

REPORT

Adoption and maltreatment of foster infants by rhesus macaque abusive mothers

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Abstract

*In this study we investigated whether infant characteristics play a causal role in the occurrence of maternal abuse of offspring in rhesus macaques (*Macaca mulatta*) and whether abusive mothers differ from controls in their tendency to adopt alien infants in a cross-fostering procedure. To this end, 13 infants born to mothers with a previous history of infant abuse were cross-fostered shortly after birth with infants born to nonabusive mothers and subsequently observed for 12 weeks. Abusive mothers were significantly more likely to reject foster infants than control mothers were. When adoption was successful, all of the abusive mothers maltreated their foster infants whereas none of the control mothers exhibited infant abuse. These findings suggest that infant characteristics do not play an important causal role in the occurrence of infant abuse and that abusive mothers may differ from nonabusive ones in maternal motivation or reactivity to stressful procedures.*

Infant abuse in group-living nonhuman primates (hereafter primates) shares several characteristics with human child abuse including its prevalence within populations, its transmission across generations, some psychological characteristics of abusive parents, and the role of environmental stress in triggering abuse (Maestriperi & Carroll, 1998a, 2000). Although some characteristics of individual parents (e.g. an early experience of abuse) and their environment (e.g. lack of social support) are well-established risk factors for abuse, the question of whether primate infants or human children make any significant contribution to the occurrence of abuse has not been unequivocally answered.

Some studies of primates reported that abused infants evidenced a delay in acquiring independence from their mothers compared to nonabused infants (Seay, Alexander & Harlow, 1964; Maestriperi, 1998; Maestriperi & Carroll, 1998b). This difference, however, probably reflected a consequence rather than a determinant of abuse. A recent study also reported that abused infants differed from nonabused ones in the acoustic structure of one of their distress vocalizations (Maestriperi, Jovanovic & Gouzoules, 2000). However, there was no

clear evidence that infant crying made a significant contribution to the occurrence of abuse. In humans, there is a relatively high incidence of abuse among premature infants or children with physical and mental handicaps, although there are some inconsistencies in the literature and in some cases the handicaps could be a consequence of abuse itself (Martin, Beezley, Conway & Kempe, 1974; Sandrond, Gaines & Green, 1974). In humans, abused infants or children are also often reported to have a difficult temperament or disruptive behavior (Trickett & Kuczynski, 1986; Greenwald, Bank, Reid & Knutson, 1997) although abusive parents may be negatively biased in the perception of their children's behavior (Reid, Kavanagh & Baldwin, 1987). Overall, in both primates and humans, the evidence that the characteristics of abused infants or children play an important causal role in the occurrence of abuse is still inconclusive.

The finding that monkey mothers abuse most, if not all, of their infants (Maestriperi & Carroll, 1998a) could suggest either that abusive behavior is a stable maternal trait that is expressed regardless of infant characteristics or that the infants born to abusive mothers share some

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genetically inherited characteristics (e.g. temperament; see Schneider, Moore, Suomi & Champoux, 1991) that increase the probability of abuse. One way of testing these two hypotheses is to cross-foster infants at birth between abusive and control mothers and assess which infants will be abused. If abusive mothers maltreat their foster infants as they maltreated their previous offspring while control mothers do not exhibit infant abuse, this will constitute evidence that infant genetic factors do not play an important causal role in the occurrence of abuse. Conversely, if abusive mothers do not maltreat their foster infants but control mothers exhibit infant abuse, this will constitute evidence that the genetic characteristics of infants born to abusive mothers contribute significantly to the occurrence of abuse. Infant cross-fostering experiments are feasible in monkeys but are obviously difficult or impossible in humans. Therefore, this is a clear case in which the use of a primate model of infant abuse can make an important contribution to human research (Maestriperieri & Carroll, 1998a; Maestriperieri, 1999a).

Cross-fostering experiments in which two infants are swapped shortly after birth have been conducted in many primate research and breeding facilities for scientific or management purposes (Deets & Harlow, 1974; Cho, Suzuki & Honjo 1986; Smith, 1986; Holman & Goy, 1988; Owren & Dieter, 1989). A previous cross-fostering study conducted with a large number of subjects reported an adoption success rate of about 70% (Smith, 1986). Adoption attempts can fail for several reasons including, for example, the difference in age between biological and foster infant or the duration of the separation between mother and infant (infant sex does not appear to be important). The outcome of many adoption attempts, however, is not predicted by any of these methodological variables (Cho *et al.*, 1986; Smith 1986), suggesting that perhaps there are broad individual differences in maternal motivation or sensitivity to stressful perturbations, which affect the propensity to adopt infants.

In the present study, we cross-fostered rhesus macaque newborns between mothers with a previous history of abusive behavior and control mothers. In doing so, we had two specific goals: to investigate possible differences between abusive and control mothers in their propensity to adopt infants, and to investigate possible differences between them in their tendency to exhibit abusive behavior when the adoption was successful. The broad goals of this study were to assess the causal role of infant genetic characteristics in the occurrence of abuse and to investigate possible differences in maternal motivation or sensitivity to stressful perturbations between abusive and control mothers.

Method

Subjects

Subjects of this study were adult female rhesus macaques (*Macaca mulatta*) living in five different social groups at the Field Station of the Yerkes Regional Primate Research Center in Lawrenceville, GA (USA). The groups were housed in 38 m × 38 m outdoor compounds with attached indoor areas and consisted of two to five adult males and 30–35 adult females with their immature offspring. All groups had a linear dominance hierarchy and adult females were classified as high ranking, middle ranking, or low ranking if they fell into the upper, middle, or lower third of the hierarchy. Dominance rank was known for all but one of the adult subjects.

Thirteen adult females had a prior history of maternal abusive behavior, having physically abused most if not all of their previous offspring. They were observed in previous years and their abusive behavior was documented (Maestriperieri, 1998; Maestriperieri, Tomaszycki & Carroll, 1999). With some exceptions, the frequency and severity of abuse displayed by individual mothers tended to be consistent over the years and with different offspring (Maestriperieri *et al.*, 1999). Only mothers whose frequency and severity of abuse did not jeopardize their infant's life were used for this study. Table 1 presents information on abusive mothers, including their age, dominance rank, number of previous offspring surviving to 1 year of age, sex of the current offspring, and age of the current offspring at the time of the cross-fostering.

Four months prior to the onset of this study, the abusive mothers were subjected to an ultrasound test to verify pregnancy and estimate their date of parturition considering a gestation length of 165 days (Ardito, 1976). The rhesus macaques at the Yerkes Field Station mate during the Fall and Winter and give birth in the Spring and early Summer. Beginning in March, all groups were monitored on a daily basis for births. Control mothers were selected opportunistically among females who gave birth to a female infant within a few hours or days of the abusive mothers. Although the sex of the control infant was not directly relevant to the present study, the subjects were also part of another study in which offspring sex was an important factor. Control individuals were selected among multiparous mothers with no previous record of abusive behavior. In four cases, however, primiparous mothers were used because of lack of alternatives. In these cases, we insured that no instance of infant abuse had previously been reported in the subject's matriline or observed in the

Table 1 Sociodemographic information on the individuals involved in the cross-fostering procedures, the duration of mother–infant separation prior to the adoption attempt, and whether or not the adoption was successful

Mother ID	Experimental group	Mother age (years)	Rank	No. of prior offspring	Infant age		Infant sex		Separation time (min)	Successful adoption
					BI*	FI*	BI*	FI*		
RAj3	Abusive	8	High	3	1	1	M	F	1	Yes
RDh1	Abusive	14	High	7	1	2	F	F	5	No
REa4	Abusive	7	Low	3	1	1	F	F	1	Yes
RFy1	Abusive	12	Middle	4	1	3	M	F	1	Yes*
RNe4	Abusive	6	Middle	2	1	4	M	F	1	Yes
RNj1	Abusive	13	Middle	7	1	2	F	F	1	Yes
ROi3	Abusive	8	Middle	2	1	4	F	F	45	No
ROo4	Abusive	6	High	1	6	7	F	F	10	No
RRf2	Abusive	11	Low	5	3	2	F	F	1	Yes
RTp3	Abusive	7	High	3	1	3	M	F	1	No*
RYd1	Abusive	15	Middle	8	1	2	M	F	15	Yes
RZm2	Abusive	9	Low	3	1	2	M	F	1	Yes
RZq3	Abusive	7	High	3	1	1	F	F	1	No
N879	Control	15	Unknown	8	2	1	F	M	1	Yes
REb5	Control	5	Middle	0	4	1	F	F	10	Yes
REj5	Control	4	Middle	0	3	1	F	M	60	Yes
RGu4	Control	5	Low	0	2	1	F	M	25	Yes
RIk3	Control	8	Low	2	1	1	F	F	15	Yes
RKj3	Control	8	High	3	4	1	F	M	15	Yes
RNo4	Control	6	High	0	7	6	F	F	1	Yes
RRk2	Control	9	Low	2	2	1	F	F	15	Yes
RUz3	Control	7	Middle	1	1	1	F	F	20	Yes
RVj3	Control	8	Middle	2	2	1	F	F	60	Yes
RWc3	Control	9	Low	3	2	3	F	F	30	Yes
RZm3	Control	8	High	4	1	1	F	M	1	Yes

BI biological infant FI foster infant

*After anesthesia

time interval between the subject's parturition and the cross-fostering procedure. Table 1 presents information on control mothers.

Cross-fostering procedure

The day of the cross-fostering experiment, the control mother and her newborn were captured and housed inside in a standard squeeze cage (in three cases, the abusive mother and her newborn were captured first). The infant was gently removed from its mother, wrapped in a towel, and taken to the compound with the abusive mother. The control mother was left alone in the cage and the time of separation from her infant was recorded. While one experimenter held the infant, two other experimenters captured the abusive mother and her newborn and housed them in a squeeze cage. The infant was removed from its mother and the foster infant was immediately placed in the cage. The infant born to the abusive mother was wrapped in a towel and subsequently placed in the control mother's cage.

If the mother, control or abusive, picked up the foster infant immediately and held it on her chest, she was transferred via a transfer box into an indoor housing area. The mother and the foster infant were observed for

a minimum of 10 min to a maximum of 4 h. If the mother continuously held the infant on her chest and showed no instance of rejection, the adoption was considered successful and both mother and infant were released into the group after 10 min. If the mother, control or abusive, rejected the foster infant in the squeeze cage, she was administered a low dose of Ketamine (5 mg/kg, injected intramuscularly) and the infant was placed on her chest while she was under anesthesia. Rejection consisted of indifference, avoidance, forcible removal of the infant from her chest and, on rare occasions, biting. If the mother rejected the foster infant again after she recovered from the anesthesia, the adoption was considered unsuccessful. The mother was released into her group without the infant, and the rejected infant was fostered onto another female or hand-reared in the nursery.

Data collection and analysis

The abusive and control mothers and their foster infants were focally observed in weekly 60 min observation sessions until the end of the twelfth week of lactation. Observation sessions were randomly distributed between 0800 and 1900 h. Data were collected by three observers

using a portable computer. The three observers were tested for reliability prior to the beginning of data collection. Inter-observer reliability was considered to have been achieved when percentage agreement in recording behavior exceeded 90% and Cohen's kappa (Cohen, 1960) exceeded 0.8.

The occurrence of any of the following maternal behavior patterns was considered as evidence of infant abuse: (1) dragging: the mother drags her infant by its tail or leg while walking or running; (2) crushing: the mother pushes her infant against the ground with both hands; (3) throwing: the mother throws her infant a short distance with one hand while standing or walking; (4) hitting: the mother violently slaps her infant with one hand or arm; (5) biting; (6) stepping or sitting on: the mother steps on her infant with one foot or both feet, or sits on her infant; (7) dangling/dropping: the mother climbs a tree or fence and holds her infant by its tail or leg or drops her infant on the ground; (8) rough grooming: the mother pulls her infant's hair or otherwise roughly grooms it causing distress calls; (9) stretching: the mother holds her infant by its arms and/or legs and stretches it; (10) somersaulting: the mother runs and somersaults with her infant clinging to her chest. One control mother (N879) and her infant were not formally observed and their behavior recorded. However, her behavior and the health status of her infant were monitored by the animal caretaking and veterinary staff as part of their daily routine procedures.

Data were analyzed with Fisher's exact probability test, Student's *t* tests and Pearson's correlation tests. All tests were two-tailed and probabilities of 0.05 or less were considered statistically significant.

Results

Twenty-six cross-fostering procedures were performed, involving 13 abusive mothers and 13 control mothers with their respective infants. Eight abusive mothers successfully adopted infants and five rejected them, whereas all of the 12 control mothers (one control was excluded from the analysis; see below) successfully adopted infants; Fisher's exact probability test, $p = 0.02$. Among control mothers, adoption of foster infants occurred immediately and without anesthesia. Anesthesia was necessary in two adoption attempts involving abusive mothers, one of which eventually succeeded and the other failed (see Table 1).

In all but two cases, cross-fostering procedures were conducted using infants born in different groups. In one case in which the abusive and the control mother lived in the same group, infants were initially adopted by their

foster mothers but the following day each mother was observed to be back with her own biological infant. The control mother was allowed to keep her offspring but was excluded from data analysis. The abusive mother (RTp3) was offered another infant for adoption on the same day but the adoption attempt failed even after the use of anesthesia. This subject was included in data analysis and classified as a case of unsuccessful adoption. The other cross-fostering procedure involving two infants born in the same group was successful and both infants were adopted by their foster mothers.

Table 1 shows information on several aspects of the cross-fostering procedures including the individuals involved, the duration of separation between mother and infant prior to the adoption attempt, and the outcome of the adoption attempt. Abusive and control mothers did not differ significantly in their age (although controls were generally younger than subjects), dominance rank (one control was excluded from this analysis because her rank was uncertain), age of their biological infant, age of their foster infant, or whether the sex of the two infants was the same or different. Abusive mothers had a higher number of previous offspring, $t = 2.05$, degrees of freedom (df) = 23, $p = 0.05$, and a shorter separation time than control mothers, $t = -2.19$, $df = 23$, $p < 0.05$.

The five abusive mothers who rejected the foster infants did not differ significantly from the eight abusive mothers who adopted them in any of the characteristics presented in Table 1, except dominance rank. The

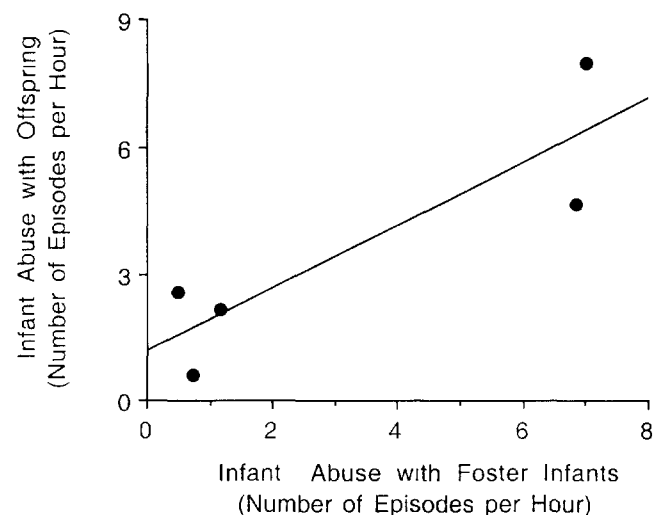


Figure 1 Mean number of infant abuse episodes per hour per individual displayed by five abusive mothers with their foster infants (current study) and their biological offspring (previous year). Means are calculated over the first 12 weeks of lactation (12 h of observation).

mothers who rejected were mostly high ranking individuals whereas those who adopted were mostly middle and low ranking individuals; Fisher's test, $p < 0.05$.

All of the eight abusive mothers who successfully adopted their foster infants exhibited infant abuse whereas none of 12 control mothers did; Fisher's test, $p < 0.001$. The abusive mothers initiated infant abuse within the first week of infant life and continued to exhibit the behavior in the following weeks, with a temporal course similar to that observed in previous years. For five abusive mothers, the frequencies of abuse of foster infants could be compared with the frequencies with which these mothers abused their own offspring in the previous year. The frequency of abuse of foster infants was not significantly different from the frequency of abuse of biological offspring. Moreover, the individual frequencies of abuse with foster infants and biological offspring were significantly correlated ($r = 0.88$, $p = 0.05$; Figure 1).

Discussion

Rhesus macaque mothers with a history of abusive behavior were less likely than control mothers to adopt foster infants shortly after parturition but, when adoption was successful, they abused them as they had done with their previous offspring. In contrast, no control mothers exhibited abuse of their foster infants. These findings support the hypothesis that infant genetic factors do not play an important causal role in the occurrence of abuse. Rather, abusive behavior appears to be a stable maternal characteristic that is likely to be displayed with young infants, irrespective of whether they are the mother's own offspring or foster infants. Interestingly, a recent study demonstrated that infant abuse in rhesus macaques does not reflect a tendency to interact negatively with infants in general (Maestripieri, 1999b). For example, abusive mothers did not interact negatively with other females' infants more than did control mothers. Thus, abusive behavior is a trait that is expressed only in the maternal role and is probably intimately associated with the controlling parenting style displayed by most abusive mothers (Maestripieri, 1998).

The abusive mothers' tendency to reject foster infants is unlikely to reflect a general tendency to neglect or abandon infants because the subjects of this study were not known to neglect or abandon any of their previous offspring. It is also unlikely that abusive mothers somehow discriminated their own offspring from the foster infants better than did control mothers. Most studies of offspring discrimination in macaques have suggested that mothers are able to recognize their

infants visually, vocally, and probably also olfactorily, within the first few days after parturition (Jensen, 1965; Negayama & Honjo, 1986; Hammerschmidt & Fischer, 1998; but see Simons & Bielert, 1973). If anything the adoption attempts in this study took place slightly earlier after parturition for abusive than for control mothers and therefore offspring recognition should have been more difficult for the former than for the latter.

The abusive mothers differed significantly from control mothers in their number of previous offspring and in their separation time during the cross-fostering procedure. The abusive mothers, on average, had a higher number of previous offspring surviving to at least 1 year of age, mostly because some primiparous mothers had to be used as controls for lack of alternatives. Abusive mothers were separated from their infants for a shorter period of time than controls prior to the adoption attempt because in most cases controls were captured and separated from their infants first. Greater previous maternal experience and shorter separation time during infant cross-fostering are usually associated with higher probability of successful adoption (e.g. Smith, 1986; Holman & Goy, 1988; Owren & Dieter, 1989). Therefore, it is noteworthy that abusive mothers were less likely to adopt foster infants than controls despite the fact that controls were in less optimal conditions for adoption.

Two plausible explanations for the abusive mothers' lower propensity to adopt foster infants are (1) that these mothers are generally less responsive to infants in the immediate postpartum period and less willing to accept them than control mothers, or (2) that abusive mothers find the cross-fostering procedure more stressful than control mothers and higher stress leads to a higher probability of infant rejection. Given the lack of information about maternal motivation or reactivity to stress in the immediate postpartum period, the discussion of these two explanations is necessarily speculative.

The willingness shown by most macaque females to adopt foster infants in the immediate postpartum period may be due more to the fact that this is a period characterized by high maternal motivation than to the fact that mothers do not yet recognize their offspring. In fact, macaque mothers sometimes adopt additional infants that have been abandoned by their own mothers and raise both infants as if they were twins (Ellesworth & Andersen, 1997). Heightened maternal motivation after parturition may be dependent on the neuroendocrine changes accompanying late pregnancy, parturition and lactation (Maestripieri, 1999a). For example, there is evidence in macaques that the high levels of circulating estradiol prior to parturition are responsible for the

increased maternal responsiveness observed in this period (Maestriperi & Zehr, 1998). Moreover, Pryce, Abbott, Hodges and Martin (1988) reported that, in red-bellied tamarins (*Saguinus labiatus*), mothers with more intense levels of postpartum care and whose infants survived had higher urinary concentrations of estradiol in the last week of pregnancy than mothers whose infants did not survive. Thus, it is possible that the lower propensity to adopt foster infants shown by abusive mothers could be due to their lower maternal motivation, in turn associated with neuroendocrine differences between these individuals and control mothers.

The alternative hypothesis is that the difference between abusive and control mothers in their propensity to adopt foster infants is due not to maternal motivation but to reactivity to stress. Although we used a cross-fostering procedure aimed at minimizing the stress for the individuals involved and in particular for the abusive mothers, any procedure involving capture, separation from the infant, and exposure to an alien infant in a small cage is bound to entail some stress. Stress is known to disrupt mother–infant interactions and is likely to interfere with adoption. For example, under conditions of high stress, some macaque mothers reject or attack their own infants (Maestriperi, 1994). Most macaque abusive mothers have a behavioral profile suggestive of an anxious and impulsive temperament (Troisi & D'Amato, 1984, 1991; Maestriperi, 1998; Maestriperi & Carroll, 1998b). Thus, it is plausible to hypothesize that abusive mothers experience the cross-fostering procedure as more stressful than control mothers and that this difference affects the outcome of the adoption attempt. In this regard, it may be worth pointing out that the abusive mothers who failed to adopt an infant were higher ranking than those who were successful and that recent studies of female baboons have suggested that high ranking individuals exhibit more physiological and reproductive signs of stress than low ranking ones (Packer, Collins, Sindimwo & Goodall, 1995; Wasser, 1995).

In summary, this study provided evidence that infant genetic characteristics do not play a primary causal role in the occurrence of infant abuse and suggested that abusive mothers may differ from controls in their maternal motivation or reactivity to stress in the immediate postpartum period. It cannot be ruled out, however, that some aspects of infant behavior at a later age may inadvertently contribute to the severity of abuse. For example, it is possible that although maternal abusive behavior is a stable individual trait, some infants may be abused more or less severely than others depending on their physical or behavioral characteristics.

In humans, there is no clear evidence that infant characteristics other than prematurity or physical/mental handicaps play a causal role in the occurrence of abuse (e.g. Belsky, 1993). Thus, when taken together, the findings of primate and human research suggest that characteristics of the parent and those of the environment are more likely to play an important causal role in the occurrence of maltreatment than the child's characteristics. Future studies should further investigate the biological and behavioral characteristics of abusive parents and attempt to ascertain whether their behavior is the result of a specific dysfunction of the parental motivation system or a more general dysfunction of the mechanisms and processes underlying emotion regulation and reactivity to stress.

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References

- Ardito, G. (1976). Check-list of the data on the gestation length of primates. *Journal of Human Evolution*, **5**, 213–222.
- Belsky, J. (1993). Etiology of child maltreatment: a developmental–ecological analysis. *Psychological Bulletin*, **114**, 413–434.
- Cho, F., Suzuki, M., & Honjo, S. (1986). Adoption success under single-cage conditions by cynomolgus macaque mothers (*Macaca fascicularis*). *American Journal of Primatology*, **10**, 119–124.
- Cohen, J.A. (1960). A coefficient of agreement for ordinal scales. *Education and Psychological Measurement*, **23**, 361–367.
- Deets, A.C., & Harlow, H.F. (1974). Adoption of single and multiple infants by rhesus monkey mothers. *Primates*, **15**, 193–203.
- Ellesworth, J.A., & Andersen, C. (1997). Adoption by captive parturient rhesus macaques: biological vs. adopted infants and the cost of being a 'twin' and rearing 'twins'. *American Journal of Primatology*, **43**, 259–264.
- Greenwald, R.L., Bank, L., Reid, J.B., & Knutson, J.F. (1997). A discipline-mediated model of excessively punitive parenting. *Aggressive Behavior*, **23**, 259–280.

- Hammerschmidt, K., & Fischer, J. (1998). Maternal discrimination of offspring vocalizations in Barbary macaques (*Macaca sylvanus*). *Primates*, **39**, 231–236.
- Holman, S.D., & Goy, R.W. (1988). Responses of foster-mothers and troop members to adopted newborns in a captive group of rhesus monkeys. *Primates*, **29**, 343–352.
- Jensen, G.D. (1965). Mother–infant relationship in the monkey *Macaca nemestrina*: development of specificity of maternal response to own infant. *Journal of Comparative and Physiological Psychology*, **59**, 305–308.
- Maestripietri, D. (1994). Infant abuse associated with psychosocial stress in a group-living pigtail macaque (*Macaca nemestrina*) mother. *American Journal of Primatology*, **32**, 41–49.
- Maestripietri, D. (1998). Parenting styles of abusive mothers in group-living rhesus macaques. *Animal Behaviour*, **55**, 1–11.
- Maestripietri, D. (1999a). The biology of human parenting: insights from nonhuman primates. *Neuroscience and Biobehavioral Reviews*, **23**, 411–422.
- Maestripietri, D. (1999b). Fatal attraction: interest in infants and infant abuse in rhesus macaques. *American Journal of Physical Anthropology*, **110**, 17–25.
- Maestripietri, D., & Carroll, K.A. (1998a). Child abuse and neglect: usefulness of the animal data. *Psychological Bulletin*, **123**, 211–223.
- Maestripietri, D., & Carroll, K.A. (1998b). Behavioral and environmental correlates of infant abuse in group-living pigtail macaques. *Infant Behavior and Development*, **21**, 603–612.
- Maestripietri, D., & Carroll, K.A. (2000). Causes and consequences of infant abuse and neglect in monkeys. *Aggression and Violent Behavior*, **5**, 245–254.
- Maestripietri, D., & Zehr, J.L. (1998). Maternal responsiveness increases during pregnancy and after estrogen treatment in macaques. *Hormones and Behavior*, **34**, 223–230.
- Maestripietri, D., Jovanovic, T., & Gouzoules, H. (2000). Crying and infant abuse in rhesus monkeys. *Child Development*, **71**, 301–309.
- Maestripietri, D., Tomaszycski, M., & Carroll, K.A. (1999). Consistency and change in the behavior of rhesus macaque abusive mothers with successive infants. *Developmental Psychobiology*, **34**, 29–35.
- Martin, H.P., Beezley, P., Conway, E.F., & Kempe, C.H. (1974). The development of abused children. *Advances in Pediatrics*, **21**, 25–73.
- Negayama, K., & Honjo, S. (1986). An experimental study on developmental changes of maternal discrimination of infants in crab-eating monkeys (*Macaca fascicularis*). *Developmental Psychobiology*, **19**, 49–56.
- Owren, M.J., & Dieter, J.A. (1989). Infant cross-fostering between Japanese (*Macaca fuscata*) and rhesus macaques (*M. mulatta*). *American Journal of Primatology*, **18**, 245–250.
- Packer, C., Collins, D.A., Sindimwo, A., & Goodall, J. (1995). Reproductive constraints on aggressive competition in female baboons. *Nature*, **373**, 60–63.
- Pryce, C.R., Abbott, D.H., Hodges, J.H., & Martin, R.D. (1988). Maternal behavior is related to prepartum urinary estradiol levels in red-bellied tamarin monkeys. *Physiology and Behavior*, **44**, 717–726.
- Reid, J.B., Kavanagh, K., & Baldwin, D.V. (1987). Abusive parents' perceptions of child problem behaviors: an example of parental bias. *Journal of Abnormal Child Psychology*, **15**, 457–466.
- Sandrund, A., Gaines, R., & Green, A. (1974). Child abuse and mental retardation: a problem of cause and effect. *American Journal of Mental Retardation*, **79**, 327–330.
- Schneider, M.L., Moore, C.F., Suomi, S.J., & Champoux, M. (1991). Laboratory assessment of temperament and environmental enrichment in rhesus monkey infants (*Macaca mulatta*). *American Journal of Primatology*, **25**, 137–155.
- Seay, B., Alexander, B.K., & Harlow, H.F. (1964). Maternal behavior of socially deprived rhesus monkeys. *Journal of Abnormal Social Psychology*, **69**, 345–354.
- Simons, R.C., & Bielert, C.F. (1973). An experimental study of vocal communication between mother and infant monkeys (*Macaca nemestrina*). *American Journal of Physical Anthropology*, **38**, 455–461.
- Smith, S. (1986). Infant cross-fostering in rhesus monkeys (*Macaca mulatta*): a procedure for the long-term management of captive populations. *American Journal of Primatology*, **11**, 229–237.
- Trickett, D.K., & Kuczynski, L. (1986). Children's misbehavior and parental discipline strategies in abusive and nonabusive families. *Developmental Psychology*, **22**, 115–123.
- Troisi, A., & D'Amato, F.R. (1984). Ambivalence in monkey mothering: infant abuse combined with maternal possessiveness. *Journal of Nervous and Mental Disease*, **172**, 105–108.
- Troisi, A., & D'Amato, F.R. (1991). Anxiety in the pathogenesis of primate infant abuse: a pharmacological study. *Psychopharmacology*, **103**, 571–572.
- Wasser, S.K. (1995). Costs of conception in baboons. *Nature*, **376**, 219–220.

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