

**K. McCormack**

Department of Psychology  
Spelman College, Atlanta, GA  
E-mail: kmccormack@spelman.edu

Yerkes National Primate Research Center  
Emory University, Atlanta, GA  
Center for Behavioral Neuroscience  
Emory University Atlanta, GA

**M.M. Sanchez**

Department of Psychiatry  
& Behavioral Sciences  
Emory University Atlanta, GA

Yerkes National Primate Research Center  
Emory University Atlanta, GA

Center for Behavioral Neuroscience  
Emory University Atlanta, GA

**M. Bardi**

Department of Psychology  
University of Richmond  
Richmond, VA

**D. Maestriperi**

Department of Comparative  
Human Development  
The University of Chicago, Chicago, IL  
Yerkes National Primate Research Center  
Emory University Atlanta, GA

---

# Maternal Care Patterns and Behavioral Development of Rhesus Macaque Abused Infants in the First 6 Months of Life

**ABSTRACT:** We investigated the maternal care patterns of rhesus macaque mothers who physically abuse their infants, and compared their infants' behavior to that of nonabused infants. Parametric and multidimensional scaling analyses indicated that abusive mothers have a distinct parenting style characterized by high rates of rejection and contact-breaking from their infants. Compared to control infants, abused infants exhibited signs of delayed independence from their mothers including higher rates of distress calls and anxiety, lower rates of contact-breaking, and differences in play. Several aspects of the abused infants' behavior were correlated with rates of abuse received during the first month, or with other maternal behaviors. These findings provide a more comprehensive characterization of the parenting styles of abusive mothers and the early behavioral development of their infants than previously available. Detailed knowledge of the early experience of abused infants is crucial for understanding possible pathological alterations in behavior and neuroendocrine function later in life. © 2006 Wiley Periodicals, Inc. *Dev Psychobiol* 48: 537–550, 2006.

**Keywords:** Rhesus monkey; *Macaca mulatta*; maltreatment; abuse; maternal behavior; infant behavioral development; multidimensional scaling; stress; infant outcomes

---

## INTRODUCTION

Child maltreatment is a complex phenomenon with different manifestations (e.g., physical, sexual, or emotional abuse, neglect), many possible causes, and a host of negative consequences for development. Maltreated children evidence impairments in social competence, attachment security, and emotional regulation and cognition later in life (Alessandri, 1991; Hart, Gunnar, & Cicchetti, 1995; Haskett & Kistner, 1991; Jacobson & Straker, 1982). Early child abuse also increases the risk of developing mood and anxiety disorders as well as many

behavioral pathologies in adulthood (Bremner, Southwick, Johnson, Yehuda, & Charney, 1993; Mullen, Martin, Anderson, Romans, & Herbison, 1996; Stein et al., 1996). Recent studies have shown that some of these developmental effects of child maltreatment are associated with long-term alterations in neurobiological mechanisms controlling emotion regulation and reactivity to stress as well as structural modifications of specific areas of the brain (e.g., Glaser, 2000; Teicher et al., 2003).

The investigation of the developmental consequences of early child maltreatment is an area of research in which work with animal models could make an important contribution. This is because animal studies allow for prospective longitudinal studies in which many variables can be controlled or experimentally manipulated in ways that would be difficult with humans. Child maltreatment is not unique to humans but has been observed in some species of nonhuman primates as well (Maestriperi & Carroll, 1998a). Infant abuse by socially deprived rhesus macaque (*Macaca mulatta*) mothers was first documented

---

Received 16 September 2005; Accepted 7 February 2006

Correspondence to: K. McCormack

Contract grant sponsor: NIH

Contract grant numbers: MH62577, MH63097, MH65046

Published online in Wiley InterScience

(www.interscience.wiley.com). DOI 10.1002/dev.20157

© 2006 Wiley Periodicals, Inc.

in the laboratory by Harlow and his collaborators (Ruppenthal, Arling, Harlow, Sackett, & Suomi, 1976). More recent research has shown that in large populations of rhesus and pigtail macaques (*Macaca nemestrina*) living in captive social groups, 5–10% of all infants born every year are physically abused by their mothers (Maestripieri & Carroll, 1998b; Maestripieri, Wallen, & Carroll, 1997a). Physical abuse includes the mother hitting, biting, dragging, crushing, stretching, and sitting on the infant (Maestripieri, 1998; Troisi & D'Amato, 1984). These behaviors cause infant distress and in some cases, serious injury and death. Most patterns of infant abuse are qualitatively distinct from any other behaviors in the maternal repertoire and are never exhibited by most individuals within a population. Therefore, abusive mothers and their behavior are readily identifiable. Infant abuse has also been observed in free-ranging rhesus macaques (D.M., personal observation) and in primates other than macaques (Maestripieri, Wallen, & Carroll, 1997b). Therefore, infant abuse is not a by-product of a particular captive environment or specific to macaque monkeys.

In rhesus macaques, maternal abuse typically occurs during the first few months of infant life and is consistent across successive infants (Maestripieri & Carroll, 1998b; Maestripieri, Tomaszycycki, & Carroll, 1999). Infant abuse is more prevalent in certain matrilineal lines and among related individuals such as mothers and daughters, or sisters (Maestripieri & Carroll, 1998a,b). A recent study in which rhesus macaque female infants were cross-fostered at birth between abusive and nonabusive mothers and followed longitudinally until they gave birth showed that abusive parenting is transmitted across generations, from mothers to daughters, and that this transmission is primarily the result of early experience and not genetic inheritance (Maestripieri, 2005). The extent to which the effects of early experience on the intergenerational transmission of abusive parenting are mediated by social learning or experience-induced physiological alterations remains to be established. Therefore, more research is needed to characterize in detail the early experience of abused monkey infants and describe their behavioral and neuroendocrine development.

This study is part of a larger longitudinal project investigating the behavioral and neuroendocrine development of rhesus macaque abused infants from birth to adulthood. The general working hypothesis of this project is that early abuse may result in long-term alterations in social behavior, emotion regulation, and responsiveness to stress, which may result in later psychopathologies including the occurrence of abusive parenting. In this particular study, we report observations of infant abuse, maternal behavior, and infant development in the first 6 months of life. The

specific aims of this study were to describe the occurrence and time course of infant abuse in this period of time, investigate other aspects of the behavior of abusive mothers relative to nonabusive controls, and compare the early behavioral development of abused and nonabused infants.

Previous studies of infant abuse in rhesus macaques reported observations of maternal behavior and infant development only during the first 3 months of infant life (Maestripieri, 1998; Maestripieri & Carroll, 1998c). Important changes in the mother–infant relationship and other social interactions, however, take place at later ages and these changes can have long-lasting consequences for development (Hinde & Spencer-Booth, 1967). Previous studies reported evidence that macaque abusive mothers have more “controlling” and “rejecting” parenting styles than controls, and exhibit higher scores of anxiety than nonabusive mothers (Maestripieri, 1998; Maestripieri & Carroll, 1998c; Troisi & D'Amato, 1991, 1994). The same studies have reported higher crying levels and lower rates of social play in abused infants (e.g., Maestripieri & Carroll, 1998c; see also Maestripieri, Jovanovic, & Gouzoules, 2000). Aside from these data, however, little is known about the behavioral development of abused infants beyond their first few months of life.

In this study, we replicated and extended the earlier investigations of mother–infant interactions and infant abuse in rhesus macaques by following the behavioral development of abused infants through the end of their 6th month of life. In addition, we aimed to provide a more comprehensive and detailed analysis of the parenting behavior of abusive mothers and the relationships with their infants by using multidimensional scaling (MDS), a statistical technique that has previously been very useful in the analysis of parenting styles and social relationships in monkeys (Bardi, Bode, Ramirez, & Brent, 2005; Nakamichi & Kato, 2001). Interindividual variability in rhesus macaque maternal behavior is most apparent in the first 2–3 postpartum months (Hinde & Spencer-Booth, 1967). Therefore, it is possible that the behavioral differences between abusive and nonabusive in the second trimester of infant life may be less marked than those previously reported in the first trimester. In contrast, we predicted that, in the second trimester of life, abused infants might evidence a greater delay in the acquisition of their independence than that shown in the first 3 months (e.g., Maestripieri, 1998). By focusing on aspects of maternal behavior that co-occur with physical abuse and their possible correlates with infant behavior in the first 6 months of life, this study can enhance our understanding of the relative contribution of physical abuse versus other aspects of maternal care in the development of abused infants.

## METHODS

### Subjects and Housing

This study was conducted at the Field Station of the Yerkes National Primate Research Center in Lawrenceville, GA. The subjects of this study were rhesus macaque mothers and infants living in four large social groups. Each group consisted of two or three adult males and 18–49 adult females with their sub-adult and juvenile offspring. The groups were housed in 38 × 38 m outdoor compounds with indoor housing areas. Animals were fed in the morning and evening, and water was freely available. The studies described in this section were performed in accordance with the NIH Guide for the Care and Use of Laboratory Animals and approved by the Emory University Institutional Animal Care and Use Committee. Ten multiparous adult females with a previous history of abusive parenting (see below for definitions) and their newborn infants (6 female, 4 male) served as study subjects while 10 nonabusive mothers and their infants served as controls. Controls were matched to subjects by infant sex (6 female, 4 male), infant age, and whenever possible, also group of origin and the mother's dominance rank so that the two groups did not differ significantly in any of these variables.

### Behavioral Data Collection

Behavioral observations were made from an observation tower situated at the corner of each compound. Behavioral data were collected using binoculars and a handheld computer (Palm Pilot IIIXE) programmed to allow the recording of the frequency, duration, and sequence of behavior. Three experienced observers collected the data. For reliability purposes, prior to the beginning of data collection, observers watched and recorded behavior until percent agreement exceeded 90% and Cohen's Kappa exceeded 0.8.

Focal observations began on the second day of infant life. Each mother–infant pair was observed for a 30-minute period, five times per week during the first month of life, two times per week during the second month of life, and one time per week from the third month through the sixth month of life. This observation schedule was chosen in order to best document the occurrence of infant abuse, as the frequency of abuse is highest in the first month and decreases steadily thereafter (Maestripieri, 1998). Observations were done between 7 and 11:00 AM, when the animals were most active. All animals were locked outdoors during observation sessions. Data collection included infant abuse and other interactions between mothers and infants as well as between infants and other individuals.

**Infant Abuse.** The following maternal behavior patterns were included in the infant abuse category (see also Maestripieri, 1998; Troisi & D'Amato, 1983): (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 at a short distance with one hand while standing or walking; (4) stepping or sitting on: the mother steps on her infant with one foot or both feet, or sits on her infant; (5) rough grooming: the mother forces her infant onto

the ground, and pulls out the infant's hair with force causing distress calls; (6) abusive carrying: the mother carries the infant with one arm away from her body, preventing the infant from clinging. Infant abuse was scored independently of all the other mother–infant interactions (e.g., rejection). Abuse events did not last more than a few seconds and therefore only their frequency was recorded. Infant abuse was recorded as two separate events if there was a transition in the pattern of behavior (e.g., from dragging to throwing) or if there was a pause of at least 10 seconds during the behavior.

**Mother–infant Interactions.** The following measures were used: (1) percentage of time spent in ventro-ventral contact and other bodily contact; (2) percentage of time spent in proximity (within arm's reach); (3) percentage of time the mother spent cradling the infant (one or both arms around the infant); (4) percentage of time the mother spent grooming the infant; (5) frequency of contacts made and broken by mothers and infants; (6) frequency of maternal restraining (the mother prevents infant from breaking contact by pulling its leg or tail); (7) frequency of maternal rejection (the mother prevents contact or infant access to nipple by holding the infant at a distance with an arm, passively blocking the chest with an arm, or twisting torso away).

**Infant–other Interactions.** The following measures were used: (1) frequency and duration of contact initiated and received by the infant, (2) frequency of agonistic interactions (threats or contact aggression) with others, (3) duration of infant kidnaps (the infant is forcibly prevented from returning to its mother) by others, and (4) duration of social play. Displacement activities (scratching, body shaking, and yawning) were used as markers of anxiety in both infants and mothers (Maestripieri, Schino, Aureli, & Troisi, 1992; Schino, Perretta, Taglioni, & Troisi, 1996); maternal displacement activities were recorded during the first 3 months only. Other infant behaviors included in the quantitative analysis were: frequency of vocalizations (screams, coos) and tantrums, and duration of solitary play. The rate of screams and tantrums were considered as markers of infant distress (Maestripieri et al., 2000).

### Data Analysis

Three types of data analysis were performed. First, behavioral data were compared between abusive and nonabusive mother–infant pairs using parametric statistics. Data were analyzed using mixed-design ANOVAs in which fixed factors were group (abuse/nonabuse) and sex and the repeated measure was time (monthly averages of behavioral scores). When the assumption of sphericity for ANOVAs was violated, the corrected Huh-Feldt statistic was used. Post hoc analyses of significant interactions were performed with Bonferroni-corrected *t*-tests, for repeated measures comparisons, or Tukey's post hoc tests. Whenever frequency and duration measures were analyzed and both were found to be significant, only results for duration are reported to avoid redundancy. In addition to comparisons between groups using parametric statistics, correlational analyses were used to examine the relationship between maternal behavior, including abuse, and infant behavior. Maternal behaviors that were found to be different between the abusive

and nonabusive mothers in the univariate analyses, were correlated with the all of the infant behavior measures.

Finally, all of the behavioral data were subjected to multi-dimensional scaling (MDS) analysis techniques. MDS is a data reduction technique used to uncover a “hidden structure” to a set of data (Kruskal & Wish, 1978). MDS refers to graphical models that provide a spatial representation of the similarity structure of variables. Using correlations, the relationships (i.e., proximities) among variables can be displayed graphically. The variables are represented by a set of points in two or higher dimensional space (a map). Thus, the closer two or more variables are on the map, the more highly correlated they are, while the farther apart they are, the less correlated they are. In order to “map” all of the variables into a desired space (two dimensional or greater), a certain lack of fit has to be accepted. This lack of fit is referred to as the *s*-stress. The values of *s*-stress range from 0 (perfect fit) to 1 (worst possible fit). The aim of MDS is to find a map of the variables that minimizes the *s*-stress for a given number of dimensions (Kemmler et al., 2002). The number of dimensions can be likened to the number of latent underlying factors in the dataset. Thus, when choosing the number of dimensions to represent the data, one must consider (1) the number of variables in the model (Kruskal & Wish, 1978), (2) the lack of fit (*s*-stress value), given the number of dimensions, (3) an index of fit of the model (*r* squared value or RSQ), and (4) interpretability of the dimensions. The first point addresses the fact that for each dimension of the data, there should be approximately four variables entered into the model. Thus, for a 2-dimensional map, approximately eight variables should be used. The second point addresses how well the MDS map actually “fits” the data. Stress values below .15 are typically deemed acceptable (Diekhoff, 1992). The third point addresses the variance accounted for within the model. As is the case with any regression analysis, one must consider the amount of variance being accounted for. Typically, RSQ values of .8 or higher are desirable (Schiffman, Reynolds, & Young, 1981). Finally, one must pick a solution based on interpretability of the dimensions. Parsimony is crucial to interpreting the “map” of any given dataset.

Nonmetric unfolding MDS can be used to produce both a map of stimulus variables (behaviors, in this case), based on the averaged inter-variable proximities from the subjects, and a subject map. This approach is useful when trying to map individual proximities to particular variables or group of variables. When subjects can be naturally grouped in two or more classes (such as abused/nonabused infants), nonmetric unfolding MDS is useful in mapping the association of subject groups with specific variables.

MDS techniques have previously been used for the analysis of social relationships in human and nonhuman primates (Bardi et al., 2005; Ding, 2005; Nakamichi & Kato, 2001; Street, Sheeran, & Orbell, 2001). It is a technique that provides additional information about the “structure” of a dataset, which is not possible with standard parametric statistical techniques. In this study, nonmetric unfolding MDS was used to examine differences in (1) the patterns of maternal care among the abusive and nonabusive mothers, (2) the patterns of behavior in abused and nonabused infants, (3) and the patterns of association between subjects (mother–infant pairs) and variables (maternal behavior, infant behavior). Several MDS analyses were run using

all of the maternal behaviors and all of the infant behaviors. The solutions that best fit the data and explain the most variance are presented here. Due to developmental changes in behavior, the behaviors just described were analyzed in two time blocks: months 1–3 and months 4–6, so as to differentiate high rates of mother–infant interactions early in life from the infants’ interactions with their environments during the second half of the first 6 months. Individual scores across each variable were transformed into *z*-scores prior to analysis.

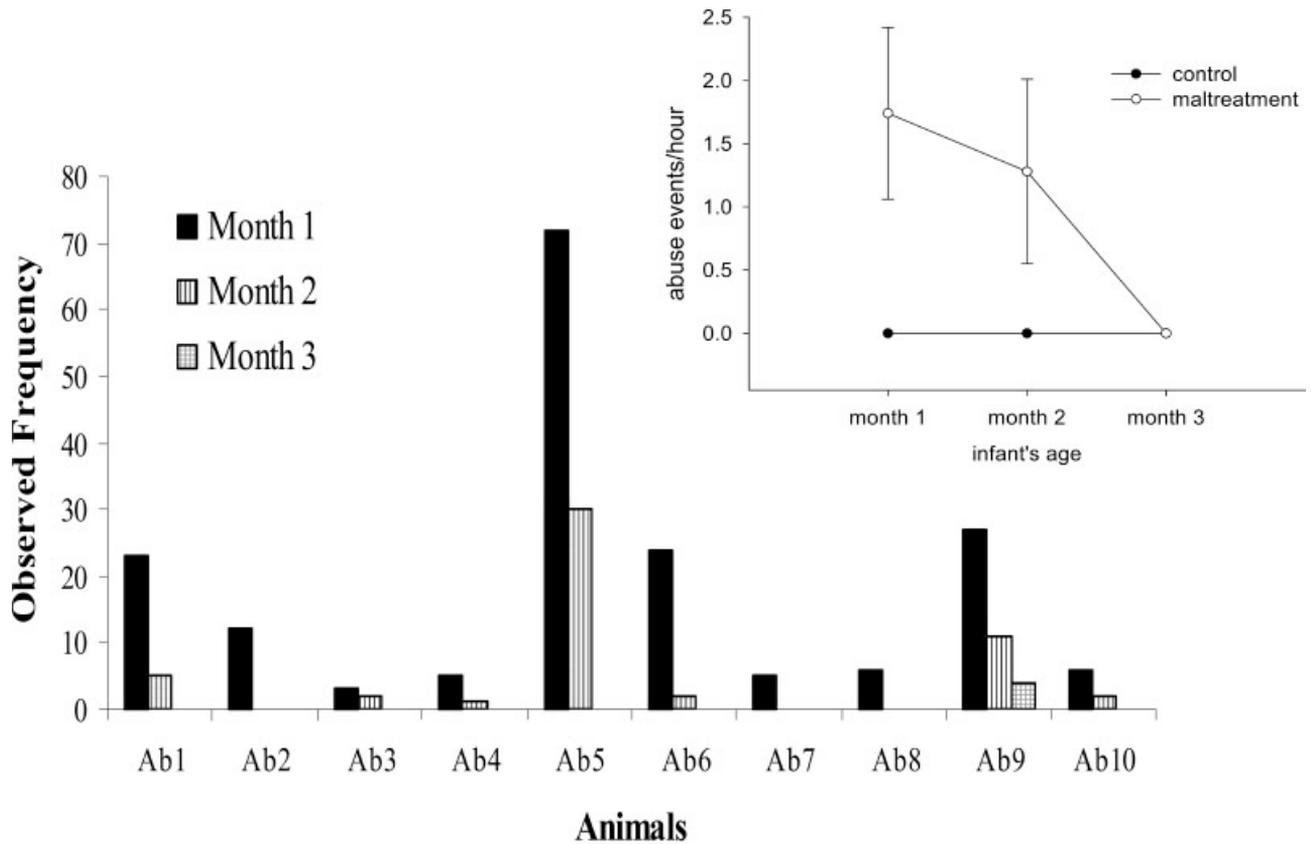
All data were analyzed using SPSS, version 9.0, and Systat, version 11.0.

## RESULTS

### Parametric Analyses of Maternal and Infant Behavior

All of the mothers that had been identified as previously abusive, abused their infants, whereas none of the control mothers exhibited such behavior. Infant abuse was concentrated in the first 3 months of life and most frequent in the first month (Fig. 1). Abuse was not observed during months 4–6. During the first 3 months (total observation time per mother–infant pair = 16 hr), there was considerable variation in occurrences of abuse among individuals (mean  $\pm$  SEM =  $22.30 \pm 9.65$  events), with hourly rates of abuse ranging from .30 to 6.4. Abusive mothers rejected their infants more frequently ( $.83 \pm .22$ ) than nonabusive mothers ( $.19 \pm .06$ ) throughout the first 6 months of life ( $F(1, 16) = 6.96, p = .02$ ; Fig. 2A). There were no significant differences in the rates of maternal restrains ( $F(1, 16) = .03, p = .87$ ), or in the indicators of maternal anxiety ( $F(1, 16) = .26, p = .61$ ). A significant group  $\times$  time interaction emerged for the proportion of time that mothers and infants spent in ventral contact ( $F(4.29, 68.62) = 2.72, p = .03$ ; Fig. 2B). Post hoc tests revealed that control mothers spent a greater proportion of time in ventral contact with their infants ( $.63 \pm .03$ ) compared to abusive mothers ( $.54 \pm .02$ ;  $t(18) = 2.52, p = .02$ ) in the first 3 months but not in the last 3 months. There were no effects for the percentage of time mothers and infants spent in other contact ( $F(1, 16) = .10, p = .76$ ) or in proximity to one another ( $F(1, 16) = 1.27, p = .28$ ).

In the first 3 months, that is, when abuse occurred, abusive mothers broke contact with their infants more often ( $1.81 \pm .24$ ) than nonabusive mothers ( $1.02 \pm .16$ ) ( $F(1, 16) = 6.32, p = .03$ ; Fig. 3A) whereas, in the same period, abused infants broke contact with their mothers less often ( $3.42 \pm .24$ ) than nonabused infants ( $4.46 \pm .13$ ) ( $F(1, 16) = 12.10, p < .01$ ; Fig. 3B). Differences in contact-breaking by mothers or infants were not statistically significant in the last 3 months. There were no significant group differences for the frequency of contacts initiated by the infant to the mother ( $F(1, 16) = 2.76,$



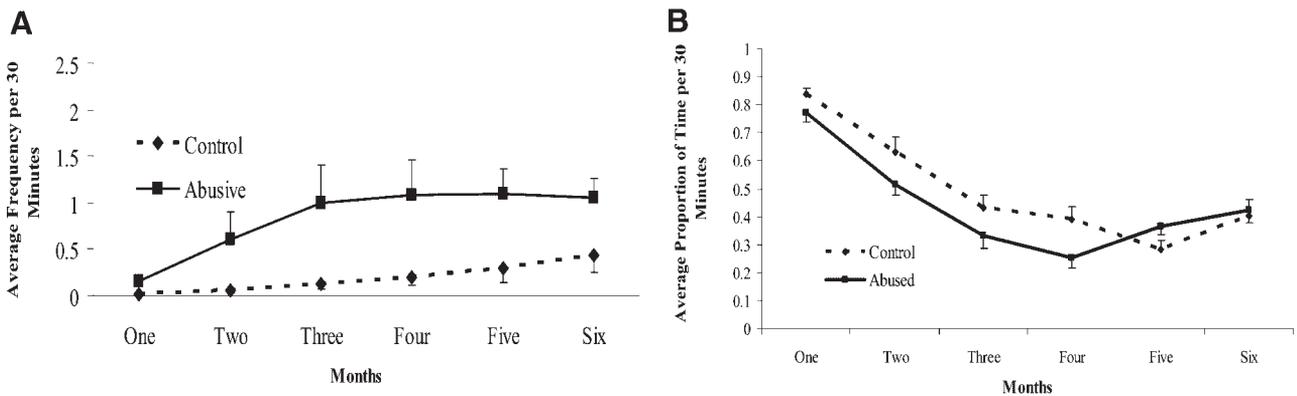
**FIGURE 1** Observed counts of abusive episodes among the 10 abusive mothers, inset: Average rate of abuse per hour (abusives and controls).

$p = .12$ ) or by the mother to the infant ( $F(1, 16) = .04$ ,  $p = .85$ ). There were also no significant group differences in the percentage of time mothers spent grooming their infants ( $F(1, 16) = .14$ ,  $p = .72$ ) or cradling their infants ( $F(1, 16) = .16$ ,  $p = .69$ ).

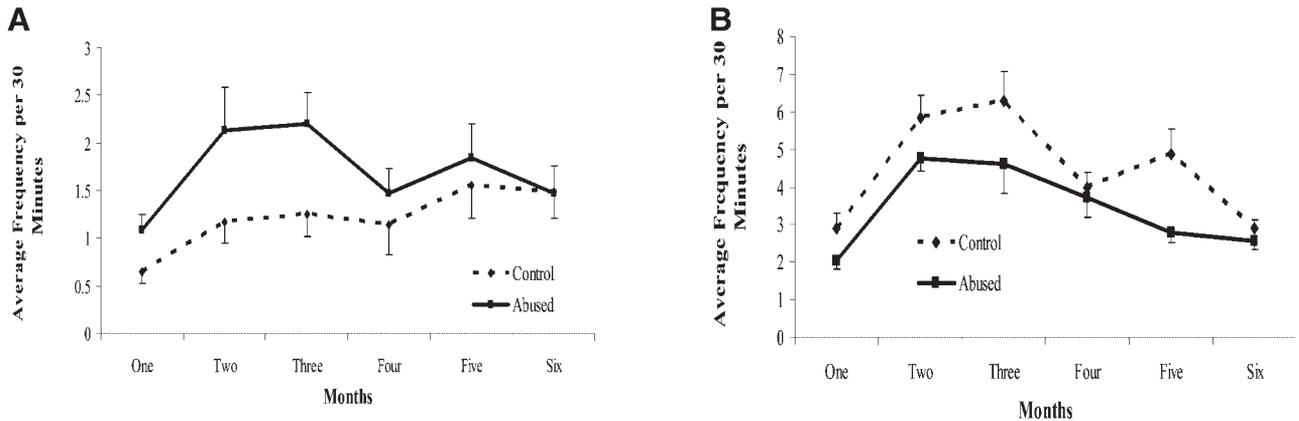
Abused infants exhibited higher rates of screams ( $.73 \pm .16$ ) than control infants ( $.12 \pm .04$ ) throughout their first 6 months of life ( $F(1,16) = 12.63$ ,  $p = .003$ ; Fig. 4A).

Abused infants also threw more tantrums ( $.56 \pm .14$ ) compared to control infants ( $.15 \pm .03$ ) during that time period ( $F(1,16) = 6.62$ ,  $p = .02$ ; Fig. 4B). Comparisons of indicators of anxiety (scratching, body-shake, yawning) failed to detect any significant differences between groups of infants ( $F(1, 16) = 1.17$ ,  $p = .29$ ).

A significant group by time interaction effect was found for proportion of time spent in solitary play ( $F(4.09$ ,



**FIGURE 2** (A) Average frequency per 30 min of maternal rejections, (B) Average proportion of time mothers and infants spent in ventral contact.



**FIGURE 3** (A) Average rate of maternal contact breaks from infant, (B) Average rate of infant contact breaks from mother.

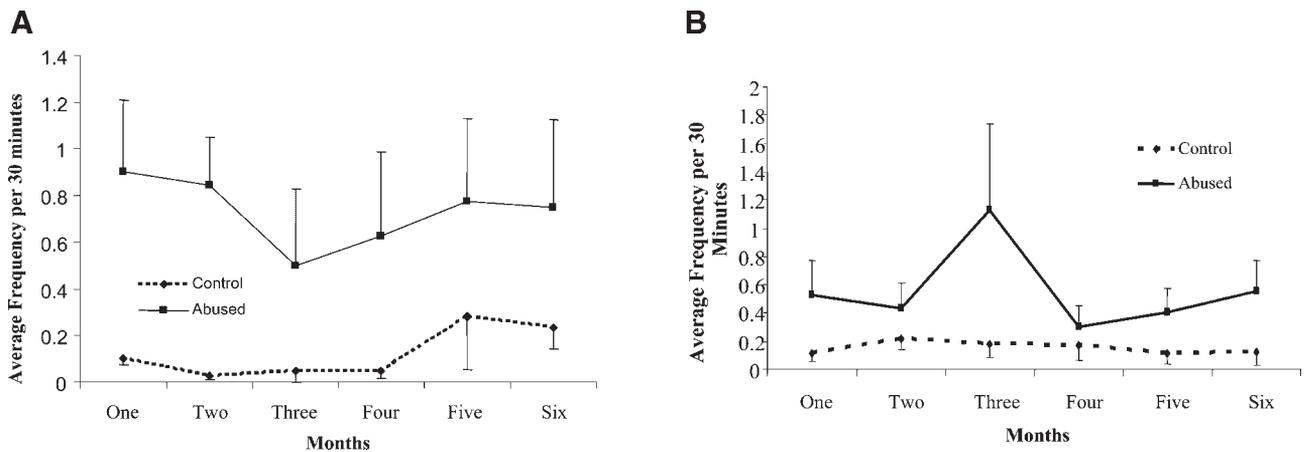
65.51) = 2.73,  $p = .04$ ; Fig. 5A). Post hoc analyses revealed that abused infants spent more time in solitary play ( $.19 \pm .02$ ) than controls ( $.15 \pm .04$ ) across the first 4 months ( $t(18) = 2.80$ ,  $p = .01$ ), with no significant group differences during months 5 and 6. A significant main effect of sex on solitary play was detected ( $F(1,16) = 4.78$ ,  $p = .04$ ), with males spending a greater proportion of time in solitary play ( $.23 \pm .02$ ) than females ( $.19 \pm .01$ ). A main effect of sex was also detected for social play ( $F(1,16) = 13.19$ ,  $p = .002$ ), with males spending a greater percentage of time playing with others ( $.04 \pm .006$ ) compared to females ( $.02 \pm .01$ ).

There was a significant group by sex effect for the frequency of contacts initiated by the infants towards others ( $F(1,16) = 4.48$ ,  $p = .05$ ; Fig. 5B). Post hoc analyses revealed that abused females initiated more contact with others ( $1.17 \pm .21$ ) compared to control females ( $.58 \pm .09$ ;  $t(10) = 2.66$ ,  $p = .02$ ), whereas there were no significant differences between control and abused males. Although a similar trend was observed for frequency of contacts

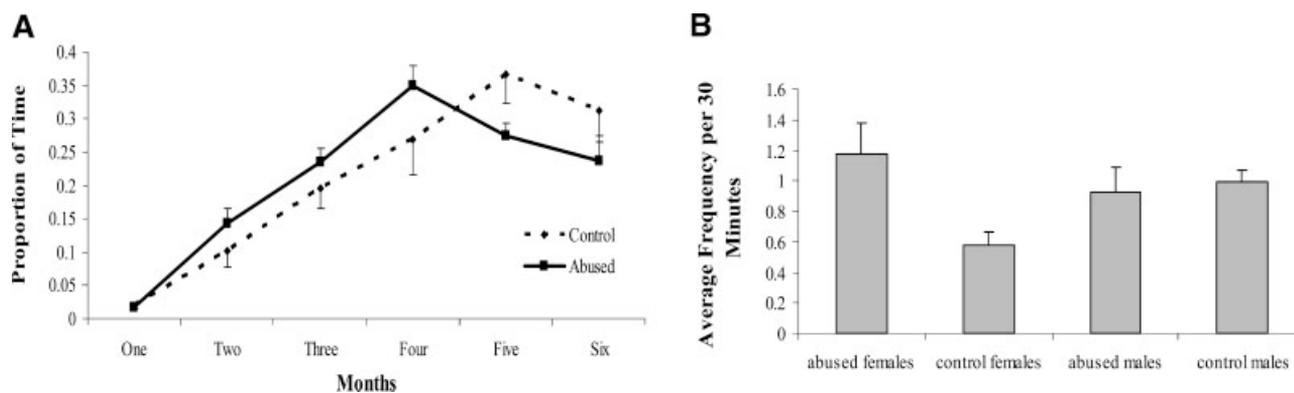
initiated by other animals towards the infant, no statistical differences were detected by post hoc tests. Group differences were not observed for the percentage of time infants spent in contact with other animals ( $F(1,16) = 2.46$ ,  $p = .14$ ). There were also no significant group differences for the duration of time infants were kidnapped ( $F(1,16) = 1.96$ ,  $p = .18$ ), or in the frequency of agonistic interactions with others (in which there were very few at these young ages) ( $F(1,16) = .01$ ,  $p = .91$ ). There were significant main effects for time for all of the variables, with the exception of infant contact time with others, and the frequency of vocalizations and tantrums. These time effects are consistent with well-known age-related changes in mother–infant interactions and infant development (e.g., Hinde & Spencer-Booth, 1967).

## Correlational Analyses

**Correlations between Abuse and Infant Behavior.** Because abuse was most frequent during the first month of



**FIGURE 4** (A) Average rate of infant screams, (B) Average rate of infant tantrums.



**FIGURE 5** (A) Rate of infant solitary play, (B) Average rate of infant initiated contacts towards others across the 6 months.

life, we examined the relationship between abuse rates during this month and infant behavior at month 1, months 1–3, and months 4–6 for the 10 abused infants. Abuse rates were positively correlated with infant screams at month 1 ( $r = .70$ ,  $p = .02$ ), duration of contact with other individuals at month 1 ( $r = .76$ ,  $p = .01$ ), and yawning rates during months 4–6 ( $r = .73$ ,  $p = .02$ ).

**Correlation between Maternal Behaviors and Infant Behavior.** Correlations were run between maternal behaviors at months 1–3 and infant behaviors at months 1–3, and between maternal behaviors at months 4–6 and infant behavior at months 4–6 for all 20 mother–infant pairs. Additionally, correlations were run between maternal behaviors during months 1–3 and infant behavior at months 4–6.

The results of these correlational analyses are reported in Table 1. Maternal contact breaks and rejections were positively correlated with infant distress vocalizations across all time points. Across several of the time points, duration of mother–infant contact was negatively correlated with infant social and solitary play. Likewise, the more mothers broke contact from their infants, the less the infants broke contact from their mothers at 1–3 months. Maternal contact breaks were also negatively correlated with infant solitary play at 4–6 months. Maternal rejections were positively correlated with the duration of time infants spent with other individuals across the majority of time block comparisons.

## Multidimensional Scaling (MDS) Analyses

**Maternal Behavior.** On the basis of previous results, the following measures were considered for the MDS analysis of maternal behavior: time spent in ventral contact and other physical contact, mother makes contact, mother breaks contact, rejections, restrains, and maternal anxiety (a composite score obtained from the three

displacement activities; these data were only available for months 1–3).

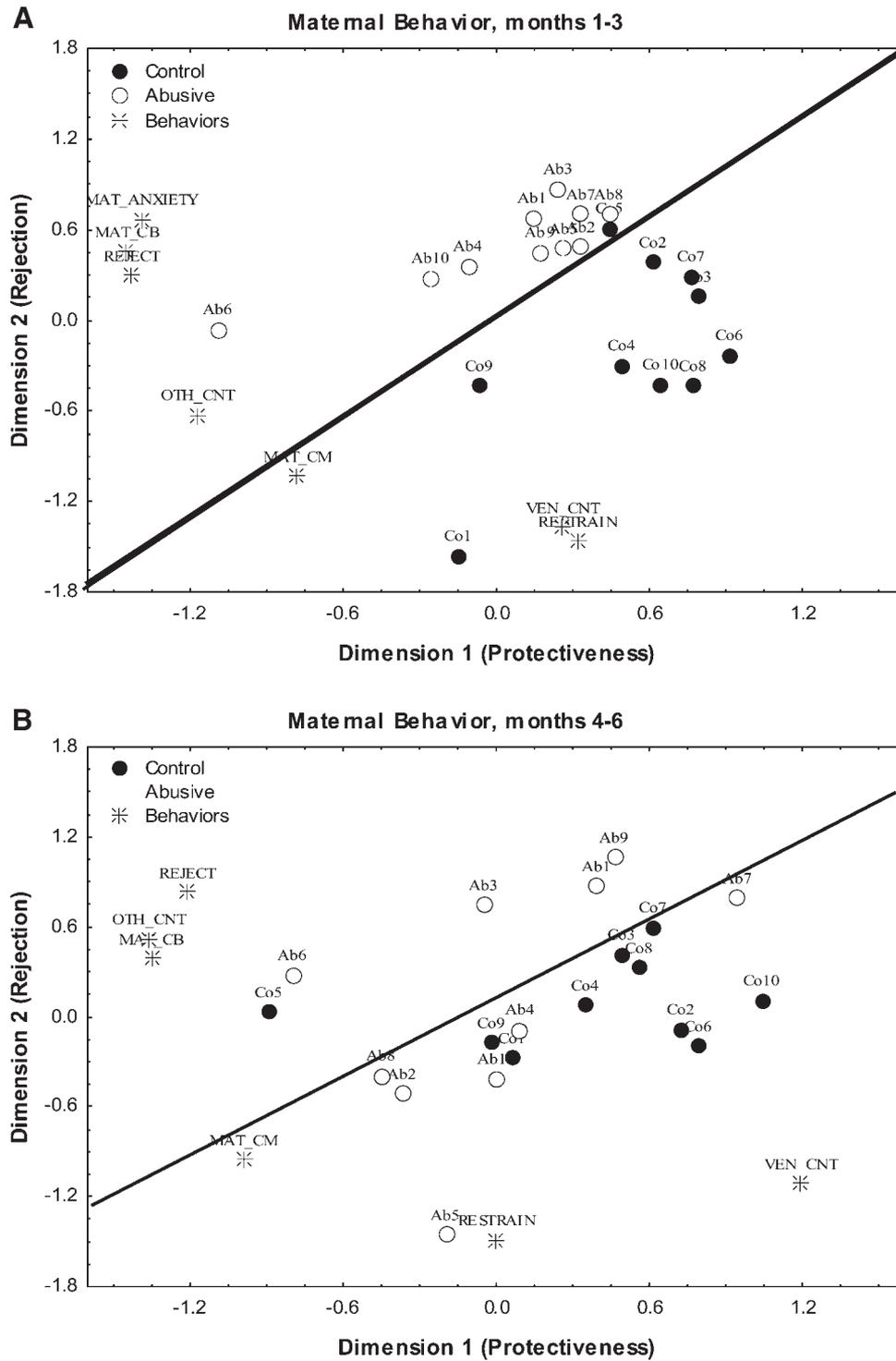
The 2 dimensional (2-D) solutions for abusive and nonabusive maternal behaviors can be seen in Figures 6A (months 1–3) and B (months 4–6). The 2-D solution for months 1–3 yielded a stress score of .05 and an RSQ value of .82. Likewise, the 2-D solution for months 4–6 yielded a stress score of .07 and an RSQ value of .70. These stress scores and RSQ values indicate that these models are explaining a large percentage of the variance and that the data are not being distorted to fit the model.

In both periods (1–3 months, 4–6 months), dimension 1 was positively correlated with maternal restrains and time spent in ventral contact, and therefore represented a protective component of maternal style, whereas dimension 2 was positively correlated with rejections, contact breaks from infant, and maternal anxiety (only during months 1–3; Fig. 6A), thus representing a rejecting component of maternal style. A positive, linear combination of the two dimensions (shown in Fig. 6A and B by a diagonal line drawn to separate the graph in two sectors), provided two primary clusters of behaviors: (1) maternal contact breaks, rejections, maternal anxiety, and time spent in other contact with infant, and (2) maternal contact makes, restrains, and time spent in ventral contact with infant. During the first 3 months of infants' life (Fig. 6A), all of the abusive mothers cluster to the top side of the graph (the rejecting side), while 9 out of the 10 control mothers cluster on the lower side of the graph (the protective side). This suggests that the maternal styles of abusive and control mothers are clearly discernible in the early months. During months 4–6 (Fig. 6B), the two groups of behaviors still showed the same association, confirming that maternal style remains consistent through time. However, the two groups of mothers did not cluster as tightly as they did during the first 3 months, suggesting that their maternal styles are not as distinctive at the later ages.

**Table 1. Correlations between Maternal Behaviors and Infant Outcomes, across Several Age Blocks**

	Maternal behaviors (months 1–3) correlated with infant outcomes (months 1–3)											
	Coos	Screams	Tantrums	Infant contact breaks	Infant contact makes	Solitary play	Social play	Scratches	Yawns	Body-shakes	Contact dur with others	Contact dur with mother
Maternal behaviors (months 4–6) correlated with infant outcomes (months 4–6)												
Mother contact breaks	0.77**	0.58**	0.54*	-0.49*	0.08	0.01	-0.06	0.18	0.01	0.18	0.17	-0.49*
Rejects	0.93**	0.72**	0.68**	-0.19	0.19	-0.15	-0.21	0.23	-0.003	0.37	0.3	-0.44*
Total contact duration	-0.33	-0.39	-0.43	0.2	-0.15	-0.34	-0.53*	-0.18	-0.18	-0.25	-0.44*	na
Ventral duration	-0.28	-0.34	-0.38	0.31	0.11	-0.36	-0.55*	-0.24	-0.07	-0.26	-0.2	na
Other contact duration	-0.13	0.02	0.07	-0.18	-0.3	0.21	0.51*	0.17	-0.24	0.18	-0.21	na
Maternal behaviors (months 1–3) correlated with infant outcomes (months 4–6)												
Mother contact breaks	0.44*	0.53*	0.59**	-0.02	0.46*	-0.65**	-0.31	0.13	-0.14	0.16	0.28	0.53*
Rejects	0.65**	0.81**	0.65**	-0.14	0.12	-0.29	0.02	0.39	-0.03	0.32	0.59**	0.1
Total contact duration	0.11	0.35	0.28	0.13	0.37	-0.67**	-0.57**	-0.18	-0.34	0.32	-0.02	na
Ventral duration	0.05	0.33	0.16	-0.05	0.13	-0.49*	-0.53*	-0.21	-0.26	0.41	-0.07	na
Other contact duration	0.23	0.04	0.25	0.22	0.39	-0.40	0.18	0.33	0.04	-0.05	0.23	na
Maternal behaviors (months 1–3) correlated with infant outcomes (months 4–6)												
Mother contact breaks	0.48*	0.68**	0.41	-0.32	-0.04	-0.36	-0.18	0.18	-0.005	0.39	0.58*	0.16
Rejects	0.51*	0.66**	0.27	-0.31	-0.20	-0.08	-0.29	0.17	0.005	0.36	0.68**	-0.04
Total contact duration	-0.48*	-0.29	-0.36	0.34	0.21	-0.17	-0.31	-0.33	-0.01	-0.04	-0.50*	na
Ventral duration	-0.64**	-0.38	-0.48*	0.42	0.26	-0.14	-0.17	-0.27	0.01	0.11	-0.56**	na
Other contact duration	0.55*	0.23	0.42	-0.29	-0.14	0.13	-0.06	0.20	0.04	-0.23	0.34	na

\* $p < .05$ .  
\*\* $p < .01$ .



**FIGURE 6** (A) Multidimensional scaling map of the relationships among the behaviors and the individuals during months 1–3. (B) Multidimensional scaling map of the relationships among the behaviors and the individuals during months 4–6.

**Infant Behavior.** Based on the results of the univariate analyses, the following behaviors were considered for the MDS analysis of infant behavior: infant makes contact with mother, infant breaks contact from mother, infant screams, infant tantrums, infant anxiety (composite score), time spent in contact with mother, and time spent in solitary play.

The 2-D solutions for the abused and nonabused infants can be seen in Figure 7A (months 1–3) and B (months 4–6). The 2-D solution for months 1–3 yielded a stress score of .10 and an RSQ value of .88. Likewise, the 2-D solution for months 4–6 (Fig. 7B) yielded a stress score of .05 and an RSQ value of .64. The 2-D solution for months 1–3 provided a clear model that explained most of the variance among the variables and presented very little distortion when fitting the data. The distortion was very good for months 4–6, but the variance explained was much lower, and, therefore, caution should be taken when interpreting the results.

An examination of the two graphs yields differences in clusters of behavior and between the two groups of infants. In both figures, lines have been drawn through the graph to help differentiate behaviors and infants. During the first 3 months of life (Fig. 7A), dimension 1 was positively correlated with solitary play, contacts broken and made, and anxiety, thus representing an “independent/exploratory” component of infant behavior. Dimension 2 was negatively correlated with infant screams and tantrums, thus representing a “distress” or “upset” component of infant behavior. A negative linear combination of the two dimensions provided two clear clusters of infant behavior: (1) infant contact makes and breaks from mother, infant solitary play, infant nervous behavior, and (2) infant screams, infant tantrums, and time spent in contact with the mother. Eight out of the 10 control infants cluster to the independent side of the graph, while 7 of the 10 abused infants cluster to the upset/dependent side of the graph, thus indicating that abused infants were clearly discernible from control infants. During months 4–6 (Fig. 7B), the configuration provided by MDS was clearly different, showing a major developmental change in the relationship between infant behavior and rearing history. Behaviors clustered into two groups along dimension 2. The behaviors are split similarly as before, however infant anxiety and solitary play move into the cluster with infant screams, tantrums, and time spent in contact with mother. The second cluster is reduced to infant makes contact and infant breaks contact. Moreover, these clusters were mostly dependent on dimension 2 alone. Clearly dimension 1 was dependent on some infant behaviors unrelated to mother–infant interactions. Based only on dimension 2, infants were still clearly clustered in two groups according to their rearing history. Once again, most of the abused infants cluster towards the

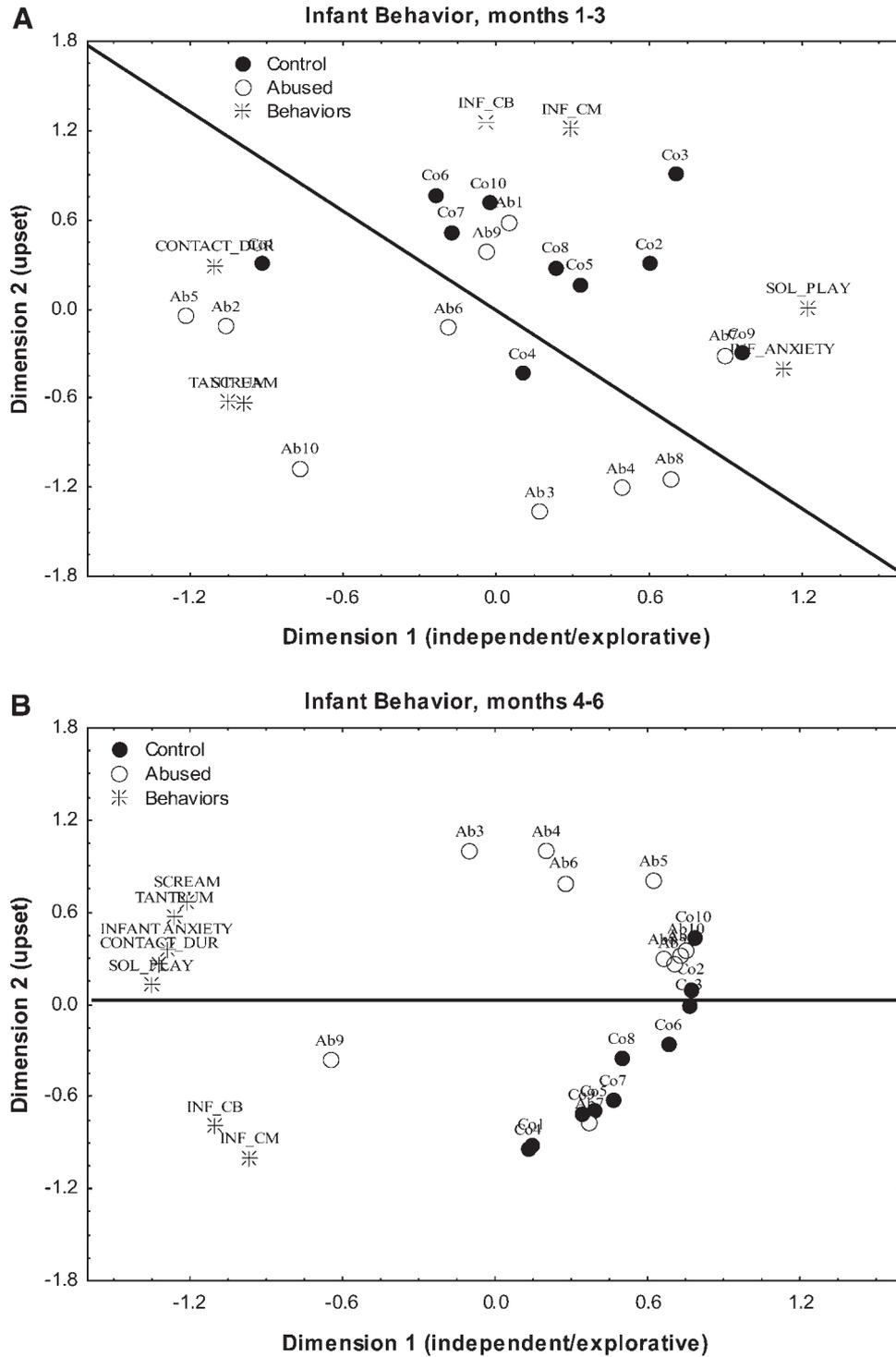
upset/dependent side, while more of the controls cluster towards the independent/exploratory side. The change in variable configuration during months 4–6 suggests that infant behavioral profiles are not as clearly distinct in this period as in the first 3 months of life.

## DISCUSSION

The results of this study confirm and extend previous findings concerning the behavioral characteristics of rhesus macaque abusive mothers and the behavior of their infants early in life. The infants of abusive mothers were exposed not only to their abusive behavior in the first few months of life but also to an overall pattern of maternal care that was different from that of nonabusive mothers in many respects. This has important implications for understanding the early experience of abused infants and how it may affect their biobehavioral development.

As previously reported for rhesus and pigtail macaques (Maestriperri, 1998; Maestriperri & Carroll, 1998c), the rhesus macaque abusive mothers in this study exhibited higher rates of infant rejection than nonabusive mothers. In addition, abusive mothers spent less time in ventral contact with their infants and broke contact with them more frequently than control mothers, particularly during the 3 first months of the infant’s life. Unlike previous studies, however, we did not find significant differences in the restraining behavior of abusive mothers (Maestriperri, 1998, Maestriperri & Carroll, 1998c; Maestriperri et al., 1999). This discrepancy may reflect methodological differences in the way restraining behavior was analyzed in this and previous studies (i.e., hourly rate vs. a proportion measure that takes into account infant activity as well).

Although the correlational analyses do not provide evidence of causation, several significant correlations between maternal behavior in the first 3 months and infant behavior at 4–6 months suggest that the infants’ early interactions with their mothers may have affected their later behavior. Infant abuse in the first months of life was positively correlated with infant screams, yawns, and contact with other individuals, while maternal contact-breaking and rejection were positively correlated with infant distress vocalizations and negatively correlated with solitary play in the same period of time. Additionally, ventro-ventral contact time during the first 3 months was negatively correlated with infant vocalizations later in life (4–6 months) and maternal contact breaks from their infants during the first 3 months were positively correlated with the duration of time infants spent with other individuals later in life. The correlations between maternal and infant behavior were particularly strong for behaviors that were characteristic of abusive mothers,



**FIGURE 7** (A) Multidimensional scaling map of the relationships among the behaviors and the individuals during months 1–3. (B) Multidimensional scaling map of the relationships among the behaviors and the individuals during months 4–6.

suggesting that exposure to a spectrum of poor maternal care-giving behaviors, in addition to physical abuse, may have a long-term impact on infant development. Clearly, further studies are needed to understand the specific contribution of physical abuse versus other aspects of maternal care to the development of abused infants.

By examining multiple maternal behaviors concurrently with the MDS technique, this study has provided a more comprehensive characterization of the parenting styles of abusive mothers than previously available. This analysis revealed overall differences in the parenting style of abusive and nonabusive mothers especially in the first 3 months of infant life, which coincides with the period in which abuse occurred. Specifically, the parenting style exhibited by abusive mothers seems better described by the “rejecting/anxious” dimension of the MDS analysis. This was in clear opposition to the “protective/nurturing” quality of maternal care exhibited by control mothers during the first 3 months of life. The parenting profiles were not as distinctive during months 4–6, perhaps because at that age, infants are beginning to play a more crucial role in the mother–infant interactions, mothers were beginning to wean their infants, and mating season was approaching for many of the mothers.

The observed difference in anxiety between abusive and nonabusive mothers is consistent with a similar finding reported by previous studies (Maestripieri & Carroll, 1998c; Troisi & D’Amato, 1991, 1994). The higher anxiety of abusive mothers may be the result of the behavior of their infants. Abused infants tended to scream and throw more tantrums compared to control infants, and their frequencies and duration of time in and out of contact were different than those of control infants. Differences in anxiety are also consistent with recent evidence suggesting that abusive mothers are characterized by neurochemical profiles suggestive of hyperactivity of stress-related neurobiological systems (e.g., high levels of corticotrophin releasing hormone and monoamine metabolites in the cerebrospinal fluid; Maestripieri, Lindell, Ayala, Gold, & Higley, 2005).

Significant differences also emerged in the behavior of abused and nonabused infants. Abused infants exhibited higher rates of screams and tantrums than control infants during the first 6 months of life. Abused infants also broke contact with their mothers less frequently and spent a higher proportion of time in solitary play than controls. The MDS analyses of multiple infant behaviors provided a general representation of the early behavior abused infants, which suggests more distress and dependency, less exploration, and play than control infants, and more generally, delayed social development. This is evident by the fact that during the first 3 months, and the last 3 months, abused infants spent more time in contact with their mothers, and less time making and breaking contact

from their mothers. This behavioral profile of abused infants is consistent with what has been reported for monkey infants exposed to repeated maternal separation (Sanchez et al., 2005) as well as maltreated human children (Cicchetti, 1998; Crittenden & Ainsworth, 1997). Although the differences in infant behavior in this study were stronger in the first 3 months of life, the abused infants continued to exhibit a different pattern of behavior (e.g., less independence and more irritability) relative to controls and to cluster separately from them in the MDS analysis in months 4–6. Since no infant abuse occurred in months 4–6, these results suggest long-term effects of early abuse on infant behavior.

Overall, this study contributes to the existing literature on infant abuse in nonhuman primates by replicating the findings of previous studies, extending the study of maternal and infant behavior beyond the first 3 months of life, and providing a better characterization of the parenting styles of abusive mothers and the early behavioral development of their infants. This study is part of a larger project in which abused infants and their controls are followed longitudinally from birth to adulthood and their social and neuroendocrine development are assessed. Possible genetic influences on the phenotype of abused infants (e.g., Caspi et al., 2003) are also being taken into consideration. The differences in early behavior between abused and control infants reported here are consistent with the hypotheses that early abuse may have long-term consequences for development and that such consequences may include alterations in both social behavior and responsiveness to stress (e.g., see Sanchez et al., 2005). The description and analysis of the infants’ early experience reported here will be crucial for understanding any behavioral or physiological differences between abused and nonabused individuals at later ages. The longitudinal investigation of abused infants with a prospective study that integrates behavioral, physiological, and genetic variables has the potential to enhance our understanding of the developmental consequences of this form of adverse experience in nonhuman primates and produce findings and generalizations that may be applicable to humans as well.

## NOTES

This work was supported by NIH grants MH62577 and MH63097 to DM, MH65046 to MMS, and RR-00165 to the Yerkes National Primate Research Center, as well as by a FIRST fellowship (NIH K-12 grant GM00680) to KM and a NARSAD Young Investigator Award to MMS. We thank Irwin Bernstein for his support throughout this project and Richelle Fulks and Anne Graff for their technical assistance. The Yerkes Center is

fully accredited by the American Association for Accreditation of Laboratory Animal Care.

## REFERENCES

- Alessandri, S. M. (1991). Play and social behavior in maltreated preschoolers. *Development and Psychopathology*, 3, 191–205.
- Bardi, M., Bode, A. E., Ramirez, S. M., & Brent, L. Y. (2005). Maternal care and development of stress responses in baboons. *American Journal of Primatology*, 66, 263–278.
- Bremner, J. D., Southwick, S. M., Johnson, D. R., Yehuda, R., & Charney, D. S. (1993). Childhood physical abuse and combat-related posttraumatic stress disorder in Vietnam veterans. *American Journal of Psychiatry*, 150, 235–239.
- Caspi, A., Sugden, K., Moffitt, T. E., Taylor, A., Craig, I. W., Harrington, H., McClay, J., Mill, J., Martin, J., & Braithwaite, A. (2003). Influence of life stress on depression: Moderation by a polymorphism in the 5-HTT gene. *Science*, 301, 386–389.
- Cicchetti, D. (1998). Child abuse and neglect—Usefulness of the animal data: Comment on Maestripieri and Carroll (1998). *Psychological Bulletin*, 123, 224–230.
- Crittenden, P. M., & Ainsworth, M. D. S. (1997). Child maltreatment and attachment theory. In D. Cicchetti & V. Carlson (Eds.), *Child maltreatment: Theory and research on the causes and consequences of child abuse and neglect* (pp. 432–463). Cambridge, UK: Cambridge Press.
- Diekhoff, G. M. (1992). *Statistics for the social and behavioral sciences*. Dubuque, IA: Wm. C. Brown.
- Ding, C. (2005). Applications of multidimensional scaling profile analysis in developmental research: An example using adolescent irritability patterns. *International Journal of Behavioral Development*, 29, 185–197.
- Glaser, D. (2000). Child abuse and neglect and the brain—A review. *Journal of Child Psychology & Psychiatry & Allied Disciplines*, 41, 97–116.
- Hart, J., Gunnar, M., & Cicchetti, D. (1995). Salivary cortisol in maltreated children: Evidence of relations between neuroendocrine activity and social competence. *Development and Psychopathology*, 7, 11–26.
- Haskett, M. E., & Kistner, J. A. (1991). Social interactions and peer perceptions of young physically abused children. *Child Development*, 62, 979–990.
- Hinde, R. A., & Spencer-Booth, Y. (1967). The behavior of socially living rhesus monkeys in their first two and a half years. *Animal Behaviour*, 15, 169–196.
- Jacobson, R. S., & Straker, G. (1982). Peer group interaction of physically abused children. *Child Abuse and Neglect*, 6, 321–327.
- Kemmler, G., Holzner, B., Kopp, M., Dunser, M., Greil, R., Hahn, E., & Sperner-Unterweger, B. (2002). Multidimensional scaling as a tool for analysing quality of life data. *Quality of Life Research*, 11, 223–233.
- Kruskal, J. B., & Wish, M. (1978). *Multidimensional scaling*. London: Sage.
- Maestripieri, D. (1998). Parenting styles of abusive mothers in group-living rhesus macaques. *Animal Behaviour*, 55, 1–11.
- Maestripieri, D. (2005). Early experience affects the inter-generational transmission of infant abuse in rhesus monkeys. *Proceedings of the National Academy of Sciences USA*, 102, 9726–9729.
- Maestripieri, D., & Carroll, K. A. (1998a). Child abuse and neglect: Usefulness of the animal data. *Psychological Bulletin*, 123, 211–233.
- Maestripieri, D., & Carroll, K. A. (1998b). Risk factors for infant abuse and neglect in group-living rhesus monkeys. *Psychological Science*, 9, 143–145.
- Maestripieri, D., & Carroll, K. A. (1998c). Behavioral and environmental correlates of infant abuse in group-living pigtail macaques. *Infant Behavior and Development*, 21, 603–612.
- Maestripieri, D., Jovanovic, T., & Gouzoules, H. (2000). Crying and infant abuse in rhesus macaques. *Child Development*, 71, 301–309.
- Maestripieri, D., Lindell, S. G., Ayala, A., Gold, P. W., & Higley, J. D. (2005). Neurobiological characteristics of rhesus macaque abusive mothers and their relation to social and maternal behavior. *Neuroscience & Biobehavioral Reviews*, 29, 51–57.
- Maestripieri, D., Schino, G., Aureli, F., & Troisi, A. (1992). A modest proposal: Displacement activities as an indicator of emotions in primates. *Animal Behaviour*, 44, 967–979.
- Maestripieri, D., Tomaszycki, M., & Carroll, K. A. (1999). Consistency and change in the behavior of rhesus macaque abusive mothers with successive infants. *Developmental Psychobiology*, 34, 29–35.
- Maestripieri, D., Wallen, K., & Carroll, K. A. (1997a). Infant abuse runs in families of group-living pigtail macaques. *Child Abuse and Neglect*, 21, 465–471.
- Maestripieri, D., Wallen, K., & Carroll, K. A. (1997b). Genealogical and demographic influences on infant abuse and neglect in group-living sooty mangabeys (*Cercocebus atys*). *Developmental Psychobiology*, 31, 175–180.
- Mullen, P. E., Martin, J. L., Anderson, J. C., Romans, S. E., & Herbison, G. P. (1996). The long-term impact of the physical, emotional, and sexual abuse of children: A community study. *Child Abuse and Neglect*, 20, 7–21.
- Nakamichi, M., & Kato, E. (2001). Long-term proximity relationships in a captive social group of Western lowland gorillas (*Gorilla gorilla gorilla*). *Zoo Biology*, 20, 197–209.
- Ruppenthal, G. C., Arling, G. L., Harlow, H. F., Sackett, G. P., & Suomi, S. J. (1976). A 10-year perspective of motherless-mother monkey behavior. *Journal of Abnormal Psychology*, 85, 341–349.
- Sanchez, M. M., Noble, P. M., Lyon, C. K., Plotsky, P. M., Davis, M., Nemeroff, C. B., & Winslow, J. T. (2005). Alterations in diurnal cortisol rhythm and acoustic startle response in nonhuman primates with adverse rearing. *Biological Psychiatry*, 57, 373–381.

- Schiffman, S. S., Reynolds, M. L., & Young, F. W. (1981). Introduction to multidimensional scaling. New York: Academic Press.
- Schino, G., Perretta, G., Taglioni, A. M., & Troisi, A. (1996). Primate displacement activities as an ethopharmacological model of anxiety. *Anxiety*, 2, 186–191.
- Stein, M. B., Walker, J. R., Anderson, G., Hazen, A. L., Ross, C. A., Eldridge, G., & Forde, D. R., (1996). Childhood physical and sexual abuse in patients with anxiety disorders and in a community sample. *American Journal of Psychiatry*, 153, 275–277.
- Street, H., Sheeran, P., & Orbell, S. (2001). Exploring the relationship between different psychosocial determinants of depression: A multidimensional scaling analysis. *Journal of Affective Disorders*, 64, 53–67.
- Teicher, M. H., Andersen, S. L., Polcari, A., Anderson, C. M., Navalta, C. P., & Kim, D. M. (2003). The neurobiological consequences of early stress and childhood maltreatment. *Neuroscience & Biobehavioral Reviews*, 27, 33–44.
- Troisi, A., & D'Amato, F. R. (1983). Is monkey maternal abuse of offspring aggressive behavior? *Aggressive Behavior*, 9, 167–173.
- Troisi, A., & D'Amato, F. R. (1984). Ambivalence in monkey mothering: Infant abuse combined with maternal possessiveness. *The 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.
- Troisi, A., & D'Amato, F. R. (1994). Mechanisms of primate infant abuse: The maternal anxiety hypothesis. In S. Parmigiani & F. S. vom Saal (Eds.), *Infanticide and parental care* (pp. 199–210). London: Harwood.