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The Development of an Instrument to Measure Global Dimensions of Maternal Care in Rhesus Macaques (Macaca mulatta)

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Abstract

One of the strongest predictors of healthy child development is the quality of maternal care. Although many measures of observation and self-report exist in humans to assess global aspects of maternal care, such qualitative measures are lacking in nonhuman primates. In this study we developed an instrument to measure global aspects of maternal care in rhesus monkeys, with the goal of complementing the individual behavioral data collected using a well-established rhesus macaque ethogram during the first months postpartum. The 22 items of the instrument were adapted from human maternal sensitivity assessments and a maternal Q-sort instrument already published for macaques. The 22 items formed four dimensions with high levels of internal reliability that represented major constructs of maternal care: 1) Sensitivity/Responsivity, 2) Protectiveness, 3) Permissiveness, and 4) Irritability. These dimensions yielded high construct validity when correlated with mother-infant frequency and duration behavior that was collected from focal observations across the first three postnatal months. In addition, comparisons of two groups of mothers (Maltreating versus Competent mothers), showed significant differences across the dimensions suggesting that this instrument has strong concurrent validity, even after controlling for focal observation variables that have been previously shown to significantly differentiate these groups. Our findings suggest that this Instrument of Macaque Maternal Care (IMMC) has the potential to capture global aspects of the mother-infant relationship that complement individual behaviors collected through focal observations.

Keywords

Maternal behavior; rhesus monkeys; sensitivity; protectiveness; irritability; infant maltreatment

Introduction

Evidence across many mammalian species indicates the importance of the mother-infant relationship for the healthy development of the offspring [Bowlby, 1958; Kraemer, 1992; Sanchez, Ladd, & Plotsky, 2001; Gunnar et al., 2006; Niccols & Feldman, 2006]. Bowlby [1969] suggested that maternal sensitivity towards the infant is fundamental for its proper development, and is predictive of later developmental outcomes. Though few researchers would argue that the quality of the caregiver-infant relationship is important for understanding child development, the methods, measures, and foci of methods used to quantify this relationship vary immensely.

The mother-infant relationship has been studied extensively in non-human primates; however, the techniques used rely mostly on collection of the frequency and duration of individual behaviors, which do not always capture the dynamic and qualitative nature of the mother-infant relationship. Interestingly, John Bowlby's human attachment theory arose from his interest in ethology, and his relationship with notable ethologists of the time, including Robert Hinde [see Van der Horst, Van der Veer, & Van Ijzendoorn, 2007 for a review], who published several papers describing the normative development of the rhesus monkey (*Macaca mulatta*) mother-infant relationship using mostly quantitative measures of individual behaviors [Spencer-Booth, Hinde, & Bruce, 1965; Hinde & Spencer-Booth, 1967; Spencer-Booth & Hinde, 1969; Hinde & Atkinson, 1970]. Additional studies have examined different aspects of the rhesus macaque mother-infant relationship [Hansen, 1966; Mitchell, 1968; Rosenblum, 1970, 1971; Berman, 1980; Stevenson-Hinde & Simpson, 1981; Johnson & Southwick, 1984; Johnson, 1986; Simpson, Simpson, & Howe, 1986; Berman, 1990; Champoux, Metz, & Suomi, 1991; Mason, Long, & Mendoza, 1993; Maestripieri, 1994, 1998; Brown & Dixson, 2000; DeVinney, Berman, & Rasmussen, 2001; Maestripieri, 2001; McCormack, Sanchez, Bardi, & Maestripieri, 2006] primarily using focal sampling techniques to observe and record frequencies and durations of individual behaviors [Altmann, 1974; Martin & Bateson, 1993]. Behaviors commonly used to quantify the mother-infant relationship include time spent in contact/proximity (including ventral contact) and grooming, as well as frequencies of contact make/break and infant restraining, rejection and aggression (e.g., bites, slaps) by the mother.

Building upon focal observations of mother-infant pairs, several researchers have tried to generate more global measures, and classifications of maternal care. The Hinde Index, for example, is a quotient developed to quantify the relative contribution of mother and infant to the maintenance of contact [Hinde & Atkinson, 1970]. More recently, using individually collected maternal behaviors in vervet monkeys, Fairbanks and McGuire [1987, 1993] applied principal component analysis (PCA) techniques and identified two maternal care factors: Rejecting (break ventral contact/proximity with infant, reject infant) and Protectiveness (initiate proximity/ventral contact with infant, restrain infant, groom infant, muzzle infant). Mothers were categorized on each factor, and classified as either: 1) Controlling (high protectiveness and high rejecting), 2) Protective (high protectiveness, low rejecting), 3) Rejecting (low protectiveness, high rejecting), and 4) Laissez-faire (low protectiveness, low rejecting). These authors demonstrated the consistency of these maternal style factors over time and the implications for offspring development (see Fairbanks, 1996

for a review). Bardi and colleagues [2001 Bardi and colleagues [2002] and Maestripieri and colleagues [2009] applied similar PCA approaches to rhesus and Japanese macaques, finding supporting evidence for the existence of the two maternal Protectiveness and Rejection factors in macaque species. Both studies also reported a third factor labeled Independence/Warmth, which consisted of maternal grooming, cradling, nursing and contact with the infant. Although the challenge of PCA techniques is that they are data-driven and therefore, study-specific, further support for the existence of Rejecting and Protective maternal styles followed in additional reports of rhesus macaques [Berman, 1990; Maestripieri, Higley, Lindell, Newman, McCormack, & Sanchez, 2006; McCormack et al., 2006], and bonobos [deLathouwers & van Elsacker, 2004].

A few attempts have been made to capture the overall quality of the mother-infant relationship, using different types of qualitative rating measures. Building upon human attachment measures, Kondo-Ikemura and Waters [1995] developed the Macaque Maternal Q-sort, which is a 93-item scale that clusters maternal behavior into three domains (supervision of infant, sensitivity to infant signals, and maternal rank and adjustment/comfort around social group members). More recently Vandeelest and Capitanio [2012] developed an adjective-rating instrument that measures maternal attitude (nurturing, restrictive, indifferent, and aggressive), as well as the quality of mother-infant interactions (conflictual, tense, calm, or aggressive), during the weaning and breeding season. Not only were the ratings correlated in the predicted directions with concurrently collected individual focal behaviors, they were also predictive of later infant behavior. Both of these instruments illustrate the ability of more global measures to measure complex and dynamic dyadic behavioral patterns, such as the affective quality of mother-infant interactions, which traditional focal observational techniques are not able to capture. However, the Q-sort is a very time-intensive procedure which only generates a single score, and the instrument developed by Vandeelest and Capitanio [2012] primarily focuses on the mother-infant relationship during and after the weaning stage.

In the human literature, there are many techniques available to assess the quality of mother-infant dyadic interactions, such as parent-report questionnaires, observational coding systems, and rating scales. These methods are frequently used simultaneously to increase the reliability and validity of each of the individual measures. Through the pioneering work of Ainsworth and colleagues [Ainsworth & Wittig, 1969; Ainsworth, Blehar, Waters, Wall, 1978;], maternal care can be evaluated across four dimensions (sensitivity, acceptance, cooperation, and accessibility), and it has been reported that the strongest predictor for the development of a securely attached infant is maternal sensitivity [Ainsworth et al., 1978], which has been further replicated [Egeland & Farber, 1984; Lyons-Ruth, Connell, Zoll, & Stahl, 1987; Bretherton, Biringen, Ridgeway, Maslin, & Sherman, 1989; Seifer, Schiller, Sameroff, Resnick, & Riordan, 1996; Vereijken, Riksen-Walraven, & Kondo-Ikemura, 1997; see also Mesman & Emman, 2013 for a review]. The Q-sort methodology can also be used to assess multiple dimensions of maternal care [Pederson and Moran, 1996], and it provides a single score of maternal sensitivity. Q-sort scores have also demonstrated strong associations with infant attachment and developmental outcomes [Atkinson et al., 2000; Lemelin, Tarabulsky, & Provost, 2006; see Van Ijzendoorn, Vereijken, Bakermans-Kranenburg, & Riksen-Walraven, 2004 for a meta-analytic review]. However, both of these

measures are time-consuming and labor-intensive processes (though see Tarabulsky et al., 2009 for an abbreviated version of the Q-sort scale).

Less time-intensive, yet comprehensive, instruments have been developed, which examine mother-infant interactions during a variety of spontaneous and fun tasks, like free play [Paavola, Kempainen, Kumpulainen, Moilanen, & Ebeling, 2006; Vliegen, Luyten, & Biringen, 2009; Dolberg, Feldman, Keren, 2010; Leerkes, 2011], or during more routine and structured tasks, like clean-up [Schneider-Rosen & Rothbaum, 1993; Gardner, Sonuga-Barke, & Sayal, 1999; Pears & Ayres, 2000; Kok et al. 2012]. These instruments provide measurements of maternal sensitivity, intrusiveness, warmth, hostility, disengagement, and structured limit-setting [Pears & Ayres, 2000; Vliegen et al., 2009; Kaitz, Maytal, Devor, Bergman, & Mankuta, 2010] and have demonstrated concurrent validity [Kaitz et al., 2010; Vliegen et al., 2009], convergent validity [Caldera & Hart, 2004; Leerkes, 2011], and predictive validity [Paavola, et al., 2006; Kok et al., 2012] with a variety of child and parental outcomes. These instruments are relatively quick and easy to use, and frequently predict later infant outcomes, often more so than coding systems that involved the quantification of individual behaviors [Munson & Odom, 1996].

The purpose of the current study was to develop and validate an instrument that would assess global, qualitative aspects of early maternal care in rhesus macaques, taking into account the social context. Our goal was to develop an Instrument of Macaque Maternal Care (IMMC) that could be easily translated and compared to existing human measurements, which could be quickly completed following mother-infant focal observations, and would complement the quantitative behavior collected using our ethogram [Maestripieri, 1998, 2001; McCormack et al., 2006]. To this end, we developed a 22-item rating instrument, the IMMC, which was adapted from the Macaque Maternal Q-sort [Kondo-Ikemura & Waters, 1995], the Human Maternal Behaviors Q-Sort [Pederson & Moran, 1995], and the Free Play and Clean-Up task for children [Pears & Ayres, 2000]. Here we report the development of this instrument, and the global dimensions of maternal care that resulted from the clustering of items. We tested the reliability of the resulting maternal care dimensions through inter-dimension correlational analyses, scale and factor analyses. Convergent validity was established by evaluating how well the instrument's dimensions correlated with relevant individual maternal behaviors coded during focal observations. We predicted that the maternal dimensions, particularly those reflecting maternal sensitivity, would be positively correlated with maternal behaviors related to competent infant care (e.g., contact, cradling, grooming, play), and negatively correlated with incompetent care of a very young infant (e.g., physical abuse, aggression, rejections). The discriminant validity of the dimensions was tested by examining the correlations between the maternal dimensions and the coded behaviors that do not reflect competent/incompetent maternal care (e.g., genital inspections of the infant), and we expected no significant correlations between them.

We also examined the sensitivity of the IMMC to distinguish between two groups of females with strong differences in maternal care (i.e., concurrent validity) across time, by comparing the maternal dimension scores of females who maltreat their infants early in life [Maestripieri, 1998; Sanchez, 2006; Sanchez & Pollack, 2009] to females that do not. Infant

maltreatment has been reported to spontaneously occur in rhesus monkeys with a prevalence of 2-5%, percentages similar to those observed in human populations [Maestripieri, 1998]. We predicted that Maltreating mothers would score lower in the maternal dimensions reflecting sensitivity and warmth compared to Competent mothers. Finally, in order to demonstrate that the IMMC dimensions provide additional and complementary information beyond that obtained in focal observations, we examined whether Maltreating mothers differed from Competent mothers on each of the dimensions, while factoring out maternal behaviors previously reported to be significantly different between Maltreating and Competent mothers [McCormack et al., 2006]. We predicted that the identified maternal behaviors would be strongly correlated with the IMMC dimensions, but that even when controlling for these behaviors, strong differences would remain between the two groups of mothers on each of the dimensions. This would provide evidence that the IMMC dimensions provide additional information about maternal care beyond that provided by the frequency data alone.

Methods

Subjects and Housing

The subjects of this study were 40 multiparous rhesus monkey (*Macaca mulatta*) mothers and their infants, studied during the first three months postpartum (2009-2012). Animals lived with their offspring in four different social groups at the Field Station of the Yerkes National Primate Research Center (Lawrenceville, GA), consisting of 38-100 adult females with their subadult, juvenile and infant offspring and 2-8 adult males. The groups were housed in outdoor compounds with indoor housing areas. Animals were fed a standard commercial low-fat, high-fiber diet (Purina Mills International, LabDiets, St. Louis, MO) *ad libitum* in the morning and afternoon, supplemented each day with seasonal fruits or vegetables, and water was freely available. All of the procedures described here adhered to the American Society of Primatologists principles for the ethical treatment of primates, and were performed in accordance with the Animal Welfare Act and the U.S. Department of Health and Human Services "Guide for the Care and Use of Laboratory Animals" and approved by the Emory Institutional Animal Care and Use Committee.

Of the 40 mother-infant pairs studied, 20 mothers were selected based on their history of nurturing, competent maternal care (Competent: 9 male and 11 female offspring), and the remaining 20 mothers were selected based on their histories of maltreating care (Maltreating: 14 male and 6 female offspring). The two groups were matched by dominance rank (Competent: high rank=7, middle=9, low=4; Maltreating: high rank=5, middle=8, low=7) and social group of origin, and mothers were selected from different matriline (i.e., they were unrelated individuals) whenever possible. Female social dominance ranks were assessed based on data on aggression and submission collected in previous studies. Infant maltreatment was defined as physical abuse, following behavioral definitions, observation protocols and inclusion/exclusion criteria described in detail for this species in previous publications [e.g., Troisi & D'Amato, 1983; Maestripieri, 1998; McCormack et al., 2006; McCormack et al., 2009]. Physical abuse was operationalized as at least three instances of violent behaviors of the mother directed towards the infant (dragging the infant by its tail or

leg, crushing it against the ground with the hand(s), sitting/stepping on it with one or both feet, throwing it, roughly grooming it, or carrying the infant with an arm away from the body preventing it from clinging) during the first three months of life [Maestripieri, 1998; Maestripieri et al., 2006; McCormack et al., 2006, 2009]. In addition, Maltreating mothers also exhibited high rates of early infant rejection, operationalized as the mother preventing contact or infant access to nipple by pushing the infant away or passively blocking chest with arm or twisting torso away. Both abuse and rejection behaviors produce high levels of distress in the infant [Maestripieri, Jovanovic, & Gouzoules, 2000; McCormack et al., 2006; Sanchez, 2006].

Procedures

Behavioral data collection—Behavioral observations of the mother-infant pairs were collected by four experienced coders from observation towers situated over each social compound, during the first three months postpartum using an adaptation of a well-established rhesus monkey ethogram [Altman, 1962], following previously published procedures [Maestripieri, 1998; McCormack et al., 2006, 2009]. Prior to data collection, inter-observer reliability was reached among the four coders, with percent agreements exceeding 80%. Each observation session lasted 30 minutes, and was performed five times per week in the first month postpartum, two times per week in the second month, and one time per week in the third month, for a total of 32 observations per mother-infant pair. This observation schedule was chosen in order to best document early maternal care received by the infant, including the occurrence of infant maltreatment, as the frequency of physical abuse is highest in the first month and decreases steadily thereafter [Maestripieri, 1998; McCormack et al., 2006]. Observations were done between 7:00 and 11:00 AM, when the animals were most active. All animals in the group were locked outdoors during observation sessions.

In addition to infant abuse and rejection the following behavioral data were collected to measure maternal behavior and mother-infant interactions: (1) percentage of time spent in physical contact and proximity (mother and infant within a 1 ft diameter of each other); (2) percentage of time cradling the infant (mother holds infant on her ventrum with one or both arms around the infant); (3) percentage of time the mother spent grooming the infant; (4) frequency of contact and proximity makes and breaks initiated by mother and infant towards each other; (5) frequency of maternal restraints (mother prevents infant from breaking contact by pulling its leg or tail); (7) frequency of maternal contact aggression (the mother bites, attacks or hits her infant); (8) frequency of maternal non-contact aggression (the mother chases, harasses or threatens her infant); (9) frequency of maternal avoidance (the mother turns or moves away in response to infant approach); (10) frequency of maternal genital inspections of infant; (11) frequency of fear grimaces directed towards each other (bared-teeth display); (12) frequency of lipsmacks directed towards each other (repeated lip movements); (13) frequency of limb carries (mother carries infant on her limb, with infant parallel to her arm); and (14) frequency of play interactions between mother and infant (including rough and tumble, chase play).

Instrument of Macaque Maternal Care development—A 22-item global rating instrument of the quality of maternal care (IMMC) was developed as a collaborative effort between a group of child development researchers familiar with both human and non-human primate development, and a team of researchers with expertise in the rhesus macaque mother-infant relationship. The instrument was created by adapting measures published in the Maternal Q-sort for macaques [Kondo-Ikemura & Waters, 1995], the Human Maternal Behaviors Q-Sort [Pederson & Moran, 1995], and the Free Play and Clean-Up task [Gardner et al., 1999; Pears & Ayres, 2000] for children (See Table 1). Items were selected from these instruments based on their applicability to rhesus monkey mother-infant behavioral interactions as well as their coverage of the full spectrum of maternal care qualities, such as maternal responsiveness, intrusiveness, protectiveness, tolerance of infant, how relaxed/comfortable she was when caring for the infant, etc. Each item was scored on a 5 point Likert scale, with 1 representing no occurrence of the behavior (0%), 3 representing moderate occurrence of the behavior (26-50%) and a 5 representing a high occurrence of the behavior (76- 100%). If the particular situation described in an item did not occur during the observation, then the event was scored as a “N/A”.

The coders completed the 22-item instrument immediately following each 30 min focal behavioral observation described above. Inter-observer reliabilities on the instrument scores were calculated between the coders, as well as with an “outside” rhesus macaque researcher who was blind to experimental condition (i.e., Competent versus Maltreating). For this, coders watched and scored a total of 10 videotapes of mother-infant interactions (5 from Maltreating mothers, 5 from Competent mothers), and the weighted percent agreements were calculated for each coder pair for the 22 items. Inter-observer agreements ranged from 69-81%, with an average of weighted agreement of 75% (78% for Maltreating, 72% for Competent), which is considered a good standard in the literature [Feinstein, 2002].

Data Reduction and Analysis

Development of maternal care dimensions—A team composed of human and non-human primate researchers, with expertise in the mother-infant relationship (n=8), reviewed the 22 items of the IMMC and categorized each into different dimensions of maternal care (e.g., Responsiveness, Protectiveness, Attachment, Warmth, Irritable, Permissiveness, etc.). Each researcher classified the items into 3-5 different categories. As a group, the researchers then evaluated the constructed categories, and determined the four primary categories that best defined the 22 items. The four maternal care dimensions were then labeled as: 1) Responsivity/Sensitivity (Items: 1-5), 2) Protectiveness (Items: 8-13), 3) Permissiveness (Items: 14-16), and 4) Irritability (Items: 6-7, 17-22).

Creation of maternal care dimension composites—After the four maternal dimensions were identified, the items were averaged to create a composite score for each dimension at each time point. Monthly scores were then created for each of the four dimensions, by averaging the composite scores for each dimension across each month. Item 6 had to be reverse-scored, and Item 13 was dropped from the analysis due to a very low occurrence of the behavior. Coherence of items within each maternal category was then tested as described below.

Analyses of IMMC reliability—Following the expert categorization, the internal reliabilities of each of the four dimensions at each month for the first three months postpartum were tested using criterion values suggested by Patterson and Bank [1986]. In order to examine the relationship of the dimensions with one another, we examined the correlations among the average scores of each of the four dimensions. We then conducted a scale analysis using SPSS. We assessed the inter-item correlations within each dimension (criterion = .20 or above), as well as Cronbach's alpha for each dimension at each time point (criterion value = .60 or above). Additionally, we conducted a principal components analysis (PCA) for each dimension at each time point to examine whether the items converged within their hypothesized dimensions, and evaluated the factor loadings for a one-factor solution (criterion value = .30 or above).

Analyses of IMMC validity—In order to assess the convergent and discriminant validity of the IMMC, we calculated Pearson correlation coefficients to examine the associations between each maternal dimension score and the individual maternal behaviors collected during the 30-minute focal observations. In order to be included in the correlational analyses, each behavior had to have been exhibited by at least 25% of the subjects, and driven by the mother. Several maternal behaviors were not included in the analyses due to low occurrences: non-contact aggression, avoidance, fear grimace, and play instances. In addition, we did not include the percentage of time mothers and infants spent in proximity/contact to one another, as this can be driven by either the mother's or the infant's behavior. We therefore correlated each of the maternal dimensions, averaged across the first three months postpartum, with the following individual maternal behaviors collected during focal observations, also averaged across the three months: (1) percentage of time spent cradling the infant; (2) percentage of time spent grooming the infant; (3) frequency of abuse, (4) frequency of contact/proximity makes towards the infant; (5) frequency of contact/proximity breaks from the infant, (6) frequency of infant restraints; (7) frequency of infant rejections; (8) frequency of contact aggression; (9) frequency of genital inspections of infant; (10) frequency of lipsmacks directed to the infant; (11) frequency of infant limb carries.

Concurrent validity was assessed by evaluating the extent to which Competent and Maltreating mothers differed on each of the maternal dimensions across the three months. For this, we used a group (Maltreating vs. Competent) $\times$ time (month 1, month 2, month 3) mixed repeated measures ANCOVA, which controlled for maternal rank. In cases where sphericity was violated, the Greenhouse-Geisser correction was used.

In our prior work, we found that Maltreating mothers differed significantly from Competent mothers on several key behaviors: infant rejection rates, infant abuse rates, and rates of contact/proximity breaks from infant [McCormack et al., 2006]. We therefore performed a series of MANCOVA's in order to determine 1) if these three maternal behaviors significantly influenced the IMMC dimensions, and 2) whether the IMMC dimensions differentiated Maltreating from Competent mothers, after controlling for infant rejection rates, infant abuse rates, and rates of contact/proximity breaks from the infant.

All data were analyzed in SPSS, v.15 and significance level set at $p < 0.05$.

Results

Internal Reliability Analyses

The inter-dimension correlational analyses revealed that all of the dimensions were significantly correlated with one another (Table II). The IMMC reliability analyses revealed high Cronbach's alphas for the four dimensions at each time point (Table III). In addition, all inter-item correlations were above .20, for each item at each time point (Table III). The PCA demonstrated that items had high factor loadings (see Table IV) for their hypothesized 1-factor solution at each time point (all above .30). These findings provide statistical support for the internal reliability of the four maternal care dimensions that were created from the 22-item scale.

Validity Analyses

The correlational analyses between the composite scores of each of the four resulting maternal care dimensions and the maternal behaviors for the first three months postpartum can be found in Table V. Strong convergent validity was demonstrated by the positive correlations found between the maternal Irritability dimension scores and the following maternal behaviors: break proximity from infant, contact aggression towards infant, infant rejections, infant restraints, infant abuse, and limb carrying of infant. The Protectiveness and Responsiveness dimensions were negatively correlated with many of the same negative maternal behaviors (break proximity from infant, rejections of infant, restrains of infant, and limb carrying of infant). Responsiveness, but not Protectiveness, was also negatively correlated with maternal contact aggression and infant abuse. Permissiveness was negatively correlated with infant rejections, abuse, and durations of infant cradle and grooming. There were no other significant correlations between the remaining three dimensions and cradle and grooming durations. None of the dimensions were significantly correlated with either maternal genital inspections or lipsmacks directed to the infant, demonstrating their discriminant validity.

We also investigated whether the correlations found between the dimensions and the maternal behaviors were being driven by the Maltreating mothers, by re-running the correlational analyses on the Maltreating and Competent mothers separately. Of the original 20 significant correlations found on the entire group, only four remained within the Maltreating mothers (Irritability and break proximity with infant, $r(18)=.52$, $p<.01$; Irritability and contact aggression towards infant, $r(18)=.47$, $p<.01$; Irritability and infant rejections, $r(18)=-.33$, $p<.01$; Sensitivity and limb carrying of infant, $r(18)=-.46$, $p<.01$), and only three remained within the Competent mothers (Irritability and restrains of infant, $r(18)=-.52$, $p<.05$; Protectiveness and restrains of infant, $r(18)=.61$, $p<.01$; Sensitivity and restrains of infant, $r(18)=.53$, $p<.05$).

Repeated measures ANCOVA's were performed to examine the instrument's concurrent validity, that is, how well the dimensions distinguished two different groups of mothers (Maltreating vs. Competent). There was a main effect of group for the Irritability dimension, $F(1,37)=149.60$, $p<.001$, with Maltreating mothers scoring higher (Mean (M)=2.10, Standard Error of the Mean(SEM)=.06) than Competent mothers (M=1.38, SEM=.02) across

the three months (see Figure 1A). There were no other main effects or interactions for this dimension. Maltreating mothers scored significantly lower than Competent mothers across the three months in the other three dimensions: Sensitivity/Responsivity ($F(1,37)=136.18$, $p<.001$, Figure 1B; Maltreating mothers: $M=3.17$, $SEM=.09$; Competent mothers: $M=4.45$, $SEM=.06$), Permissiveness ($F(1,37)=40.42$, $p<.001$, Figure 1C; Maltreating mothers: $M=3.30$, $SEM=.12$; Competent mothers: $M=4.14$, $SEM=.06$), and Protectiveness ($F(1,37)=72.26$, $p<.001$, Figure 1D; Maltreating mothers: $M=3.39$, $SEM=.10$; Competent mothers: $M=4.34$, $SEM=.06$). All of these were group main effects, with no other main or interaction effects detected for these dimensions, except a significant main age effect detected for Protectiveness ($F(1.72, 63.80)=5.36$, $p=.01$), which significantly decreased across the three months for both groups. The ANCOVA analyses revealed that maternal rank did not significantly influence any of the effects reported here.

A MANCOVA was performed to determine whether the IMMC dimensions differentiated the groups after controlling for focal observation measures shown in previous research to most differentiate maltreating from non-maltreating mothers (infant rejections rates, infant abuse rates, and rates of contact/proximity breaks from the infant). As expected, the covariates significantly influenced the combined dependent variable, Pillai's Trace = 1.08, $F(12, 102)=4.77$, $p<.001$. However, even after controlling for these variables, the IMMC dimensions significantly differed for the Maltreating and Competent mothers, Pillai's Trace=.75, $F(4,32)=24.26$. Follow-up univariate effects reported in the MANCOVA indicated that each of the four dimensions differentiated the two groups: Sensitivity/Responsivity: $F(1,35)=48.99$, $p<.001$; Permissiveness: $F(1,35)=11.80$, $p<.01$; Protectiveness: $F(1,35)=34.09$, $p<.001$; Irritability: $F(1,35)=59.46$, $p<.001$. Table VI presents the adjusted and unadjusted means for the Maltreating and Competent mothers across each dimension.

Discussion

The goal of this study was to develop an instrument to measure global dimensions of maternal care in rhesus monkeys that would complement and add information to the behavioral data collected using a well-established ethogram during the first months postpartum. Our findings indicate that the 22 items used in the IMMC can be reliably scored, and can be reduced to four distinct dimensions of maternal care with high levels of internal reliability and validity: 1) Sensitivity/Responsivity, 2) Protectiveness, 3) Permissiveness, and 4) Irritability. Although the inter-dimension correlations in Table II indicated that three of the four dimensions were positively correlated with one another, this is not uncommon in many studies on maternal care [Pederson, Moran, Sitko, Campbell, Ghesquire, & Acton, 1990; Kertes, Donzella, Talge, Garvin, Van Ryzin, & Gunnar, 2009]. The follow-up reliability and validity analyses provided further evidence for the utility of examining these dimensions separately. The internal reliability analyses indicated that the items within each dimension strongly represented each of the identified constructs, with the PCA results providing further support that each of the four dimensions is unidimensional. The four dimensions of maternal care had high construct validity, as demonstrated by the correlations with relevant mother-infant frequency and durational behaviors. In addition, the sensitivity of the scales to discriminate between two types of mothers (Maltreating versus

Competent) indicates that this instrument has strong concurrent validity. The group differences remained for the dimensions, even after factoring out individual maternal behaviors previously identified to be different between Maltreating and Competent mothers, indicating that the dimensions explained additional variance between the groups. Our findings suggest that the IMMC has the potential to capture global aspects of the mother-infant relationship that complement individual behaviors collected through focal observations, with good sensitivity to detect maternal care differences between Maltreating and Competent mothers.

Not only were there multiple indices of strong internal reliability among the four maternal dimensions, but these reliabilities remained strong across time. We focused on the first three months postpartum because it is when the most intense caregiving takes place, prior to weaning. Although the rhesus mother-infant relationship changes across the first three months, specifically in relation to the duration and frequency of caregiving and protective behaviors as the mothers let infants explore more [Hinde & Spencer-Boothe, 1967; Simpson & Simpson, 1986; Berman, 1990; Maestripieri, 1994], the four dimensions of maternal care remained stable across this developmental period. The stability of the dimensions suggests that the individual items of each dimension remain closely associated with one another, despite fluctuations in the occurrences of each item. Future studies should evaluate the reliability and validity of the scale at later ages, particularly during weaning.

Strong convergent validity was demonstrated by the significant correlations detected between the four maternal dimensions and the relevant individual maternal behaviors. As expected, the more negative maternal behaviors (abuse, contact aggression, rejection, restraints, limb carries, and proximity breaks) were negatively correlated with the positive dimensions of maternal care (Protectiveness, Sensitivity/Responsiveness, and Permissiveness), and positively correlated with Irritability. The remaining negative behaviors (break proximity, restrain, abuse, and limb carry) correlated in the expected directions with most of the dimensions, while contact aggression only correlated with two of the dimensions: Irritability and Sensitivity/Responsiveness. These different patterns of association with the individual behaviors further attest to the utility of measuring the four dimensions of the IMCC separately.

Our findings also revealed that the majority of the significant dimensional correlations were with negative (and not nurturing) aspects of maternal behavior. In fact, the only correlations detected between nurturing maternal behaviors and the IMMC dimensions were the negative correlations between durations of grooming or cradling the infant and Permissiveness. These negative correlations make sense given that if the mother is cradling and grooming her infant for extended periods of time, she is most likely not demonstrating permissive behavior. In order to determine if, perhaps it was the Maltreating mothers that were driving these effects, we split the correlational analyses by group. Only four of the original twenty correlations remained within the Maltreating mothers. These supplemental correlations indicate that the maltreating mothers did not drive the original twenty correlations, but it was the variability in maternal behavior across all 40 animals that contributed to the significant findings. These results, taken together, suggest that the more negative maternal behaviors may better characterize different maternal styles, and can be used to distinguish groups of

animals. This also suggests that the more negative maternal behaviors may be stronger predictors of infant developmental outcomes. Although there is little doubt that positive parental behaviors influence infant development, the human literature also indicates that it is the more negative aspects of parental care that have the greatest impact on infant developmental outcomes [Lyons-Ruth et al., 1987; Martins & Gaffan, 2000; Goodman, Rouse, Connell, Broth, Hall, & Heyward, 2011; Lindert, von Ehrenstein, Grashow, Gal, Braehle, & Weisskopf, 2014].

It is important to discuss the differences between the maternal care dimensions created in this study and the factors identified in earlier reports [e.g., Protectiveness, Rejection, and sometimes Warmth/Independence; Fairbanks, 1996; Bardi et al., 2001; Bardi & Huffman, 2002; Maestripieri et al., 2006; Maestripieri et al., 2009]. Though there is some overlap in the previously reported factors, and the dimensions used in this study, there are important differences between them regarding their computation, meaning, and the context in which the behaviors were manifested and coded. In earlier studies, the Protectiveness factor has generally consisted of maternal contacts and approaches to the infant, and maternal restraints and grooms of the infant; the Rejection factor has generally consisted of maternal contact breaks and leaves from the infant, less time in contact with the infant, and rejection of infant; and the Warmth/Independence factor consisted of maternal grooming and nursing/ cradling of the infant, and time in contact with the infant [Fairbanks, 1996; Bardi et al., 2001; Bardi & Huffman, 2002; Maestripieri et al., 2006; 2009]. Unlike the current study, these behaviors were coded without specifying the social context in which they took place, contributing to the factor loadings and creation. However, in our study, the context in which the behavior takes place is extremely important for most of the items contributing to each dimension. For example, the Protectiveness dimension captures the extent to which the mother not only protects, but monitors and signals to the infant when it is away from her (Q8-9), as well as the response of the mother to the infant during threatening situations (Q10-12). Although the current maternal Irritability dimension does include items that address maternal contact breaks and rejections, it is conceptually different from the previously identified Rejection factor to the extent that it also captures the degree of several forms of maternal negative behavior (e.g., maternal abuse, restrains, bites, threats), under several different contexts (Q18-22). Although the Maternal Sensitivity and Permissiveness dimensions reported in this study do include measures that are found in the previously reported Warmth/Independence factor, such as maternal contact, grooming and cradling [Bardi et al., 2001, 2002; Maestripieri et al., 2009], the two IMMC dimensions also assess how well the mother adjusts her caregiving in response to infant cues and behaviors (Q1-3; 14-16). This was done specifically because the nature of the mother-infant relationship is often better understood under a variety of contexts. Maestripieri [2001] argues that when comparing the maternal styles of various non-human primates, inconsistencies may appear because of the environmental pressure differences on each of the primate groups. Therefore, in order to understand and compare mother-infant interactions, either within or between primate groups, it is crucial to account for the environmental pressures or context in which they are exhibited. In addition, investigations of maternal styles in human populations consistently take into consideration the context and environmental factors [e.g., Schneider-Rosen & Rothbaum, 1993; Pears & Ayres, 2000; Vliegen, Luyten, & Biringen, 2009;

Dolberg et al., 2010; Leerkes, 2011]. We therefore argue that we have made a significant contribution to the non-human primate literature with the development of this scale, as the dimensions provide information that is context-specific, and allow for greater comparisons with the human literature.

Strong concurrent validity was demonstrated for the IMMC when we compared Maltreating to Competent mothers. Maltreating mothers were more Irritable than Competent mothers. Previous research [Maestripieri, 1998; Maestripieri et al. 2006] has reported that Maltreating mothers tend to reject their infants more than Competent mothers. Our research complements this finding, and also suggests that Maltreating mothers tend to use punishment and physical behaviors to control their infants with greater frequency than Competent mothers. On the other hand, Maltreating mothers scored lower than Competent mothers on the Protectiveness dimension, contrary to previous reports that Maltreating mothers were more protective than Competent mothers [Maestripieri, 1998], or not different at all [Maestripieri et al., 2006]. Again, this is probably due to the fact that our Protectiveness dimension addresses context, assessing maternal monitoring of infant, and her response during threatening situations, and not simply the contact makes and restraints of infant. Maltreating mothers also scored lower on the Permissive dimension. The behaviors in this dimension tap into measures of Secure Base behavior and the extent to which the mother allowed her infant to come and go from her, and freely explore on and around her. In the human literature, these behaviors often characterize a mother of a securely attached child [Bowlby, 1969; Ainsworth et al., 1978]. Maltreating human mothers have consistently been found to have insecurely attached children [see Cyr, Euser, Bakermans-Kranenburg, & Van Ijzendoorn, 2010 for a meta-analytic review], adding additional validity to the current study. Finally, in this study Maltreating mothers scored lower than Competent mothers on the Sensitivity/Responsivity dimension, indicating that Maltreating mothers were not as likely to adjust their maternal care behaviors based on infant needs and cues. These findings are consistent with the frequent reports in the human literature that abusive and neglectful mothers are less responsive and sensitive to the cues of their infant(s) [Lyons-Ruth et al., 1987; Cicchetti, Rogosch, & Toth, 2006]. Taken together, the strong group differences noted in this study on the four maternal dimensions, along with the congruence with reports in human populations, suggests that this instrument may be useful in the characterization of maternal care qualities among rhesus macaques, and the differentiation of “at risk” groups of animals.

The MANCOVA analyses revealed that maternal behaviors, previously identified as being different between Maltreating and Competent mothers, significantly influenced the four dimensions. This is not surprising, given that many of the IMMC questions specifically pertain to maternal rejection, abuse and contact breaks from the infant. However, even after factoring out the influence of these three variables on the dimensions, there were still strong differences between the maternal groups on all of the IMMC dimensions. This indicates that the IMMC is indeed providing additional information about the global quality of overall maternal care that are not captured by the collection of individual behaviors.

There are several strengths and weaknesses of the IMMC developed in this study. As previously discussed, the instrument demonstrated strong validity, and the findings converge

nicely with similar findings of maternal style differences between maltreating and non-maltreating human populations [Lyons-Ruth et al., 1987; Cicchetti, et al., 2006]. Secondly, inter-rater reliability was high among the four observers, and was relatively easy to reach, with no additional training needed after the first round of observations. All 22 items were easily rated and completed immediately following a focal observation of the mother-infant pair, and on average took 5 minutes to complete. The fact that this instrument can be completed so quickly is an important consideration for other researchers who may be interested in capturing additional information on mother-infant pairs. That said, there are several considerations that should be noted. The IMMC was completed following every 30-minute focal observation, in which the observers collected specific information related to maternal and infant behavior. We would advise other researchers who are interested in using this scale to follow a similar procedure; the IMMC was developed to supplement behavioral data, and scoring of the IMMC may be more sensitive following an observational period; however, this is an empirical question that should be tested in future studies. Secondly, although statistical criteria were met for all four dimensions, there was some variability across the Permissiveness and the Irritability dimensions. The inter-item correlations had wider ranges for these two factors, and in addition, the factor loadings and Cronbachs alpha's were lowest for item 15 (included in the Permissiveness) and item 20 (part of the Irritability dimension). Future researchers who use our scale should pay particular attention to these two items. Third, there were instances for all items in which the event described did not occur during the focal observation, resulting in a "N/A" score. In the current study, this was only problematic for Item 13, which was scored as "N/A" on 93% of the observations. Although this item was initially placed in the Protectiveness dimension, it was not included in the analyses of the dimensions. Should future researchers choose to collect data on this item, a statistical assessment should be run to determine whether this item truly belongs in the Protectiveness dimension.

Further studies are needed to confirm the predictive validity of the IMMC. Previous research has shown that adolescents of more protective mothers are more cautious in novel situations, and less interested in the external environment [Fairbanks & McGuire, 1988; Bardi & Huffman, 2002], while adolescents of more rejecting mothers initiate more contacts with other group members, and are more bold in approaching an unknown male [Fairbanks, 1996; Bardi & Huffman, 2002]. These findings suggest that more restrictive and controlling maternal care may delay infant independence and exploration, while more rejecting maternal care may actually foster it. The development of the IMMC by our group has been part of a larger developmental study in which we collect many behavioral measures on the offspring throughout infancy and into adolescence. Future studies will need to evaluate whether the four dimensions of maternal care predict later infant developmental outcomes, particularly social relations with other animals.

In conclusion, the newly developed instrument reported in this paper provides a novel approach for researchers interested in measuring global aspects of maternal care in rhesus macaques across a variety of social contextual situations. The statistical analyses suggest that the four dimensions have strong psychometric characteristics, as evidenced by the validity analyses. It was also demonstrated that the dimensions of the IMMC may be useful in distinguishing between groups of mothers with very different maternal care styles

(Maltreating vs Competent), and that these dimensions correlated strongly with negative maternal behaviors. Future studies need to evaluate the extent to which the four maternal dimensions predict infant developmental outcomes.

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Figure 1.

(A) Maltreating mothers scored higher on the Irritability dimension compared to Competent mothers (Group effect: $F(1,37)=149.60$, $p<001$). (B) Maltreating mothers scored lower on the Sensitivity/Responsivity dimension compared to Competent mothers (Group effect:

$F(1,37)=136.18, p<001$). **(C)** Maltreating mothers scored lower on the Permissiveness dimension compared to Competent mothers (Group effect: $F(1,37)=40.42, p<001$). Note: Figures A-C, no time effect; data plotted across time for illustrative purposes only. **(D)** Maltreating mother scored lower on the Protectiveness dimension compared to Competent mothers (Group effect: $F(1,37)=72.26, p<001$). Maternal Protectiveness also decreased across time for both groups (Time effect: $F(1.72, 63.80)=5.36, p=.01$).

Table I

Instrument of Macaque Maternal Care (IMMC)

For the below items, rate how often each behavior occurred during the observation period. For items that refer to events that never occurred during the observation, please rate "N/A" (i.e. for Item 1, if infant never approaches mother, then score "N/A").

Use the following scale for all questions:

N/A	1 Never (0%)	2 Rarely (1-25%)	3 Sometimes (26-50%)	4 Often (51-75%)	5 Always/almost all time (76-100%)
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Sensitivity/Responsivity Items:

- 1 Mother makes herself available when infant approaches her (opens body to infant, does not walk away or block nipple).
- 2 Mother responds to infant's signals (e.g. distress) and bids for contact/grooming.
[Note: bids for contact may be screams/tantrums because mother left it]
- 3 Mother adjusts caretaking behavior based on infant's response (e.g. stops grooming if infant doesn't like it).
- 4 Mother comforts infant when distressed/upset/fearful.
- 5 Mother holds infant on ventrum right away when it is distressed and returns to mother for contact.

Protectiveness Items:

8. Mother monitors infant when away from her.
9. Mother signals infant to follow when she moves away.
10. During threatening events, mother makes/maintains contact with infant or prevents it from leaving.
[Note: if infant is away, mom knows exactly where it is.]
11. Mother retrieves infant right away if it is attacked/threatened or emits distress calls.
12. Mother "guards" infant (restrains/cradles/draws it closer) when a potentially threatening animal walks by (adult male, high ranking/aggressive female).
13. If infant is kidnapped, mother monitors the situation (follows kidnapper, makes bids for contact).

Permissiveness Items:

14. Mother allows infant to use her body to play, explore, climb from, etc.
15. Mother allows infant to explore its surroundings and/or play.
16. Mother allows infant to leave and return to her (refueling: e.g. play & return; explore & return).

Irritability Items:

6. Mother is comfortable and relaxed when in contact with infant.
[Opposite: mother seems uncomfortable by infant's behavior on ventrum, moves infant's position, jerks or shows other annoyed behaviors].
7. Mother appears distressed/annoyed by infant's demands.

17. Mother is inconsistent in responding to infant's needs or bids for contact/interaction.
[1: very consistent; 5: very inconsistent]
18. Mother goes from cradling/caring for infant to abuse/rejection (or vice versa) without clear reason.
19. Caretaking bouts are brief. Mother stops infant's care without clear reason (e.g. interruption, infant signal).
20. Mother uses only physical behaviors to control infant (e.g. restrains, punishes by biting), instead of using facial expressions or gestures (e.g. threat, lip smacking).
21. Mother punishes infant (bites, slaps) for minor negative behaviors.
22. Mother continues/repeats punishment even after infant stops negative behavior.

Note: Items were scored in their numerical order, without the inclusion of dimension names.

Table II

Inter-dimension correlational analysis

	Permissiveness	Protectiveness	Irritability
Sensitivity/Responsivity	.79**	.92**	-.85**
Permissiveness		.62**	-.69**
Protectiveness			-.75**

p<.01

Table III
Cronbach's alphas and ranges of inter-item correlations for each dimension

	Month 1		Month 2		Month 3	
	Cronbach α	Inter-item correlations	Cronbach α	Inter-item correlations	Cronbach α	Inter-item correlations
Sensitivity/Responsivity (Items: 1-5)	0.98	.94-.97	0.99	.96-.98	0.97	.90-.97
Protectiveness (Items: 8-12)	0.79	.61-.75	0.90	.65-.87	0.92	.73-.88
Permissiveness (Items: 14-16)	0.80	.50-.85	0.83	.54-.86	0.69	.25-.70
Irritability (Items: 6,7,17-22)	0.92	.48-.93	0.92	.47-.93	0.87	.33-.81

Table IV
PCA factor loadings for a one-factor solution, across dimensions

	Month 1	Month 2	Month 3
Sensitivity/Responsivity			
Item 1	0.96	0.97	0.96
Item 2	0.98	0.98	0.98
Item 3	0.98	0.98	0.95
Item 4	0.98	0.99	0.96
Item 5	0.97	0.98	0.94
Protectiveness			
Item 8	0.90	0.76	0.87
Item 9	0.74	0.88	0.83
Item 10	0.89	0.92	0.83
Item 11	0.72	0.92	0.93
Item 12	0.84	0.87	0.89
Permissiveness			
Item 14	0.88	0.88	0.92
Item 15	0.74	0.76	0.48
Item 16	0.94	0.95	0.90
Irritability			
Item 6	0.92	0.89	0.89
Item 7	0.96	0.88	0.85
Item 17	0.91	0.95	0.89
Item 18	0.86	0.89	0.76
Item 19	0.84	0.85	0.70
Item 20	0.64	0.54	0.39
Item 21	0.75	0.80	0.67
Item 22	0.61	0.79	0.60

Table V
Pearson correlations between maternal dimensions and maternal behaviors

		Cradle infant (d)	Groom infant (d)	Break proximity from infant (f)	Make proximity to infant (f)	Contact aggression to infant (f)	Reject infant (f)	Restrain infant (f)	Abuse infant (f)	Limb carry infant (f)	Genital inspect infant (f)	Lipsmack to infant (f)
Irritability	<i>r</i>	0.04	0.02	.52**	0.20	.47**	.79**	-.33*	.58**	0.39*	0.08	0.01
	<i>p</i>	0.80	0.89	0.001	0.21	0.002	<.001	0.04	<.001	0.01	0.62	0.95
Protectiveness	<i>r</i>	0.12	0.10	-.51**	0.04	-0.30	-.60**	.41**	-0.27	-.36*	0.10	0.09
	<i>p</i>	0.47	0.54	0.001	0.79	0.06	<.001	0.008	0.10	0.02	0.55	0.59
Sensitivity/Responsivity	<i>r</i>	0.003	0.002	-.50**	-0.10	-.34*	-.67**	.36*	-.49**	-.40*	0.01	0.01
	<i>p</i>	0.99	0.99	0.001	0.53	0.03	<.001	0.02	0.001	0.01	0.93	0.97
Permissiveness	<i>r</i>	-.33*	-.35*	-0.20	-0.07	-0.19	-.59**	0.11	-.68**	-0.20	-0.05	-0.12
	<i>p</i>	0.04	0.03	0.21	0.67	0.24	<.001	0.52	<.001	0.21	0.75	0.45

duration

frequency

p<.01

p<.05

Table VI
Adjusted and Unadjusted means for Maltreating and Competent Mothers by Dimension

Dimension	Competent Mothers		Maltreating Mothers	
	Unadjusted Mean	Adjusted Mean	Unadjusted Mean	Adjusted Mean
Sensitivity/Responsiveness	4.45	4.32	3.17	3.31
Permissiveness	4.14	3.99	3.30	3.44
Protectiveness	4.34	4.30	3.39	3.43
Irritability	1.38	1.51	2.09	1.96