 1983; Lewis & Brooks-Gunn 1979). Hereafter, any of these procedures will be identified simply as mark (or self-recognition) tests unless it is necessary to describe methods in greater detail.

Recent research indicates that the occurrence of self-recognition in chimpanzees is a less robust phenomenon than previously believed, and that occurrences of "self-directed" responding may not predict positive results during the mark

test (Swartz & Evans, 1991, in press). The broad aim of the present work was therefore to investigate the phenomenon of self-recognition among chimpanzees, as well as the apparent failure to self-recognize by monkeys.

Status of the phenomenon among chimpanzees

A few researchers have reported negative results after conducting tests for self-recognition among chimpanzees, and interpretations of negative findings vary among researchers. For instance, Gallup, McClure, Hill, and Bundy (1971) tested self-recognition among six preadolescent chimpanzees, of which three were wild-born (reared in group cages) and three were born in captivity (reared in isolation). It was reported that while the group-housed, feral chimpanzees self-recognized, the captive-born, isolated animals failed to do so. In the absence of further investigation and replication, however, these negative results can be interpreted with respect to individual variation or other factors. Povinelli (1987), in discussing this study, argued that the difference in responding between chimpanzee groups was unlikely to be the result of cognitive deficits arising from isolate-rearing, pointing out that Gallup and his colleagues described self-recognition for two additional chimpanzees which had been provided with remedial social

experience after being reared in isolation[1] until 18 months of age (Hill, Bundy, Gallup, & McClure, 1970). Povinelli's argument would be strengthened, however, if it referred specifically to the six subjects described in the 1971 work, since there are likely to be individual variations in the cognitive deficits arising from isolation rearing. Further, it can be speculated that remedial social stimulation affects cognitive capacities other than those involving "self-awareness."

Unfortunately, information is unavailable in the Gallup et al. (1971) study regarding the behavior of individual subjects, a serious criticism when so few subjects comprised each group and when some subject(s) exhibited mark-directed responding in the absence of the mirror reflection (see Figure 2 in Gallup et al., 1971). It is feasible that high levels of mark-directed activity among one or two of the feral, group-housed chimpanzees masked low levels of similar activity among the remainder of the self-recognizing subjects. Regardless of interpretation, however, several important differences in responding were described for the two chimpanzee groups: 1) self-recognizing animals were said to spend a significantly shorter period of

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1 Questions arise regarding the term, "isolation" in this context. Subjects were reared with continuous auditory and olfactory access to one another as well as mutual visual access during caretaking activities.

time watching the mirror reflection than the isolated subjects, 2) while the self-recognizing chimpanzees were observed to exhibit the expected pattern of "social" responsiveness to the mirror reflection (i.e., decreasing with continued mirror exposure and replaced by "self-directed" behavior), the isolate-reared animals failed to exhibit "typical social patterns" directed toward the mirror reflection, and 3) the isolate-reared animals failed to exhibit dishabituation of looking behavior on the day of the mark test. It should be noted, however, that one cannot expect dishabituation in the absence of habituation and the first point described above weakens the third.

In essence, Gallup et al. (1971) described tests for self-recognition among nine chimpanzees, of which at least three failed to exhibit positive responding or mirror-oriented, mark-directed behavior. Future research should attempt to replicate the findings of Gallup et al. (1971) since at this time it is difficult to make strong assertions regarding causality. It may be true that early rearing experience affects the ontogeny of self-recognition among potentially capable individuals, yet it is not known if a richly stimulating environment lacking conspecific social cues is adequate for the phenomenon to occur. In light of more recent failures by other researchers to demonstrate the

phenomenon among non-isolated chimpanzees, it becomes clear that social experience is not the only prerequisite.

Swartz and Evans (1991) performed mark tests with 11 wild-born, non-isolated chimpanzees, aged 4-19 years. These authors reported that self-recognition or unequivocal mirror-oriented, mark-directed responding occurred for only one of these animals, although high levels of mirror-oriented, "self-directed" behavior were exhibited by three additional chimpanzees.

Calhoun and Thompson (1988) emphasized the stability of mirror-oriented, mark-directed responses for individual subjects. Two chimpanzees (aged four to five years) were mark-tested by means of the Gallup procedure and then re-tested one year later. One of these animals satisfied the self-recognition criterion (mirror-oriented, mark-directed responding) for both the test and re-test. During the initial test, the second subject exhibited high levels of mirror-oriented, "self-directed" responding but failed the first test for self-recognition. An additional six weeks of mirror exposure followed for this subject and a second mark test yielded positive results, as did the retention test one year later. Prior to the experiments to be reported here, Thompson and his colleagues tested for self-recognition among a total of 9 chimpanzees, with only a single chimpanzee yielding unequivocal results during mark testing

in close to exact replications of the Gallup (1970) procedure.

At this time, Swartz and Evans (1991) are supported in suggesting that self-recognition by chimpanzees is a less robust phenomenon than earlier reports indicated. It also becomes clear that criteria for self-recognition vary among researchers.

Furthermore, assessment of relationships between "self-directed" responding and later occurrences of mirror-oriented, mark-directed responding (self-recognition) are difficult unless data are presented for individual subjects. At the start of the present research, it appeared that "self-directed" responding reliably precedes self-recognition among chimpanzees, but that "self-directed" responding does not serve as a reliable predicter of the phenonenon (Swartz & Evans, 1991; Calhoun & Thompson, 1988). Yet, the category of "self-directed" activity, as it is generally used, describes a broad range of activities. Observations of these responses are often highly interpretive. For instance, Gallup (1970) defines the category of "self-directed" responding in the following:

> Such self-directed responding took the form of grooming parts of the body which would otherwise be visually inaccessible without the mirror, picking bits of food from between the teeth while watching the mirror image,

> visually guided manipulation of anal-genital areas by means of the mirror, picking extraneous material from the nose by inspecting the reflected image, making faces at the mirror, blowing bubbles, and manipulating food wads with the lips while watching the reflection. In all instances of self-directed behavior, the self is the referent through the reflection, whereas in cases of social behavior the reflection is the referent. (p. 86)

Chimpanzee inspection of the anal-genital areas while watching the mirror reflection seems to indicate use of the mirror as a source of visual feedback regarding body appearance, and like others among the activities described above, appears analogous to mirror-oriented, mark-directed responding during the self-recognition test. On the other hand, inclusion of responses such as "making faces" while looking at the mirror requires more interpretation and it is feasible that mirror-looking and these facial gestures occur in temporal association through chance factors[1]. "Self-directed" responding by chimpanzees is said to occur at a

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1 According to my observations and those of M. Matevia (personal communication, 1991), chimpanzees typically "make faces" while alone or when apparently unattentive to social stimuli (i.e., in the absence of a mirror). For instance, Matevia reported several occurrences in which a chimpanzee pulled its lower lip down over its chin and repeatedly patted its mouth with its hand, and was observed to walk around making this face for minutes at a time.

time when the mirror is no longer a novel stimulus and after reduction of "social" responsiveness to the mirror, hence, one would expect increases in some alternative form(s) of responding. Behavior interpreted as "self-directed" may be accompanied by mirror-looking because the resultant self-image is interesting to observe, yet the behavior may not be generated for the purpose of observing the effects via a mirror reflection. An additional problem occurs because in self-recognition studies, the mirror is usually placed on or near the front of the cage. Many primate cages have perches located toward their rear where the animal spends much of its time. This may directly affect direction of gaze in the mirror situation. To my knowledge, investigations of the self-recognition phenomenon among non-human primates have consistently neglected to control relevant variables regarding gaze direction prior to mark testing and have failed to assess the relative and expected probabilities of mirror-looking accompanying responses interpreted as "self-directed" (or of the same responses in the absence of a mirror).

Likewise, use of the term, "social" to describe the initial responses of self-recognizing chimpanzees toward their mirror reflections (as well as the on-going responses of normally-reared monkeys) is too broad a category and relies heavily upon observer interpretation. Species-

typical responses which occur in a social context can also be elicited by non-social stimuli.

In the Hunter College laboratory, an adult pigtailed macaque jawthrusted (with lip extension and scalp retraction) toward a red balloon during her first experience with that object, as well as toward the balloon's mirror reflection (Boatright, 1987). Topographically, jawthrusting toward the balloon seemed indistinguishable from similar responses directed on other occasions toward caretakers or toward other monkeys in the monkey colony. Gallup (1968, p.788) described lip extension and brow retraction (the two major components of jawthrusting) as "social," and more specifically, as "aggressive" when directed toward the mirror self-image. Kaufman and Rosenblum (1966) described brow movements as a dominance manifestation or low intensity threat among pigtailed and bonnet macaques when not accompanyed by jaw movement. Jawthrusting, however, was categorized as a form of sexual behavior among pigtailed macaques, but the authors mentioned its occurrence in other contexts (e.g., maternal). Van Hooff (1967) suggested that the "protruded lips face" among pigtailed macaques occurs in situations where a tendency to approach dominates over the tendency to flee. It was also suggested that this facial display frequently alternates with the "lip-smacking face," occurring in similar contexts and sharing motivational

properties. ("Lip-smacking" was described by Van Hooff as an infrequent occurrence when monkeys are associated in an established relationship with one another, and as more frequent when these animals first meet or when contact is re-established). However, while jawthrusts (with lip extensions and brow retractions) are often directed toward conspecifics and in many cases, may be termed "social," they are not confined to social contexts. Instead, novel objects (such as mirrors) may serve as strong triggers for facial displays and unless there are other indications, primate facial gestures can be viewed as expressive, as much as communicative, although the two are not mutually exclusive. Because these two terms, "social" and "self-directed," are frequently used in association with mirror self-recognition, the terms will be used here also. However, categories of mirror behavior are not fully understood and quotation marks serve to remind one to question their usefulness or validity.

In conclusion, relationships among categories of mirror behavior, (i.e., "social" responding, "self-directed," and mark-directed responding) are not clear at this time. Here, as in some previous studies (e.g., Calhoun, 1983; Swartz & Evans, 1991), mirror-oriented, mark-directed responding will be considered the sole criterion for self-recognition for

subjects exhibiting little or no mark-directed activity in the mirror-absent condition.

Status of the phenomenon among monkeys

Researchers have consistently failed to demonstrate mirror-oriented, mark-directed responding among monkeys. More than a dozen monkey species were tested with negative results. Rather, several mirror studies with caged monkeys indicated that species-typical displays occur even with continued mirror exposure over a period of five months (Gallup, 1977a), for a period of one year (Calhoun, 1983), or even a seven year period (Gallup, Wallnau, & Suarez, 1980), although at a diminished rate. However, two additional studies suggest that monkeys may exhibit behavior which is precursive to or a component of self-recognition.

In a field study using Japanese macaques, Platt and Thompson (1985) reported the relative absence of species-typical behavior directed towards the mirror in adult monkeys when the mirror had been in place in an outdoor compound for a period of approximately one year. Mark tests for self-recognition among these monkeys (and with two additional vervet monkeys) used fluorescent orange poster paint with negative results. The authors concluded that while the mirror image was not perceived as a self-image by these monkeys, neither was it perceived simply as another monkey.

In a study with pygmy marmosets, a prosimian species, Eglash and Snowden (1983) reported a decline in the occurrence of "social" responding toward the mirror with continued and varied exposure to mirrors, although mirror-oriented, self-directed responding was not reported to occur. These authors suggested that "self-directed" movements may not be part of the behavioral repertoire of some monkey species and that observations of decreased social responding may be associated with at least partial self-recognition. A mark test was not included in the procedures because, according to the authors, self-grooming is not part of the behavioral repertoire of this species. It is not clear, however, that a tendency for self-grooming underlies or motivates the self-recognition response, and it is hoped that future research with this species will include the criterion procedure.

It is interesting to note that Eglash and Snowden (1983) attempted in this study to discriminate between the marmosets' responses to novel stimuli and those believed to indicate that the mirror image was perceived as another (non-self) animal. In this analysis, "threats" such as genital displays, cackles, and arch-walks (p. 213) constituted the behavioral category for "social" responding. Behavior interpreted to occur in response to novel stimulation took the form of piloerection, sniff/touch, look

behind object, and look at side of object. Habituation occurred with respect to each of these responses, except looking at the side of an object. Behavior considered to be mirror-related (e.g., look at self, touching the mirror image) showed no similar decline with continuing exposure to mirrors over a four week period. While categorizations of mirror behavior with non-humans need to take into account the novelty of the mirror stimulus, it is difficult to define the subtle differences in responding occurring as a function of the mirror image and those related to the novelty of the reflective surface. It is also feasible that if "social" responses are directed toward the mirror reflection, they will not be confined to "threat" displays, instead responses may be affiliative or even neutral. Thus, Eglash and Snowden's (1983) observations of habituation of "threat" displays among pygmy marmosets may be similar to behavior previously reported for monkeys (e.g., Gallup, 1970) when observations of mirror behavior were based upon broader categories of "social" responding (i.e., inclusive of non-threat displays).

In sum, while researchers have consistently failed to demonstrate self-recognition among monkeys, some investigations suggest that monkeys display other forms of mirror behavior consistent with (or precursive to) its occurrence. Habituation is reported to occur with respect

to at least some forms of "social" responding. It is not known, however, if, as Eglash and Snowden (1983) suggested, habituation of "social" responding is a prerequisite for self-recognition. Further, problems arise in attempts to define "social" in this context, especially in comparisons between species. Resolution of this issue may require comparison of the facial expressions of monkeys in a variety of social and non-social conditions, perhaps using an analytical procedure such as that described by Schneider-Rosen and Ciccetti (1991) with human children. Facial analyses, however, are beyond the scope of the present work. Instead, it is intended here to provide a behavioral analysis of the phenomenon referred to as mirror or visual self-recognition, beginning with a discussion of the reflective properties of mirrors.

The mirror as a stimulus: A functional definition

Loveland (1986a, p. 15) described four perceptual characteristics relevant to all plane mirrors, or "invariant relations that hold between reflection and reflected." These are: 1) "reflection of layout", accuracy of the layout of surfaces perceived in a mirror excepting the direction and orientation of virtual or reflected image 2) "reflection of the preservation of the relational, ordinal, and rhythmical properties of events viewed directly in a plane mirror 3) "the domain of reflection," or the dependency of

the portion of the layout viewed upon the observation point from which stationary plane mirror is viewed and 4) "movement relative to the mirror", or the progressive magnification or "minification" of the reflected object as it or the observer approaches or retreats from the mirror.

In the present work, the constant perceptual characteristics of plane mirrors will be treated somewhat differently. The following description of mirrors seems, within this context, useful to a discussion of self-recognition in primates. Plane mirrors can be described functionally as providing two contingent relationships between objects and their reflections, specifically contingencies of appearance and of movement.

Plane mirrors provide virtual images of appropriately positioned objects so that there is correspondence of movement between an object and its reflected image and it appears to an observer that movements are simultaneous. For this analysis, the faithful reflection of both appearance and movement of appropriately positioned objects serve as necessary and sufficient conditions for labeling the reflecting surface as a mirror. And here, any virtual image (such as closed-circuit television) which exhibits these two properties may be viewed functionally as a mirror. (Problems of image reversal and image degradation are not

discussed here, although it should be noted that in specific conditions, partial image degradation results in a shadow.)

Failure of some individuals or species to self-recognize indicates failure to demonstrate perception of one or both of these reflective mirror properties (i.e., appearance and/or movement). It was therefore hypothesized that there may be individual or species differences in detecting and learning to use a mirror's reflective properties. In the Hunter College laboratory, one monkey was observed to exhibit behavior cued by the first, "appearance contingency," in the presence of reflected food, yet remain uninfluenced (as far as one could tell) by the second, "movement contingency." This animal was trained to locate and acquire slices of orange through use of a mirror reflection. The typical behavior for this monkey was to first look toward the mirror then move to a position within her cage in the vicinity of the food (or its reflection), and finally to reach out and grope "blindly" for the food without further reference to the mirror image of the orange slice. Hence, this demonstration was viewed as involving an "open" control system (Mittelsteadt, 1962) and the animal's reaching toward food can be described as <u>mirror-indicated</u> because the mirror reflection was only used to indicate the presence of food or its approximate location. The visual feedback from the mirror reflection here did not seem to

continuously influence the magnitude and direction of the monkey's reaching response as it might in demonstrations of mirror-guided reaching. There was no evidence that the animal relied on the mirror reflection on a moment-by-moment basis to determine if its reaching hand was moving closer or farther from the food target with consequent adjustments of movement. It was further hypothesized that despite this monkey's behavior, some individuals or species including some monkeys may be shown to detect and use both mirror properties, reflection of appearance and movement, forming what Mittelsteadt (1962) termed a "closed" feedback system. Finally, it was conceived that for some individuals or species, an intermediate system may be applicable.

Analysis of a mirror's stimulus properties provides a basis for interpretation of primate behavior in the presence of mirror reflections, and serves as the basis for the next section.

Attempts to demonstrate self-recognition among monkeys

Researchers have gone to great lengths to provide monkeys with an opportunity to learn the contingencies of mirror use, and to thus encourage mirror-oriented, mark- or "self-directed" responding. In addition to prolonging the duration of mirror exposure, several procedures have been tried. In the Hunter College laboratory, one pigtailed macaque had access to a mirror mounted inside of its cage

for one year. The interior mounting was intended to add tactile experience to the visual effects. Social responding persisted throughout the year and mark tests were negative (Calhoun-Radano & Thompson, 1978; Calhoun, 1983).

Anderson (1983) positioned two mirrors so as to form several reflections inside each individual monkey's cage, permitting several infant stumptailed macaques continuous access to the mirrors during the first year of life. The mark tests which followed were negative. The same monkeys later received an additional six months of group exposure to a large mirror, again with negative results. During 21 daily sessions of 30 to 60 minutes each, Anderson (1984b) placed an adolescent stumptailed macaque on his lap so that the animal faced a mirror located one meter away. Anderson then groomed the animal while keeping it oriented toward the mirror. An attempt was also made to train the animal to touch its head when verbally commanded to do so. The latter was unsuccessful and the mark test which followed was negative.

Exploratory studies performed in the author's laboratory used two small mirrors (about 22 cm by 45 cm) which were placed daily inside the cage of an individually housed pigtailed macaque. The animal was groomed by the experimenter as she faced one or the other mirror located only a few centimeters away from her body and/or face. The

mirrors were moveable and were nonsystematically manipulated throughout each session so as to reflect the monkey's (and sometimes the experimenter's) image from many different angles. Occasionally, the animal's nose or chin were marked with black marker pen while the animal was fully conscious. Also, during the third and fourth week, brightly colored "sticky dots" (white, yellow, and red Avery Self-Adhesive Color Coding Labels) or dabs of honey with red food coloring were placed on various parts of the monkey's body, both on areas directly visible to the animal and on body parts only visible to the monkey via its mirror reflection. At no time during this study did the monkey exhibit mirror-oriented, "self-" or mark-directed responding. Marks which were directly visible to the animal, however, were frequently inspected by the subject and if possible, removed and ingested.

Gallup, Wallnau, and Suarez (1980) permitted infant-infant and adult-infant pairs of rhesus macaques access to a mirror for more than 1370 hours and more than 1170 hours, respectively. The results of the mark test which followed were negative.

Anderson (1984b) described another attempt to train a monkey to make mirror-oriented, mark-directed responses. A monkey was marked (without use of a general anesthetic) at two day intervals in a sequential fashion, from hands to

head. It was found that only those marks which were directly visible to the animal were inspected.

Itakura (1987a) trained two Japanese monkeys to obtain pieces of apple visible only by means of a mirror. Training was accomplished by gradually increasing the number of target locations until the subjects could locate food placed in one of eight locations. Generalization for the task was apparent because responding improved over trials, with decreasing disruption of performance due to increases in number of target locations.

Next, Itakura (1987a) trained the same two monkeys in a task which, according to the author, demonstrated mirror-guided reaching and required continuous feedback from the mirror reflection to guide movement. Subjects were trained to look at a mirror reflection to determine which of four keylights were illuminated and then to reach toward and touch the lit key. As each key was touched, the keylight turned off, and another keylight was illuminated to cue responding, and so on, until reinforcement occurred after four correct sequential responses. The timing of events in this task and the limited number of target sites detract from Itakura's claim that continuous visual feedback via the mirror was required for the monkeys to respond to the keylights. For instance, learning to touch one of four sites would not be difficult in the absence of a mirror if

an alternative form of cue is made available to specify which site to touch. These procedures required a simple conditional discrimination which here would be described as "mirror-indicated." Procedures for demonstration of mirror-guided reaching, as will be discussed later, could involve interruption of the visual feedback via the mirror with consequent disruption of accurate responding, or alternatively, providing a moving target for manual tracking.

A subsequent test by Itakura (1987b) using the same two monkeys involved presentation of mirror images of pictorial stimuli (depicting monkeys, humans, or food) projected onto one of two screens to the left or right of the area behind the test cage. Holes drilled through opposite cage walls permitted direct viewing of each screen. One monkey was observed to view the reflected pictorial image via the mirror and then to gaze through the correct peephole at the screen for 93% of trials tested, while the second animal did so for 87% of the test trials. Itakura suggested that the performance by these two monkeys demonstrated generalization of mirrored tool-use by monkeys from a training situation (1987a) to a novel test situation (1987b). Problems of interpretation arise, however, since only the first and novel trial can be said to involve transfer of learning. Thereafter, responding was reinforced, if correct, for

selection of the appropriate peephole because the consequence was direct visual access to the pictorial image. Unfortunately, during this first trial, each animal was tested with only two alternative responses (i.e., there were only two peepholes) and the correct response for each subject can be thought of as having a probability of 0.50 by chance factors alone.

Itakura (1987b) then used a Gallup mark test procedure with the same monkeys to determine if visual self-recognition was a consequence of extensive training with mirror reflections (described above). Green dye marks were placed on each monkey's brow and wrist during a first test, and on an ear and below the nose during a second test which occurred one week later. Although one monkey was reported to touch a mark under its nose in the presence of a mirror, Itakura concluded that evidence for self-recognition was unconvincing for these subjects.

In a final procedure, Itakura (1987b) tested the same two monkeys (plus two additional monkeys which were relatively naive with regard to mirrors) using a procedure referred to as a "flower test." Subjects were permitted to habituate to the presence of a collar for four days, then while the animals were anesthetized, a cloth flower (weighing 0.5 g) was attached to the end of a stick and onto the collar. Behavior in the presence of a mirror was then

observed. According to Itakura, the two relatively naive animals made no effort to touch the flowers above their heads, while both experienced monkeys attempted to do so. One of the latter was successful in grasping the flower, and Itakura stated that the monkey achieved this with difficulty after first gazing toward its mirror reflection. In view of the negative results for monkeys when tested by means of the Gallup mark test, Itakura's observations are provocative. Although it might be argued that the monkeys sensed the weight and movement of the target objects, the two naive animals made no attempt to grasp the flowers. Interpretation is difficult, however, when comparisons are made between groups comprised of only two subjects.

This section surveyed many of the methods used to encourage mirror-oriented, mark-directed responding or self-recognition among monkeys. (Additional studies will be presented later in discussing suggestions to account for the apparent failure of these animals to exhibit the phenomenon). At the start of the experiments to be presented here, there was said to be a categorical difference between monkeys and at least some of the great apes with respect to behavior directed toward the mirror self-image. Even more recently, researchers have speculated about the possible evolutionary origins of this difference (Gallup, 1991, in press). However, the nature of the

differences, if they exist, is unknown. In an effort to understand monkey responses toward mirror self-reflections, it is helpful to examine the behavior of humans in the presence of their mirror reflections, with special attention to the behavior of non-self-recognizing individuals.

Self-recognition among humans

Some humans reportedly fail to self-recognize in the presence of their mirror self-reflections. It is well-established that very young children behave differently from normal adults in the presence of a mirror. Dixon (1957) stressed the influence of maturation on the acquisition of visual image self-recognition. Dixon's criterion for self-recognition was the occurrence of repetitive movements as each child appeared to intently observe the mirror reflection. On this basis, Dixon suggested that self-recognition occurs at about six to seven months. Dixon (1957) also described the occurrence of "social play" in the pre-self-recognizing child (i.e., responding to the mirror as if it were another child).

Other researchers, however, have reported that self-recognition is acquired at a later age. Amsterdam (1972) used a method similar to Gallup's mark test in order to test for self-recognition among infants. Each child was marked on the nose with rouge and then placed in front of a mirror. Self-recognition was presumed to occur if the mark was

touched or if the child appeared to examine its nose via the mirror. Acquisition of self-recognition was determined by Amsterdam (1972) to occur between 18 and 24 months of age for human infants. Several problems are inherent in testing children, however. Subterfuge, if attempted, is difficult during marking. The nose is to some extent directly visible and rouge (such as Amsterdam used) may have been scented. Therefore, some researchers have included a control procedure in which each child is marked and observed in the absence of a mirror.

Lewis and Brooks-Gunn (1979), using a procedure similar to that of Amsterdam (1972), indicated that self-recognition is acquired in some cases at about nine months, yet more often by 24 months of age. Additional tests showed that most infants of nine months would turn in order to directly view an object (an unfamiliar adult) whose presence behind them was detected via (self-reflecting) closed-circuit television. The turning response was not observed for these children when the video image consisted of the same object intruded behind the image of another child of similar age, gender, and dress, and whose movements were not contingent with the subject's own movements. Further, pre-self-recognizing infants were reported by Lewis & Brooks-Gunn (1979) to respond to their mirror images with more sustained attention, smiles, kisses, and touching of the mirror's

surface as compared to self-recognizing children. It was also observed that pre-self-recognizing children, when compared to older children, were less apt to act silly or coy in the presence of their self-image and were more likely to touch specifically that portion of the mirror image which reflected the child's own body.

In a more recent study, Robinson, Connell, McKenzie, and Day (1970) demonstrated that some 22-month-old and few 18-month-old infants turned in order to directly view a toy first seen via his/her mirror reflection. Further, among those children who succeeded in performing this task (i.e., used the mirror reflection to locate the toy), responding was not dependent upon the presence of the mirror self-reflection in conjunction with the toy's reflection. The authors concluded that tasks involving localization of non-self objects by means of mirror reflections do not serve as indices of self-recognition.

Persons other than young children have been shown to fail to self-recognize in the presence of mirror self-reflections. Pollack, Karp, Kohn, and Goldfarb (1962) studied responses to mirrored self-reflections for subjects 65 years and older. A 9 in by 11 in mirror was placed in front of each subject's face as the experimenters asked each subject, "What do you see?" If the reply did not include some form of self-identification, then the question was

repeated. A small number of institutionalized aged patients were reported to fail to self-recognize according to these criteria. Discussion of these patients emphasized the seeming contradiction between their high level of linguistic competence and apparent perceptual defects underlying "disorientation of self" (p. 407).

Pechacek, Bell, Cleland, Baum, and Boyle (1973) used a modified mark test to investigate self-recognition among profoundly retarded institutionalized males. After three days of exposure to a full-length mirror, subjects were marked on their foreheads during sleep using a nontoxic marker. Upon waking, subjects were again placed in front of the mirror and observed for mark-directed responding. The authors reported that none of their subjects behaved in such a way as to unambiguously indicate the occurrence of self-recognition. These patients were reported to spontaneously turn away from the mirror in apparent disinterest or to simply stared vacuously in the direction of the mirror. In a continuation of this study, a second group of subjects were reinforced with marshmallows and social praise for direct gazes toward a mirror over a three day period. Self-recognition testing followed and consisted of requesting subjects to select a photograph of themselves from a group of peer photographs. It was concluded that this form of training did not produce self-recognition in any subjects

tested. Harris (1977) replicated the work of Pechacek et al. with similar results.

Young preverbal retarded children have been tested for self-recognition. Hill and Tomlin (1981) used a mark test with closed-circuit television and pretaped video images. In a control or baseline procedure, unmarked subjects were presented with their closed-circuit television images. Then, marking took place surreptitiously during a peek-a-boo game as each subject's eyes were covered with a tissue. (The specific facial areas marked, however, were not specified). It was reported that all but one of the Down's syndrome children tested showed increased touching of the marked facial areas for the marked compared to the unmarked condition. These children were also reported to respond appropriately (with fewer mark-directed responses) in the presence of a pretaped video image of a marked peer. It is also interesting to note that the authors reported no significant difference in responding to a marked closed-circuit television image when compared to a marked pretaped self-image for these Down's syndrome children. Evidently the correspondence between the child's movements and those of the reflected images was not an important factor in making the self vs. other discrimination. On the other hand, less than half of a group of multi-handicapped children were reported to self-recognize according to Hill

and Tomlin (1981). While the behavior of the Down's syndrome children was characterized as curious and self-conscious in the presence of the mirror self-image, the multi-handicapped children were reported to exhibit a more restricted range of behavior in the presence of their mirror reflections. Multi-handicapped children were described as exhibiting either disinterest in the mirror reflection or mirror-directed, "social" responding more characteristic of normal children during the first year of life.

Loveland (1986b) compared the mirror behavior of Down's syndrome children with that of normal children. In this study, mark testing procedures were used in combination with mirror tests which presented reflected non-self images (the mother or a toy) cuing each subject to turn and directly view the mother or toy. Loveland found that Down's syndrome and normal children did not differ significantly in performance of these tasks, although the retarded children were observed to exhibit more exploratory behavior directed toward the mirror than the normal children.

Neuman and Hill (1978) tested autistic children, aged 5 to 11 years, for self-recognition. Each child's face was marked using subterfuge. It was found that mark-directed responses occurred significantly more frequently during presentations of a closed-circuit television image compared to a condition with a pre-taped self-image without facial

marks. It was also reported that the autistic children spent more time viewing the movement-contingent image than the pre-taped video image.

Eighteen individuals diagnosed with senile dementia of the Alzheimer type were observed for five minutes in the presence of their mirror reflections. They were then tested using the Gallup procedure for self-recognition with a re-test occurring three weeks later (Biringer, Anderson, & Strubel, 1989). Severity of dementia symptoms among these patients was reported to be negatively associated with attempts to remove the mark or, in the case of a single subject, with verbal comments regarding the mark's presence. Further, all of the subjects who exhibited self-recognition during the initial test did so in the re-test situation. Two subjects exhibited positive responding for the re-test situation only, but were described as displaying little or no appropriate behavior in the presence of the mirror reflection (e.g., fixing the hair). Subjects who consistently failed to detect the mark were reported to have no observable reaction to the mirror image, to speak to the self-image, or less often, to display an interest in and touch the mirror. Moving the head while observing the mirror reflection was reported to occur for two subjects (one of whom exhibited mark-directed responding for both tests, while the second of these subjects responded to the

mark during the re-test only). Unfortunately, while subterfuge was used to mark each subject's forehead, a control condition was not included in these procedures to determine if mark-directed activity occurred in the absence of a mirror reflection.

Schizophrenic adults have been reported to correctly label their own photographs and sound motion picture self-images (Cornelison & Arsenian, 1960). Yet, other studies report that persons diagnosed as schizophrenic display symptoms indicative of an indefiniteness or distortion of perceived or conceived body self-image. For example, Cleveland (1960) reported that adult schizophrenic patients consistently overestimated the size of their own conceived body parts (unviewable due to a covering cloth) in comparisons with a series of photographed body parts ranging from smaller than to larger than the subject's own. These patients reportedly made fewer estimation errors when comparisons involved non-self objects such as real and photographed baseballs. A control group consisting of non-psychotic patients was shown to exhibit relatively accurate responding in similar comparisons regarding their own bodies.

Dillon (1962) devised an instrument to measure perceived body size in terms of full-body height, width, and depth, as well as perceived body size of specific body parts

(length of arm, width of head, etc.) The testing apparatus consisted of wooden doorway-like structure with movable horizontal and vertical beams. Psychophysical procedures were used to estimate each subject's perceived body dimensions through experimenter adjustment of the dimensions of the apparatus. Psychotic individuals were not found to differ significantly from a normal control group with respect to errors in these estimations.

Similar psychophysical studies of body-image have used distorted mirrors which could be gradually undistorted by the experimenter by means of a motorized mechanism to bend or unbend the mirror along two dimensions (Traub & Orbach, 1964). Preliminary work (Orbach, Traub, & Olson, 1966) using this adjustable mirror device indicated defects in body-image among patients described as chronic schizophrenics.

Ben-Tovim and Walker (1990), on the other hand, investigated the effect of a full-length mirror on body-width estimates among 66 normal adolescent females and reported that estimates were significantly greater than real body size. In this study, estimates of body size (faces, shoulders, chests, waists, and hips) were obtained using a horizontal array of light-emitting diodes which could be controlled by a joy stick so that two points of light either converged or diverged from a single point. It was found

that estimates of waist and hip size correlated significantly with real body size and were relatively unaffected by presence or absence of a full-length mirror. Estimates of shoulder size were correlated with real body size only when the mirror was available, and estimates of face and chest were never correlated with real body size. It is interesting to note, although the authors do not address this issue, that estimates of body parts such as the waist and hips (which are frequently and easily viewed without aid of a mirror) showed a stronger correlation with real body size for these subjects than did estimates for the face (which can never be viewed directly). Investigations of the effect of a mirror on body size estimation should determine the effect, if any, of obstruction of view for directly visible body parts.

In summary, some young or abnormal (e.g., mentally retarded, schizophrenic) human populations behave differently in the presence of their mirror reflections when compared to normal or adult humans, or even in comparison to some great apes. In the absence of mirror-oriented, mark-directed responding, some humans exhibit high levels of interest in the mirror reflection or are observed to engage in exploratory behavior with the mirror image (e.g., Biringer et al., 1989), while others display certain types of "social" behavior directed toward the mirror image (e.g.,

Dixon, 1957; Hill & Tomlin, 1981; Biringer, 1989), and still others show a lack of interest in the mirror image (Pechacek et al., 1973; Hill & Tomlin, 1981). Some self-recognizing humans, on the other hand, are reported to show excessive interest in the mirror reflection or some form of exploratory behavior with the mirror (e.g., Neuman & Hill, 1978; Lewis & Brooks-Gunn, 1979; Loveland, 1986; Biringer et al., 1989). To conclude, some (but not all) humans who fail to exhibit mirror-oriented, mark-directed responding in tests for self-recognition behave in a way (e.g., talking to the self-image) suggestive of a perceptual deficit in that the mirror reflection is acted upon as if it were another individual.[1] A variety of sensory, perceptual, cognitive, or motivational factors may affect behavior in this context. Similarly, a variety of factors influence the behavior of monkeys in the presence of their mirror reflections. Investigations of perceived or conceived body self-image (e.g., Orbach et al., 1966) permit an alternative means of testing self-perception among humans, and through instrumental procedures may have future application for use with non-human primates.

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1 Novelty of the mirror stimulus is not usually an issue with human subjects.

Suggestions to account for apparent differences in mirror behavior for the great apes and monkeys

Differences in mirror behavior between monkeys and the great apes (chimpanzees and orangutans, if not gorillas) have led to numerous speculations among researchers. Monkeys are typically viewed as being deficient in some sense, usually in terms of cognitive ability, or are viewed as displaying behavior(s) which interfere with the acquisition of appropriate mirror behavior.

For instance, many species of monkeys exhibit a tendency to avoid direct gazes toward the facial regions of conspecifics (gaze aversion). In these species, sustained eye contact with other individuals is frequently accompanied by bouts of characteristic facial and body displaying, referred to as "threats," leading to retreat or submissive displays on the part of the target animal. Premack (1983) suggested that gaze aversion may generalize to a mirror situation thus precluding the occurrence of self-recognition among monkeys. Gallup, Wallnau, and Suarez (1980), however, argued against a gaze aversion hypothesis as an explanation of the failure of mother-infant and infant-infant monkey pairs to self-recognize. Two five-month-old rhesus infants, male and female, were presented with a mirror on a daily basis for a period of 14 weeks. Both infants were reported to maintain a high rate of sustained mirror-looking,

evidently gazing at the mirror image 19% of the time in which it was available. An adult rhesus macaque, however, looked at the mirror approximately 8% of the time it was available during a period of 12 weeks. Therefore, the claim that monkeys fail to self-recognize in the absence of gaze aversion was based upon observations of five-month-old infant macaques. Since it can be speculated that age limits for self-recognition occur for species other than humans, these infant monkeys may have lacked the prerequisite cognitive and perceptual maturity.

Gallup (1977b, p. 334) has suggested that monkeys as a phylogenetic group lack the cognitive capacity for self-recognition. According to Gallup, "...monkeys can learn to use mirrors to manipulate objects (Brown, McDowell, & Robinson, 1965), [but] they seem incapable of learning to integrate sufficiently features of their own reflection to use mirrors to respond to themselves." A critical analysis of the 1965 study, however, requires one to question this conclusion. Brown et al. (1965) trained rhesus macaques to look into a mirror suspended over a table (a modified Wisconsin General Test Apparatus) and trained the animals to pull one of two strings to obtain an attached piece of apple which was visible only by means of the mirror. It can be argued that performance of this task does not indicate that the animal has learned that mirrors reflect either movement

or appearance. Instead, one could conceivably have replaced the mirror's cues with a light which by virtue of being on and off, indicated the correct string for the monkeys to pull in order to obtain the apple. This procedure tested subjects for a capability to perform simple visual discriminations. A more rigorous test for comprehension of a mirror's reflective properties might consist of exposure to mirrors, followed by a test situation where subjects are provided the opportunity to spontaneously (in the absence of instrumental training) select and pull the correct string from among many choices. It is doubtful, however, that many monkeys would respond in this fashion for reasons to be discussed below.

Gallup has further suggested that monkeys, lacking a cognitive capacity for self-recognition, respond to the mirror as if it were a conspecific (e.g., Gallup, 1968; Suarez & Gallup, 1986). This suggestion has intuitive support since a monkey's mirror reflection shares many visual attributes with other "live" monkeys. Yet, monkeys are likely to detect the attributes of a mirror reflection which differ from presentation of a "live" conspecific (or from a conspecific viewed through a window) resulting from odor, movement and/or appearance correspondence, absence of auditory cues, and so forth. Research conducted in the Hunter College laboratory systematically tested a single

pigtailed monkey with sequential presentations of a mirror and a stimulus monkey (distance of image and luminance factors were matched between the two conditions). During this study period, the test animal spent longer periods of time observing the stimulus monkey than her own mirror image (see Figure 1) indicating discrimination between the two conditions.

Inferences regarding primate perception are problematic when based solely upon occurrence or nonoccurrence of "social" responding. As discussed previously, monkeys exhibit similar facial displays in the presence of (and directed toward) non-social stimuli, hence inferences regarding perception are untenable when based upon the occurrence of species-typical displays. Further, some researchers (e.g., Platt & Thompson, 1985) report low levels of "social" responding after prolonged (one year) exposure to mirrors for adult Japanese macaques housed as a group in an outdoor compound. The authors speculated that this group of monkeys viewed the mirror reflection as an image other than a conspecific and as other than a self-reflection. It may be beneficial, as these authors suggest, to avoid imposing a self vs. other dichotomy on descriptions of monkey mirror perception and behavior.

In attempting to understand the apparent lack of mirror-mediated, mark-directed responding in monkeys,

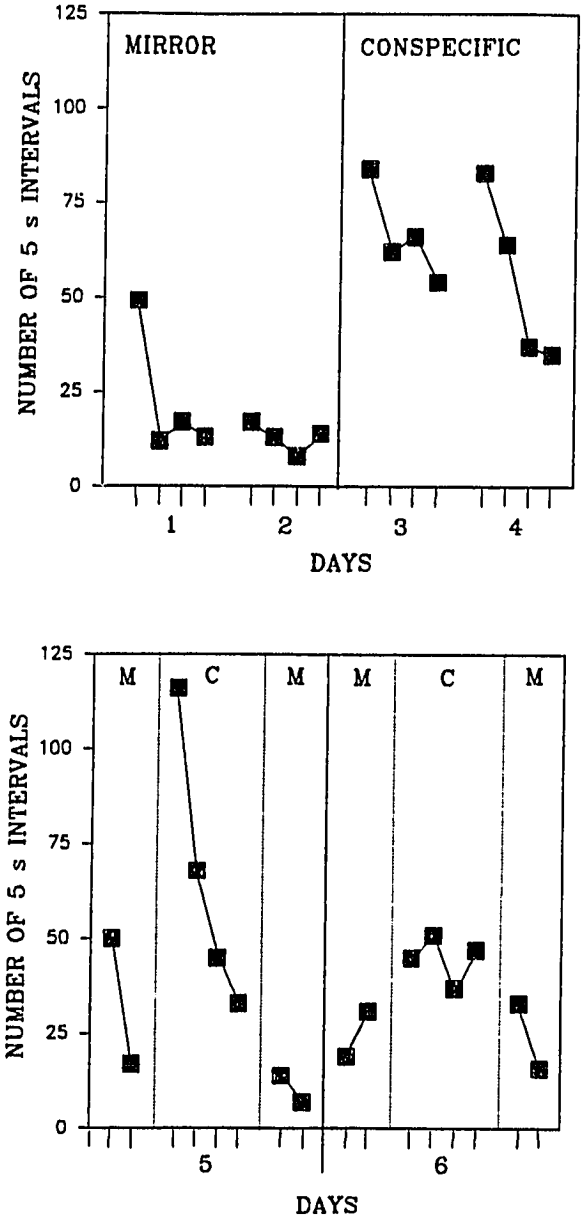

Figure 1. Number of 5 s intervals with camera-defined "eye contact" per 15 minute observation period within each daily session for the monkey Roberta when provided visual access to a mirror (M) or a conspecific (C) under viewing conditions matched for distance (image size) and overall luminance.

Menzel, Savage-Rumbaugh, and Lawson (1985) questioned the facility with which monkeys interact with mirrors to detect and locate non-self objects. Two chimpanzees (previously trained in American Sign Language) were reinforced with fruit for reaching through an opaque barrier to touch a target visible only by means of a mirror or via a closed-circuit television. The target was a black spot randomly positioned on any one of the white squares of a checkerboard pattern. While these chimpanzees apparently learned to perform the task with ease, even after rotation of the video monitor (and image), rhesus monkeys failed to do so. It is interesting to note that rotation of the video image provided a novel source of visual feedback for the chimpanzees although the mirror's two contingencies, appearance and movement remained constant. Transfer of learning therefore occurred from the instrumental situation to a novel test situation indicating that the chimpanzees' responding was affected by the mirror's contingent properties. This study, like the Gallup mark test, demonstrated differences between chimpanzees and monkeys in behavior affected by the contingencies of mirror use. Menzel et al. attributed their findings to species differences in perception and capacity to use spatially displaced visual feedback regarding self-movement.

Recent evidence, however, suggests that monkeys are capable of using spatially displaced visual feedback to guide their actions. Rumbaugh, Richardson, Washburn, Savage-Rumbaugh, and Hopkins (1989) trained two rhesus monkeys to manipulate a joystick to respond to a variety of computer-generated targets. The authors state that these two monkeys mastered precise control of a joystick using feedback from a video monitor located 9 to 18 cm from the manipulandum.

Anderson (1986, p. 237) described "spontaneous" mirror-mediated location of food by two macaques, consequently favoring the view that failures to self-recognize by monkeys stem from placement of the target (the dye mark) on the monkey's own body opposed to a non-self location. In Anderson's procedure, subjects were trained to reach through the front of their cage to obtain honey-dipped raisins placed by the experimenter onto a horizontal target area. Subjects were then exposed to a 1 m by 1 m mirror for a period of two weeks. During the test situation which followed, the experimenter made six to eight baiting movements, only one of which actually placed the bait onto the target area. Two dependent measures were recorded, success vs. lack of success in obtaining raisins within a two minute criterion period, and latencies with respect to successful trials. Although several species were tested,

only one Japanese macaque and one stumptailed macaque were reported to exhibit mirror-mediated responding.

Anderson therefore suggested that in testing for self-recognition, large sample sizes are necessary in order to conclude that a particular taxonomic category lacks a given capacity. Anderson's (1986) Japanese macaque (which appeared to be the more successful of the two animals) required an average of three attempts to locate the raisins during the first 25 test trials, with an average latency of 18 s. Performance by this monkey improved, however, and the animal learned to use the mirror to locate the food in a single attempt within two seconds, as compared to latencies of more than 20 s in the absence of a mirror. Data for the second animal are somewhat less impressive. Anderson's stumptailed macaque eventually learned to locate the food within 7 s of its placement, as compared to 19 s in the no-mirror condition. Yet, this second animal, unlike the Japanese macaque, exhibited <u>inhibition of searching</u> when the mirror reflected a no-food condition.

An important comment here involves Anderson's (1986) use of the word, "spontaneous." Its usage implies that the monkeys learned about the mirror's reflective property(s) during the initial (pre-test) exposure to the mirror, immediately exhibiting behavior during the test situation indicative of control by the mirror's contingent or

reflective properties. This was not the case, although Anderson suggests that the demonstration involved "... the spontaneous development of mirror use to direct manual searches for otherwise invisible targets...." Instead, subjects were initially trained to make reaching movements when presented with the test apparatus (in the absence of a mirror). Further, instrumental procedures were required to train the monkeys to reach accurately toward the food (correct reaches were reinforced with honey-dipped raisins) and latencies were observed to decrease with trials.

Anderson (1986) suggested that his successful animals may have been performing a simple visual discrimination (similar to the situation discussed previously regarding Brown et al., 1965). Anderson therefore suggested that future research incorporate several procedures to clarify monkeys' usage of mirror cues: 1) determine the extent to which monkeys visually track their hands during mirror-mediated reaching tasks, 2) determine the effect on successful reaching when the mirror is presented only briefly, and 3) determine the effects on behavior of feedback from partial or displaced images of the searching hand.[1]

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1 In essence, Anderson's suggestions employ tactics similar to those described by Land (1971) and Mittelsteadt (1962) in investigations interrupting feedback loops underlying movement among spiders and insects.

Following the training procedures described above, Anderson (1986) tested his subjects for generalization to a novel mirror situation by changing the target area from a horizontal to a vertical configuration. The Japanese macaque was observed to gaze at the reflected food and then to begin searching for the food, locating the food after four attempts and within six seconds. Thus, in this generalization test, the Japanese macaque alone spontaneously and immediately searched for the food, although its reaching toward the food target lacked accuracy. Based upon Anderson's description, this animal exhibited generalization of mirror-indicated, but not mirror-guided reaching toward the food target. Control procedures (e.g., masking of possible food odors) would benefit future investigations with similar aims.

Itakura (1987b) suggested that monkeys fail to self-recognize resulting from a lack of motivation to touch marks on the face. Boccia (1991) has informally observed that in autogrooming, monkeys tend to "... pass over objects (e.g., a piece of woodchip bedding) in the fur..." suggesting that monkeys lack interest in the body surface and are unresponsive to deviations from normal appearance. The latter suggestion has some support from observations of a pigtailed monkey in the Hunter College laboratory who underwent amputation of a finger as a result of injury. This

monkey was observed and videotaped as she recovered from the anesthetic on the day the bandage was first removed. Although this was in no sense a controlled or systematic observation, the monkey appeared to display little interest in the changed appearance[1] of her hand. The animal was observed to sit with both hands grasping the cagebars at her chest height with gaze forward toward her hands. Yet, she appeared to visually and manually inspect the site of the missing finger only after the injured hand contacted the undamaged hand during general movements about the cage, and then only briefly (i.e, inspection occurred only once during the hour observed and lasted only a few seconds). In contrast, both Anderson's (1984b) and my own observations provide evidence that monkeys attend to and manually inspect marks on directly visible body parts. Further, pigtailed

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1 Self-recognizing non-humans may respond to the changed aspect of their appearance (i.e., the presence of a dye mark) as detected via a mirror image or, as a simpler explanation, may be responding merely to the red mark itself without reference to the head or face other than as a background which makes the mark noticeable. This is a subtle distinction, but an important one. In this sense, the term, "self-recognition" may be a misnomer since its use implies something about self-perception. Further, the term, "recognition" is associated more often with matching-to-sample procedures than with demonstrations of oddity learning or difference discriminations (here, regarding changes in the appearance of the face or head). It should be noted that humans generally experience a reinforcement history which specifically trains discriminations with sequential presentations of reflected self-images. Similar training with monkeys or chimpanzees may be possible, but would require many trials with highly desirable reinforcers for correct responding.

macaques, when engaged in mutual grooming with caretakers, often focus their ministrations on sites of small freckles or smudges, sometimes scratching and manipulating these areas to the caretaker's discomfiture. It remains to be determined whether a monkey's motivation to touch marks on its face differs substantially from motivation to touch marks on other body sites once the animal has detected the presence of the mark. Methods (in the absence of a mirror) which increase levels of interest among monkeys for marks on visible body sites should aid in resolving the issue, by concommitantly increasing interest in facial marks.

A final suggestion in the literature to account for the repeated failures of monkeys to self-recognize is one which in part, will be investigated here. Epstein and Koerner (1986) speculated that the mirror self-image serves as an unconditioned stimulus for the occurrence of ("social") facial displays directed toward the mirror, precluding acquisition of other mirror responses.

In conclusion, monkeys have been shown to learn some, but not all, contingencies of mirror use. Some monkeys among those tested (e.g., Anderson, 1986) exhibited behavior (mirror-indicated reaching) from which it could be inferred that the mirror's reflection of appearance affected responding. Further, some monkeys tested by Anderson (1986) and Itakura (1987a) generalized with respect to mirror-

indicated reaching after changes from a training situation to a novel test situation (configuration changes of the test apparatus and gradual increases of target number for Anderson and Itakura, respectively). It remains controversial, however, whether monkeys are capable of learning to use moment-by-moment feedback via a mirror to guide reaching movements. While Itakura (1987a) claimed that his two monkeys exhibited this latter form of mirror use (i.e., mirror-guided reaching), there were only four targets in the keylight task and mirror-indicated reaching could account for his results. On the other hand, Anderson (1986) used 20 target locations providing stronger, yet not conclusive evidence for mirror-guided reaching by monkeys. It also remains uncertain if criterion responding for self-recognition as demonstrated by the Gallup mark test requires mirror-guided reaching in conjunction with detection of the dye mark via the mirror image. Future research might employ psychophysical methods in investigations of the temporal relationships between movement to touch self vs. non-self targets and visual feedback from mirrors or other reflective images.

More important here, current evidence suggests that researchers have yet to demonstrate full comprehension of mirror reflections by monkeys, even with reflections of non-self objects. The absence of self-recognition among monkeys

may thus be due to a variety of factors including failure to detect the stimulus properties of mirrors (perhaps resulting from a tendency to avert gaze from the self-reflection), interference with learning resulting from the occurrence of species-typical facial displays, lack of motivation to touch marks on the face, among many other factors. Inferences (e.g., Gallup, 1991) regarding the absence of "self-awareness" or an inadequate "self-concept" for these animals remain interesting, but speculative. Certainly, a behavioral analysis of the classes of behavior comprising competent "knowledge" or use of the information available via mirrors is far from complete for either humans or non-human primates.

Behavior required for self-recognition

It would be naive to assume that all monkeys fail to exhibit mirror-oriented, mark-directed responding (self-recognition) as a result of some single causal factor. A review of studies involving non-self-recognizing humans reveals differences in responding to their mirror self-images, ranging from disinterest for the reflected self-image, to high levels of interest, the latter sometimes accompanied by some form(s) of exploratory activity with the reflective surface. Investigations with monkeys parallel these findings. Self-recognition should be viewed as a

complex phenomenon whose occurrence is dependent upon a number of different behavioral classes.

An animal such as a monkey placed in front of a mirror for the first time may detect the similarity(s) between the appearance of its mirror reflection and that of other monkeys, providing it has had appropriate social experience. While Gallup et al. (1971) reported that isolate-reared chimpanzees failed to respond "socially" to their mirror images and subsequently failed to demonstrate self-recognition, it is not known at this time if a transient period of "social" gesturing toward the mirror is a prerequisite for mirror-oriented, mark-directed responding. On the other hand, an animal's tendency to look at the mirror reflection is of vital importance in learning to self-recognize. An individual which averts its gaze from the mirror or which only monitors the reflection with brief or infrequent looks is unlikely to detect the contingencies for mirror use. If adequate mirror-looking does occur, the self-recognizing animal must then display the appropriate sensory, perceptual, cognitive, and motivational tendencies for behavior to be affected by a mirror's reflective properties.

A capacity for unimodal and cross-modal same/difference discriminations is relevant to the phenomenon of self-recognition. The animal may detect similarities of

appearance for the non-self objects in its environment and the mirror reflections of those objects, or it may detect the similarity of appearance for one or more of its own directly visible body parts (e.g., the torso or hand) and the appearance of those body parts via a mirror. Transfer (or stimulus generalization) must occur for the animal to learn that the appearance of objects which cannot be viewed directly (e.g., the animal's own head or face) may be detected and examined using the mirror. Transfer, in some cases, may be aided by multi-modal perceptual learning (i.e., "...when I move my head, the image in the mirror moves its head"). Integration of multi-modal perceptions may also take the form of "...that (the mirror image) looks like this (my face) feels" if one imagines a monkey stroking or otherwise touching its face while gazing at the mirror.

In this analysis, potentially self-recognizing animals must detect the contingency of appearance between objects and their mirror reflections in order to learn that their own full body is also reflected. A tendency to engage in further exploration or manipulation of the mirror's properties may ensure more solid generalization or transfer. Self-recognition may ultimately be enabled by, but may not require, animals learning that mirrors reflect movements of objects, including their own movements.

In a mark test situation, additional behavioral tendencies come into play. An animal which has been under the effects of an general anesthetic, dye marked, allowed to recover, and then placed in the presence of its mirror reflection must look at the reflection in order to detect the dye mark, and must be motivated to do so regardless of any residual effects of an anesthetic. (It is feasible that a variety of motivational factors are affected for some period of time even after eye-hand coordination has returned to normal). Minimally, the self-recognizing animal must exhibit behavior (mirror-indicated reaching) from which it can be inferred that the animal has learned that mirrors reflect the appearance of appropriately positioned objects, including itself. It is not clear whether mirror-guided reaching to the dye mark is required since it is usually small rather obviously bounded areas such as ears and eyebrows which are marked. (These target areas are not expansive and learning of point-by-point correspondences may have been aided at some earlier time by cross-modal perceptions). Accurate mark-directed responding, however, may be enhanced by the finer calibrations of movement possible if the movement contingency were also influencing behavior. It is unlikely, however, that the movement correspondence alone would affect self-recognizing behavior since the animal would not then be motivated to touch the

dye mark on its face. Finally, an animal which has learned the contingency(s) of mirror use must also be physically capable of and motivated to touch dye marks, regardless of any residual effects of an anesthetic. While an animal looking at its reflection in the mirror may know in some fashion that there is a spot on its own face and may be capable of touching the spot using the mirror for visual feedback, it may not be motivated for a variety of reasons to investigate or remove the spot.

In sum, failure by individuals or species to self-recognize may involve any number of sensory, perceptual, motivational, or cognitive limitations. Here, the intention was to investigate further the underlying factors relevant to the success or failure of apes and monkeys to exhibit mirror-oriented, mark-directed behavior. These experiments began with an attempt to replicate investigations demonstrating self-recognition among chimpanzees (*Pan troglodytes*) for comparison with the behavior of monkeys (*Macaca nemestrina*) in the presence of mirror self-images. Specifically, mirror-looking was measured for both species and an attempt was made to increase levels of mirror-looking by monkeys through manipulation of the events accompanying or contingent upon mirror gazing. Finally, given increased levels of mirror-looking, these same monkeys were tested by means of the Gallup mark test for visual self-recognition.

EXPERIMENT 1:

CHIMPANZEE SELF-RECOGNITION

Gallup's (1970) demonstration of self-recognition among chimpanzees has been replicated several times (e.g., Suarez & Gallup, 1981; Robert, 1986). Few investigations, however, have included repeated mark tests with individual subjects. Calhoun and Thompson (1988) used a test/re-test procedure for two chimpanzees with a one year interval between tests. Results were interpreted as indicating that the self-recognition phenomenon occurs reliably for individual subjects. Swartz and Evans (1991) described the use of repeated mark test procedures with seven of eleven chimpanzees. Only one of these animals exhibited mirror-oriented, mark-directed responding, doing so on three separate occasions. The remaining six subjects consistently failed tests for self-recognition.

The purpose of the first experiment presented here was to replicate Gallup's (1970) demonstration of self-recognition among chimpanzees, with an additional interest in confirming preliminary findings that mirror-oriented, mark-directed responding occurs reliably with repeated testing among individual subjects. Duration and frequency of mirror-looking by a self-recognizing chimpanzee could then be assessed for later comparison with the behavior of monkeys in the presence of mirror self-images.

Methods

Subjects

Subjects were three juvenile[1] chimpanzees (*Pan troglodytes*), one female and two males, named Amy (CH404, 22.3 kg), Reggie (CH391, 18.0 kg), and Rocky (CH403, 18.4 kg) aged approximately five years (ranging from 5.0 to 5.2 years) at the time of testing. Each subject was individually caged (see Figure 2 for cage dimensions) at the Laboratory for Experimental Medicine and Surgery in Primates (LEMSIP) located in Sterling Forest, Tuxedo, New York. During the study period, the three chimpanzees were maintained in a single room with visual and auditory access to one another. Subjects were participants in on-going investigations of hepatitis-B but were asymptomatic for this disease at the time of the present study. Lighting was controlled on a 12-hour light/dark cycle. Feeding took place in the late afternoon and diets consisted of standard commercial primate laboratory chow in combination with a variety of fruits and vegetables. Water was available on an *ad lib* basis.

With the exception of Rocky, who occasionally exhibited some forms of repetitive "acrobatic" activity

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1 Chimpanzees achieve locomotor independence at six months and sexual maturity at 8-12 years (Yerkes and Yerkes, 1929). Independence from the mother occurs at about two years of age (Riopelle & Rogers, 1965).

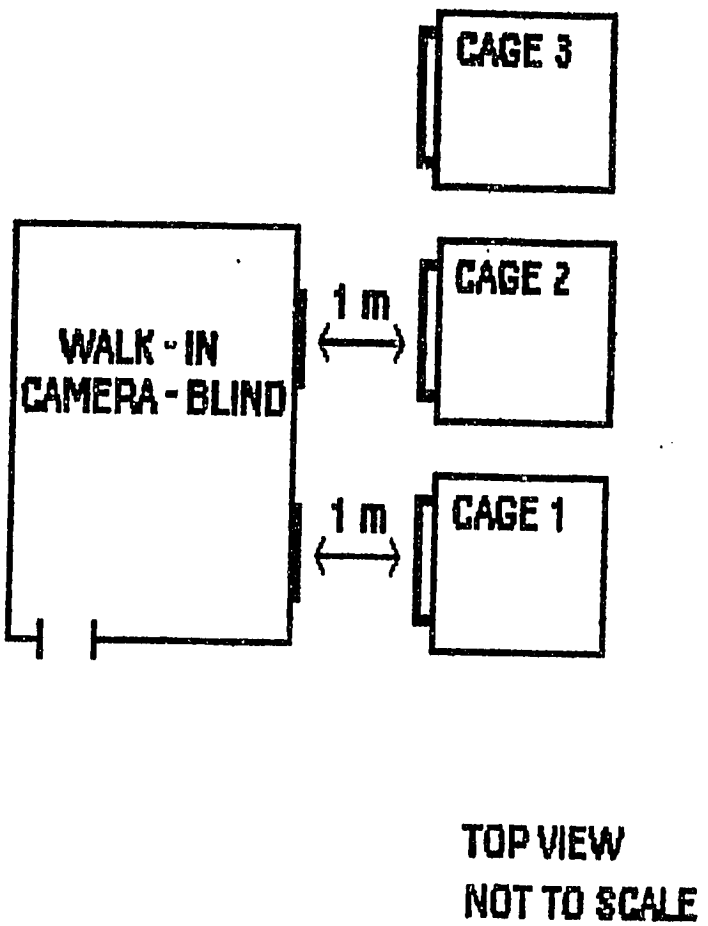

Figure 2. Spatial arrangement of chimpanzee cages (0.81 m x 0.81 m x 1.19 m), transparent Lexan windows (0.45 m x 0.53 m, installed on the fronts of two cages) and the two one-way mirrors (0.74 m x 0.74 m, installed in the camera-blind) in Experiment 1. Subjects were able to view one another directly and when housed in cages 1 or 2, were also able to view their own mirror self-reflections. Subjects housed in cages 1 and 3 were visible to one another via the mirror in front of cage 1. Mutual visual access via mirror reflections was otherwise restricted as a result of room arrangement.

(e.g., spinning in place, grasping the sides of his cage and executing 360 degree entire body "flips"), subjects appeared free of stereotypical behavior and in good "psychological" health. According to the facility's records, Amy was reared in the special primate nursery at LEMSIP, while the two male chimpanzees remained housed with their mothers until weaned.[1]

Apparatus

Cage doors, located on the front of each test subject's cage, were replaced with a transparent Lexan window through which each animal could view its mirror self-reflection (without visual obstruction by the metal mesh which comprised the cage). One-way mirrors were located one meter from the cages and were installed in a large walk-in camera blind constructed from plywood (see Calhoun, 1983). Figure 2 shows dimensions and arrangement of windows and mirrors. Videotaping by use of Panasonic color video cameras (WV-3240/12X) took place through the one-way mirrors (and through the Lexan cage windows) with observer(s) and

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1 Reggie (CH391) was the offspring of two chimpanzees, Andrea (CH124) and Sean (CH643), also located at the LEMSIP facility. Rocky (CH403) was the offspring of Stella (CH136) and Herbie (CH194) at LEMSIP. Both male infants were weaned at approximately two years of age and were socialized together. Amy (CH404) was the offspring of two chimpanzees named Mollie and Big Daddy and arrived from the University of Texas, Bastrop when she was almost one year of age. Amy was nursery reared at the LEMSIP facility and later joined Reggie and Rocky to form a social group.

video cameras located within the darkened (light-sealed) camera blind. Both the inside and outside of the camera blind were painted flat black and the blind was draped with black cloth at points of entry and at joints.

For control observations, an additional camera was located outside of the camera blind on mark test days and was positioned to the side and front of the cage being videotaped at approximately a 45 degree angle to the midline (front to back) of each cage. Control procedures took place with the mirrors covered by dark green opaque plastic shades which could be released from inside the camera blind to uncover the mirrors. Six reflector flood lamps (GE 150 Watt) were positioned around the test cages to increase illumination during videotaping. Flood lamps were turned on at least 10 minutes prior to each session, remained on throughout all observations, and were positioned to avoid discomfort to the animals resulting from associated increases in room temperature. Data analysis of resultant videotapes used an interactive BASIC computer program (see Appendix A, modified for use with the chimpanzees) which recorded time of onset and termination of mirror-looking behavior. Inter-rater reliability measures for use of this recording system could not be obtained. Although an attempt was made to train four individuals in its use, none learned to respond accurately as indicated by low intra-rater

reliability measures. Behavioral recording was therefore performed by a single individual (the author) whose intra-rater measures were judged acceptable. For the author, indices of concordance for durations of mirror-looking were 94% or greater, while those for interlook intervals were 85% or greater.

Procedure

Observations of Amy and Reggie occurred simultaneously, while those of the third animal, Rocky, occurred subsequently as will be discussed. For each subject, adaptation to the testing room and to the covered mirrors took place over a three day period, followed by continuous mirror exposure for an additional 12 day period until the first mark test. The mirrors remained uncovered throughout this experiment except on mark test days when control (no-mirror) conditions were in effect. All subjects were videotaped for one hour each in the morning or early afternoon on Mirror Days 1, 5, 8, and 12. Data regarding mirror-looking were analyzed during the first ten minutes of each hour of observation. For the chimpanzees, mirror-looking was judged to occur when gaze appeared to the observer (via the video camera) to be directed at the portion of the mirror reflecting the animal's head or face.

Accuracy of judgment for mirror-looking was thus limited by the one meter distance between cage and mirror.[1]

The first mark test for self-recognition took place on Mirror Day 13 (after about 144 hours of mirror exposure) for each chimpanzee. For this initial mark test, subjects were sedated at about 10 am by means of intramuscular injections of ketamine HCl (Ketaset, Bristol; equivalent to 100 milligrams ketamine per milliliter) in a dosage appropriate to each animal's weight, followed by intravenous injection(s) of the same drug as required to permit the LEMSIP veterinary staff to perform routine medical procedures (including liver punch biopsies). Following medical procedures, and while subjects were still under the effects of ketamine, dye marks were placed on a single eyebrow ridge as well as on the upper half of the opposite ear. Three marking substances were used in this experiment: an odorless red dye, rhodamine-B dissolved in 70% ethyl alcohol (in all mark tests), and White-Out Typewriter

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1 Prior to the onset of this experiment, limitations of judgments of gaze direction were examined in the following fashion. A colleague sat in each (otherwise empty) chimpanzee cage and was requested to look in various locations relative to the mirror self-image. Gaze direction as reported by this individual was compared with the apparent direction of gaze observed via the video monitor. Judgments were found to be accurate with respect to looks toward or away from the reflected head and face, however, finer discriminations regarding gaze directed toward specific portions of the reflected head or face were not possible.

Correction Fluid (the first mark test), and white Avery Self-Adhesive Color Coding Labels (the second mark test). Control marking procedures invariably involved application of 70% ethyl alcohol in a matched fashion to the otherwise unmarked eyebrow ridge and ear. After dye marking, subjects were returned to their respective cages and observed continuously during recovery from the anesthetic. Videotaping in the presence of a covered mirror began at least three hours post-injection, followed by videotaping for 60 minutes or longer through the one-way mirror in the experimental situation.

Behavioral observations included duration and frequency of mirror-looking during the first 10 minutes of mirror exposure, as well as frequency of mark-directed touches and of touches to the unmarked brow and ear during the first 15 minutes of mirror exposure. Judgments of each chimpanzee's mark-directed behavior were similar to those of Swartz and Evans (1991) in that they included any touch to the relevant site regardless of topography. This definition of touching behavior was extended to observations of responding to unmarked brows and ears. Mirror-oriented, mark-directed behavior was determined to occur if touches to dye marks occurred simultaneously with mirror-looking, or if touches followed looks with a latency of one second or less.

After the initial mark test on Mirror Day 13 for each subject, additional mark tests took place. These occurred during Mirror Days 20 and Mirror Day 55 for both Amy and Reggie, Mirror Day 76 for Reggie only, and during Mirror Day 20 for Rocky.1 Thus, Rocky was tested for self-recognition on only two occasions, while Amy and Reggie were tested on three and four occasions, respectively. In general, procedures during these later mark tests remained unchanged from those described above except that some variation occurred with respect to marking substances, videotaping schedules (sometimes modified to ensure that subjects were alert and fully recovered from the effects of the ketamine), and during the second mark test for Amy and Reggie, rotation of the chimpanzees' cages so that the mirror self-image was observed through the side of the cage (Lexan windows were no longer clear or transparent because the chimpanzees scratched the plastic surface with their teeth). These variations in the test situation for additional mark tests will not be reported in greater detail since they were not judged to affect the relevant test results.

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1 Since mirrors were continuously present (except during control conditions) and room lighting was controlled on a 12 hour light/dark cycle, the number of hours of mirror exposure can be approximately calculated for each subject.

Results

The results for the first mark tests with these animals were mixed. During the control (no-mirror) condition, Amy was observed to lift her left arm in front of her face and then lower it so that the hand probably contacted her marked left brow region. Approximately one minute later, the chimpanzee again lifted her left arm and wiped the entire left side of her face with the inside of her wrist in a single downward movement. Therefore, according to a broad definition of mark-directed behavior (i.e., any topography), this animal was judged to exhibit two mark-directed responses during the control condition.

After the mirror had been uncovered and available for about two minutes, Amy touched the mark on her left brow with her fingertips, making a single contact with the mark which occurred lasted less than one second. After approximately four and a half minutes of exposure to her marked self-image, Amy touch her fingertips to her marked brow three times with less than 1-2 seconds between successive contacts. She then briefly touched her unmarked brow. After almost 10 minutes with the mirror reflection, Amy again touched the dye mark on her brow using her fingertips. About one minute later, another bout of touching occurred, with three contacts of the chimpanzee's fingertips to the marked site of her brow. Approximately

six seconds later, an additional touch to the same mark occurred, again with the fingertips. Finally, after about 12 minutes of mirror exposure, Amy used her left hand to wipe at the brow mark, contacting it only once. In all cases of mark-directed responding during the mirror condition, behavior was observed to be accompanied by mirror-looking. Thus, the chimpanzee Amy was judged to show six bouts of mirror oriented, mark-directed responding with a total of 10 contacts with the marked brow during the first mark test for self-recognition.

For Reggie, touching and manipulation of the marked brow with the fingers occurred during recovery from the effects of the ketamine and while the mirror was absent. Therefore mark test results for Reggie were not considered to be unequivocally positive, although he was observed to touch to his marked ear on two occasions while gazing at his mirror reflection.

During the second dye test, Amy alone exhibited mirror-oriented, mark-directed behavior, contacting the marked brow with her hand on two occasions compared to an absence of such contacts in the control (no-mirror) condition. Results for both Amy and Reggie were then consistently negative during subsequent mark tests. The third chimpanzee, Rocky,

was never observed to touch his marked brow or ear while looking at the mirror reflection.[1]

It was concluded that Amy exhibited the strongest evidence for mirror-oriented, mark-directed responding (self-recognition) among these three chimpanzees. Amy's data was therefore selected for further analysis of mirror-looking behavior by a self-recognizing chimpanzee.

The upper panel of Figure 3 shows total (cumulative) durations of mirror-looking for Amy during the first 10 minutes each day she was observed and videotaped. There was a decrease in looking behavior with continued mirror exposure after Mirror Day 1 which lasted until Mirror Day 12. Looking behavior then increased during the first mark test (Mirror Day 13), followed by low levels of mirror-looking during the second mark test on Mirror Day 22. For Amy, a third mark test took place during Mirror Day 55. (The results for this third and unsuccessful mark test with Amy are not included in Figure 3. However, mirror-looking

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1 The consistently negative results for my third chimpanzee, Rocky, were interesting since this animal alone displayed what was judged to be stereotypical behavior. Anderson and Chamove (1981) suggested that abnormal behavior such as self-aggression may be associated with failure to self-recognize among non-human primates. Although current data are too scarce to substantiate this idea, there are likely to be perceptual, motivational, or cognitive deficits associated with stereotypy. While Rocky's "acrobatic" behavior was not obviously self-destructive, the findings reported here support the basic notion put forth by these authors.

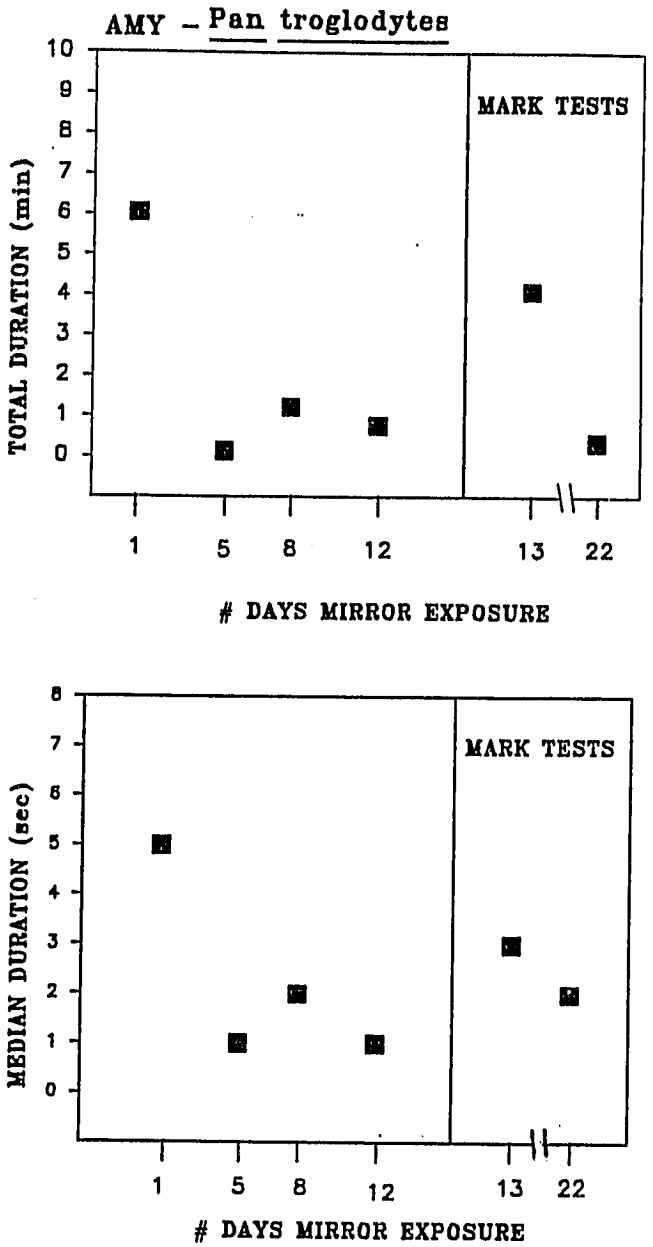


Figure 3. The upper panel represents total durations of mirror-looking per 10 minute observation period by the chimpanzee Amy in Experiment 1. The lower panel shows median durations of mirror-looking during the same observation periods. For Days 1, 5, 8, 12, 13, and 22, numbers of mirror-looks were 55, 10, 32, 25, 58, and 9, respectively.

remained at low levels during this last mark test with only 2.5 minutes of mirror-looking occurring during the first 15 minutes of mirror exposure (i.e., 17% of the observational period). The lower panel of Figure 3 shows similar results with respect to the median durations of Amy's looks toward her mirror reflection. On the first mirror day, the median duration of looking toward the mirror reflection was 5 s. On later days, median looking decreased to 1-2 s, followed by a slight increase of mirror-looking for the first mark test day when the median duration of looks reached 3 s. Median durations were then low (on the order of 2 s) for the second mark test.

Figures 4-5 provide frequency distributions representing durations of individual looks for Amy during selected sessions. On the first day of mirror exposure, Amy exhibited longer duration and more frequent looks toward the mirror compared to subsequent days of mirror exposure, looking at her mirror reflection on 55 occasions during the first 10 minutes of mirror exposure with five looks lasting 15 s or longer. By Mirror Day 12 (see lower panel, Figure 4), Amy looked at the mirror on only 25 occasions during the first 10 minutes, with all but one of these looks lasting less than 4 s. During the first mark test day (Mirror Day 13, see Figure 5), a total of 58 mirror-looks occurred with 15 looks greater than 5 s in duration.

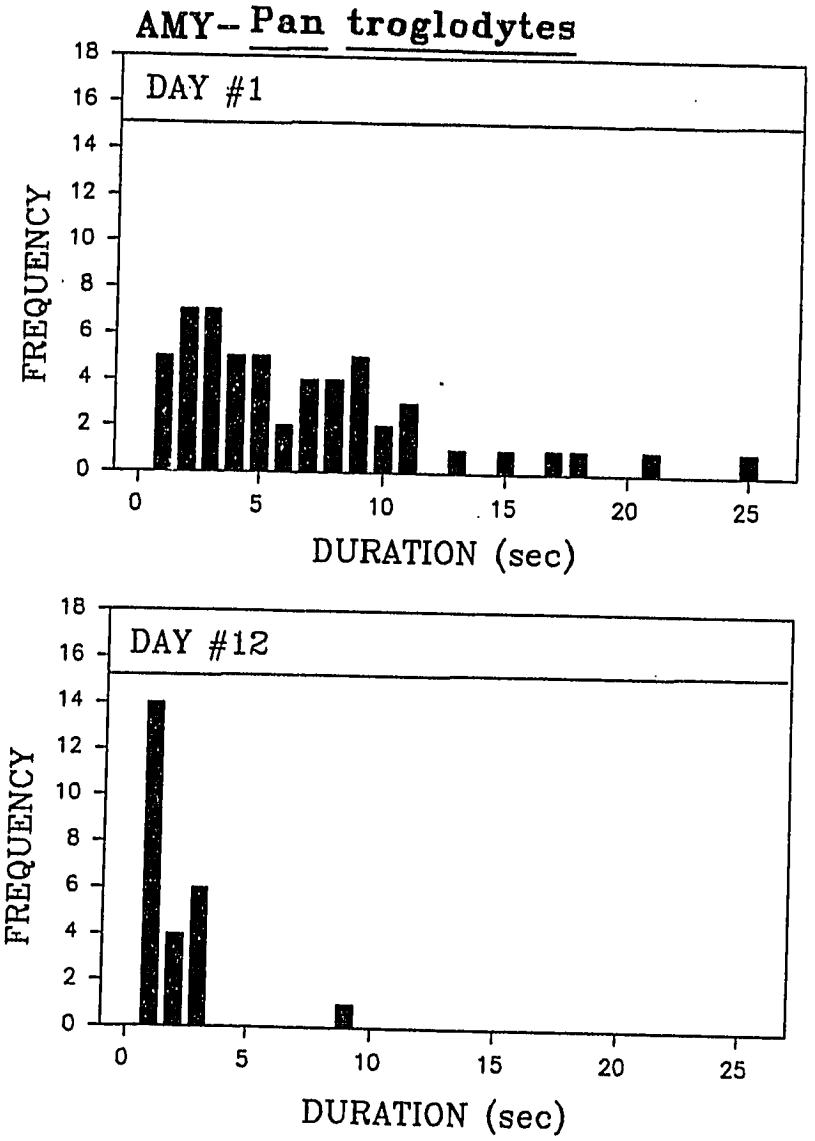


Figure 4. Frequency distributions of durations of mirror-looks by the chimpanzee Amy during the 10 minute observation periods on Days #1 and #12 in Experiment 1.

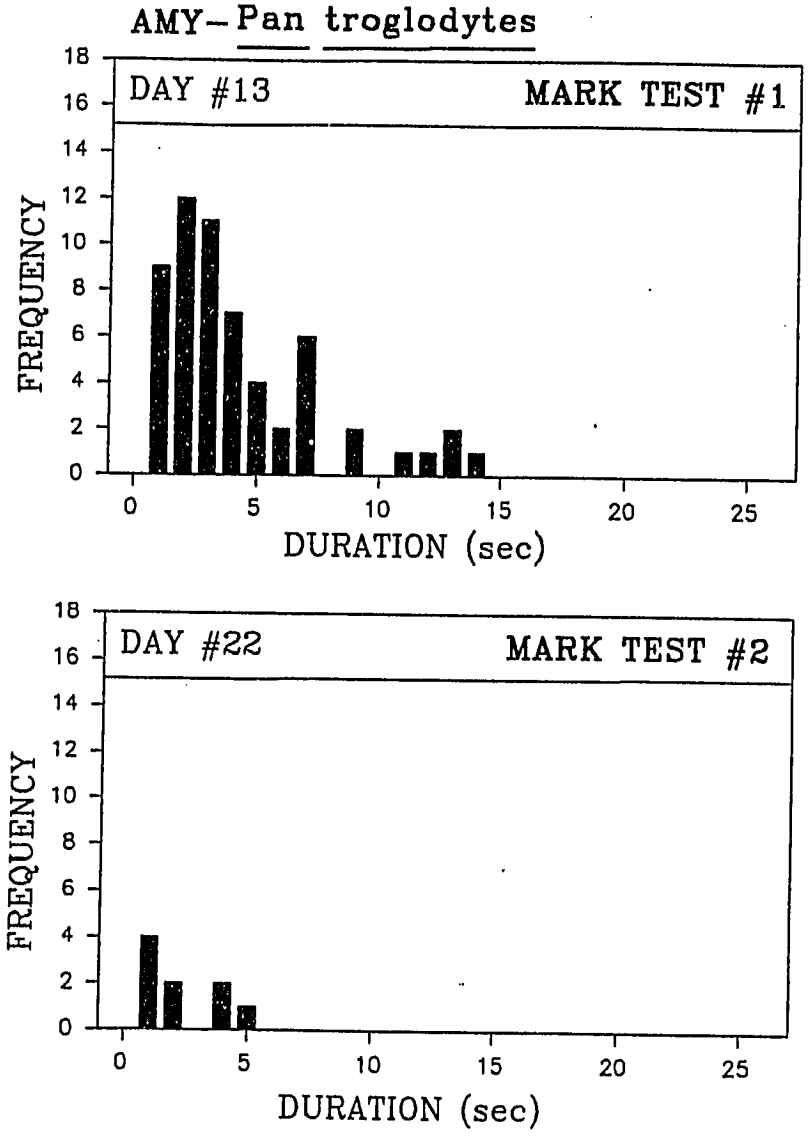


Figure 5. Frequency distributions of durations of mirror-looks by the chimpanzee Amy during the 10 minute observation periods on Days #13 and #22 (Mark Test Days) in Experiment 1.

Finally, during Amy's second mark test (Mirror Day 22, see lower panel of Figure 5), looks toward the mirror decreased to durations of 5 s or less (with only 9 looks occurring during the entire 10 minute period). In general, Amy's mirror-looking declined with continued exposure to the mirror reflection, increased during the first mark test day, and declined during subsequent mark tests across all measures of interest (total, frequency, median, and maximum durations).

Discussion

Based upon observations of mirror-oriented, mark-directed responding the chimpanzee Amy was judged to display the strongest evidence for self-recognition among the three subjects in this experiment. This animal was also informally observed to spend more time looking at her mirror reflection throughout testing compared to the other two chimpanzees. When considered subjectively, Amy's mirror behavior was more varied and more interesting to observe than that of the other two subjects. For example, Amy was frequently observed to press her lips or tongue against the Lexan cage panel or the mesh of her cage and thus to "make faces" while looking at the mirror. *Post-hoc* analyses of her first mark test, however, revealed that this behavior occurred on 10 occasions (with a total duration of 20 seconds) in the window condition and on only five occasions

(with a total duration of 18 seconds in the mirror condition. While these results are suggestive with respect to durations of responses, it is difficult to suggest that the behavior constitutes "self-directed" or "self-referential" activity. On the other hand, Amy was observed to exhibit more lip-flips (flipping her lower lip downward and maintaining this facial expression for several seconds at a time) in the mirror condition (10 responses, all accompanied by mirror-looking) compared to the control condition (2 responses). Furthermore, on one occasion during the first 15 minutes of mirror exposure, Amy performed a lip-flip while watching the mirror, then extended her lips outward and appeared to looked directly toward her lips, and then looked back at the mirror reflection as she exhibited a second lip-flip. On another occasion, Amy lip-flipped, then slapped her lips with her open palm while watching the mirror. Finally, during the first dye test, after about ten minutes of mirror exposure, Amy was observed to lie down on the bottom of her cage facing her mirror reflection and to slowly stroke her marked brow. This slow visual-tactile inspection of the novel mark is similar to what one would expect of humans in a similar situation particularly if the facial mark could not removed easily. These three behavioral sequences exhibited by the chimpanzee Amy during the first mark test were relatively

unique and suggestive of "self-conscious" behavior, yet further evidence is required for inclusion in a category of "self-directed" activity or to state definitively that responses were performed for the purpose of watching the effects via the mirror.

The results of this experiment support Swartz and Evans (1991) in questioning the reliability of demonstrations of self-recognition among chimpanzees. According to a criterion of mirror-oriented, mark-directed responding for self-recognition, only one of the three chimpanzees tested in this experiment was judged to be positive for self-recognition. The findings of the present study differ from earlier reports by Calhoun and Thompson (1988) and Swartz and Evans (1991), however, with respect to individual results of repeated testing. Previous reports indicated that self-recognition among chimpanzees is a relatively stable phenomenon and that repeated tests with the same animal yielded consistent results. Here, one subject exhibited critrion responding during the first two of three tests. It should be noted, however, that these earlier studies involved a total of three subjects positive for self-recognition and probably did not represent a large enough sample size for trends to become apparent.

Further, while Swartz and Evans (1991) reported that their overall results (i.e., success vs. failure to self-

recognize) during repeated tests were consistent for a single animal, examination of the topography of mark-directed behavior by this animal revealed systematic changes with repeated testing. Specifically, Swartz and Evans (1991) reported that, for their one subject who unequivocally exhibited self-recognition, latencies to touch the dye marks increased and the number of touches decreased across tests. This report is consistent with the finding for Amy in the present study that mirror-looking habituated with continued mirror exposure, as did mirror-oriented, mark-directed responding. (It should be noted, however, that the length of the interval between mark tests is probably an important factor in determining whether an animal will be motivated to inspect, either visually or manually, red marks on its brows or ears). Consideration of the human literature regarding self-recognition provides further evidence for a habituation effect during repeated tests for self-recognition. In a study discussed previously, Biringer et al. (1989) reported that one individual (diagnosed as exhibiting dementia of the Alzheimer type) responded positively for only the first of two mark tests occurring with a three week inter-test interval. These findings all highlight the complexity of the self-recognition phenomenon, as well as the need to

re-consider the means by which it is assessed among humans, apes, and monkeys.

EXPERIMENT 2:

SCHEDULE INDUCTION OF MIRROR-LOOKING BY MONKEYS

A major consideration in the failure of monkeys to exhibit mirror-oriented, mark-directed responding (self-recognition) involves the amount of mirror-looking exhibited by these animals. Premack (1983) suggested that monkeys exhibit gaze aversion with respect to their mirror self-images and that this may account, at least in part, for failures among monkeys to exhibit the phenomenon. As discussed previously, although Gallup et al. (1980) argued that five-month-old infant rhesus monkeys showed levels of mirror-looking comparable to those of chimpanzees, Gallup's infant monkeys (like humans less than nine months of age) may have been too immature to exhibit self-recognition. On the other hand, the same authors indicated that mirror-looking among adult rhesus monkeys was significantly less than that of self-recognizing chimpanzees. Thus, contrary to the conclusions of Gallup et al. (1980), gaze aversion may be a factor in the failure of monkeys to exhibit mirror-oriented, mark-directed responding. It is also feasible that a mirror self-image is not an aversive stimulus *per se* for most monkeys, but that levels of mirror-looking are low for other reasons (e.g., once habituation occurs, the mirror

image is not interesting to monkeys and/or responses such as self-grooming compete with the looking response. (During self-grooming, monkeys look intently look toward the body site being groomed). While a variety of procedures have been tried to encourage self-recognition among monkeys, these efforts have not included behavioral attempts to influence mirror-looking through indirect or direct reinforcement.

It was not known at the time of the present research whether mirror-looking among monkeys could be affected by its consequences or by the events which precede or accompany its occurrence. Numerous responses, however, are known to be induced indirectly by scheduled delivery of food or water (e.g., Falk, 1961; Wetherington, 1982), or scheduled delivery of access to visual stimuli (Hudson & Singer, 1979). Most reports of schedule-induced responding have used scheduled presentation of food (often fixed time or fixed interval schedules of reinforcement at 60 s inter-reinforcement intervals) with subjects, usually rodents, reduced in body weight, and excessive drinking of water (polydipsia) relative to baseline levels as the dependent variable (e.g., Falk, 1961; 1966). Researchers who have demonstrated schedule-induced polydipsia (SIP) have also shown that drinking characteristically occurs during the portion of the inter-reinforcement interval with the lowest

probability for delivery of food (i.e., immediately after food delivery). To date, SIP has been demonstrated for a variety of species including rats, mice, chinchillas, pigeons, squirrel monkeys, rhesus monkeys, and chimpanzees (e.g., see Falk, 1977 and Fried, 1985 for reviews).

Responses other than drinking have been shown to be subject to change through schedule induction procedures. Rayfield, Segal, and Goldiamond (1982) in one experiment used fixed time presentation of food to induce high levels of defecation among rats. Pigeons have been shown to attack live and taxidermically-prepared conspecifics as a result of scheduled presentation of food or water (e.g., Campagnoni, Cohen, & Yoburn, 1981; Flory & Robinson, 1982). Cohen and Looney (1973) have demonstrated schedule-induced attacks of mirror self-images by pigeons. Reinforcers other than food or water can also give rise to schedule-induced responding. Hudson and Singer (1979) provided free-feeding *Macaca fascicularis* visual access to commercially available films as well as scheduled delivery of light to view conspecifics and found that both procedures resulted in polydipsia. Based upon these and other studies, it seemed feasible that scheduled delivery of water might result in an increase in mirror-looking or other forms of behavior among water-deprived monkeys.

Methods

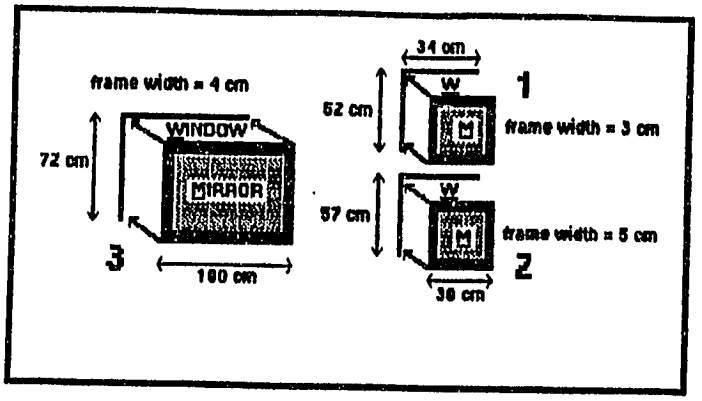
Subjects

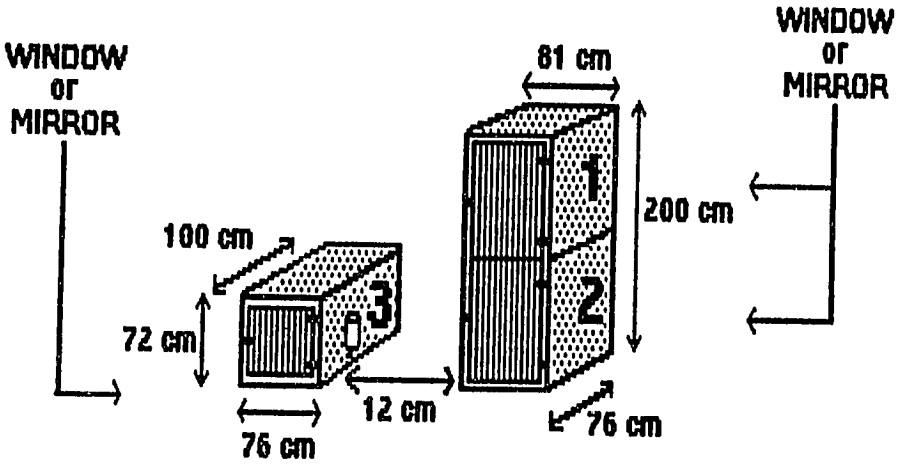
Subjects were three adult female pigtailed macaques (*Macaca nemestrina*) named Roberta, Bibi, and Pavlova. Weights at the start of this work were 8.9, 5.0, and 7.6 kilograms, respectively. Subjects were obtained at least seven years previously from a commercial primate importer (Primate Imports, Port Washington, NY) and each was reportedly wild-caught at a young age. Estimated ages for the three monkeys at the start of this work were 9 years (Roberta), 18 years (Bibi), and 9 years (Pavlova). Each monkey was experienced with her mirror reflection, having had approximately 156 hours of mirror exposure (plus exposure to a window with video camera) over a 36 day period during the winter of 1987. One subject, Roberta, received extensive exposure to mirrors prior to 1987, inclusive of training in a mirror-mediated reaching task. Bibi, prior to 1987, took part in an investigation of behavior in the presence of video images (i.e., video noise, her own self-image, and a familiar conspecific; Calhoun, 1983). The project described here began in July of 1988 after an eight month period without mirror (or video) exposure.

Subjects were individually caged throughout this testing and were maintained in a single room permitting auditory access to one another. Mutual visual access was restricted as a result of relative cage positions. Food consisted of standard primate laboratory chow (Purina) combined with occasional fruits and a vitamin supplement, Nutri-Cal (EVSCO Pharmaceuticals). Water deprivation periods ranged from about 22 to about 46 hours (as will be discussed) and varied as seemed appropriate to maintain lever-pressing for water. With the exception of Bibi who exhibited some repetitive fur-plucking, all subjects were free of behavioral stereotypies and appeared in good physical and "psychological" health.

Apparatus

Subjects were continuously maintained in individual test cages modified to permit videotaping through either a transparent Lexan window or through a one-way mirror (see Figure 6 for details of cage design and window/mirror dimensions for each subject). Changes between window and mirror conditions involved placement (or removal) of a wood-framed one-way mirror which could be bolted to the side of each cage directly against the Lexan window. During testing, a Panasonic color video camera (WV-3240/12X) was located in a wooden camera blind adjacent to each monkey's cage located approximately 22 cm from each window





NOT TO SCALE

Figure 6. Spatial arrangement and dimensions of monkey cages (1, 2, and 3) with their transparent windows (permanently attached to monkey cages), and mirrors (fitted over the windows so that they were removable) in Experiments 2-4.

(see Figure 7). Black cloth was attached to the top and sides of the camera blinds and connected to the primate cages to minimize the amount of light entering the camera blinds. An additional camera for Pavlova was located approximately one meter from the front and side of her cage and oriented at approximately a 45 degree angle from the longitudinal cage midline. Camera extension cables (6.2 m) extended from each camera through an access tube in the animal facility wall to video monitors in an adjacent room.

General room lighting in the test room was maintained on a 12-hour light/dark cycle and was provided by standard overhead fluorescent fixtures. Circular fluorescent fixtures (22 or 32 Watt; 8 or 22 inch diameter, see Figure 7) were located within each camera blind and were illuminated during window conditions to minimize window reflectivity. Additional lighting (150-Watt GE reflector flood lamps) illuminated the animals during mirror conditions and served to enhance the visual images of the animals on the video monitors. An attempt was made to match overall luminance between conditions (window and mirror) during testing. Photometric measurements were taken by means of a Spectra Pritchard Photometer (#1980A-PL, neutral density filter 2, 3 degree visual field). While there was some variation in luminance across each mirror (or window) as well as between mirrors (or between windows),

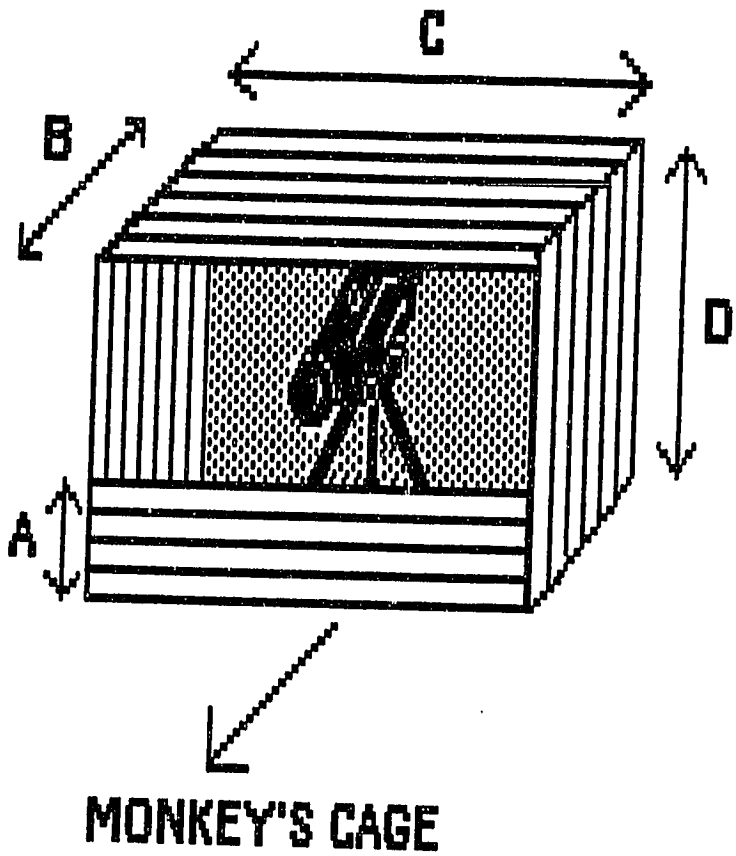


Figure 7. Camera-blind (illuminated by circular fluorescent fixture located on interior floor) and video camera, each visible through transparent window in Experiments 2-4. For the monkeys, Roberta and Bibi, diameters of the 22W fluorescent fixtures were 8 in, and for Pavlova, 32W, 12 in. For Roberta, A=51 cm, B=50.5 cm, C=43 cm, and D=108 cm. For Bibi, A=26.5 cm, B=50.5 cm, C=43 cm, and D=93.5 cm. For Pavlova, A=32 cm, B=51 cm, C=93.5 cm, and D=107 cm.

measurements of the central area of each ranged from 4.4 to 6.3 ft-L with differences on the order of 1-2 ft-L or less between each window and its attachable mirror. These differences were judged acceptable given the sequential nature of the condition changes (mirror vs. window).

Masking noise (58 dB SPL) was present during testing and was generated using a Model 901B Grason-Stadler White Noise Generator located in the adjacent room. This instrument was calibrated with a Type 1551-B Sound-Level Meter (General Radio Co., Cambridge, MA, 1958) and placement of the loudspeaker in the animal test room was such that measurements taken from the front of each animal's cage were judged identical.

Water was presented by use of a Coulbourn Instruments Modular Test Panel (Lehigh Valley, PA, Model #E30-10) modified to be placed within each individual monkey's cage. The test panel was attached to a stainless steel box (52.1 cm x 26.7 cm x 26.7 cm) containing the lever-activated pump (Liquid Solenoid Valve, Model #E34-03) and water reservoir. The test panel itself was stainless steel and contained a water spout (located centrally with respect to panel width, 29.2 cm from base), a recessed lever operandum (Model #E36-03, located on the right side of the panel, 22.2 cm from base), and a green cue light (modified E31-03 Stimulus Display) to serve as a discriminative stimulus for the

availability of water. The green cue light was located within a transparent Lexan box placed centrally with respect to panel width, 3.2 cm above the spout. Cables exited through the rear of the stainless steel box and were protected by an iron pipe (61 cm long, 2 cm in diameter).

The volume of water delivered was regulated by an electronic timer to yield 1.2 or 2.0 ml as noted below. Relays and timing devices controlling reinforcement schedules were located in the adjacent room out of the hearing range of the monkeys. The access tube connecting the two rooms (through which all cables passed) was packed with paper towels during testing to further ensure that the monkeys were isolated from the noise arising from relay activity and from movements of the experimenter. Lever-pressing for water was recorded with a cumulative recorder.

Procedure

Five phases were presented in sequence: Baseline 1, Fixed Time (FT) water availability, two Fixed Interval schedules (FIa and FIb) of water availability, and Baseline 2. The number of sessions in each phase varied among subjects as shown in Table 2. Session duration was uniformly 80 minutes throughout this experiment. Each session consisted of sequential exposures to window (W) and mirror (M) in counterbalanced (WMMW or MWWM) order. Each session began with 10 minutes in the first condition, then

SUBJECT	SCHEDULE	SESSIONS
Roberta	Baseline 1	1-31
	Fixed Time	32-74
	Fixed Interval (a)	75-83
	Fixed Interval (b)	84-94
	Baseline 2	95-104
Bibi	Baseline 1	1-31
	Fixed Time	32-86
	Fixed Interval (a)	87-102
	Fixed Interval (b)	103-127
	Baseline 2	128-143
Pavlova	Baseline 1	1-31
	Fixed Time	32-95
	Fixed Interval (a)	96-117
	Fixed Interval (b)	118-132
	Baseline 2	133-133

Table 2. Session numbers for each baseline or schedule of reinforcement for the three monkeys in Experiment 2. For each subject, the middle block of sessions for Baseline 1 and the Fixed Time schedule of reinforcement began with mirror presentation; all other sessions began with window presentation.

60 minutes in the second condition (of which only the first 20 minutes were videotaped), followed by an additional 10 minutes in the first condition. Therefore, while the animals were monitored continuously, videotaping and data analysis were confined to 40 minutes (20 minutes per condition) for each session.

In Baseline 1 and FT phases, the order of window and mirror presentation (WMMW vs. MWWM) varied over blocks of sessions. During the two Fixed Interval schedules and Baseline 2, all sessions followed the WMMW order of presentation. Between sessions, the window or mirror was present for 23 hours per day[1] depending on condition order (e.g., if the session order was MWWM, then the mirror was on the cage for 23 hours). Sessions were run daily, seven days per week, while the animals were on 22-hour deprivation and water reinforcers were 1.2 ml. The 22-hour schedule proved inadequate to maintain responding (lever-pressing) for Roberta, so from session 61 onward, she was tested on alternate days with approximately 46 hours water deprivation and 2 ml water per reinforcement. Subject order was randomized until sessions 61, 71, and 72 for Roberta, Bibi,

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1 For sessions with WMMW order of presentation, the fluorescent fixtures in the camera blinds remained illuminated overnight, although the room was darkened. If session order was MWWM, then room lighting was modified using 100W incandescent bulbs so that luminance measures of the mirrors ranged from 3-4 ft-L with the room darkened.

and Pavlova, respectively. Thereafter, since time-of-day effects were judged to be negligible, subject order was fixed in the sequence: Bibi (about 10 am daily), Roberta (about 1 pm, alternate days), Pavlova (about 4 pm daily).

Schedules of reinforcement

Baseline 1. Initial baseline levels of camera-defined "eye contacts" with the windows or mirrors were obtained while subjects were not deprived of water and with the test panel absent from each monkey's cage. Because of the large size of Pavlova's test cage and since she tended to remain on the perch at the back of her cage, the camera (inside the camera blind) was aimed toward this location. Subjects continued to be observed in this phase until looking behavior was clearly stabilized for all subjects (criterion-by-inspection over a six day period).

Fixed Time. Water availability on a fixed time (FT) schedule began during session 32 for each subject. Here, passage of a specified time period resulted in illumination of the green cue light (on the test panel) which served as a discriminative stimulus signalling that a single lever-press would dispense water. The FT interval was gradually increased over eight sessions from 15 s to 30 s. Session 40 began with a FT-1min schedule of water availability for each subject. The data presented will omit the transition sessions (32-39) because one minute FT intervals appeared to

be optimal for responding with respect to amount of mirror-looking and because minor equipment malfunctions occurred during sessions 32 and 34. Subjects were maintained on a FT-1min schedule for water until each individual monkey exhibited stabilized responding with respect to number of water reinforcers (i.e., at least nine reinforcers were obtained per 10 minute interval of window or mirror for six consecutive sessions).

During this FT schedule as well as for the remainder of this experiment, Pavlova was videotaped from the camera blind when she was in a position at the front of her cage close to the test panel. An additional camera was placed at the front of Pavlova's cage (beginning with session 72) because the monkey began to remain on her perch until water was available.

Fixed interval(a). Water presentation during the first fixed interval (FIa) schedule[1] also involved one minute intervals, yet here the availability of water was unsignalled until a lever-press illuminated the green cue light one minute after the last delivery of water. The next lever-press then resulted in operation of the solenoid valve and presentation of water. Subjects were permitted to adjust to the change in reinforcement schedule for two

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1 Technically, a chain FI 1 FR 1 schedule of reinforcement in the notation of Ferster and Skinner (1957).

sessions; data for each subject will be presented beginning with the third session of this FIa schedule. Stabilized responding was judged to occur when cumulative records of lever-pressing for six consecutive sessions took the expected form for fixed interval schedules (i.e., the "FI scallop," see Appendix B).

Fixed interval(b). In the second and strictly conventional FI schedule of reinforcement, FIb, water was made available at one minute intervals after which a single lever-press would simultaneously illuminate the green cue light and operate the solenoid valve. The cue light remained on during the release of water. Sessions continued until each subject again demonstrated stabilization with respect to cumulative records of lever-pressing for six consecutive sessions (see Appendix B). Data will be presented beginning with the first session of this schedule.

Baseline 2. Final baseline measures were obtained with the test panel placed in each subject's cage. Lever-pressing was under extinction and water was not available during sessions. A pre-loading technique was used prior to each session in which each monkey had one hour access to water from a drinking bottle. Water deprivation levels otherwise remained unchanged. Observations in this phase continued until lever-pressing stabilized and data will be

presented beginning with the first session of this extinction schedule.

Each session of this experiment began with activation of the masking noise generator and placement of the video camera in the camera blind. Flood lamps were then placed in position and were illuminated if the session began with mirror presentation. The monkey was then removed from her cage to a transport cage so that the window and its opposite cage wall could be cleaned with a commercially available cleaner (Windex). The cage perch was also cleaned at this time and any uneaten food pellets were removed from the cage tray. Mirrors were washed with Windex and depending on the order of presentation required, either placed onto the cage or left in a safe but accessible location. The test panel, if used, was then placed in the monkey cage and the subject was returned to her cage for testing. Finally, an additional camera was placed in the testing room, if required.

Each subject was permitted a 10-minute adaptation period prior to the first 10-minute observation period. Changing conditions during a session required the experimenter's presence in the testing room to replace or remove the mirror from the cage. The subject was again provided a 10 minute adaptation period to the new test conditions (while the animal was observed but not typically

videotaped). This second condition then continued without interruption for 60 minutes, after which the experimenter again entered the test room to remove or replace the mirror. There then followed an additional 10 minute adaptation period, followed by 10 minutes of observation. During adaptation periods, extinction of lever-pressing was in effect and no videotaping occurred unless interesting behavior (i.e., unusual behavior or behavior which could be interpreted to be "self-referred") was observed by means of the video monitors. The end of adaptation periods and the beginning of data-recording were initiated by the experimenter briefly entering the test room to start the digital timer on the video camera.

Behavior was recorded during sessions using a one/zero time sampling method (Altmann, 1974) with five second observational intervals[1] (i.e., occurrence vs. nonoccurrence of responding was reported for each five second interval). Measures of interest at the time of the experiment included camera-defined "eye contact"[2] with the mirror or window,

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1 The difficulty in scoring "live" behavior in this fashion, however, combined with the long duration of this experiment (with the consequent possibility of "observational drift," Martin and Bateson, 1986) indicated the need to repeat this analysis at a later date based upon videotaped records.

2 In Experiment 1, mirrors were located one meter from each test chimpanzee's cage. In Experiment 2, however, mirrors were placed directly onto each monkey's cage. Consequently, judgments of mirror-looking were less accurate for the chimpanzees than the monkeys, hence use of the term camera-

facial displays[1] directed toward the mirror or window (e.g., jaw-thrusting, open-mouth "threats", and brow retraction as described by Kaufman and Rosenblum (1966), as well as instances of self-grooming. *Post-hoc* analyses of the videotapes also included observations regarding self-directed touches to the monkey's body or head (scratching, rubbing, or any form of self-directed touches with hand or foot that could not be considered to be self-grooming). Inter-rater reliability measures for two of these responses were acquired after a second observer received 15 hours of training. Frequency ratios for camera-defined "eye contact" and self-grooming were 97% and 94%, respectively. Point-by-point ratio measures for the same responses were 94% and 63%, respectively.[2] A continuous cumulative record of lever-pressing was also kept. All subjects were provided free access to water for one hour at least 60 min post-session via a drinking bottle. Feeding and general cage cleaning took place about 6 pm daily.

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defined "eye contact" to describe gaze direction for the monkeys. The quotation marks are required because gaze was assessed during a control (window) condition.

1 Lipsmacking was not recorded here because the monkeys were thirsty and were periodically provided with water. Movements of the mouth and lips were therefore affected by experimental conditions.

2 Reliability for the additional forms of behavior recorded in this experiment were less formally assessed but were judged acceptable because scoring of responses often occurred in the presence of observers without dissent regarding occurrence or nonoccurrence of behavior.

Results

Mirror-looking by water-deprived monkeys was clearly affected by presentation of 1.2-2.0 ml water at one minute intervals. All three subjects evidenced a transient increase in camera-defined eye contact with the mirror reflection. The change in mirror-looking varied among subjects with respect to both the amount of looking per session and the duration of the effect over sessions. Figure 8 shows the percentage of five second intervals in which each subject was observed to make at least one camera-defined "eye contact" with the mirror or window. Bibi exhibited the most mirror-looking among the three subjects, increasing from about 20% at the end of Baseline 1 to 90% levels during the early sessions under FT (middle panel, Figure 8). Roberta's eye contacts with her mirror reflection were less frequent compared to the other two monkeys, increasing to slightly less than 50% in the first sessions of FT (see upper panel of Figure 8). Duration of the experimental effect across sessions was longest for Bibi, lasting through the entire fixed time schedule of water presentation and continuing through the first few sessions of the following fixed interval schedule (middle panel of Figure 8). For Roberta and Pavlova, the

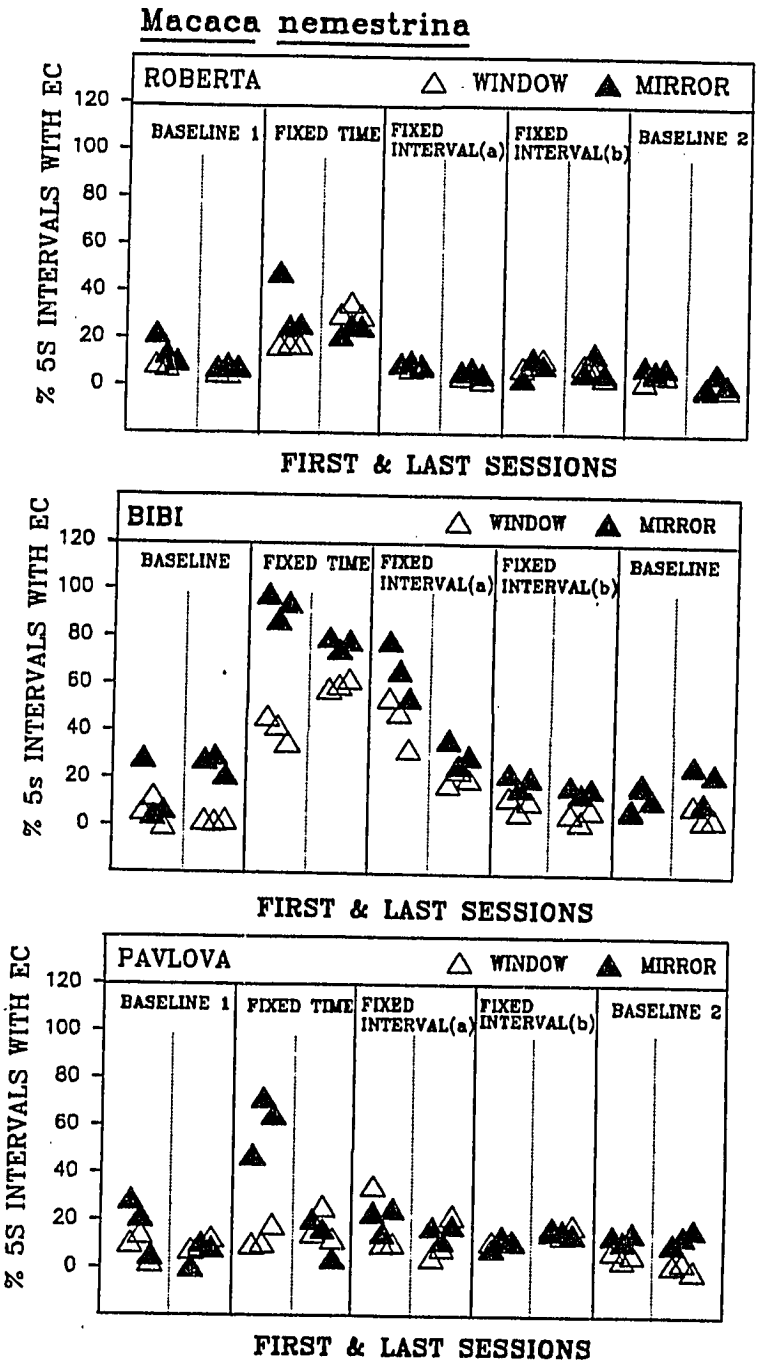

Figure 8. Percentage of 5 s intervals with camera-defined "eye contact" (EC) for each subject during first and last three sessions of each baseline and reinforcement schedule in Experiment 2. For points which are superimposed, only mirror points are shown.

experimental effect dissipated without recurrence during the fixed time schedule of water reinforcement (see upper and lower panels, Figure 8, respectively).

Window-looking also increased among these monkeys, although the experimental effect was consistently weaker for the window compared to the mirror condition. Bibi showed an increase in window-looking from about 10% to 40-60% when water was presented on a FT-1min schedule (middle panel, Figure 8). In general, the three monkeys appeared to look at the window or mirror during 0-25% of the available 5s intervals for baseline conditions. Induced mirror-looking, however, ranged from about 50% to 100% in individual sessions for the three monkeys. Maximum levels of window-looking occurred during the last sessions of the FT schedule for both Roberta and Bibi, reaching about 35% and 60%, respectively (upper and middle panels of Figure 8). Pavlova, on the other hand, exhibited little, if any, induction of window-looking with maximal responding (about 35%) occurring on the first session of the first fixed interval schedule (FIa, lower panel, Figure 8).

Figure 9 shows the mean percentage of five second intervals with at least one facial display (jawthrust, open-mouth "threat," or brow retraction) per session for each monkey during the first and last three sessions of each baseline or reinforcement schedule. Results for the mirror

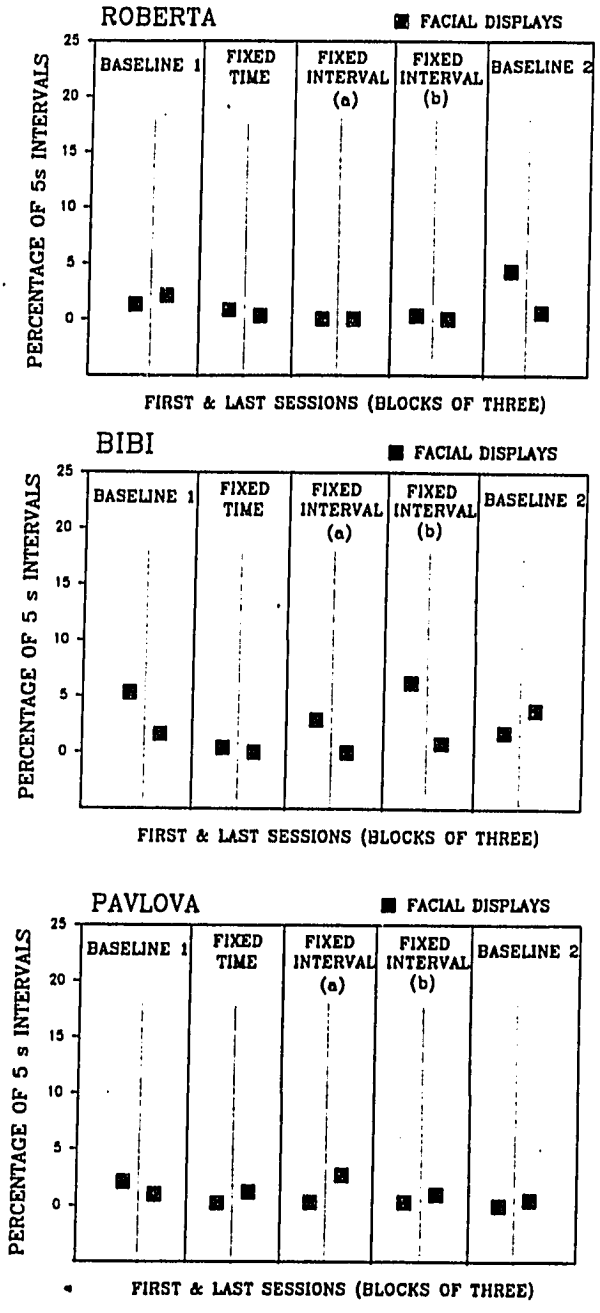

Figure 9. Percentage of 5 s intervals with a facial display (brow-lift, jawthrust, or open-mouth "threat") by each monkey during first and last sessions of baseline and reinforcement schedules in Experiment 2.

condition alone are shown here because subjects rarely, if ever, exhibited similar responses toward the windows. Facial displays were a relatively infrequent response among the three monkeys. Bibi exhibited more facial gesturing toward the mirror compared to the other two monkeys (maximally, during about 6% of the observed intervals, see middle panel of Figure 9). Facial displaying by Roberta and Pavlova typically occurred during less than 3% of the observed intervals (upper and lower panels of Figure 9). In this analysis, none of the subjects exhibited habituation of facial displaying across schedules. The majority of responses represented here, however, were jawthrusts or brow retractions. Open-mouth "threats" occurred on only four occasions during these observations and were confined to the initial baseline. Three of these four "threat" responses occurred during the first minute of the session in which it occurred.

Self-directed touches to body or head were also assessed for these monkeys throughout this experiment. Bibi exhibited the highest levels of self-touching among the three monkeys with head touches occurring during an average of 2-3% of the five second intervals observed, while body touching occurred during about 3.5-4.5% of observed intervals. Roberta touched her body during an average of

1-2% and her head during about 1% of the intervals observed. In this analysis, self-touching by Pavlova was observed infrequently compared to the other two monkeys (body touches for Pavlova were observed on the average during 0.5-1% and head touches during 1-1.5% of the observed intervals), yet these values reflect only those time periods in which the monkey was visible by means of the camera located in the camera blind. Pavlova was observed on other occasions to scratch or rub parts of her head or body while she was on her perch at the back of her cage and visible for observation only by means of the second camera.

Figure 10 provides information regarding the relationship between looking behavior toward window or mirror and occurrences of self-directed touching throughout this experiment. Expected probabilities of camera-defined "eye contact" and self-directed touches to body or head occurring during the same five second interval were calculated: mean probability (head touch) x mean probability ("eye contact") or mean probability (body touch) x mean probability ("eye contact") assuming that self-touches and looking behavior were independent events. Observed probabilities of "eye contact" and touches to body or head exceeded expected probabilities of the same events for all three monkeys in the mirror condition. Because Pavlova was often out of the view of the primary camera, this analysis

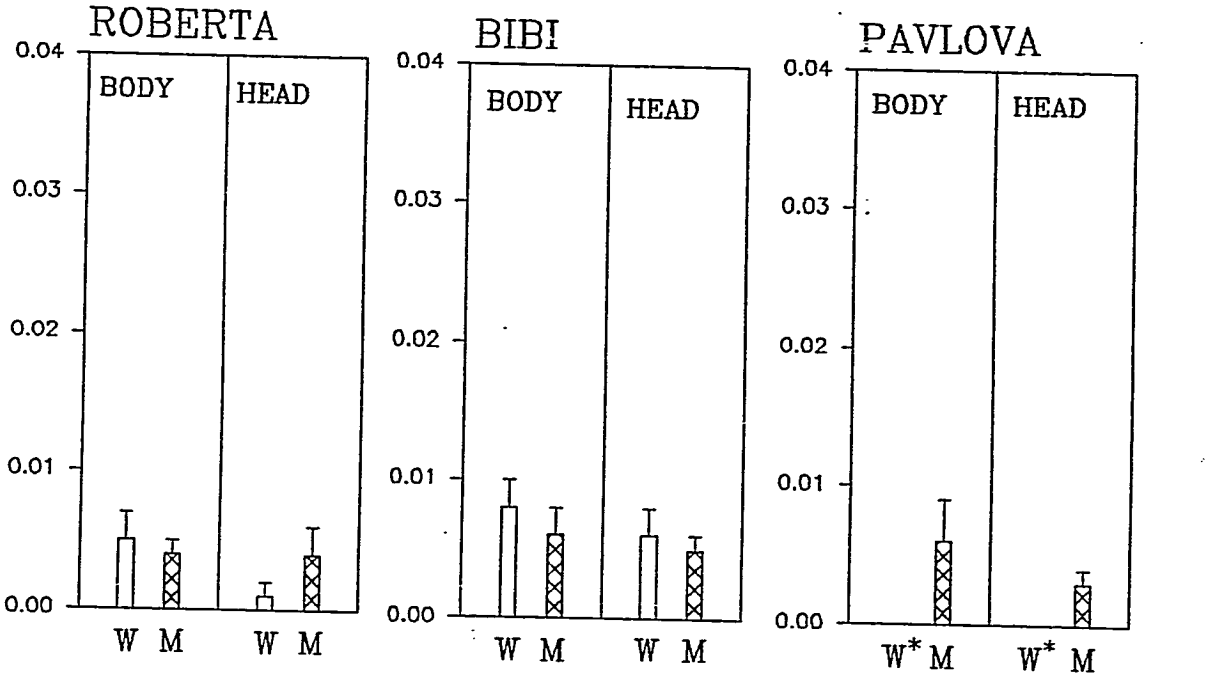

Figure 10. Joint probabilities of self-directed touching and camera-defined "eye contact" within the same 5 s interval of window (W) or mirror (M) exposures for each monkey in excess of the expected joint probability assuming independence. Data were pooled over all observed sessions (first and last three sessions of baseline and reinforcement) during Experiment 2 for which the expected probabilities exceeded zero. Error bars represent standard errors.

included only those sessions for which expected probabilities were greater than zero.[1]

Of the three subjects, only Pavlova appeared to discriminate between the window and mirror, looking at the mirror (but not at the window) when self-directed touching occurred. Problems arise, however, in comparisons of responding between window and mirror conditions in this experiment because each session in this analysis began with window presentation. On the other hand, Pavlova showed no tendency to discriminate between window and mirror conditions with respect to overall levels of touching directed to her head (for the window condition, the mean percentage of five second intervals with a head touch was 1.4% and for the mirror condition, 1.1%) or body (for the window condition, mean percentage of intervals with a body touch was 0.8% and for the mirror condition, 0.4%). For this animal, differential responding between the two conditions was apparent for only those intervals with both "eye contact" and self-directed touching. During the window condition for Pavlova, head and body touches each accompanied "eye contact" during 0.1% of the observed five

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1 When the same analysis was based upon observations during all sessions in Experiment 2 regardless of expected probability values, the results were similar, i.e., in the window condition, p(observed) - p(expected) for Pavlova was -0.001 for both head and body touches. In the mirror condition, p(observed) - p(expected) was 0.002 and 0.001 for head and body touches, respectively.

second intervals. In the mirror condition, head touches occurred during the same five second interval as eye contact for 0.4% of the observation period, while body touches accompanied looking behavior for 0.2% of the intervals observed. Therefore it is likely that for this single subject, discrimination occurred between the window and mirror conditions with respect self-directed touching and any order effects were less influential.

Tables 3-5 show the percentage of 5s intervals containing at least one camera-defined "eye contact" over successive thirds (20 s blocks) of each reinforcement interval. Data are presented for the last three sessions of each reinforcement schedule (FT, FIa, and FIb). Overall, there was no strong tendency among the three subjects for looking behavior (toward window or mirror) to occur consistently during a specific 20 s period of each one minute reinforcement interval. The only evidence for temporal patterning of this response occurred during the second fixed interval schedule (FIb) for Bibi (see Table 4). This effect was present for both window and mirror conditions, with "eye contact" occurring during 56% (window) and 35% (mirror) of the first four 5 s intervals post-reinforcement. The maximum percentage of the remaining 5 s post-reinforcement intervals was 17% and 13% for window and mirror conditions, respectively. Pavlova may have exhibited

ROBERTA

PERCENTAGE OF 5s INTERVALS
WITH CAMERA-DEFINED EYE CONTACT

SESSIONS:		0-19s	20-39s	40-59s	60s+	N
72-74 FT	W	26	31	40	7	195
	M	13	28	32	8	157
81-83 FIa	W	2	7	8	2	31
	M	7	7	6	7	45
92-94 FIb	W	2	15	4	1	43
	M	2	19	5	0	57

Table 3. Percentage of 5 s intervals with camera-defined "eye contact" with window or mirror by the monkey Roberta during successive thirds of the one minute inter-reinforcement intervals. Data are presented for the last three sessions of each reinforcement schedule in Experiment 2.

BIBI

PERCENTAGE OF 5s INTERVALS
WITH CAMERA-DEFINED EYE CONTACT

SESSIONS:		0-19s	20-39s	40-59s	60s+	N
84-86						
FT	W	49	62	70	5	282
	M	57	81	95	29	506
100-102						
FIa	W	35	16	12	10	126
	M	44	35	14	12	191
126-127						
FIb	W	56	17	0	0	35
	M	35	13	2	1	107

Table 4. Percentage of 5 s intervals with camera-defined "eye contact" with window or mirror by the monkey Bibi during successive thirds of the one minute inter-reinforcement intervals. Data are presented for the last three sessions of each reinforcement schedule in Experiment 2.

PAVLOVA

PERCENTAGE OF 5s INTERVALS
WITH CAMERA-DEFINED EYE CONTACT

SESSIONS:		0-19s	20-39s	40-59s	60s+	N
93-95						
FT	W	16	33	0	7	19
	M	13	33	33	0	12
115-117						
FIa	W	16	9	6	2	43
	M	25	0	13	35	77
130-132						
FIb	W	42	3	3	0	36
	M	25	5	10	2	37

Table 5. Percentage of 5 s intervals with camera-defined "eye contact" with window or mirror by the monkey Pavlova during successive thirds of the one minute inter-reinforcement intervals. Data are presented for the last three sessions of each reinforcement schedule in Experiment 2.

a similar tendency during the same (FIb) period. Here, 42% (window) and 25% (mirror) of the initial 5 s intervals post-reinforcement contained at least one "eye contact" (compared to 10% or less later in the inter-reinforcement interval), yet results for Pavlova need to be interpreted cautiously since she may have been looking at the mirror during later portions of the inter-reinforcement interval (i.e., while sitting on the perch and visible only by means of the second camera).

Discussion

Schedule-induced mirror looking?

While all three monkeys exhibited increased mirror-looking when presented with sips of water at one minute intervals, the effect was transient and mirror-looking was not necessarily confined to a specific portion of the inter-reinforcement interval (i.e., the time period immediately post-reinforcement). One subject (Bibi) and possibly a second animal (Pavlova), exhibited temporal patterning of responding during the last fixed interval (FIb) schedule of reinforcement when responding was no longer excessive relative to baseline levels. It is difficult to interpret these findings, although there is precedence in the literature. In discussing schedule-induced behavior, Staddon (1977) referred to excessive responding throughout the inter-reinforcement interval as "facultative," with the

implication that the response is not actually potentiated by the reinforcement schedule (and consequently should not be considered "schedule-induced" behavior).[1] Several researchers have reported "schedule-induced" or excessive activity as occurring other than immediately post-reinforcement (often when access to responding is temporarily prevented), while other researchers have demonstrated transience of responding (see Wetherington, 1982). In this discussion, it need not be argued that this demonstration of (transiently) increased mirror-looking among monkeys should be referred to as "schedule-induced" since it cannot be known if its determinants were similar to those for the many other forms of behavior so described.[2] Instead, these results are reported with speculations about possible causal factors specific to these procedures.

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1 Roper (e.g., 1982, 1983), however, argued that causal factors underlying the excessiveness of responding in the schedule induction paradigm may be different from those affecting the temporal characteristics of responding, and therefore that a single term (schedule-induction) for both phenomena was not justified. Roper's argument has merit since some researchers (e.g., Wetherington & Brownstein, 1979) report schedule control (temporal patterning) of eating among water-deprived rats in the absence of excessiveness of responding. See Wetherington (1982) for an updated discussion.

2 These procedures did not include appropriate baseline measures (e.g., massed rather than intermittent water presentation) necessary to determine causal relationships among variables. Further, these procedures did not include systematic attempts to investigate other aspects of schedule-induced responding (e.g., effects of changes in body weight or of changes in length of the inter-reinforcement interval; see Falk, 1971).

Several factors seem relevant to this experimental situation. First, monkeys typically exhibit behavior referred to as "checking" in a social situation (Kaufman & Rosenblum, 1966), described as brief and frequent looks toward a conspecific. Observations in this first experiment suggest that "schedule-induced" mirror-looking here may be an exaggerated form of checking behavior. Checking behavior among monkeys may be further elicited by stimuli which are interesting, which move, or which are threatening to the animal. Arousal level is also relevant here, these monkeys were water-deprived and in general, highly motivated to drink. Informal observations revealed a comparatively higher overall activity level during scheduled presentation of water compared to baseline conditions for these monkeys.

Competition of other responses is another factor to be considered here. Self-grooming is a frequently occurring response among individually caged monkeys and is an activity which presumably would have interfered with monitoring of the discriminative stimulus for water in the first FT schedule of reinforcement. (The self-grooming monkey looks closely at the body site being groomed). It is feasible that as self-grooming was reduced among these monkeys, alternative responses such as mirror-looking increased in duration or frequency. Once temporal conditioning began (i.e., each animal learned to accurately judge the

probability of water availability relative to the one minute reinforcement interval as was required by the two FI schedules), an activity such as self-grooming could then reappear. During this experiment, observations regarding self-grooming only partially supported this theory. While levels of self-grooming were lower during the FT schedule compared to initial baseline measures (mean intervals with self-grooming decreased from 31% to 10% for Roberta, and from 38% to 6% for Bibi), mirror-looking and occurrences of self-grooming were not inversely correlated across schedules (Spearman rank correlation coefficients were 0.52 and -0.07 for Roberta and Bibi, respectively). The third subject, Pavlova, did not self-groom while in close proximity to the operant panel and the primary camera.

An alternative suggestion to account for incremented mirror-looking in this experiment involves monkey perception of mirror self-images. It could be argued that the monkeys perceived the self-reflection as another monkey and therefore, as a possible competitor for water. Since the experimental effect was transient, then the perception of the self-image as a conspecific or as a competitor must also have been transient. This theory has little credibility, however, because incremented window-looking was also observed for these animals, although the effect was weaker than when mirrors were available. It is unlikely that the

video camera viewed through the window was perceived by these monkeys to be a conspecific animal, although it may have been perceived as a threatening object. The threatening aspect of an unmoving object such as a camera, however, should be minimal after almost 200 sessions. Future investigations designed to address these issues will need to manipulate the positions of windows (or other control stimuli) relative to the position of mirrors in order to avoid possible respondent conditioning effects. To conclude, while it can be reported that the procedures described here resulted in transient incremented mirror-looking among monkeys, explanation of why this occurred must await future research.

Possible correlates of increased mirror-looking

An unexpected observation during this experiment was the occurrence of "head tilts" for two of the three subjects. These responses were never previously observed among these or other pigtailed monkeys in the Hunter College colony. "Head tilts" were infrequent responses and were confined to the mirror condition. Figure 11 topographically illustrates "head tilting" for Bibi during session #90 (FIa). These responses combined with relatively long looks at the mirror reflection suggests that subjects were engaged in examination of some aspect(s) of the mirror's reflective properties. The slow movement of the head while looking at

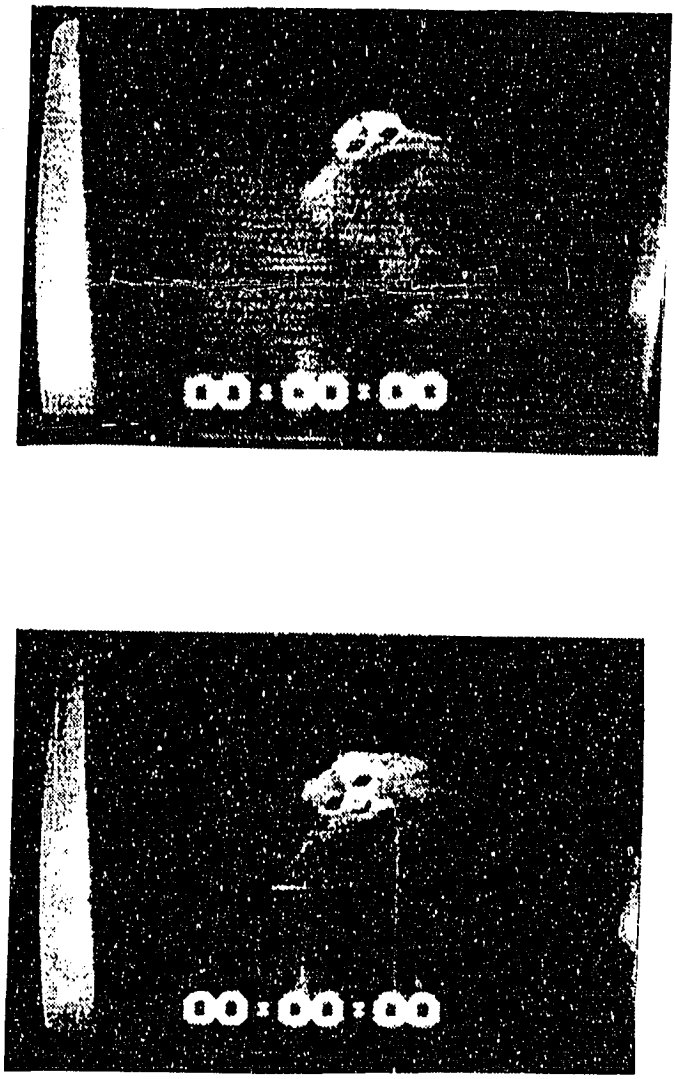

Figure 11. "Head tilt" by the monkey Bibi while looking at the mirror self-reflection during session 90, Fixed Time (a), Experiment 2, taken from digitized video images. Here, a jawthrust directed toward the self-image (top view) was followed within 1-2 s by tilting of the head as the monkey stared at its reflected image (bottom view). This response was observed during the habituation period following placement of the mirror onto the monkey's cage and hence the camera timer was not operating during this behavioral sequence.

the mirror and the odd angle at which each animal viewed its self-reflection were reminiscent of behavior one intuitively expects of a human who is unfamiliar with the mirror self-image and is examining the mirror's reflective attributes (i.e., subjectively, "head-tilting" appeared to be "self-conscious"). Comments regarding these observations, however, are necessarily highly speculative.

According to some authors (e.g., Gallup, 1970), animals such as chimpanzees which self-recognize will first exhibit habituation of facial displays directed toward the mirror (i.e., facial displaying was reported to be inversely correlated with mirror exposure). Others (Epstein & Koerner, 1986) suggested that the mirror self-image serves as an unconditional stimulus for facial displaying among monkeys, thus precluding learning about a mirror's reflective properties. In the present experiment, facial displaying by the three monkeys was therefore assessed before, during, and after induction of mirror-looking through water presentation. There was little evidence that facial displays decreased with continued exposure to the mirror self-reflection in this experiment. Instead, responding fluctuated, although at low levels. In particular, Roberta exhibited uniformly low levels of facial displaying throughout this experiment except during the initial sessions of Baseline 2, thus the onset of extinction

procedures may have increased facial displaying by this animal. However, other unknown factors were probably more relevant since a pre-loading technique was used and the effect was absent for the other two monkeys. It is interesting to note that while occurrences of mirror-looking were greatest during the FT schedule of reinforcement for all three monkeys (see Figure 9), there was no corresponding increase in facial displaying for these sessions. These results, like those of Eglash and Snowden (1983) suggest that "threat" displays are confined to initial exposures to the mirror self-image or to initial presentations during re-acquaintance with mirrors. Jawthrusts and brow retractions, however, continued to occur even with prolonged exposure to mirrors, and occurred in an unpredictable fashion. The motivational factors therefore remain elusive for facial displaying by monkeys in mirror contexts. Future research may examine the influence of factors such as hormonal levels or menstrual cycling on the occurrence of facial displays directed toward the mirror image, or attempt to measure corticosteroid levels as a function of monkey mirror-looking or facial gesturing to mirrors. An alternative direction for research would examine the attributes of the mirror image (e.g., reflected face, reflected eyes, reflected "stares" vs. "checks" by conspecifics) which give rise to facial displaying among monkeys.

In this experiment, *post-hoc* assessments of self-directed touching showed that these three monkeys touched their heads or bodies during 0.50% to about 4.5% of the intervals observed. Earlier reports of "self-directed" activity in the presence of mirrors were confined to the great apes and humans and (as discussed previously) and typically used broad or interpretative categorizations of behavior. The topography of self-directed responding among the monkeys in the present experiment was usually in the form of scratching or rubbing of the head (including the face) or of the body (on a site below the neck). Touching sometimes involved a slow action of the hand or foot with the consequent impression by the experimenter that the movement was "deliberate." More often, however, movements were fairly rapid and did not give rise to this impression. The goal here was to avoid interpretation of the behavior of monkeys, attempting instead to describe empirically the degree to which each subject provided herself the opportunity to learn about the mirror's reflective properties. Self-directed touching while looking at a mirror allows opportunity for cross-modal perceptions both with respect to appearance and movement of the body.

An additional issue involves the factors underlying the generation of movement as the animal watches its mirror reflection. Is the movement or self-directed action

generated for the purpose of testing or exploring the mirror's reflective properties? Or, is the animal responding to other stimuli (e.g., an itch on the chin) and then watching the mirror because the image is interesting.[1] These questions are beyond the scope of the present work, requiring sequential analysis of primate mirror behavior. However, the factors described as potentially affecting mirror-looking (e.g., arousal level, removal of competing responses, respondent conditioning effects) may also have operated to affect self-directed activity.

Overall levels of self-directed touches were slightly less than those described in a previous study (Suarez & Gallup, 1986). These authors reported that face-touching among pigtailed and rhesus monkeys occurred about 0.59 times per minute. This was in contrast to an earlier investigation by Dimond and Harries (1984) suggesting that face-touching is a rare response among monkeys, occurring only 1.35 times per 20 minute observation period (or only 0.07 times per minute). The differences in findings among these authors were likely the result of modifications in

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1 Another question which may be asked is whether the mirror self-image itself gives rise to "itches" or other tactile sensations, particularly for an animal which has only recently learned the correspondence between the mirror image and its own body. It is difficult to provide a means to answer this question, yet if gaze toward the mirror could be measured with enough sensitivity, electromyographic recordings of the specific body regions being viewed may reveal minute but measurable muscle contractions.

observational procedure, since Suarez and Gallup restricted their observations to alert animals and varied their observations with respect to time of day. Since self-touches by monkeys are generally performed in less than 5 s, 0.59 touches per minute (as reported by Suarez & Gallup) would be equivalent to touches occurring during about five (5 s) intervals per 10 minute period, or approximately 5% of the available observational intervals. Similar calculations suggest that Dimond and Harries (1984) observed face-touching by monkeys for less than 1% of the observed intervals. The monkeys observed here exhibited self-directed touching of the head (a broader response category than face-touching) during about 0.5% to 3% of the observed intervals.

Further, all three subjects in the present study showed a tendency for mirror-looking to accompany self-directed touching. Only one subject (Pavlova) among the three exhibited a tendency for an association between looking and touching to occur for the mirror, but not for the window condition. In conclusion, these monkeys exhibited a transient increase in mirror-looking as a result of scheduled presentation of water, and in doing so, also tended to watch the mirror self-image whenever touching their own heads or bodies. In this analysis, one subject (Pavlova) demonstrated differential responding with respect

to mirror and window conditions suggesting detection of some aspect(s) of the mirror's reflective properties.

Gaze aversion with the mirror self-image?

A third issue to be considered with regard to the findings of this experiment concerns generalization of gaze aversion from social situations to situations with mirror self-images. Discussion is limited by the absence of a baseline condition for each subject measuring occurrences of looks toward a conspecific. However these data are still informative. Examining both initial and final baseline measures of looking behavior for each subject (see Figure 8), the trend, if any, is for mirror-looking to occur more frequently than window-looking. The same is true for reinforced sessions. Comparisons of behavior between window and mirror conditions in this experiment are problematic, however, since most sessions began with window presentations permitting satiation of drinking behavior or other confounding factors. Figure 8 omitted sessions which began with mirror presentation. Examination of the results for the middle blocks of sessions for Baseline 1 and the FT schedule reveals a similar trend (see Appendix C which presents the results for sessions beginning with mirror presentation). Finally, the present data were based upon a single control condition in which subjects were presented with a window through which each animal viewed a video

camera and tripod. It may be that this stimulus, as well as the mirror reflection, was aversive for these monkeys and/or that the monkeys perceived the camera with its lens as a large "eye" thus giving rise to gaze aversion (the latter suggestion provided by F. Roche, 1988). While the results of this experiment suggest that monkeys do not exhibit gaze aversion with mirror self-images, further research (with more varied control procedures) is essential to provide a definitive answer.

EXPERIMENT 3:

REINFORCEMENT CONTINGENT UPON MIRROR-LOOKING BY MONKEYS

The results from the previous experiment demonstrated that frequency of brief looks toward a mirror can be increased at least transiently among monkeys through manipulation of accompanying events. The purpose of this third experiment was to train monkeys to look toward the mirror self-reflection for sustained periods of time. Kaufman and Rosenblum (1966, pp. 213 and 215) described "stare" (considered a dominance manifestation) in addition to "check" (a subordinance manifestation) as gaze-related responses which may occur among social groups of pigtailed macaques. If sustained eye contact with the mirror reflection shares features with other species-typical displays among monkeys, then increments in responding due to direct reinforcement may be absent, unstable, or weak (see

Breland & Breland, 1961 for discussion). Louboungou and Anderson (1987) demonstrated differential conditionability of three responses among pigtailed macaques. These authors reported that while responses such as yawning and scratching were readily conditionable through contingent presentations of food, a facial display, "protruded lips" (jaw-thrusting) was not susceptible to operant procedures. However, looking behavior (the response to be trained here) serves an additional function beyond expression and/or communication, namely that of visual examination of the environment. Direction of gaze must therefore be affected to some extent by its consequences in order for visually dominant animals to survive. It was therefore suspected that stares toward the mirror image would prove to be less "hard-wired" (a term used by Louboungou and Anderson among others) than the "protruded lips" response which these authors attempted to train. On the other hand, if sustained eye contact with the self-reflection is aversive for monkeys, then it may be difficult to train for reasons other than mere conditionability (or may be accompanied by other responses such as facial displays indicating discomfort).

The aim of this third experiment was to train monkeys to maintain eye contact with the mirror reflection at levels comparable to those of a "self-recognizing" chimpanzee (about 20 s durations, see Figure 4). It was also intended

to demonstrate unequivocally that mirror-looking (or camera-defined "eye contact") can be affected by its consequences. Demonstrations of operant control minimally require conditioning, extinction, and re-conditioning in order for inferences to be made regarding causality (Sidman, 1960).

Methods

Subjects

Two of the monkeys described previously (Roberta and Pavlova) were used in this experiment (Bibi died of causes related to endometriosis during session 2). Subjects were again individually caged throughout testing and maintained in a single room with auditory, but not visual access to one another. Daily care was identical to that described for the previous experiment except that both subjects were placed on a 45 to 46-hour water deprivation schedule to ensure that they would be highly motivated for this task. Subjects were examined regularly for any signs of dehydration, excessive weight loss, or other possible harmful effects.

Apparatus

The experimental apparatus was that used in the previous experiment. During the initial training phase of this work, the green signal light on the test panel indicated the availability of water given a lever-press. As a result, the competing response of looking at the test panel interfered with the monkeys' learning to look at the

mirror. The green signal light was then removed from the test panel and replaced with auditory discriminative stimuli (as of Session 27 of this experiment for each subject). Water availability was then signalled by a 1000 Hz tone for Roberta (produced by a Hewlett-Packard Wide Range Generator, Model #200CD) and a clicking sound (Foringer Click Generator, Model #1293) for Pavlova. Sound peak amplitude outputs were approximately matched using a 502 dual beam Tektronix oscilloscope.

The test apparatus used in Experiment 2 was further modified to permit the experimenter to control presentation of water so that the discriminative stimulus (visual or auditory) signalled that a single lever-press would result in water presentation. An electric metronome which emitted a soft auditory signal every second was used by the experimenter to assess durations of mirror-looking by the monkeys. The animals were again isolated from noise produced by the experimental apparatus both as a function of spatial arrangements and through the use of a 58 dB SPL masking noise in the test room. Two video cameras were present during tests of Pavlova (in the locations described previously).

Procedure

Subjects were trained on alternate days in order to maintain the 46-hour water deprivation schedule. Throughout

this experiment, subjects were provided 1-hour access to water beginning about 15 minutes after each session. Initial baseline measures were taken over six days, but due to interruption of laboratory routine (Bibi's death), only data beginning with session 3 will be presented. Presentations of window and mirror within each session occurred as described in the previous experiment.[1] Sessions were 80 minutes in length. For each session, subjects were videotaped for 20 minutes each during window and mirror conditions. The order of presentation (WMMW or MWWM) was varied over blocks of four sessions so that initial conditions across sessions were consistent with an ABBA design (beginning with window presentation for Roberta and mirror presentation for Pavlova).

Shaping of gaze began during session 7 for each subject and used a moving criterion within sessions. In general, when five reinforcers were obtained, the criterion was raised by 1-3 seconds. If reinforcement did not occur within a five minute period, then the criterion was lowered to the level previously attained. Problems arose with respect to ratio strain and satiety during the first training phase of this experiment. These were resolved by

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1 Events between sessions differed from the preceeding experiment since mirrors were never left on the cages overnight and camera-blinds were not illuminated except during sessions.

adjusting the amount of reinforcer for each subject (2 ml for Roberta and 0.5 ml for Pavlova) and by restricting criterion changes to one second increments. Durations of gaze directed toward the mirror self-reflection (or the window equivalent) for each subject were gradually increased to 20 seconds and maintained at this criterion throughout four sessions. Extinction procedures began during the following session with the change in procedure (from reinforcement to extinction) occurring after 20 minutes of reinforcement. The extinction phase lasted an additional three sessions with each session of extinction videotaped in its entirety. Reinforcement was then again available on the following session for each subject, and the change in procedure (from extinction to reinforcement) occurred after 20 minutes of extinction. This final phase of the experiment began with reinforcement of 20-second looks toward window or mirror and looks of this duration were maintained for two additional sessions.

Daily events were identical to those described in the previous experiment unless stated otherwise. For the final analysis, onset and termination of looking behavior were recorded by means of the computer logging system described in Appendix A.

Results

Cumulative total and median durations of camera-defined "eye contacts" with mirrors (or windows) are provided in Figures 12-15 for baseline, conditioning, extinction, and reconditioning phases of this experiment. These figures show final sessions of the first baseline and reinforcement conditions, the entire extinction sessions, and entire reconditioning sessions. Recall that sessions were comprised of either WMMW or MWWM presentation of window (W) or mirror (M) for 10 minutes each, and note that first and second 10 minutes of each W or M condition are displayed in separate figures. Both Roberta and Pavlova increased mirror-looking when water reinforcement was contingent upon sustained looks toward the self-reflection. During the first baseline, both monkeys exhibited uniformly low levels of responding, i.e., cumulative total durations of 30 seconds (5% of available intervals) or less during each 10-minute condition. For both subjects, reinforcement of sustained looking (20 seconds or longer) resulted in total durations per session ranging from about two to five minutes for each 10-minute condition (or 20% to 50% of the intervals). The initial training phase of this experiment required 49 sessions or more to obtain sustained camera-defined eye contacts of 20 seconds or longer. (Future research along these lines may proceed more rapidly if

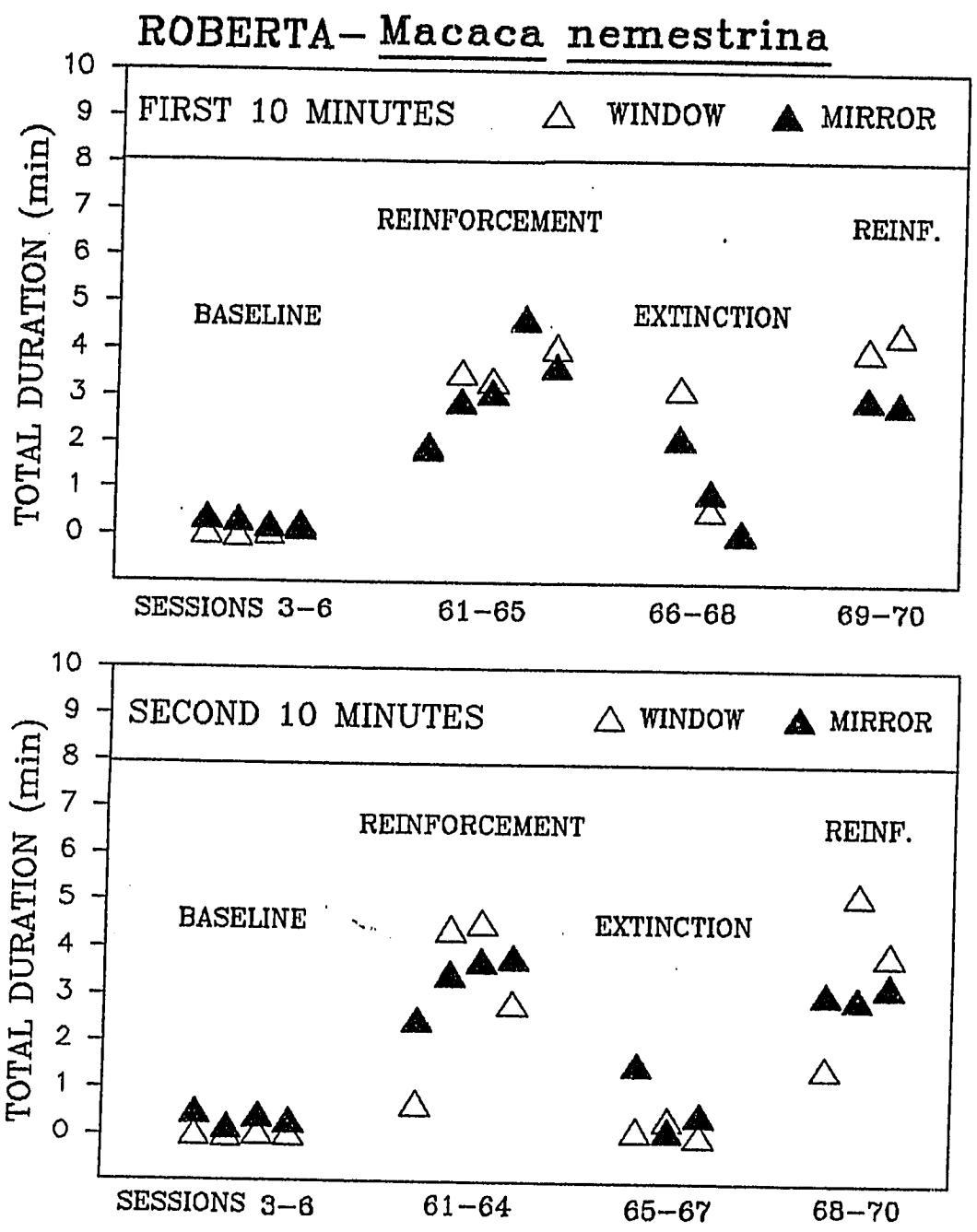

Figure 12. Conditioning and extinction of gaze shown as total durations of camera-defined "eye contact" with window or mirror by the monkey Roberta during first and last 10 minutes of critical sessions in Experiment 3. Note that extinction procedures for this subject began mid-session during session 65 and ended mid-session during session 68. For points which are superimposed, only mirror points are shown.

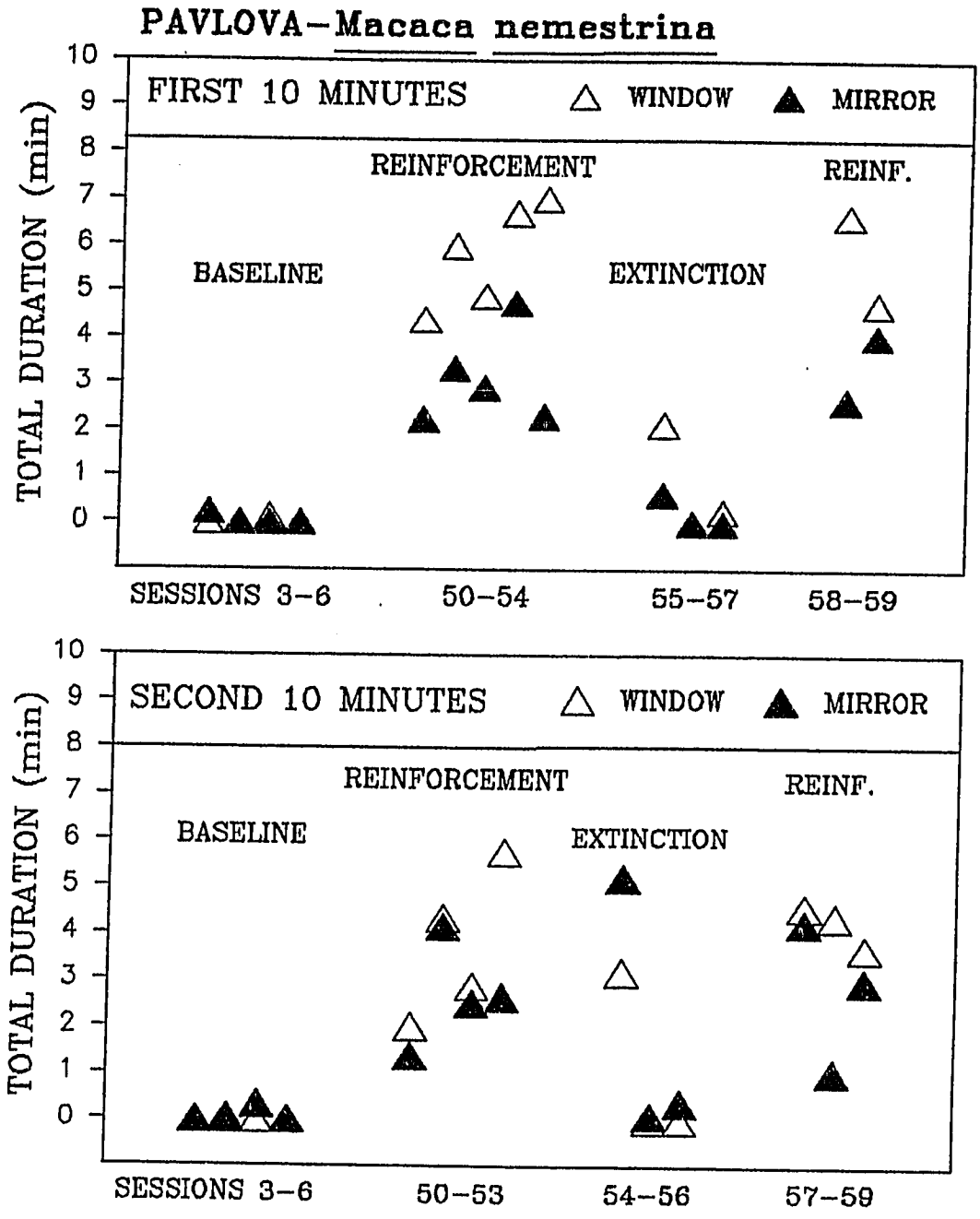

Figure 13. Conditioning and extinction of gaze shown as total durations of camera-defined "eye contact" with window or mirror by the monkey Pavlova during first and last 10 minutes of critical sessions in Experiment 3. Note that extinction procedures for this subject began mid-session during session 54 and ended mid-session during session 57. For points which are superimposed, only mirror points are shown.

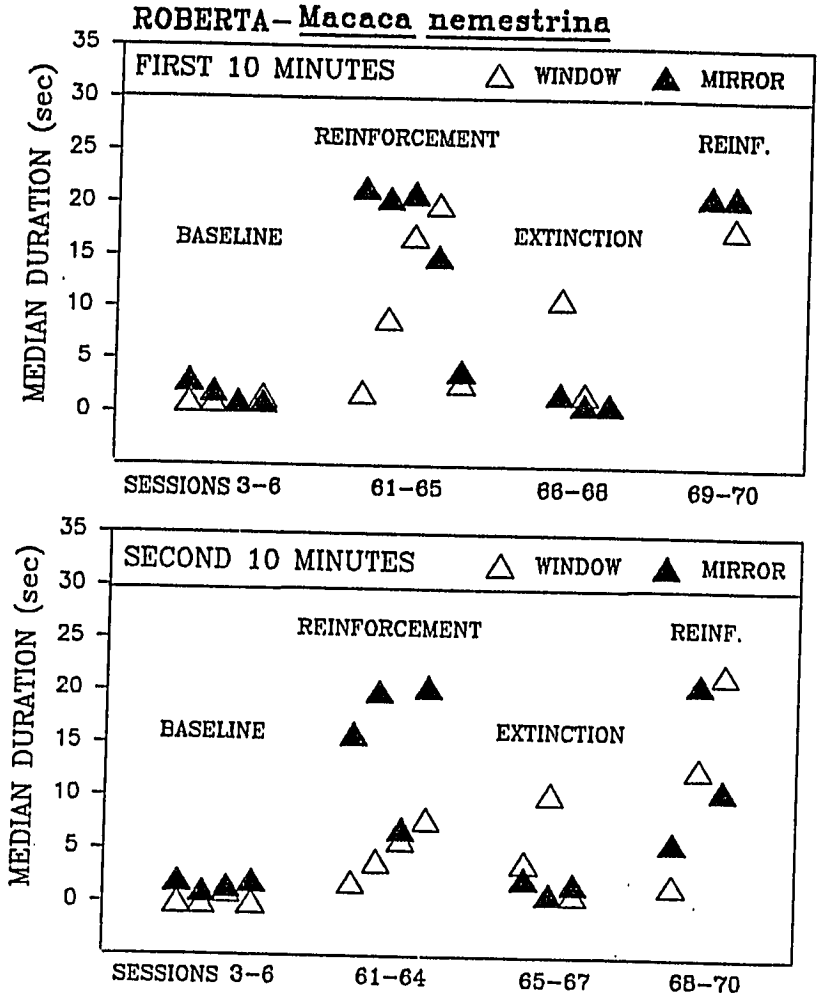

Figure 14. Conditioning and extinction of gaze shown as median durations of camera-defined "eye contact" with window or mirror by the monkey Roberta during critical sessions in Experiment 3. In the first 10 minutes of the window condition, the number of looks were 4, 1, 3, 8, 28, 23, 16, 19, 34, 10, 6, 5, 16, and 18, and for mirror conditions, 7, 9, 9, 9, 9, 12, 9, 17, 22, 15, 9, 8, 12, and 8 for each session, respectively. In the second 10 minutes of the window condition, numbers of looks were 0, 0, 3, 0, 12, 40, 33, 20, 2, 2, 4, 28, 24,and 14, and for mirror conditions, 5, 3, 9, 10, 12, 14, 24, 14, 10, 7, 3, 23, 14, and 19 for each session, respectively. For points which are superimposed, only mirror points are shown.

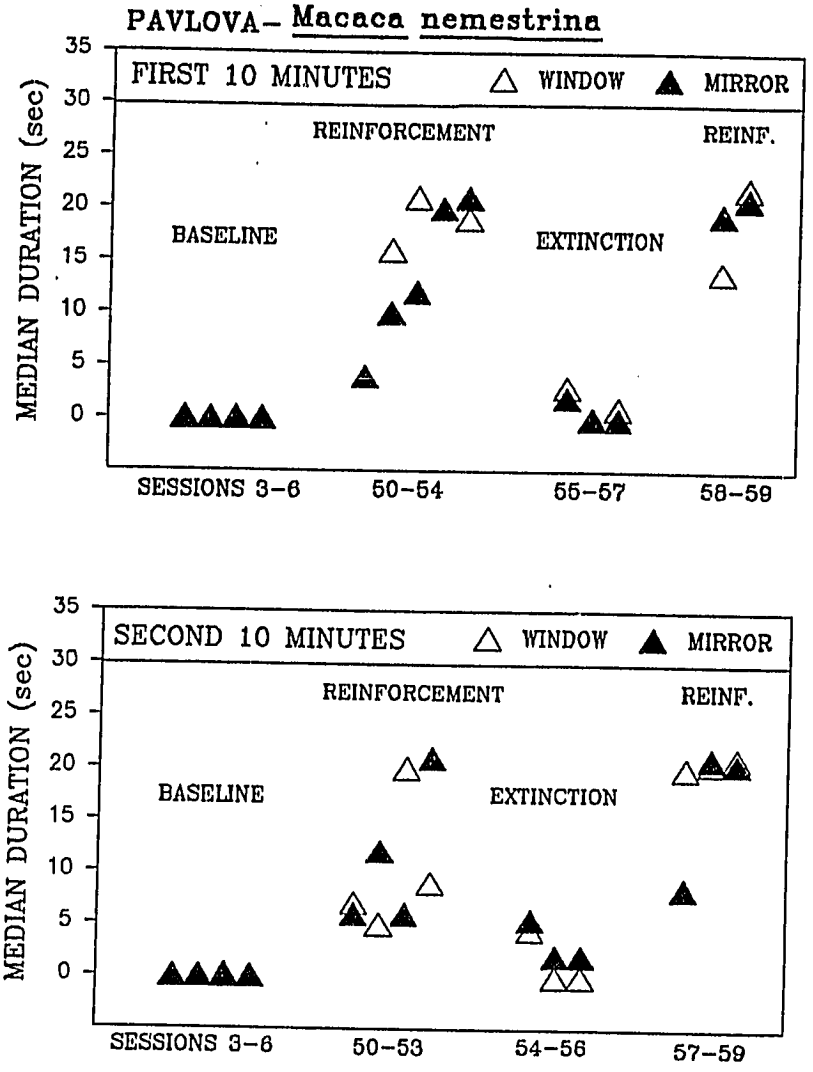

Figure 15. Conditioning and extinction of gaze shown as median durations of camera-defined "eye contact" with window or mirror by the monkey Pavlova during critical sessions in Experiment 3. In the first 10 minutes of the window condition, the number of looks were 0, 0, 0, 0, 22, 27, 21, 26, 31, 15, 0, 7, 31, and 15, and under mirror conditions, 0, 0, 0, 0, 15, 18, 14, 18, 9, 10, 0, 0, 10, and 13 for each session, respectively. In the second 10 minutes of the window condition, number of looks were 0, 0, 0, 0, 12, 32, 12, 29, 21, 0, 0, 17, 16, and 11, and under mirror conditions, 0, 0, 0, 0, 10, 20, 18, 9, 18, 3, 9, 26, 3,and 8 for each session, respectively. For points which are superimposed, only mirror points are shown.

problems of satiation and ratio strain are avoided.) Extinction of responding for each subject occurred rapidly during a single session until durations of mirror-looking reached levels comparable to those of initial baseline sessions. While Pavlova exhibited a temporary increase in the total duration of mirror-looking as a function of the change in procedures from reinforcement to extinction (due to an increased frequency of short duration responses), Roberta did not (see Figures 12 and 13, sessions 65 and 54 for Roberta and Pavlova, respectively). Retraining of sustained mirror-looking used a priming technique which immediately increased total durations of mirror-looking per session to the levels previously obtained in the reinforcement phase of this experiment.

Total duration per session of camera-defined eye contacts in the window condition also increased through contingent water reinforcement. Window-looking, like mirror-looking, responded to both extinction and retraining procedures.

Figures 14-15 show median durations of camera-defined eye contact for each 10-minute interval per session. Median durations of looking behavior clearly increased during training and retraining phases of this experiment. Median durations were 20s (the criterion value) for at least half of the reinforced 10-minute intervals, and were consistently

greater for reinforced compared to non-reinforced periods. During the initial two criterion sessions with reinforcement, Roberta exhibited longer median durations of looking in the mirror condition than in the window condition. This tendency was absent in the second monkey and quickly dissipated for Roberta.

The next series of figures (16-25) provide frequency distributions of the durations of looks toward window or mirror for selected sessions. Roberta made few camera-defined eye contacts during the first and last baseline sessions of this experiment (upper and lower panels of Figure 16, respectively). Looks which occurred during these sessions were brief, typically 4s or less in duration. Figure 17 shows Roberta's responding during the first reinforcement phase of this experiment. Reinforcement of sustained looks (20s or more) resulted in increased looking directed toward window or mirror for looks of shorter durations, as well for those meeting criterion. In session 65, Roberta was reinforced for sustained looking for a 20 minute period (10 minutes each condition, see upper panel of Figure 18), then extinction occurred during the mirror condition (lower panel of Figure 18). In session 68, procedures changed in midsession from extinction to reinforcement with consequent increases in durations of looks toward window or mirror (see upper and lower panels of

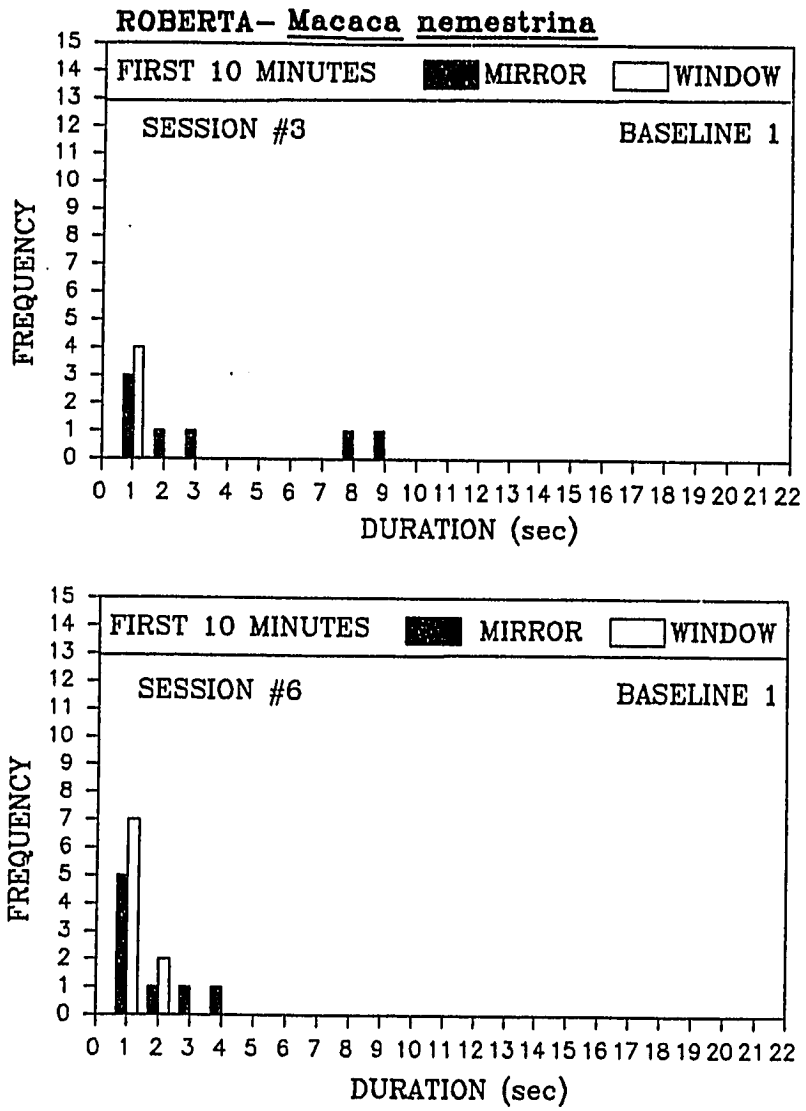

Figure 16. Frequency distributions of durations of camera-defined "eye contact" by the monkey Roberta during each 10 minute sampling period of Sessions 3 and 6 (Baseline 1) in Experiment 3.

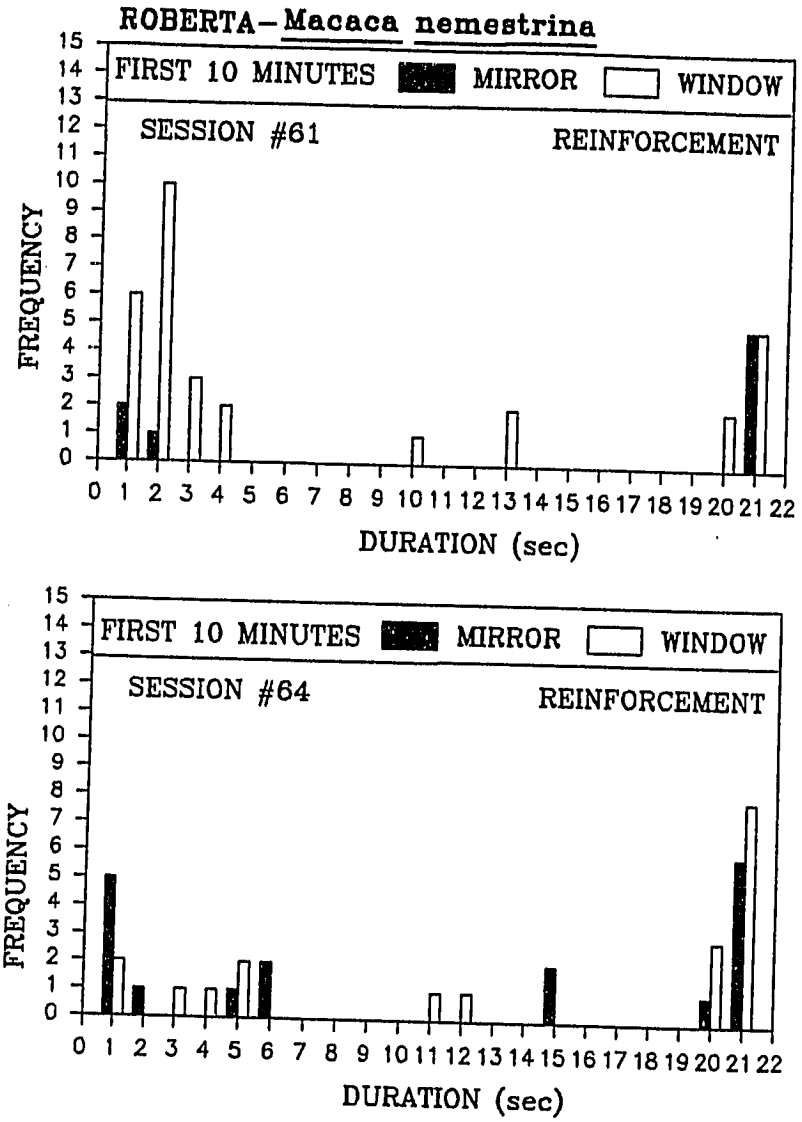

Figure 17. Frequency distributions of durations of camera-defined "eye contact" by the monkey Roberta during each 10 minute sampling period of Sessions 61 and 64 (reinforcement phase) in Experiment 3.

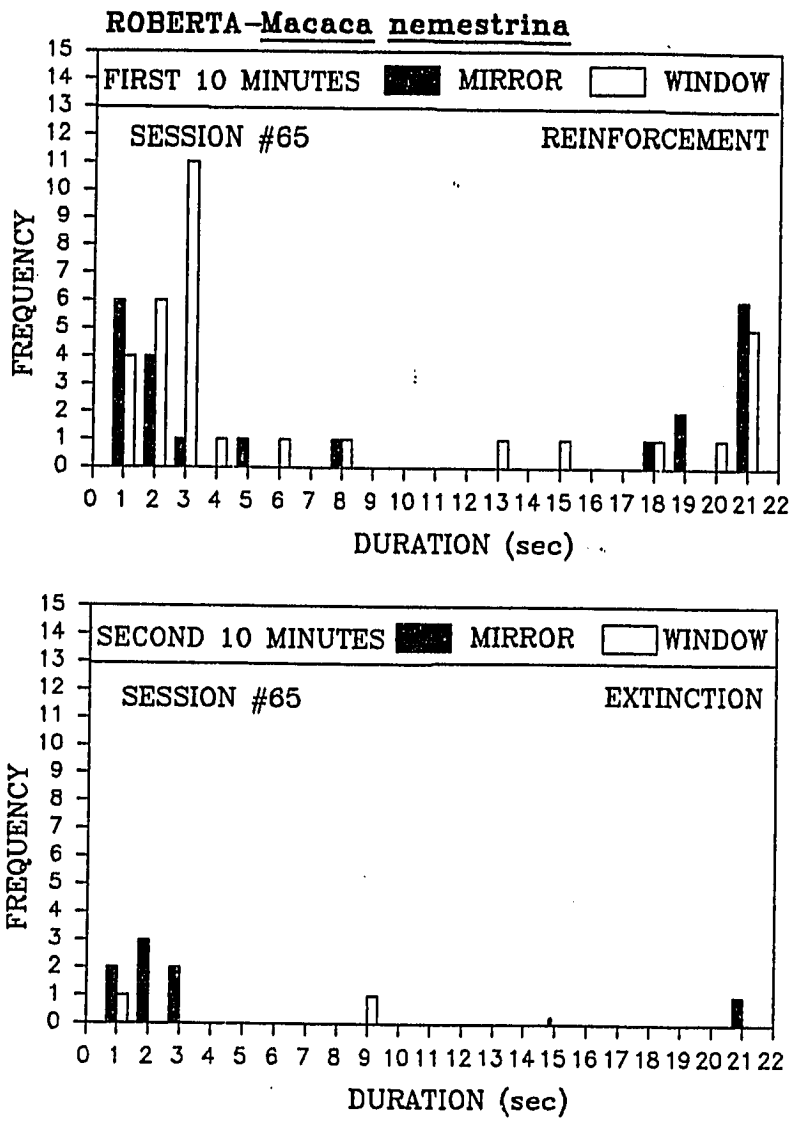

Figure 18. Frequency distributions of durations of camera-defined "eye contact" by the monkey Roberta during each 10 minute sampling period of Session 65 (reinforcement phase immediately followed by extinction) in Experiment 3.

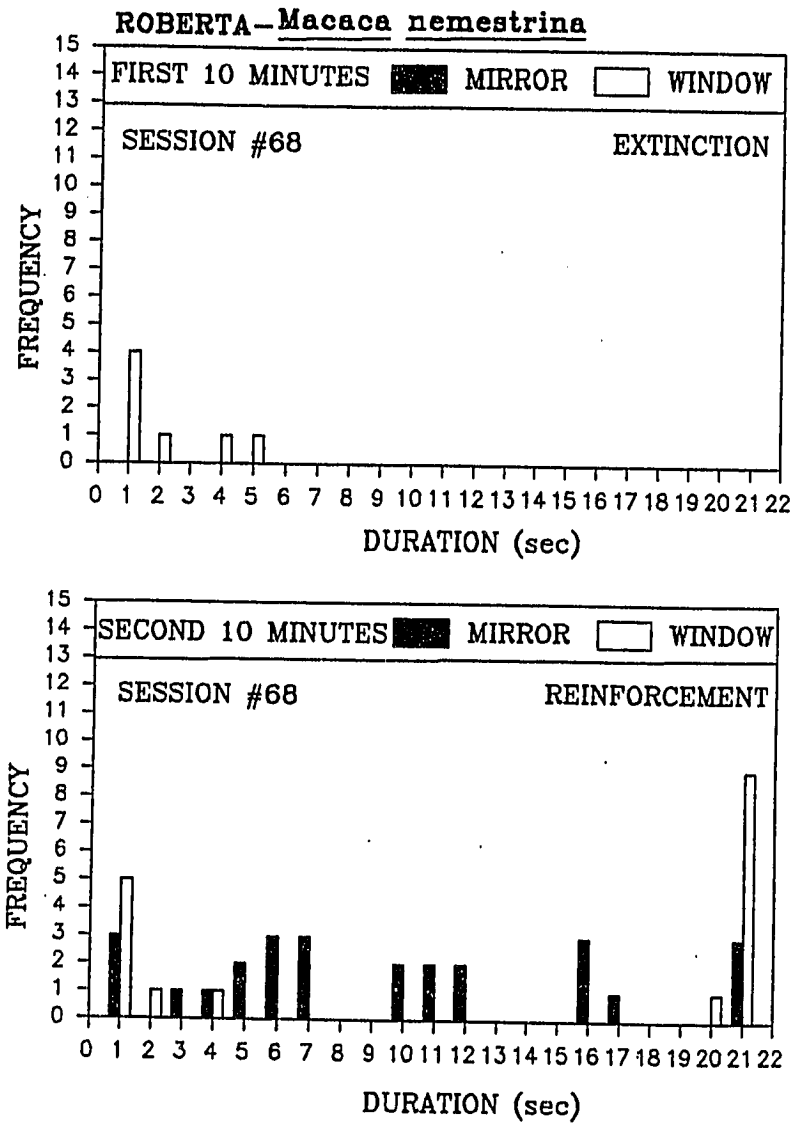

Figure 19. Frequency distributions of durations of camera-defined "eye contact" by the monkey Roberta during each 10 minute sampling period of Session 68 (extinction immediately followed by reinforcement phase) in Experiment 3.

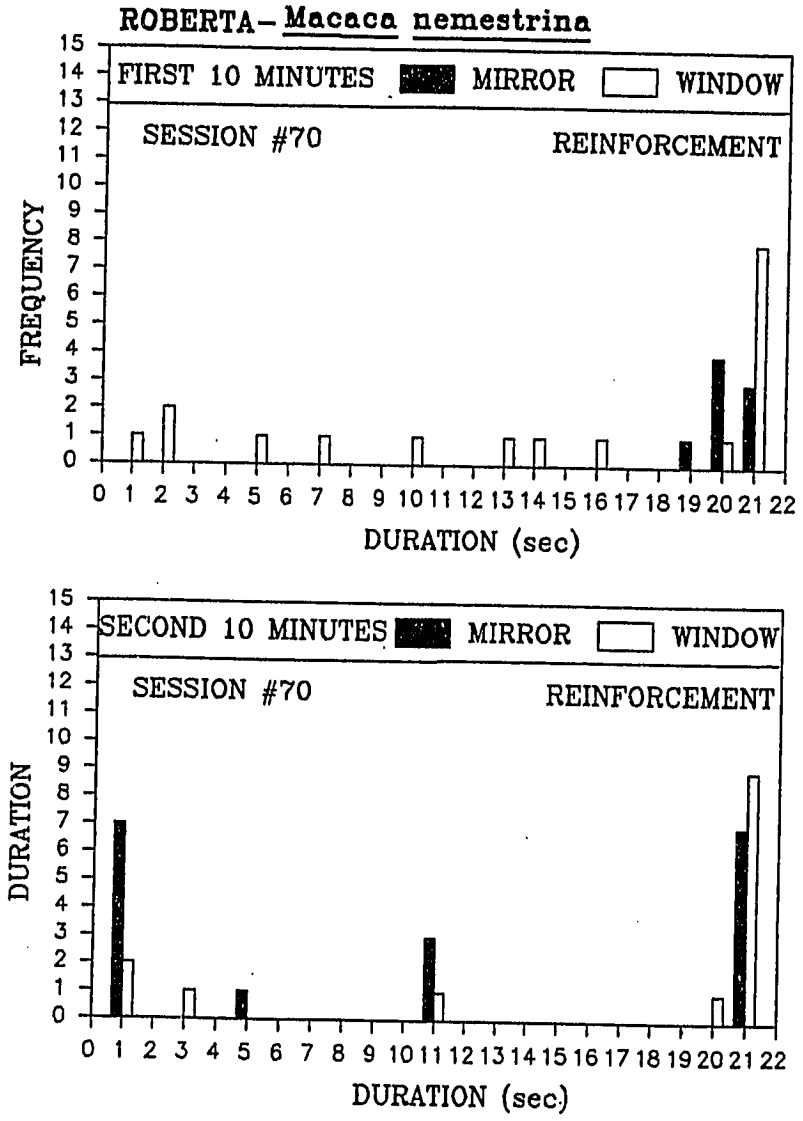

Figure 20. Frequency distributions of durations of camera-defined "eye contact" by the monkey Roberta during each 10 minute sampling period of Session 70 (reconditioning phase) in Experiment 3.

Figure 19). It is interesting to note that Roberta exhibited a greater percentage of reinforced responses (i.e., responded more efficiently) on the last day of this experiment compared to earlier sessions (compare Figures 18 and 20, i.e., about 22% compared to 53% during sessions 65 and 70, respectively).

Figure 21 shows initial baseline levels of responding, and here, camera-defined "eye contact" for Pavlova is absent entirely. This figure does not, however, convey information about looking behavior when Pavlova was sitting on the perch at the back of her cage. For instance, during session 6 of this experiment, observations via the second camera, at the front and side of Pavlova's cage, revealed that she spent about 6.5 minutes oriented toward the mirror during the first 10 minutes of this condition.[1] Figure 22 shows Pavlova's responding (as observed via the camera in the camera-blind) when water reinforcement was contingent upon camera-defined "eye contacts" lasting 20s or longer. During session 54 for Pavlova, reinforcement was available during the first 20 minutes of the session (see upper panel,

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1 Camera-defined "eye contacts" were visible via the camera located inside the camera blind. The second camera, positioned to the front and side of the cage, was less sensitive to gaze direction. Therefore, occurrences of mirror-looking as judged by observations via the second camera will be referred to here as "orientation" toward the mirror.

Figure 23), after which looking behavior was extinguished (lower panel, Figure 22). For Pavlova, responding remained under extinction until mid-session of 57, when reinforcement was again available (see upper then lower panel of Figure 24). As shown in Figures 23 and 25, Pavlova (like Roberta) responded more efficiently during the final session of this experiment (48% of her looks were reinforced compared to 91% during sessions 59 and 54, respectively).

Discussion

Contingent reinforcement of mirror-looking

These data demonstrate unequivocally that mirror-looking by monkeys is affected by its consequences. Both Roberta and Pavlova increased duration of looks toward the mirror (and window) when access to water was contingent upon "eye contact" duration as the reinforcement criterion was raised to 20 s. Further, looking behavior was reduced as a function of extinction procedures and increased as a result of reconditioning. After training and during the reinforcement phase of this experiment, median durations of mirror-looking for these monkeys were greater than those of a "self-recognizing" chimpanzee (see lower panel of Figure 3; median durations of looking across sessions for Amy ranged from 1-5 s). With training, cumulative total durations of looking for the monkeys during each 10 minute reinforced session ranged from 1-4 min and thus were

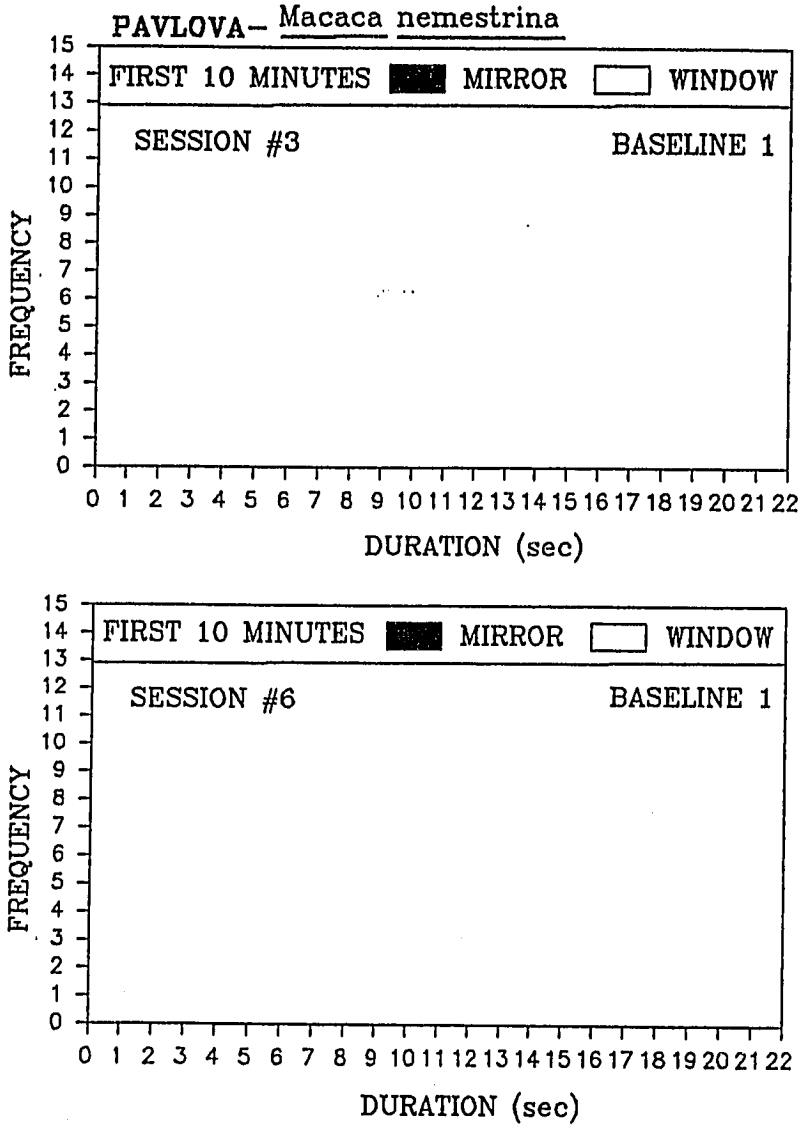

Figure 21. Frequency distributions of durations of camera-defined "eye contact" by the monkey Pavlova during each 10 minute sampling period of Sessions 3 and 6 (Baseline 1) in Experiment 3. No camera-defined "eye contacts" occurred which were greater than about half a second in duration.

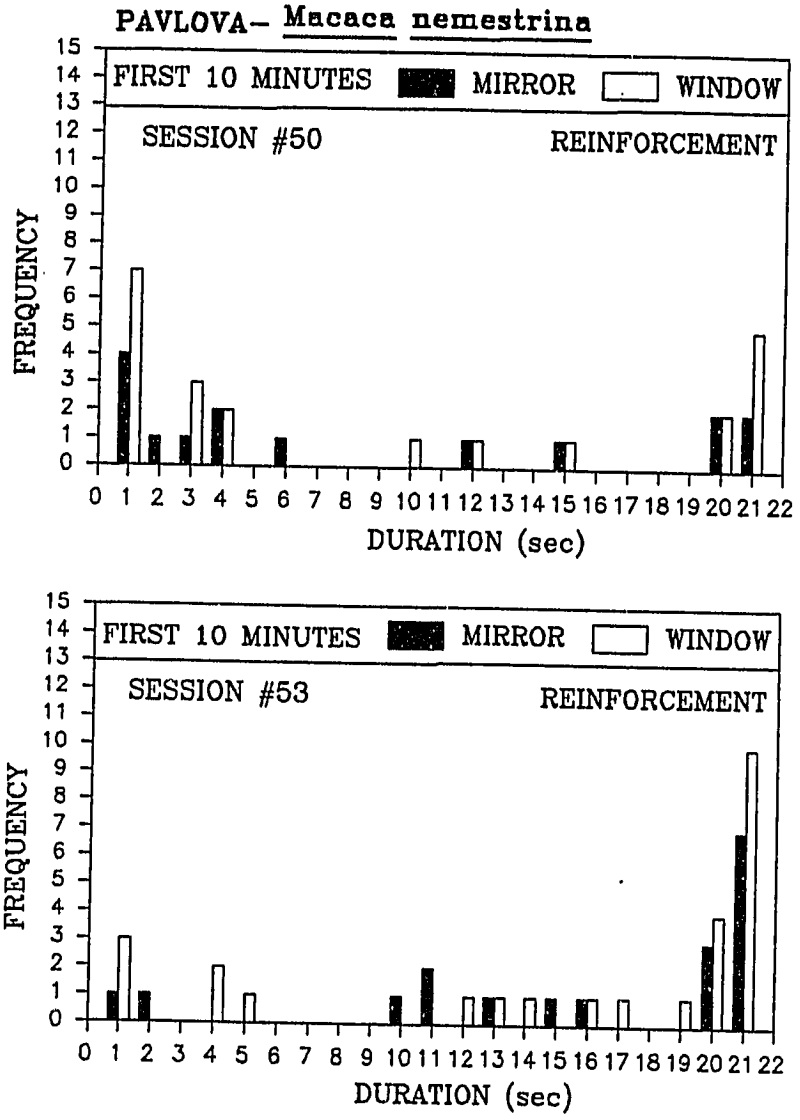

Figure 22. Frequency distributions of durations of camera-defined "eye contact" by the monkey Pavlova during each 10 minute sampling period of Sessions 50 and 53 (reinforcement phase) in Experiment 3.

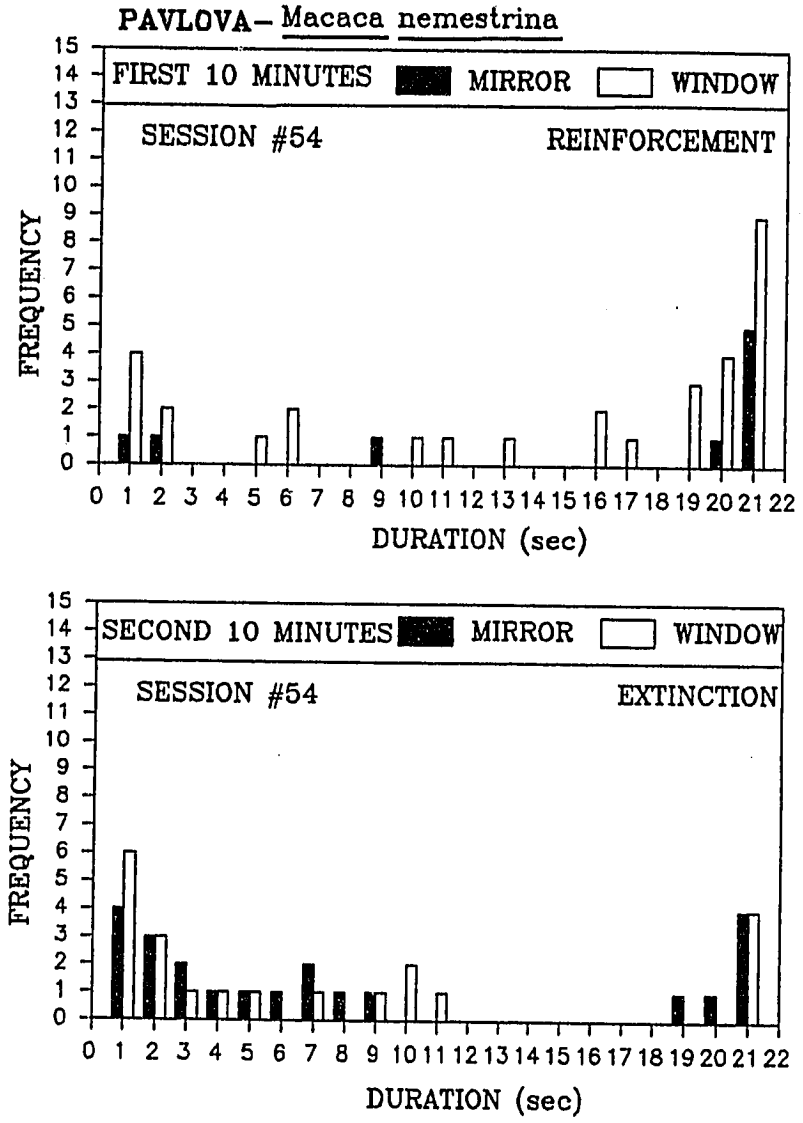

Figure 23. Frequency distributions of durations of camera-defined "eye contact" by the monkey Pavlova during each 10 minute sampling period of Session 54 (reinforcement phase immediately followed by extinction) in Experiment 3.

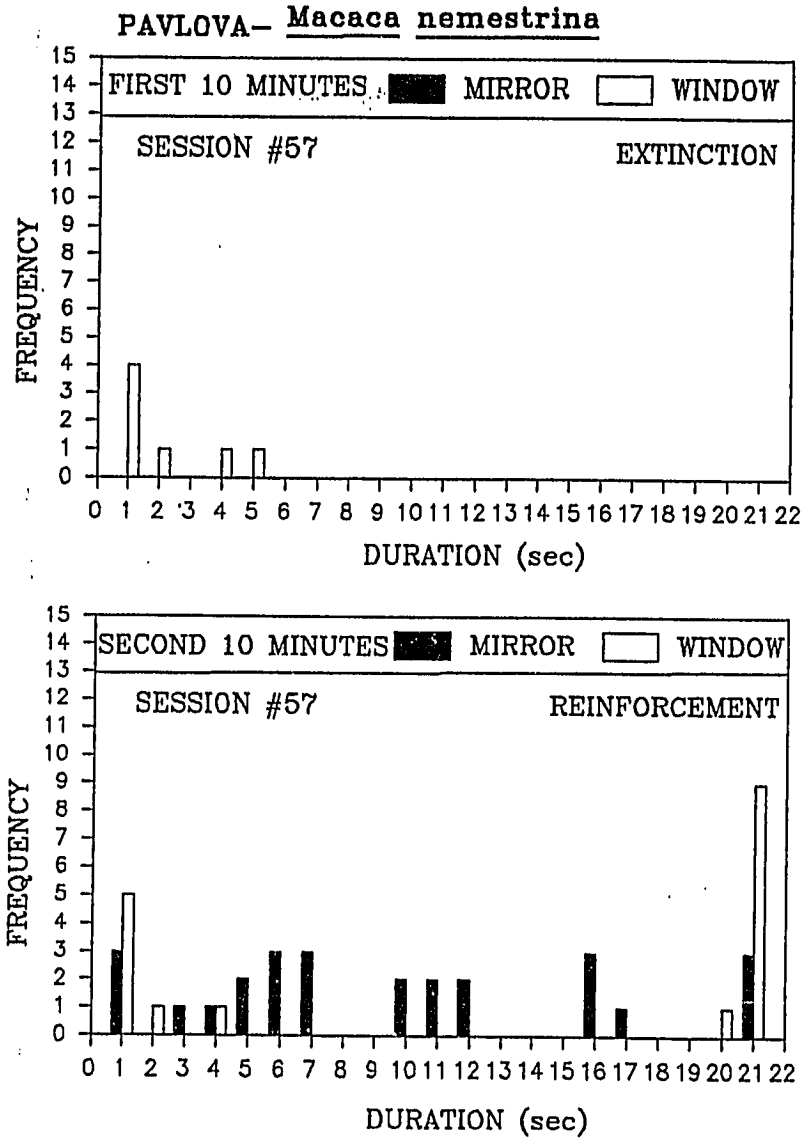

Figure 24. Frequency distributions of durations of camera-defined "eye contact" by the monkey Pavlova during each 10 minute sampling period of Session 57 (extinction immediately followed by reinforcement phase) in Experiment 3.

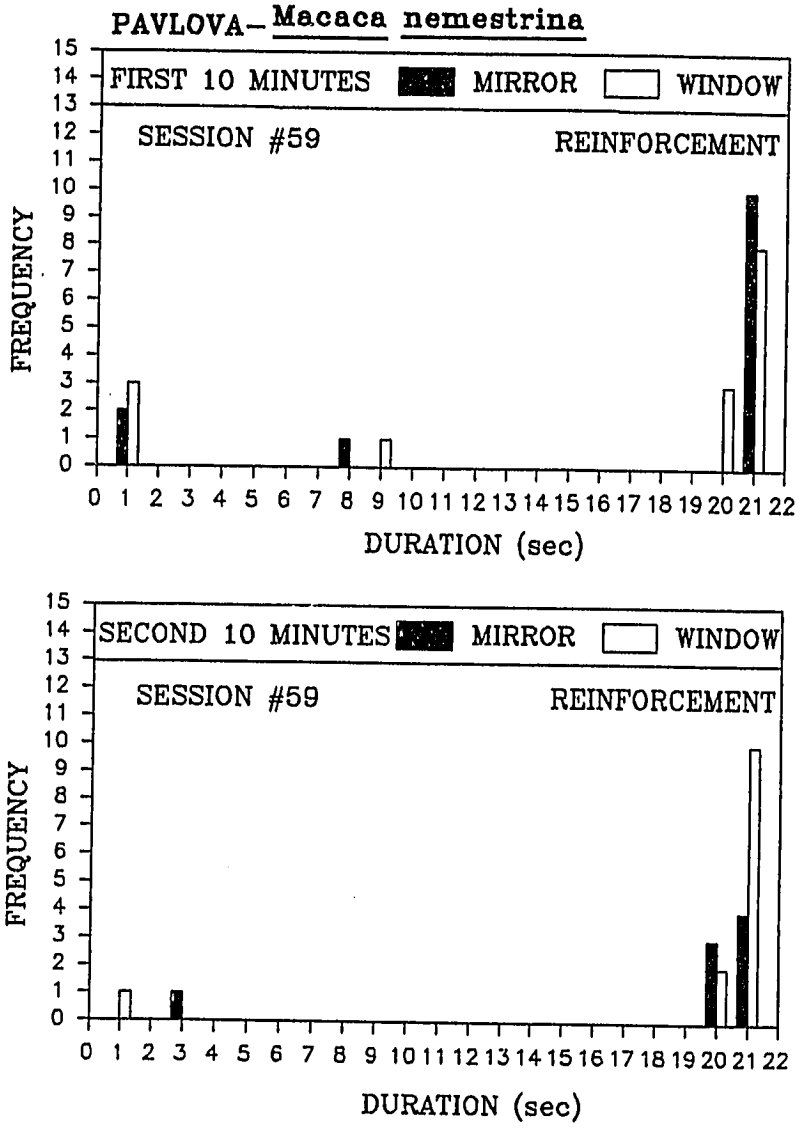

Figure 25. Frequency distributions of durations of camera-defined "eye contact" by the monkey Pavlova during each 10 minute sampling period of Session 59 (reconditioning phase) in Experiment 3.

slightly less than that of the chimpanzee during its first ten minutes of mirror exposure (i.e., about 6 min, upper panel of Figure 3).[1] Overall, it can be argued that the cumulative amount of mirror-looking by these monkeys during Experiments 2 and 3 (104-145 sessions and 59-70 sessions, respectively) was probably comparable to, if not in excess of, that exhibited by the chimpanzee Amy during her 12 days of mirror exposure preceeding the first (positive) mark test.

Possible correlates of increased mirror-looking

An interesting aspect of sustained camera-defined eye contacts for these two monkeys was the reliable occurrence of characteristic movements of the head and upper body which will be referred to here as "head swoops." These motions consisted of clear movements across the lateral range of the video camera, with some variation occurring with respect to the vertical position of the head. This behavior is topographically illustrated in Figure 26 for Roberta during the initial minutes of the mirror condition in session #70, the last session of this experiment. "Head swoops" by both subjects were apparent in both the window and the mirror conditions throughout this experiment, and it is not known

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1 Recall, however, that distances between subjects and mirrors differed between the two experiments and that the category of responses constituting mirror-looking for the chimpanzee was therefore broader than the category, camera-defined "eye contacts" used with the monkeys.

at this time that differences in topography exist between the two conditions. It should be noted that the animals were sometimes penalized for making these movements because in doing so, their heads (and eyes) would move off-camera with the result that duration counts for looking restarted at zero. "Head swooping" as the monkeys stared toward the mirror in Experiment 3 was an interesting and seemingly persistent phenomenon.

Determinants for these swooping movements remain unknown, but it is useful to speculate regarding their possible consequences. Loveland (1986b) described the behavior of normal and Down's Syndrome (DS) children (aged 16 to 32 months) in the presence of their mirror self-images and reported that the behavioral category, "observes self-image while moving" was a frequent response for both groups, although higher among the DS children. It was also reported that among DS subjects, the category of responding, "observes self-image while moving" occurred more often among subjects who exhibited criterion mark-directed responding than among the children failing this test. A category, "touching own body" while looking at the self-image was characteristic of both DS and normal children who self-recognized during a mark test, and was judged to be the most important factor predicting mark-directed responding for normal children of this age group. In a study with

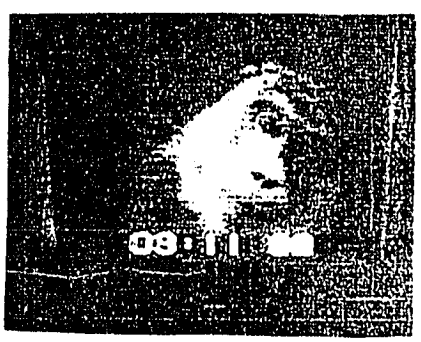
A. Head is located to the right of camera.

B. Less than 2 s later, head is to the left.

C. Less than 1 s later, head is to the right.

D. About 1 s later, head is to the left.

E. Less than 2 s later, head is to the right.



F. Less than 1 s later, head is to the left.

Figure 26. "Head-swooping" by the monkey Roberta while looking at the mirror self-reflection during Session 70 of Experiment 3. Taken from digitized video images.

Alzheimer's patients discussed previously, Biringer et al. (1989) described the behavior of subjects to include head movements while watching the mirror reflection, and stated that each of these individuals passed mark tests for self-recognition on at least one occasion.

The "head swooping" behavior of the monkeys in Experiment 3 may not be comparable to that of the children observed by Loveland (1986b) and the Alzheimer patients observed by Biringer et al. (1989) since at least one attribute of the behavior (watching the mirror) was specifically trained. On the other hand, the effects were probably similar. In each case, the effect was to provide opportunity to view the moving mirror self-image and thus to learn the association with self-movement. It is feasible that movements of the head and upper body occurred for these two monkeys as a means of reassurance regarding the origin of the mirror self-image. The monkeys may have been continuously testing the mirror's contingencies in order to gain reassurance that they were not (perhaps, rudely) staring at the face of another monkey. Yet, "head swoops" occurred for both window and mirror conditions, and unless the window came to serve as a conditioned stimulus for mirror responses (as a function of sequential presentations in the same location), this explanation seems unlikely.

As an alternative explanation, stares of 20 s duration may be difficult for monkeys regardless of the form of the object viewed. Head movement may permit movement of the eyes while gaze is directed toward a target (here, window or mirror). Another possible factor is the arousal level of these animals as they earned sips of water and were required to stare at the window or mirror. Still another factor is that a moving image may be more interesting to view if the subject is required to gaze in a single direction for long durations. Another alternative is that these animals may have been attempting to look behind their own images in the mirror as they moved to and fro. Several factors make this last suggestion untenable. Movements occurred during window presentations and were repetitive (almost rythmical) for both conditions. Further, the response measured here was camera-defined "eye contact" and hence, direction of gaze was judged to be toward the face of the self-reflection rather than toward the reflected environment.

Unfortunately, a strong argument cannot be made at this time regarding the determinants of the "head swoops" observed for the two monkeys in this experiment, nor can a definitive statement be made that "head swoops" were not inadvertantly shaped in the process of training mirror-looking. It seems likely, however, that these responses will prove a reliable correlate of these procedures.

Gaze aversion for the mirror self-image?

Comparisons between window and mirror conditions for one subject in this experiment provided evidence for gaze aversion with the mirror self-image. Pavlova, during the first ten minutes of each reinforced session (see upper panel, Figure 13) looked for longer cumulative total durations toward the window compared to the mirror. There was a similar, yet weaker trend for the second ten minutes of each session (lower panel, Figure 13) at a time when satiation effects may have been present. Gaze aversion with the mirror self-image therefore may only occur for some individual monkeys and only in situations when relatively long duration looks toward the mirror-image take place or are required. It may also be the case that gaze aversion develops as a function of learning that the mirror reflects one's own "self," although this is highly speculative.

EXPERIMENT 4:
MONKEY SELF-RECOGNITION

In the past, monkeys have consistently failed tests of self-recognition (e.g., Gallup, 1970; 1977a). Although monkeys have been exposed to mirrors continuously for periods as long as seven years (Gallup, Wallnau, & Suarez, 1980), it is feasible that looks (particularly, sustained looks) toward the mirror self-reflection are aversive or are avoided by monkeys. Premack (1983) suggested that gaze

aversion by monkeys may occur in the presence of mirrors (as well as conspecifics) preventing acquisition of mirror tool-use when the target is located on the animal's own body. Experiments 2 and 3, here increased camera-defined eye contact by monkeys through schedule induction and direct reinforcement procedures, respectively. These monkeys may therefore have learned that the mirrors reflected their own faces and bodies, and consequently may be demonstrated to self-recognize.

Methods

Subjects

Subjects were two pigtailed macaques (Roberta and Pavlova) used in the preceeding experiments. The monkeys were again maintained in individual cages with auditory, but not visual access to one another. Subjects received water for one hour about 45 hours prior to mark testing. Feeding and daily maintenance remained unchanged from earlier experiments.

Apparatus

Experimental apparatus was the same as described previously, except that for Pavlova, the primary video camera (inside the camera blind) was aimed toward the perch at the rear of the cage. A second camera was again located to the front and side of Pavlova's cage.

Procedure

Subjects were tested by means of the Gallup mark test on three occasions with some variations in procedure. The first mark test for each subject occurred less than 40 hrs following the last session of the preceeding experiment and began early in the morning when the experimental apparatus (lights, sound generator, and so forth) was placed in position. The mirrors were then cleaned and placed in an accessible location outside of the test room. Each monkey was sedated at approximately 9 am by means of intramuscular injections of ketamine HCl (Ketaset, equivalent to 100 mg per ml ketamine) at a dosage appropriate to each animal's weight. Dye marking took place while the monkeys were anesthetized. Marks consisted of rhodamine-B dissolved in 70% ethyl alcohol[1] applied to the upper half of the right ear and the left brow of each animal. Control procedures involved application of 70% ethyl alcohol alone to the otherwise unmarked brow and ear.

Subjects were continuously observed on the video monitors and their behavior recorded as they began to recover from the effects of the ketamine. Of particular interest were self-touches to brows and ears, although all

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1 Concentrations have not been standardized for this procedure and the method here was to use a clean "popsicle stick" to scoop a generous portion of the dehydrated dye for mixing with the 70% ethyl alcohol in a 100 ml beaker.

instances of self-touching were recorded. Mirror-oriented, mark-directed responses were judged to occur if a touch to any dye mark accompanied mirror-looking, or if touching followed looking within one second. Videotaping began at least three hours post-injection immediately after the first occurrence of well-coordinated self-grooming (indicating recovery of visual and motor abilities). Subjects were then observed an additional 10 minutes in the control (window) condition. The mirror was placed on the animal's cage while the video camera was operating in order to record each animal's initial response to its dye marked mirror reflection. Observation of each monkey's behavior in the presence of the mirror continued for one hour. Next, an attempt was made to increase mirror-looking through water reinforcement (i.e., primed by presentation of the auditory discriminative stimulus). These efforts failed, however, despite several attempts by both monkeys to drink from the empty water bottles attached to the side of each subject's cage. Subjects then received an additional 25-30 minutes of mirror exposure while water was available via the test panel, even though they were apparently unmotivated to maintain gaze with the self-image for water. Finally, the mirror was removed and observations and videotaping continued through the following 10 minutes of the window (control) condition.

The first mark test was followed by training procedures with the same two monkeys intended to increase the relevance or importance of red marks visible to each without aid of a mirror. Roberta and Pavlova were first trained to touch red marks (made by red felt-tipped marking pens or placement of red Avery Color Coding Labels) on pieces of paper held up by the experimenter. The monkeys were then trained to touch red marks (produced by marking pens or coding labels and without an anesthesic) on various locations, generally the arms and face, of the experimenter's body and on one occasion, on body of another relatively unfamiliar human. During these procedures which lasted about two weeks, reinforcers consisted of grapes, raisins, and monkey chow pellets dabbed with Nutri-cal. (Roberta and Pavlova were rarely fed without "earning" their food by touching red marks). Subjects were gradually trained until they reliably produced four consecutive responses to red marks on their own bodies. Repeated touching of a single mark was counted as a single response and minimally, alternations between two marks was required for reinforcement. Several new marks were presented daily so that generalization or transfer would be encouraged with respect to novel red marks in novel locations.

An additional week of training then accompanied the procedures described above, during which each subject was

provided water reinforcement (available via the test panel) contingent upon touches to red marks on their own bodies or on the surface of the window or mirror. During this last phase, experimental conditions (e.g., presentation of window or mirror, water deprivation level) and daily events (e.g., cleaning) were identical to those described for the preceeding experiment. It is important to emphasize that throughout these procedures, red marks were never placed on the head, ears, or face of either monkey. A second mark test followed for both monkeys using the procedures described previously.

A third and final mark test was also administered to each monkey after a series of modifications to Pavlova's cage. Before testing, an attempt was made to eliminate reflectivity of interior cage walls by applying opaque white Plexiglas to the inner surfaces. Before the third mark test, Pavlova was permitted to adapt to the modified cage over a two day period with a single session to retrain "eye contact" (as in Experiment 3). Roberta did not undergo retraining to look at her mirror image because her cage, presumably contributing to the configuration of discriminative stimuli for the occurrence of "eye contacts", remained unchanged. Both subjects were marked on the chest area beneath the chin, on a single brow and the opposite ear. An attempt was made to place the dye mark on each

subject's chest so that it was not directly visible to the animal, however, this may not have been the case. Procedures during the third mark test were otherwise similar to those described previously.

Results

The results of the first mark test will be discussed first and in greatest detail. One subject, Pavlova, was observed to make one mirror-oriented, mark-directed response to the brow area about 16 minutes after exposure to the mirror. Location and size of the brow mark for this animal is illustrated in Figure 27 and the topography and timing of criterion responding is illustrated in Figure 28. Mark-directed responses were absent for both subjects during window (control) conditions. The second animal, Roberta, made a brief glance toward the mirror, followed by a wiping response toward the marked brow as her head was turned away from the mirror. Roberta's posture, however, made it difficult to classify this response as either mirror-oriented or mark-directed.

The circumstances surrounding Pavlova's "mirror-oriented, mark-directed" response will be described in more detail than Roberta's ambiguous response. The written comment in the notebook for Pavlova's first self-recognition test reads: "...38 (indicating minutes) SG (i.e., self-grooming) JT (i.e., jawthrust) wipe head (i.e., she wiped

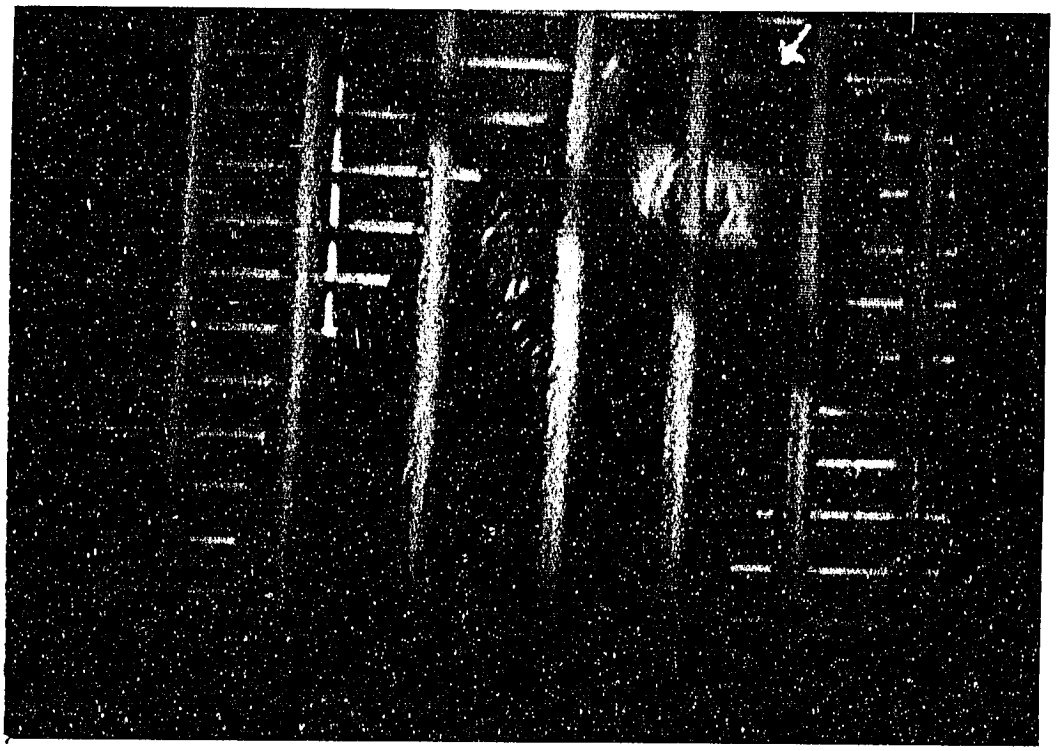


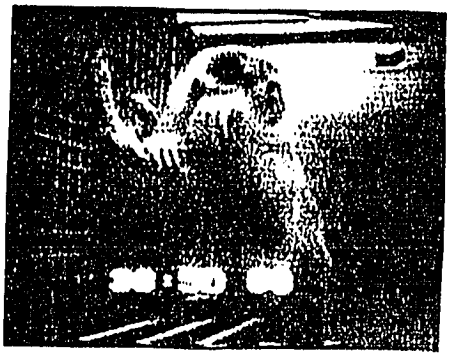
Figure 27. Location of the small red dye mark on the left brow of the monkey Pavlova during the first mark test for self-recognition in Experiment 4. Taken from photographed video image.

A. Self-grooming with back to the mirror.

B. Looks at reflected mirror self-image.

C. Jawthrusts at self-image.

D. Touches dye mark.



E. Rubs dye mark.

F. Inspects back of wrist.

Figure 28. Behavioral sequence of criterion responding for self-recognition (mirror-oriented, mark-directed behavior) by the monkey Pavlova during the first mark test in Experiment 4. Taken from digitized video images.

at her head)..." Prior to the time of this notation, Pavlova sat on the perch of her cage for about nine minutes without looking toward the mirror. She then rose and went to the front of the cage, picked up and ingested some litter from the cagetray, returned to her perch appearing to glance briefly at the mirror reflection on the way, and then sat on the perch and ate the remainder of the litter from her hand. The animal then sat with her back to the mirror and self-groomed for about six minutes. After the mirror had been in place for about 16 minutes, Pavlova looked up and stared at her mirror reflection, jawthrusted toward the mirror, appeared to touch her left knuckle to the small red mark on her brow, then in a continuous movement, rubbed the back of her left hand against the marked brow, inspected the back of her left hand, then jawthrusted again and turned rapidly away from the mirror. The behavioral sequence from onset of the stare toward the self-reflection to turning away from the mirror lasted only 3-4 seconds. No further mark-directed responses occurred during this test.

Following the first mark test, training of mark-directed responses (without aid of a mirror) occurred for both subjects. At the start of this phase of the work, Roberta would frequently touch the face or body of the experimenter during bouts of mutual grooming. Pavlova, however, had never been known to do so since her arrival at

the Hunter College facilities. It was therefore slightly more difficult to train Pavlova during the initial sessions since she often retreated to the rear of her cage.[1] Once this initial difficulty was overcome, Pavlova began to respond more readily to red marks than did Roberta, and based on informal observations, displayed more inspection of her body for novel marks and more variation with respect to the specific marks selected for touching. Pavlova also seemed to respond with shorter latencies between touches than Roberta, and generally showed more "enthusiasm" for the game. Both subjects, however, began to respond to novel marks during these procedures indicating stimulus generalization. In two instances, Pavlova twisted her body and looked downward as she touched red portions of her swollen perineum among the other red "marks" on her body. These responses were not reinforced and according to several observers, Pavlova otherwise appeared to directly touch red rather than other unmarked areas of her body.

Second and third mark tests for both monkeys were judged negative. Roberta made no mark-directed responses during either test. On the other hand, Pavlova was observed

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1 It is interesting to note that these training procedures (with the red marks) appeared to facilitate the development of a relationship between the experimenter and this monkey with the lasting effect that the animal permitted and initiated mutual grooming with this caretaker.

to make mark-directed responses during both second and third tests, however, mark-directed responses also occurred during the window condition for both tests. For example, prior to placement of the mirror on the cage during the second mark test, Pavlova was observed to lie on her stomach (a highly unusual posture for this monkey) so that her face was just centimeters from a slightly reflective cage wall. She appeared to be gazing at the cage wall as she slowly stroked or rubbed at the dye mark on her brow. In Pavlova's third and final mark test for self-recognition, the dye mark was placed too low on her brow and while two mirror-oriented, mark directed responses occurred, several mark-directed responses also occurred during the window condition. (Videotapes through the window clearly show profiles of Pavlova as she looked upward at her brow while touching the dye mark). More specific information regarding Pavlova's responding during the third mark test is provided in Tables 6 and 7. As Table 6 indicates, the results for Pavlova during this third and final mark test were ambiguous (and hence, negative) although the behavior observed was consistent with self-recognition behavior. Although levels of mark-directed activity in the window (control) condition were comparable to those in the mirror condition for Pavlova during this third mark test, two mirror-oriented, mark-directed responses occurred with latencies of less than a

FREQUENCY OF RESPONSES DIRECTED TO DYE MARKS OR CONTROL SITES

SITE OF TOUCH	WINDOW		MIRROR	
EYE OR BROW	MARKED: 4	CONTROL: 2	MARKED: 1	CONTROL: 5
EAR	MARKED: 0	CONTROL: 0	MARKED: 1	CONTROL: 0
CHEST	0		1	

Table 6. Mark-directed responses by the monkey Pavlova during the third and final mark test for mirror self-recognition in Experiment 4.

SHOWS LATENCY TO RESPOND AFTER CAMERA-DEFINED "EYE CONTACT"

SITE OF TOUCH	WINDOW		MIRROR	
	MARKED	CONTROL	MARKED	CONTROL
EYE OR BROW	1. >17S 2. 22S 3. >18S 4. >3S	1. >18S 2. 3S	1. 1S	1. 21S 2. 14S 3. 16S 4. >9S 5. 13S
EAR	MARKED	CONTROL	MARKED 1. 13S	CONTROL
CHEST			1. 1S	

Table 7. Latencies of mark-directed responses by the monkey Pavlova during the third and final mark test for mirror self-recognition in Experiment 4.

second between looking toward the mirror and mark-directed touching (see Table 7), giving rise to the impression that these responses were "self-conscious."

Discussion

One monkey (Pavlova) was observed to exhibit mirror-oriented, mark-directed responding on one occasion during three mark tests. Replication is essential in attributing self-recognition to monkeys, although Boccia (1991, submitted for publication) has recently reported criterion responding for self-recognition with an additional pigtailed macaque. It is interesting note that in the experiments reported here, Pavlova was the subject who exhibited discrimination between window and mirror conditions for self-directed touches accompanying mirror-looking. This was also the one subject to exhibit gaze aversion with the mirror, although only when looking behavior was trained to occur for relatively long (20 s) durations. It is also interesting that Pavlova seemed to show greater transfer than Roberta during training of mark-directed responding (without a mirror) after the first mark test, as evidenced by a greater tendency to actively search for and touch novel red marks on her body. (However, it is also possible that this animal was initially more attentive to red marks). Further, during session 41 of this experiment and before the first mark test, Pavlova was observed to pull on a warty

growth on her left brow as she looked at the mirror reflection. Although gaze was directed toward the mirror momentarily when her fingers contacted the wart, Pavlova then looked away almost immediately while her hand was still touching her brow. This occurrence was noted at the time and it lead to speculations as to whether it should be interpreted as "self-directed." Yet, the animal did not then move closer to the mirror to examine her brow or the wart more closely. It is therefore likely that while certain attributes of mirrors (appearance, if not movement contingencies) were learned by this monkey, other aspects of mirror use may not have been detected (e.g., the progressive magnification or minification of the reflected object as it approaches or retreats from the mirror).[1] Evidence suggests that there is individual variation among primates regarding the characteristics of mirrors which are detected and used. For instance, Anderson (1986) described a monkey which used a mirror to locate otherwise unviewable food, but the animal apparently never learned that mirrors can reflect a no-food

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1 Two contingencies of mirror use have been stressed throughout this work, namely those of appearance and movement, and it was suggested that these constitute the necessary and sufficient conditions for labelling a reflective surface as a mirror. In this sense, a closed-circuit television provides a "mirror" reflection, although approach or retreat from the self-image on a video monitor does not necessarily result in magnification or minification of the self-reflection.

condition (i.e., the monkey did not simultaneously learn to inhibit searching when food was not reflected by the mirror.

In retrospect, rapid turning away from the mirror after "self-" or mark-directed responding may be characteristic of monkeys. It is feasible that some monkeys who have learned the contingencies of mirror use with respect to their own bodies and faces may in some sense be "embarrassed" by their mirror self-reflection. For example, Lewis, Sullivan, Stanger, and Weiss (1989) described the behavior of human infants in the presence of a mirror and reported that "embarrassment" occurred more frequently for subjects who exhibited criterion responding during mark-testing than for subjects who failed to exhibit the response. "Embarrassment," in this study, was defined as a smiling facial expression (Is the monkey equivalent of a smile an affiliative jaw-thrust?), followed by gaze aversion and movement of the hands to touch hair, clothing, face, or other body parts. Pavlova's mirror-oriented, mark-directed behavior occurred in the sequence: look at mirror, jawthrust, touch mark, inspect site on hand where it contacted the dye mark, jawthrust again, and then rapidly turn away from the mirror to self-groom. Jawthrusting toward mirrors by monkeys is usually classified as a "social" response, therefore its occurrence in close temporal association with this monkey's criterion response

for self-recognition adds to the complexity of observations of primate mirror behavior.

As described in the introduction to the present work, the exclusive classification of primate mirror behavior as either "social" or as "self-directed" may prove untenable. Interpretation of primate perception of mirror images limited to a "self" vs. "other" dichotomy is a simplistic perspective.[1] Researchers working in the area of human development have questioned classifications of infant responses to mirrors as "social." In a recent study by Priel and Zeidman (1990), 6- to 13-month-old infants were described to exhibit more "social" responses to a mirror self-image than to familiar and unfamiliar peers. It was reported that while the frequency of responses which did not involve contact with the mirror (such as smiling, vocalizing, and approaching at a distance) were similar among these subjects for peer and mirror conditions, "social" responses involving grasps or touches (and in particular, grasps with an open hand) were more frequent for

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1 Plutchik (1974; p. 21) describes several characteristics of functional categorizations of behavior. Some of these are met by the above classification scheme, yet future research will reveal whether or not these response categories have a broad range of application across species, or whether they are indeed exhaustive (note that Swartz and Evans, 1991 required an "other" category for ambiguous responses), or whether categories such as "social" or "self-directed" responding will be shown to be sensitive to experimental operations such as reinforcement, deprivation, or stress.

the mirror condition. Priel and Zeidman suggested that the latter responses (viewed as "social" in the infant literature) are better described as exploratory behavior.

It is difficult to interpret the results of Priel and Zeidman (1990) in relation to Gallup's (1968) discussion of social facilitation effects with mirrors since the behavior of the children serving as social stimuli was not simultaneously recorded, and it is not known if the circumstances were such that a coaction effect could have occurred. Further, certain responses (e.g., smiling and vocalization) were observed with similar frequencies for peer and mirror conditions. It remains questionable, however, whether the two conditions were perceived as identical by these children since more sensitive measurements may reveal more subtle differences. Most of the children in this study (maximum age, 13 months) were too immature for positive performance during the Gallup mark test and their behavior with the mirror does not appear to be markedly different from the smiles, kisses, and touching of the mirror's surface described by Lewis and Brooks-Gunn (1979) for pre-self-recognizing infants.

It is further suggested here work that other forms of "social" behavior (e.g., smiling among infants or facial gestures by monkeys) may occur as a form of exploratory behavior during a period when a child (or monkey) is first

learning the contingent properties of mirrors. Smiles and vocalizations may serve as a form of exploratory behavior in the presence of a mirror self-reflection since their effects can be viewed via the mirror.

In support of the finding that "social" displays may accompany mirror-oriented, mark-directed responding, Swartz and Evans (1991) reported that their one self-recognizing chimpanzee exhibited seven "social" responses during her third mark test, although the specific type(s) of gesture was unspecified. Continuation of "social" responses after mirror-oriented, mark-directed responding (self-recognition) can be interpreted in several ways. First, the individual (or species) may not fully comprehend the contingencies of mirror use and may still view the self-image (either periodically or only certain of its attributes) as "social." This is feasible since that it is not known at this time what is required for self-recognition to occur. Second, the individual may understand the relevant aspects of mirrors but periodically the individual tests the mirror's properties (through "social" or other behavior) in order to reconfirm that the mirror is indeed still a mirror. Third, mirrors may be discomforting for the individual and this emotion is expressed through what is generally considered "social" behavior. Fourth, the responses referred to as "social" may actually be social in most contexts, but are

sometimes displayed in the absence of social stimuli. At this time it is difficult to make a strong argument regarding any of these interpretations. Examination of data presented by Gallup (1970, Figure 1, p. 86), however, supports the suggestion that at least some social responses among self-recognizing chimpanzees continue to occur even after "self-directed" responses are observed to be reliable.[1] It remains to be seen if levels of "social" responding among chimpanzees after demonstration of mirror-oriented, mark-directed responding are significantly less than those for monkeys.

To conclude, Gallup and his colleagues (e.g., 1977a) may be correct in suggesting that differences exist between the behavior of monkeys and some great apes in the context of the mirror self-reflection. The difference, however, probably does not lie in the presence vs. absence of a "self-concept" or of "self-awareness," or even of mirror-oriented, mark-directed responding. Instead, differences may be said to take the form of probability of criterion responding during repeated mark tests for self-recognition

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1 Gallup (1970) sampled behavior each 30 s during two 15 minute periods per day. He reports as many as two "social" responses during these daily observational procedures. Direct comparisons with the data presented here are not possible since it is difficult make assumptions regarding duration of responses within the category, "social," however, this analysis suggests that levels of responding may be comparable between the two species.

and may also involve the topography of the criterion response.

GENERAL DISCUSSION

In this work, mirror-oriented, mark-directed responding (self-recognition) was demonstrated for a single chimpanzee (Experiment 1). It was then shown that mirror-looking among monkeys can be increased through manipulation of accompanying events (Experiment 2) and contingent events (Experiment 3). Finally, the present work constituted the first demonstration of mirror-oriented, mark-directed responding (self-recognition) for a single pigtailed macaque (Experiment 4). Criterion responding for self-recognition here required that individual subjects exhibit high levels of mirror-oriented, mark-directed responding relative to a control (no mirror) condition. Further, mirror-oriented behavior was not judged to occur in the absence of sustained looking toward the mirror (i.e., more than a few seconds). Brief looks (1-2 s or less) occasionally immediately preceeded (within 1-2 s) mark-directed activity for both Amy (chimpanzee) and Pavlova (monkey) during the third mark tests for these animals and may have indicated knowledge of the mirror's properties combined with habituation to the mark testing procedures. In both cases, however, results for third mark tests were judged to be negative due to high levels of mark-directed activity during control conditions.

These findings and those of other researchers emphasize the need to reconsider the criteria used in assessing mirror "self-recognition," as well as the interpretation of its occurrence (or absence) for individuals or species. Repeated use of the Gallup mark tests with individual subjects is likely to result in some variation of responding. Mirror self-recognition therefore should not be viewed as an all-or-nothing phenomenon for any species, including humans.

Contingencies of mirror use were discussed previously and it was suggested that positive performance during the Gallup mark test requires use of a mirror's contingency of appearance, but may not require moment-by-moment feedback from the mirror as the subject touches the mark. Research with normal infants (Bahrick & Watson, 1985) suggests that detection of movement synchrony with video images developmentally precedes detection of similarity of appearance, an interesting finding because the implication is that a cross-modal perceptual capacity is acquired at an earlier age than a unimodal perceptual ability. Similar research has not been performed with non-humans, but would be interesting with respect to self-recognizing primates and individuals or species which fail to demonstrate the phenomenon. On the other hand, Hill and Tomlin (1981) reported that self-recognizing Down's syndrome children

responded equally often to a pretaped marked image of themselves compared to a video image with contingent movement which showed their marked faces. There may also be an interactive effect in the detection of the appearance and movement contingencies characteristic of self-reflections. Cameron and Gallup (1988) reported that among human infants, mirror self-recognition precedes recognition of self-images in the form of shadows (when the latter were designed to be the same size as the subjects), and these authors demonstrated that shadow recognition does not develop among most children until about three years of age. Since the shadows accurately reflected movement and only partially reflected the appearance of the children, this study suggests that sensitivity to a self-reflection's movement contingency may be offset by partial degradation of the reflected appearance. Investigations regarding shadow recognition among non-human primates remain to be performed, but would be interesting in the context of visual self-recognition.

It is not yet known whether knowledge that mirrors reflect movement plays an important role in the acquisition of visual self-recognition with mirrors. It is feasible that detection of a mirror's movement contingency may occur first with respect to gross body movement, increasing the likelihood that the other reflective attributes of mirrors

will be detected. Knowledge that mirrors reflect movement may then extend to situations in which the mirror image is used to guide more precise motor movements to a target such as a dye mark in the Gallup mark test.

In the experiments reported here, observations of monkeys and chimpanzees suggest that movements to touch dye marks can be rapid and relatively precise. Other observations (e.g., the chimpanzee, Amy during the third mark test) involved mark-directed touches in alternation with touches to unmarked areas such as the nose or eyelid. The latter may represent inaccurate reaching or exploration of the face and boundaries of the mark. These data do not permit this judgment. Resolution of questions about the degree of mirror competence for mirror-oriented, mark-directed responding require procedures discussed earlier (Anderson, 1986) including limited presentation of the mirror image.

While two pigtailed monkeys (Pavlova, described here and that of M. Boccia, 1991) have demonstrated mirror-oriented, mark-directed behavior, it appears that the phenomenon is rare among monkeys. The experiments reported here were not designed to specify the causal factors for monkey self-recognition.[1] Nor do they provide definitive

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1 For example, these procedures with the monkeys did not include mark tests between experiments so it is not known

answers to questions about why monkeys typically fail to exhibit criterion responding during the Gallup mark test, although mirror-looking is probably a major factor. These experiments, however, were the first systematic attempt to increase mirror-looking among monkeys, and also the first demonstration of criterion responding for self-recognition by monkeys despite many attempts by many researchers. The monkeys in these experiments required contingent water reinforcement in order for sustained looking toward the mirror to consistently occur. The one monkey judged here to exhibit unambiguous criterion responding during the first mark test was the only subject to demonstrate gaze aversion toward the mirror during the training phase for sustained looking. A second monkey demonstrating the least induction of mirror-looking among the three animals failed to show convincing evidence of mirror-oriented, mark-directed responding. Further research is required, however, to conclude that high levels of mirror-looking predict criterion responding for non-human primates during tests for self-recognition.

The importance of facial displays remains speculative in the failure of most monkeys to self-recognize. The self-recognizing monkey (Pavlova) in Experiment 4 was described

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when adequate learning took place for mirror-oriented, mark-directed responding to occur.

as jawthrusting immediately before and after the criterion response, it is possible that the rapid turning away from the mirror afterwards was related to the jawthrusting self-image. In retrospect, bouts of facial displaying occurred throughout these experiments and many bouts were followed by rapid rather than slow turns away from the mirror image. It is important to note therefore that speed of movement may affect what is observed by monkeys via mirror self-reflections (and hence, what is learned about the mirror's properties), in addition to influencing the probability that observers will detect self- or mark-directed responding by monkeys when attempting to record behavior. The notation in the relevant laboratory notebook regarding the monkey's criterion response was written for the purpose of noting a time period when the brow may have been touched. Second and third viewings of this videotape segment were required before topography was perceived clearly (i.e., before the precise nature of the touching response addressed to the small red mark became apparent to viewers). Monkeys may not exhibit the slow "deliberate" inspections of marks typical of some chimpanzees, and/or monkeys may show less interest in facial marks once detected (although Pavlova was observed to respond to her marked brow slowly and "deliberately" during the window condition of the second mark test as she gazed toward a reflective cagewall).

Another possible factor in the failure of monkeys to readily demonstrate self-recognition involves the head and face structure of monkeys compared to that of chimpanzees. In the Gallup mark test procedure, marks are typically applied on one eyebrow ridge and the upper portion of the opposite ear. Since monkeys' ears are in many cases relatively smaller than those of chimpanzees and are generally located farther back on the head, opportunities for mark-directed responding by monkeys may effectively be reduced by half.

Experiment 4 provided some indication that the motivation of monkeys for certain activities may be influenced by residual effects from anesthetization. Although subjects were water-deprived and presumably thirsty (i.e., they attempted to drink from empty water bottles attached to the cages), sustained looking toward the mirror did not occur when reinforcement was available. Hence, some activities among monkeys may be affected by anesthetization even after eye-hand coordination has returned to normal.

It should also be noted that research with humans indicates that self-directed touching and movements of the body while watching the self-image are events which predict positive responding during mark tests for self-recognition. Loveland (1986b) observed both normal and Down's Syndrome (DS) children in the presence of the mirror self-image and

reported that among these children, two forms of behavior predicted criterion responding. The first, "touch own body" was observed among both groups and was judged to be the most important factor for normal children in predicting criterion responding for the mark test. The second response, "observes self-image while moving," was also an important predicter in this sense, especially for the DS children. Note also that these two responses, "touch own body" and "observes self-image while moving" correspond to what was described here as the two major contingent relationships provided by mirror images, namely reflections of appearance and movement. The monkeys in the present work demonstrated seemingly analogous behavior (at least with respect to effect if not motivation), i.e., self-directed touches while watching the mirror reflection (Experiment 2) and "head swoops" while gazing at the mirror (Experiment 3). Either of these responses may prove to be more rapidly or more easily trained than mirror-looking for monkeys and may prove to be more reliable in facilitating mirror-oriented, mark-directed responding during later tests for self-recognition.

Interpretation of self-recognition behavior by non-human primates also requires reconsideration. Gallup (e.g., 1991) and others suggest that self-recognition as demonstrated by means of the Gallup mark test implies something about self-perception and about an organism's

"concept of self." Instead, the implications regarding mirror-oriented, mark-directed responding are probably much more restricted. Positive performance during the mark test provides information regarding an individual's capacity for mirror tool-use. The site of the mark or target (located on self vs. other) may be irrelevant. In demonstrations of mirror self-recognition among non-human primates, the mark is touched because it is a relatively novel or interesting stimulus. Without further investigation, little can be concluded about the animal's perception of the background for the mark (i.e., its own face or head) other than sufficient relative contrast.

To clarify this, imagine a chimpanzee facing a mirror and detecting via the mirror reflection the presence of a red mark on the lampshade of an adjacent lamp. It cannot see the dye mark except by means of the mirror reflection, but being experienced with mirrors, the chimpanzee reaches out to touch the mark. It is difficult to believe that this demonstration implies that the chimpanzee has a well-integrated sense of lampshades (or of lamps). Alternative procedures, however, directly address issues of self-perception among non-human primates. For example, as described previously, studies of body size estimation (Ben-Tovim & Walker, 1990) or psychophysical studies regarding body image (e.g., tests with distorting mirrors

such as those used by Traub and Orbach, 1964) are applicable in this context and through instrumental procedures may be used to test non-verbal individuals or species. Such studies can take the form of measuring conceived (without direct visual feedback) as well as perceived body image and thus, can provide a direct means of assessing how a monkey or chimpanzee "thinks" about itself.

Appendix A

Datalogging program for use with IBM compatible PC. Keypunch onset and offset times were recorded relative to time of program start allowing measurements of duration and frequency of looking behavior. Looks away from windows or mirrors less than 0.45 s in duration were regarded as being part of a single look for Amy (Experiment 1) and for Pavlova (Experiment 3). The program was modified for use with the monkey, Roberta so that looks away less than 0.55 s were regarded as part of a single response. For all subjects, looks lasting less than one second were omitted from the analysis.

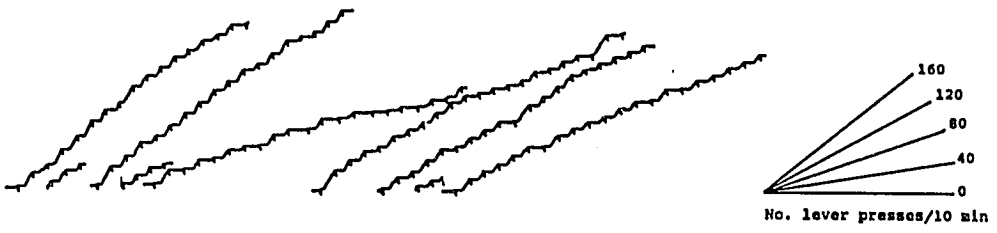
```
2 CLS
5 CLEAR
10 DIM BEG$(300):DIM FIN$(300)
20 DIM DURN(300)
25 DIM IRI(300)
27 PRINT:PRINT:PRINT:PRINT
30 PRINT TAB(10) "LOOK AT FIRST FEW SECONDS OF VIDEOTAPE.": PRINT TAB(5) "IS THE
 SUBJECT RESPONDING DURING THE FIRST SECOND? (Y/N)"
40 INPUT FG$
50 IF FG$<>"N" AND FG$<>"n" AND FG$<>"Y" AND FG$<>"y" THEN GOTO 40
100 PRINT:PRINT:PRINT TAB(10) "EXPERIMENT #?":INPUT E$
105 IF E$<>"1" AND E$<>"2" AND E$<>"3" THEN GOTO 100
110 PRINT:PRINT TAB(10) "SUBJECT NAME?"
120 PRINT TAB(15) "B = BEBE"
130 PRINT TAB(15) "P = PAVLOVA"
140 PRINT TAB(15) "R = ROBERTA"
150 INPUT S$
160 IF S$<>"B" AND S$<>"b" AND S$<>"P" AND S$<>"p" AND S$<>"R" AND S$<>"r" THEN
GOTO 110
163 IF S$="b" THEN SS$="B":GOTO 170
165 IF S$="r" THEN SS$="R":GOTO 170
167 IF S$="p" THEN SS$="P":GOTO 170
169 SS$=S$
170 PRINT:PRINT TAB(10) "DAY #?":INPUT DA$
180 PRINT:PRINT TAB(10) "WINDOW or MIRROR (W or M)?"
190 INPUT CND$
200 IF CND$<>"w" AND CND$<>"m" AND CND$<>"W" AND CND$<>"M" THEN GOTO 180
205 IF CND$="w" OR CND$="W" THEN CCND$="W"
207 IF CND$="m" OR CND$="M" THEN CCND$="M"
210 PRINT TAB(15) "FIRST or SECOND (1 or 2)?"
220 INPUT CNUM
230 IF CNUM<>1 AND CNUM<>2 THEN GOTO 210
235 IF CNUM=1 THEN CNUM$="F"
237 IF CNUM=2 THEN CNUM$="S"
240 PRINT:PRINT TAB(10) "RESPONSE TYPE ?"
250 PRINT TAB(15) "G = GAZE DIRECTED AT WINDOW/MIRROR"
260 PRINT TAB(15) "J = JAWTHRUST"
270 PRINT TAB(15) "O = OPEN MOUTH"
280 PRINT TAB(15) "L = LIPSMACK"
290 PRINT TAB(15) "E = EAR RETRACTION"
300 INPUT RSP$
310 IF RSP$<>"G" AND RSP$<>"g" AND RSP$<>"j" AND RSP$<>"J" AND RSP$<>"O" AND RSP
$<>"o" AND RSP$<>"L" AND RSP$<>"l" AND RSP$<>"E" AND RSP$<>"e" THEN GOTO 240
320 IF RSP$="G" THEN RRSP$="g"
322 IF RSP$="J" THEN RRSP$="j"
324 IF RSP$="O" THEN RRSP$="o"
326 IF RSP$="L" THEN RRSP$="l"
330 IF RSP$="E" THEN RRSP$="e"
340 IF RSP$="g" OR RSP$="j" OR RSP$="o" OR RSP$="l" OR RSP$="e" THEN RRSP$=RSP$
350 FLN$=SS$+E$+CCND$+CNUM$+RRSP$+"."+DA$
500 CLS:PRINT:PRINT:PRINT TAB(10) "DO YOU WISH TO BE TOLD THE FILENAME (Y or N)?
"
```

```
510 INPUT TEL$
520 IF TEL$<>"y" AND TEL$<>"n" AND TEL$<>"Y" AND TEL$<>"N" THEN GOTO 500
530 IF TEL$="y" OR TEL$="Y" THEN PRINT TAB(10) FLN$
540 IF TEL$="Y" OR TEL$="y" THEN PRINT
541 IF TEL$="Y" OR TEL$="y" THEN PRINT TAB(15) "PRESS ANY KEY TO CONTINUE"
550 IF TEL$="Y" OR TEL$="y" THEN INK$=INKEY$
560 IF (TEL$="Y" OR TEL$="y") AND INK$="" THEN GOTO 550
570 CLS:PRINT:PRINT:PRINT:PRINT:PRINT TAB(10) "DO YOU NEED TO READ INSTRUCTIONS
?"
580 INPUT INS$
590 IF INS$<>"Y" AND INS$<>"y" AND INS$<>"N" AND INS$<>"n" THEN GOTO 570
600 IF INS$="Y" OR INS$="y" THEN GOTO 10000
610 CLS:PRINT:PRINT:PRINT:PRINT:PRINT TAB(10) "set clock timer to ... ? (e.g.,00
:00:00)"
620 PRINT TAB(39) "(hr:min:sec)"
630 INPUT CLK$
640 IF VAL(LEFT$(CLK$,2))>24 THEN GOTO 610
650 IF VAL(MID$(CLK$,4,2))>59 THEN GOTO 610
660 IF VAL(RIGHT$(CLK$,2))>59 THEN GOTO 610
670 IF LEN(CLK$)<>8 THEN GOTO 610
680 IF MID$(CLK$,3,1)<>":" THEN GOTO 610
690 IF MID$(CLK$,6,1)<>":" THEN GOTO 610
692 PRINT:PRINT TAB(10) "TIME AT WHICH SCORING SHOULD STOP (HR:MIN:SEC) ?":INPUT
 SSTP$
693 IF VAL(LEFT$(SSTP$,2))>24 THEN GOTO 692
694 IF VAL(MID$(SSTP$,4,2))>59 THEN GOTO 692
695 IF VAL(RIGHT$(SSTP$,2))>59 THEN GOTO 692
697 IF LEN(SSTP$)<>8 THEN GOTO 692
698 IF MID$(SSTP$,3,1)<>":" THEN GOTO 692
699 IF MID$(SSTP$,6,1)<>":" THEN GOTO 692
700 Q=((VAL(LEFT$(CLK$,2)))*3600)+((VAL(MID$(CLK$,4,2)))*60)+((VAL(RIGHT$(CLK$,2
))));Z=((VAL(LEFT$(SSTP$,2)))*3600)+((VAL(MID$(SSTP$,4,2)))*60)+((VAL(RIGHT$(SST
P$,2))));IF Q>Z THEN GOTO 610
702 CEAS=Z-Q
705 PRINT:PRINT:PRINT:PRINT:PRINT "PRESS ANY KEY TO START"
710 INK2$=INKEY$
720 IF INK2$="" THEN GOTO 710
723 ON TIMER(CEAS) GOSUB 1032
725 TIME$=CLK$
727 TIMER ON
730 CLS
1000 R$=INPUT$(1)
1010 PRINT R$
1015 GF$="999"
1020 T=TIMER:CLOK1$=TIME$:IR=T-TIM2
1025 WHILE INP(96)<128:Y$=INKEY$
1027 WEND
1028 IF CUMTM+(TIMER-CUMTM)=CEAS OR CUMTM+(TIMER-CUMTM)>CEAS THEN GOTO 1032
1030 GF$="0"
1032 TIM2=TIMER:CLOK2$=TIME$:DUR=(TIM2-T):EV=EV+1:CUMTM=CUMTM+DUR+IR
1033 IF EV=1 AND (FG$="Y" OR FG$="y") THEN CLOK1$="00:00:00"
1034 IF EV=1 AND (FG$="Y" OR FG$="y") THEN IR=0
1035 IF EV=1 AND (FG$="Y" OR FG$="y") THEN DUR=TIM2
1036 IF EV=1 AND (FG$="N" OR FG$="n") THEN IR=T
1041 BEG$(EV)=CLOK1$:FIN$(EV)=CLOK2$:DURN(EV)=DUR:IRI(EV)=IR
1043 PRINT CLOK1$ TAB(20) CLOK2$ TAB(40) DUR TAB(60) IR
1045 IF CUMTM=CEAS OR CUMTM>CEAS THEN GOTO 20000
1050 GOTO 1000
10000 CLS:PRINT:PRINT:PRINT TAB(25) "*********DATA LOGGER*********"
10010 PRINT:PRINT TAB(10) "YOU MAY SCORE A SINGLE OBSERVATIONAL RESPONSE BY PRES
SING ANY KEY ON THE":PRINT "KEYBOARD (e.g., spacebar) FOR THE DURATION OF THE OB
SERVED RESPONSE."
10015 PRINT:PRINT "ONSET AND OFFSET TIMES WILL BE RECORDED, AS WELL AS DURATION
OF RESPONSES AND OF INTERRESPONSE INTERVALS"
10020 PRINT:PRINT TAB(10) "YOU WILL BE PROMPTED TO SET SESSION START AND STOP TI
MES.  AFTER SETTING THESE":PRINT "TIME VALUES, THE NEXT KEYSTROKE STARTS THE CLO
CK TIMER."
10022 PRINT:IF FG$="Y" OR FG$="y" THEN PRINT TAB(5) "BEGIN SCORING BY HOLDING KE
Y DOWN FOR DURATION OF RESPONSE."
10024 PRINT:IF FG$="N" OR FG$="n" THEN PRINT TAB(5) "START CLOCK BY MAKING A BRI
EF KEYPRESS."
10030 PRINT:PRINT:PRINT TAB(20) "PRESS ANY KEY TO CONTINUE"
10040 IJ$=INKEY$
10050 IF IJ$="" THEN GOTO 10040
10060 GOTO 610
20000 CLS:PRINT:PRINT:PRINT:PRINT:PRINT TAB(10) "DO YOU WISH TO SAVE THE DATA ON
 DISK (Y or N)?"
20010 INPUT SAV$
20015 CUMTIM=CUMTM-(DUR+IR)
```

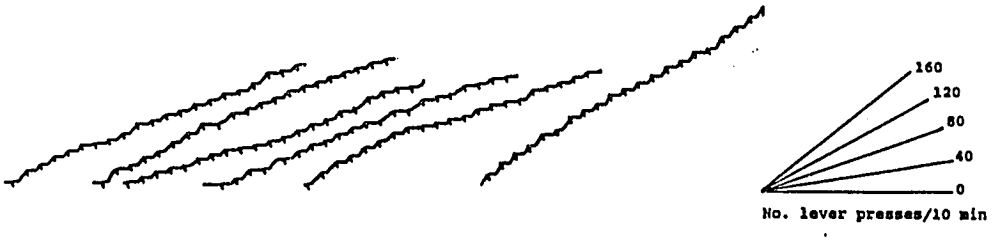
```
20020 IF SAV$<>"Y" AND SAV$<>"y" AND SAV$<>"N" AND SAV$<>"n" THEN GOTO 20000
20030 IF SAV$="N" OR SAV$="n" THEN GOTO 40000
20040 TIMER OFF
30000 R=1
30010 OPEN "R",#1,FLN$
30020 FOR XX=1 TO (EV-1)
30030 FIELD #1,8 AS U$,8 AS V$,6 AS IRI$,6 AS B$
30040 LSET U$=BEG$(XX)
30050 LSET V$=FIN$(XX)
30057 IF (FG$="Y" OR FG$="y") AND R=1 THEN LSET IRI$=STR$(0)
30058 IF (FG$="Y" OR FG$="y") AND R=1 THEN LSET B$=MKS$(DURN(XX))+MKS$(IRI(XX))
30059 IF (FG$="Y" OR FG$="y") AND R=1 THEN GOTO 30070
30065 LSET IRI$=MKS$(IRI(XX))
30067 LSET B$=MKS$(DURN(XX))
30070 PUT #1,R
30080 R=R+1
30090 NEXT XX
30100 CLOSE
40000 CLS:PRINT:PRINT:PRINT TAB(10) "DO YOU WISH TO PRINT OUT A HARDCOPY ?":INPU
T OO$
40010 IF OO$<>"Y" AND OO$<>"y" AND OO$<>"N" AND OO$<>"n" THEN GOTO 40000
40015 IF (SAV$="N" OR SAV$="n") AND (OO$="Y" OR OO$="y") THEN GOTO 60000
40020 IF OO$="N" OR OO$="n" THEN GOTO 50000
40050 R=1
40055 LPRINT TAB(5) FLN$
40060 LPRINT "_____
_____"
40070 LPRINT TAB(5) "EVENT #" TAB(15) "TIME BEGIN" TAB(30) "TIME END" TAB(48) "I
RI" TAB(59) "DURATION"
40080 LPRINT "_____
_____"
40090 OPEN "R",#1,FLN$
40100 R=1
40110 FOR X=0 TO 299
40120 FIELD #1,8 AS U$,8 AS V$,6 AS IRI$,6 AS B$
40130 GET #1,R
40140 IF VAL(LEFT$(V$,2))=0 AND VAL(MID$(V$,4,2))=0 AND VAL(RIGHT$(V$,2))=0 AND
VAL(B$)=0 THEN GOTO 40185
40150 LPRINT TAB(6) R TAB(15) U$ TAB(30) V$ TAB(46) USING "###.##          ";CVS(
IRI$),CVS(B$)
40160 INK$=INKEY$
40170 IF INK$<>"" THEN GOTO 40185
40180 R=R+1:NEXT X:CLOSE
40185 LPRINT TAB(46) USING "###.##";CEAS-CUMTIM:LPRINT
40187 VVV=CEAS-CUMTIM:CUM=CUMTIM+VVV:IF CUM<60 THEN LPRINT "SESSION LENGTH= ";CU
M;" SECONDS"
40188 IF CUM<60 THEN GOTO 50000
40189 FOR PPP=1 TO 60:MIN=MIN+1:CUM=CUM-60:IF CUM<60 THEN GOTO 40191
40190 NEXT PPP
40191 LPRINT TAB(30) MIN;" MINUTE(S) ";CUM;" SECOND(S)"
50000 CLS:PRINT:PRINT:PRINT TAB(10) "DO YOU WISH TO SCORE ANOTHER SESSION ?"
50010 INPUT AA$
50020 IF AA$<>"y" AND AA$<>"Y" AND AA$<>"n" AND AA$<>"N" THEN GOTO 50000
50030 IF AA$="Y" OR AA$="y" THEN GOTO 2
50040 END
60000 LPRINT TAB(5) FLN$
60010 LPRINT "_____
_____"
60020 LPRINT TAB(5) "EVENT #" TAB(15) "TIME BEGIN" TAB(30) "TIME END" TAB(48) "I
RI" TAB(59) "DURATION"
60030 LPRINT "_____
_____"
60040 FOR MM=1 TO (EV-1)
60050 LPRINT TAB(6) MM TAB(15) BEG$(MM) TAB(30) FIN$(MM) TAB(46) USING "###.##
      ";IRI(MM),DURN(MM)
60090 NEXT MM
60091 LPRINT TAB(46) USING "###.##";CEAS-CUMTIM:LPRINT
60092 VVV=CEAS-CUMTIM:CUM=CUMTIM+VVV:IF CUM<60 THEN LPRINT TAB(46) "SESSION LENG
TH=";CUM;" SECONDS"
60093 IF CUM<60 THEN GOTO 50000
60094 FOR PP=1 TO 10
60095 MIN=MIN+1
60096 CUM=CUM-60:IF CUM<60 THEN GOTO 60098
60097 NEXT PP
60098 LPRINT TAB(30) MIN;" MINUTE(S) ";CUM;" SECOND(S)"
60100 GOTO 50000
```

Appendix B

Cumulative records of leverpressing for water by the three monkeys in Experiment 2 during the last six sessions of each fixed interval (FIa and FIb) schedule of reinforcement. The first 20 minutes of the mirror condition is shown for each session.

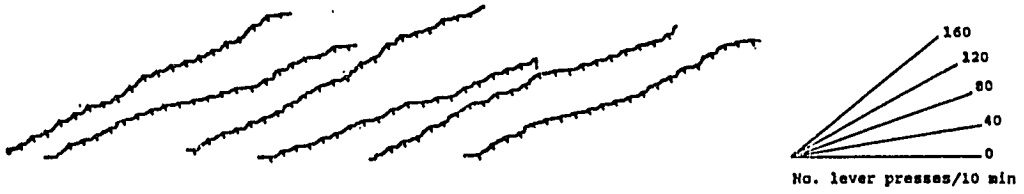


Roberta: Fixed Interval (a)
Sessions 78-83

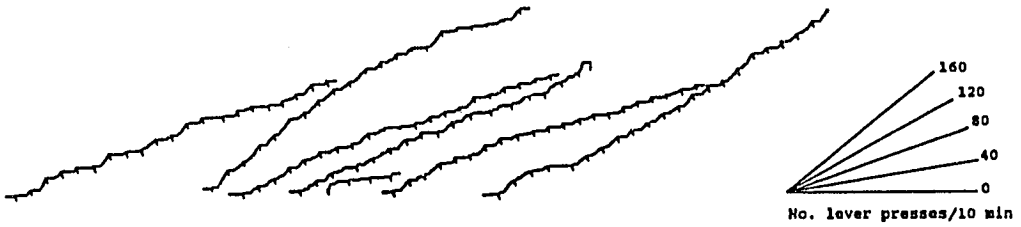


Roberta: Fixed Interval (b)
Sessions 89-94

Bibi: Fixed Interval (a)
Sessions 122-127



Bibi: Fixed Interval (b)
Sessions 97-102



Pavlova: Fixed Interval (a)
Sessions 112-117

Pavlova: Fixed Interval (b)
Sessions 127-132

Appendix C

Percentage of 5 s intervals with camera-defined "eye contact" for the middle three sessions in Baseline 1 and the Fixed Time schedule of reinforcement in Experiment 2. Sessions began and ended with 10 minutes of mirror presentation, with observations during the first 20 minutes of one hour of window presentation (MWWM). In Experiment 2, when water was available at scheduled intervals, camera-defined "eye contact" toward the mirror exceeded that directed toward the window regardless of sequence of presentation (see p. 118).

ROBERTA		WINDOW	MIRROR
BASELINE 1:	SESSIONS 15–17	2	3
FIXED TIME:	SESSIONS 56–58	21	39
BIBI			
BASELINE 1:	SESSIONS 15–17	4	2
FIXED TIME:	SESSIONS 62–64	52	85
PAVLOVA			
BASELINE 1:	SESSIONS 15–17	7	10
FIXED TIME:	SESSIONS 66–68	2	7

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AFTERWORD

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