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Challenges to Bonnet Monkey (*Macaca radiata*) Social Groups: Mother–Infant Dyad and Infant Social Interactions

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Abstract

The mother-infant dyad is crucial to early development in a variety of species. The complexity of social groupings in nonhuman primates makes this relationship resilient as well as susceptible to early challenges associated with environmental chaos. Quantitative behavior observations of bonnet monkey mother-infant interactions were collected from 28 mother-infant dyads between one and twelve months of age. Social groups were subjected to several prenatal and/or postnatal housing relocations within a single year resulting in two study groups. One group experienced relocations (ATYPICAL, $n = 14$) and the second group (TYPICAL, $n = 14$) was conceived and reared in the same location. Behaviors in the ethogram included mother-infant interactions and infant social interactions with other members of the group. Observations between ages of two to four months were analyzed by a mixed model analysis of variance including fixed effects of per and postnatal history (TYPICAL, ATYPICAL), age, and history by age interaction and random effects of mother and infant nested within mother. A significant effect of relocation history was noted on a number of infant behaviors. ATYPICAL infants were out of direct contact with their mother at an earlier age but remained in her proximity. Control of proximity shifted to offspring in the ATYPICAL group compared to the TYPICAL group. Furthermore, greater social interactions between two and four months of age with other members of the social group as well as the ir mother were observed in the ATYPICAL group. It is suggested that continuous challenge associated with relocation may affect the infant at later developmental ages due to these early differences in ways that are yet unclear.

Keywords

Hinde Proximity Index; mother–infant relationship; developmental challenge; social relationships

Introduction

Stressors and challenges affecting the mother–infant dyad in the prenatal and postnatal period have the potential to disrupt developmental trajectories of behavioral and physiological systems in the offspring (Coe & Laudenslager, 2007). For example, prenatal conditions that lead to reduced birth weight and/or later endocrine dysregulation are also associated with increased risk for a number of neurodevelopmental psychopathologies such as schizophrenia (Roseboom et al., 2001; St Clair et al., 2005) perhaps via changes in gene expression (Hall, 2007). The Barker hypothesis (Barker, 2004) of prenatal origins of adult disease suggests that prenatal events may program the developing organism before birth to prepare for later environmental challenges such as reduced food resources and thereby reset endocrine and cardiovascular set-points for example. Postnatal events are equally powerful in altering the developmental trajectory and act continuously with events occurring prenatally.

In rodents, the patterning of maternal licking of pups redirects the regulation of her offspring's hypothalamicpituitary adrenal (HPA) axis regulation via basic processes such as DNA methylation (Kaffman & Meaney, 2007; Meaney & Szyf, 2005; Meaney, Szyf, & Seckl, 2007; Szyf, Weaver, & Meaney, 2007). In nonhuman primates, differences in the early mother–infant relationship impacts subsequent behavioral responses of adolescents to new social groups (Weaver, Richardson, Worlein, De Waal, & Laudenslager, 2004), interactions with novelty (Simpson, Gore, Janus, & Rayment, 1989), as well as characteristics such as impulsivity (Fairbanks, 1993; Fairbanks & McGuire, 1993; Fairbanks, Melega, Jorgensen, Kaplan, & McGuire, 2001).

The study of nonhuman primates permits assessment of effect(s) of early challenges and/or interventions on their developmental trajectory within a relatively brief period of time whereas similar studies in humans take as many as 15 or more years for validation (Olds, Kitzman, et al., 2007; Olds, Sadler, et al., 2007). The macaque monkey begins weaning around 4–5 months, the onset of puberty occurs between 2–3 years, and reproductive maturity is reached at 3–6 years depending on species as well as gender (Nowak, 1999; Rao et al., 1997; Rao et al., 1998; Rawlins & Kessler, 1986). The effects of early social challenges have been followed longitudinally with regard to biomarkers of immune function (Laudenslager, Berger, Boccia, & Reite, 1996) as well as cross-sectional observation of adults (Laudenslager, Capitanio, & Reite, 1985). Importantly, extensive information regarding typical development processes in macaque infants and mother–infant dyads is available (Berman, 1990, 1992; Berman, Rasmussen, & Suomi, 1997; Kaufman & Rosenblum, 1966; Maestripieri, 1994; Maestripieri, Lindell, & Higley, 2007; Reite & Short, 1980; Reite & Short, 1986). Complexity of their social organization makes nonhuman primates ideal for the study of biobehavioral developmental processes.

The social environment of captive nonhuman primates is frequently modified in association with colony management or for empirical studies. For example, the introduction of a new male into a social group of vervet monkeys, *Chlorocebus aethiops sabaesus* (previously called *Cercopithecus aethiops sabaesus*), is associated with significant alterations of the mother's relationship to her offspring (Fairbanks & McGuire, 1987). Following the introduction of the new male to the social group, vervet mothers with young infants restrain them more often, spending more time in ventral contact with their infants. Two orthogonal mothering dimensions were observed: protection and rejection. Mothers who scored low on both dimensions were labeled "laissez faire." In a recent study of 60 adolescent vervet monkeys, we noted that plasma γ -INF (a soluble immune regulatory molecule involved in inflammation) showed consistent and significant relationships to their early maternal experience (Laudenslager, Fairbanks, & Jorgenson, 2006). Infants experiencing less contact with their mother in the second and third month of life had higher plasma γ -INF levels as juveniles. Relatively neglectful mothers were less likely to restrain them. Infants with neglectful mothers had significantly higher rates of both approaching and leaving their mothers, suggesting that they were taking a more active role in exploring the environment at an earlier age. To summarize, early mother–infant relationships of nonhuman primates affect a number of biobehavioral dimensions.

Under free-ranging conditions variations in availability of resources are a way of life (Laudenslager & Kennedy, 2007). Manipulating foraging demands of captive bonnet monkeys, *Macaca radiata*, has significant effects on the mother–infant dyad (Andrews & Rosenblum, 1988, 1991; Plimpton, Swartz, & Rosenblum, 1981; Rosenblum & Andrews, 1994; Rosenblum & Pauly, 1984). When bonnet monkey mothers experienced unpredictable foraging demands, they showed elevated aggressive and fewer affiliative interactions with members of the social group and spent less time with their infants. The offspring reared during periods of unpredictable foraging demands displayed a number of biobehavioral consequences in comparison to infants raised under conditions when foraging requirements were minimal. Infants raised during high foraging demand clung to their mother and participated in less social play within the group. Long-term consequences included a greater increase in cortisol and transforming growth factor- β following social challenge in adolescent bonnet monkeys that experienced these unpredictable high demand foraging situations compared to reared infants under low foraging demands (Smith, Batuman, Trost, Coplan, & Rosenblum, 2002). These experiences may predispose the offspring to increased risk for the metabolic syndrome (increased body mass index, insulin level, and triglycerides) as adults (Kaufman et al., 2005). The Barker hypothesis spills over to postnatal events as well and reflects the importance of both pre- and postnatal periods.

Here we report the consequences of social housing relocation challenges on offspring of bonnet monkeys and compare them to offspring who experienced no relocation. These relocation experiences are not viewed as a single event but a continuous challenge affecting mother and infant prenatally and postnatally. These observations form the background for the study of longitudinal effects on the offspring of these typical and atypical early experiences.

Methods

Subjects

A total of 28 young bonnet macaque (*M. radiata*) monkey offspring (15 males and 13 females) were observed between 2 and 4 months of age. All subjects were born to single male harem groups and reared with their mothers until 24 months of age. The breeding colony experienced two relocations as described below. This study was approved by each institution's Animal Care and Use Committee. Each institution has full AALAC accreditation and all experimental procedures were conducted in accordance with the National Institute of Health Guide for the Care and Use of Animal Subjects.

Detailed characteristics of the subjects are provided in supporting material (Appendix 1).

Relocation and Housing Settings

Two housing relocations were experienced: the first occurred within the same institution (06/15/05) to a retrofitted facility (Site 1 to Site 2) which did not provide concealed observation of the groups (University of Colorado Denver) and the second move (06/19/06) was to an out-of-state institution (Site 2 to Site 3) without concealment of observers and with indoor-outdoor enclosures (Wake Forest University). Timing of these relocations relative to conception are indicated in Figure 1.

At Sites 1 and 2, subjects were housed indoors in breeding groups that consisted of an adult male, 2–4 adult females, and offspring of various ages in pens ranging from 2.7 m×4.1m×4m to 4.5 m × 4.06 m × 4 m with sanitizable walls, wire mesh ceilings, and randomly located PVC piping for sitting and climbing. Lighting was a 14hr/10hr light/dark cycle (lights on at 0700 hr) with temperature maintained at $23 \pm 3^{\circ}\text{C}$ (Laudenslager et al., 1995; Laudenslager, Held, Boccia, Reite, & Cohen, 1990). Pens were joined to an adjacent pen via a transfer door through which subjects could move back and forth providing 16–26 m² of floor space. Floors were spread with a wood chip substrate for foraging. Commercial monkey biscuits (Purina # 5045) were provided at 0900 hr; food and water (via two sipper tubes/pen) were available ad libitum. Fresh supplemental forage (fruit, raw vegetables, and seeds) and were placed in the pen between 1230 and 1430 hr. Each pen at Site 1 included a one way observation window for collecting behavioral observations unobtrusively. At Site 2, pens had open caging such that behavioral observers, care staff, and other social groups were visible to the monkeys. Observers sat within 1 meter of the pen.

Site 3 was similar in space consisting of interconnecting quadrant style pens with two indoor and two outdoor sections (2.4 m×2.4 m×2.7m/section or a total of 23 m² floor area) for each social group. Structures for climbing and swinging as in Sites 1 and 2 were also available as well as weather permitting ad lib access to any of the quadrants. Housing at Site 3 included two quadrants located outdoors which was restricted when outdoor temperature dropped below 5°C or during pen cleaning. Indoor pens were heated during the winter months and maintained between 16 and 24° C. Pens were exposed to natural lighting from the outside. Inside pens were maintained on a 12:12 light cycle. Feeding (Purina Monkey Biscuits #5038) occurred approximately 30 min prior to afternoon (PM) behavioral observations and 2–3 hr prior to morning (AM) observations. Fruit, vegetables, ice cubes containing small

fruit, vegetable, seeds, flavors and colors, popcorn, and/or seeds were distributed in the afternoon following observation.

Study Group Definitions

For the present analysis, groups were defined as either TYPICAL or ATYPICAL based the timing of relocation(s) relative to estimated conception and early postnatal housing, Figure 1. Conception was estimated as 166 days before birth based on the average gestation period for the bonnet macaque (Rao et al., 1998). Subjects ($n = 14$) were considered TYPICAL only if conceived more than three months after relocation to Site 3. This permitted habituation to the new housing before a conception occurred. The ATYPICAL group experienced relocation to a new facility either during their mother's pregnancy ($n = 11$) or shortly before conception ($n = 3$, B36, B37, and B44). We have not distinguished pre from postnatal relocations but include relocation(s) occurring during gestation or conceptions within three months after relocation in the ATYPICAL group. The first animal (B46) born in the TYPICAL group (04/19/07) was estimated to have been conceived more than 4 months (11/04/06) following the colony transfer to Site 3 after the colony had completed quarantine and adapted to the new setting. The TYPICAL group was housed under constant conditions beginning before conception and not disturbed in any manner during the three month postnatal period.

Behavioral Observations

Observations encompassed 2–4 months of age (see supplemental Appendix 1) using commercial software (The Observer 5.0, The Netherlands) to record behaviors (see supplemental Appendix 2). Observations were either coded from videotaped sessions or in real-time by an observer in full view of the animals. This ethogram was based on previous ethograms developed by our group (Laudenslager et al., 1990; Reite & Short, 1980; Reite & Short, 1986; Weaver et al., 2004) and modified for both video as well as live observations. A total of four behavioral classes (1. Mother–Infant, 2. Other–Infant, 3. Infant Self, and 4. Infant Social) were scored simultaneously but were mutually exclusive within a class. Behaviors in the mother–infant and other–infant classes included modifiers that indicated initiate (I), receive (R), or unknown (U) with respect to dyadic interactions. Since Vocalization and Nursing could not be reliably scored from video media, they were not included as distinct behavioral categories in the analysis. State behaviors within each class were mutually exclusive and exhaustive. For analysis, *state behaviors* were converted by The Observer software to percent of total time observed within the class and *event behaviors* were converted to rate/minute. Behaviors on which the present report is based are indicated in ***bold italics*** in supplemental materials (Appendix 2).

Wide angle video observations were collected from a fixed location that covered the majority of the pen(s) at Site 2 and by tracking the focal animal at Site 3. These were stored in digital format for subsequent scoring using the ethogram in supplemental Table 2.

Once reliability was established, live observations began. Animals that began with video observations were continued in that format including both TYPICAL and ATYPICAL groups. Video observations were coded by two observers (Sites 1 and 3) that obtained

acceptable inter-observer reliability (Cohen's kappa = .70). Two Site 3 observers were reliable across video sessions (Cohen's kappa = .83) as well as live sessions (Cohen's kappa = .82). The values reflect substantial agreement (.61–.80) by Landis and Koch (1977). Observations (video and live) were collected for 10 min/session, counterbalancing morning (AM) and afternoon (PM) sessions, beginning at 2–4 months of age (Appendix 1). The data presented represent a total of 5980 min of individual observations between 2 and 4 months of age. Due to the relocations and quarantine periods, fewer total observations were available for the ATYPICAL (2430 min, 174 min/subject) versus the TYPICAL (3650 min, 260 min/subject) offspring ($p < .003$). Five of the 14 ATYPICAL subjects were born at Site 3. Site per se as a main factor was not included in the analysis.

Analyses

Hinde Proximity Indices (Hinde & Atkinson, 1970), a measure of which dyad member is in control of proximity, were computed. From our ethogram, the index was derived from the percent of all initiate or receive proximity by both the mother and infant (“approaches” in Hinde's terms) due to the infant and the total percent of the all initiate or receive away by both the mother and infant (“leaves” in Hinde's terms) due to the infant.

Paired *t*-tests tested for potential differences between morning (AM) and afternoon (PM) in the amounts of each bold/italized behavior in the ethogram (Tab. 2) for each age (2, 3, 4 months). These behaviors failed to show a consistent AM/PM difference. From 42 behavioral comparisons using paired *t* tests for AM and PM differences, only two were significant: Away Mother at 4 months ($t_{(24)} = 2.12, p = .044$) and Proximity Other at 3 months of age, ($t_{(24)} = 2.508, p = .016$). Given the likelihood that these differences were due to chance, we combined morning and afternoon observations for all subsequent analyses.

Continuous behavioral variables were analyzed with mixed model analyses of variance (ANOVAs) using SAS Proc Mixed (SAS, 2008). Each outcome was assessed with the same mixed model design including fixed effects of history (TYPICAL, ATYPICAL), age, and history by age interaction and random effects of mother and infant nested within mother. The three repeated measures on infants (averaged within 2, 3, and 4 months of age) were assumed to have an unstructured covariance structure. Individual contrasts were used to test history effects separately at each age. Gender effects were examined by evaluating each model with gender and its interactions with history and age. In a manual step-down (backward regression) procedure, each nonsignificant term was removed and the model was rerun, beginning with removal of the highest-order threeway interaction term: gender×history×age. Likelihood ratio tests and minimum values for Akaike's Information Criterion (AIC) determined the best model (Jones, 1993). All comparisons utilized a two-tailed, .05 significance level.

Results

Within the social group, the focal offspring can be either near their mother and/or near other members of the social group. This nearness provides opportunities for social interactions in the group. Nearness is quantified by contact, proximity and away in the ethogram (see supplemental Appendix 2) with regard to either the mother or other group members. The

TYPICAL/ ATYPICAL experiences affected these relationships and the control of proximity of the offspring to the mother by the offspring.

Mother–Infant and Other–Infant Proximity

Mother–infant proximity measures comprise contact with mother (including bouts of nursing), proximity to mother (within an arm's length) and away from mother. A significant effect of history (TYPICAL vs. ATYPICAL) on the percent of total time in proximity to the mother was observed with ATYPICAL offspring in proximity (arm's length from mother) more than the TYPICAL offspring ($F_{(1,21.7)}=9.08, p=.007$) with a trend toward less contact with their mother in the ATYPICAL group ($F_{(1,19.7)}=3.19, p=.09$). Overall time away from their mother was not different between the two groups but increased with age ($F_{(2,22.7)}=32.80, p<.0001$) as expected. The percent of total time observed for these behaviors with respect to mother and other social group members is presented in Figure 2. Regarding other members of the social group, contact with others was not different between TYPICAL and ATYPICAL offspring. However, percent of time in proximity to others was greater in the ATYPICAL group ($F_{(1,25.3)}=83.521, p<.0001$) with a significant age by gender interaction ($F_{(2,22.7)}=6.44, p=.0061$) such that proximity of females was similar across 2–4 months of age but for males proximity was greatest at 2 months and declined to the level of females by 4 months of age. TYPICAL offspring spent more time away from others (Fig. 2B) than ATYPICAL offspring ($F_{(1,20.6)}=24.50, p<.0001$) which is consistent with their greater time in contact with their mothers (Fig. 2A). Who in the mother–infant dyad is responsible for this shift in maintaining proximity?

The Hinde Index allows for dissection of which member of the dyad is responsible for maintaining proximity (Hinde & Atkinson, 1970). A Hinde Index of zero indicates equivalent control in the maintenance of proximity whereas a negative index indicates greater control by the mother and a positive index reflects greater control by the offspring. The Hinde Index was significantly higher ($F_{(1,13.7)}=6.09, p=.0274$) in ATYPICAL offspring as shown in Figure 3, indicating that ATYPICAL offspring show greater control of proximity to their mother compared to TYPICAL offspring. The Hinde Index was also computed with regard to other members of the social group and no difference was noted between TYPICAL and ATYPICAL offspring.

Thus a picture emerges wherein the ATYPICAL offspring are out of contact with their mothers but remain in her proximity compared to TYPICAL offspring. Thus ATYPICAL offspring are more likely to be in proximity to other members of the social group as a consequence of being out of contact with their mothers. This has the potential to create a uniquely different developmental experience for the ATYPICAL offspring as far as social interactions in the groups. Did increased time off the mother, while remaining in her proximity, permit the offspring to engage in more social interactions with the group?

Social Behaviors and Interactions With Other Group Members

Many of the social behaviors between 2 and 4 months of age occurred infrequently and were collapsed across all event and state behaviors (Appendix 2, Class 4) into two summary variables called Total Other Social Behavior Events (initiate and receive Aggression,

Restraint, Affiliation, Submit, as well as Struggle and Protect/ Retrieve) and Total Other Social Behavior States (initiate and receive Play and Groom). These variables included only interactions with other young monkeys, the adult male and other adult females but not the mother. Although ATYPICAL offspring showed greater overall time observed in social exchanges, there were significant history by gender interactions for these two summary variables. Figure 4 indicates that both Other State and Event Social Behaviors were affected as a function of relocation(s). Thus ATYPICAL males participated in more social events compared to TYPICAL males whereas TYPICAL and ATYPICAL female offspring were equivalent with regard to social events ($F_{(1,23.9)}=5.43, p=.0286$), Figure 4A. The same relationship was noted for Social Behavior States ($F_{(1,58)}=17.14, p=.0001$), Figure 4B. Of note, there were no gender interactions with either of these behavior categories with the mother and the offspring. However, Total Maternal Social Behavior Events (initiate and receive Aggression, Restraint, Affiliation, Submit, as well as Struggle and Protect/ Retrieve) were significantly higher in ATYPICAL offspring ($F_{(1,20.2)}=5.54, p=.0286$). Total Maternal Social Behavior States (initiate and receive Play and Groom) were also higher for the ATYPICAL offspring but declined with maturation resulting in a group X age interaction ($F_{(2,23.8)}=4.54, p=.0214$).

Infant Self-Behaviors

Included in the self-directed behavior class (Appendix 2, Class 3) was locomotor activity, passive, self-play, object explore, and eat/drink. Other behaviors in this category were low frequency occurrence or did not occur (scratch, yawn, forage, self-sex, and temper tantrum) and were not analyzed. The duration of locomotor activity (% of total time observed, TTO) increased from 2 to 4 months of age indicating a significant age effect ($F_{(2,28.3)}=3.38, p=.0483$). Additionally, there was a significant gender by history interaction on locomotion ($F_{(1,9.81)}=11.16, p=.0077$) such that TYPICAL females moved about the enclosure more than TYPICAL males and ATYPICAL males moved about the enclosure more than ATYPICAL females. Conversely TYPICAL females spent less time passive than TYPICAL males and ATYPICAL males were less passive than ATYPICAL females ($F_{(1,15.9)}=18.69, p=.0005$). The TYPICAL offspring spent more time exploring objects in the environment than the ATYPICAL offspring ($F_{(1,18.1)}=8.60, p=.0086$). This was surprising since the ATYPICAL offspring appeared to have more opportunities to interact with the environment while off their mother but in her proximity. ATYPICAL offspring spent more time in self-play than the TYPICAL offspring ($F_{(1,16.6)}=5.20, p=.0366$).

Discussion

There were significant differences in offspring whose mothers were exposed around conception or after to challenges associated with social group relocations compared to offspring whose mothers did not experience these changes. These differences were reflected in the mother–infant relationship, control of proximity, and offspring interactions with the social group. ATYPICAL offspring were independent of their mothers at an earlier age and had greater social interactions with other members of the social group. Greater time out of contact with the mother may have provided greater opportunity for social interactions in the ATYPICAL offspring.

An issue emerges from these observations. We defined the ATYPICAL and TYPICAL distinction by relocation experiences only because the relocation experience(s) (ATYPICAL) is generally not characteristic for monkeys reared socially and housed in a laboratory setting. Relocations and cage moves of captive populations have been shown to affect health (Capitanio & Lerche, 1998) as well as reproduction (Ha, Robinett, & Davis, 2000). Yet in naturalistic settings, the bonnet macaque is exposed to variations in access to resources, changes in the makeup of the social group, and troop movements (Coss, Marks, & Ranmakrishnan, 2002; Silk, 1994) with consequential changes in social organization (Sinha & Sinha, 2005). In a captive colony, resources are always plentiful and the housing environment is typically constant. Changes in these *typical* conditions affect social groups. For example, restricting food resources to a location that can be monopolized is associated with reduced play and increased aggression in captive bonnet monkey social groups (Boccia, Laudenslager, & Reite, 1988). When maternal foraging is variable and unpredictable requiring high maternal investment (Rosenblum & Andrews, 1994; Rosenblum & Pauly, 1984), bonnet macaque infants show reduced play (Andrews & Rosenblum, 1991), similar to when food is restricted to a location which can be monopolized by a single monkey (Boccia et al., 1988).

When the present study is compared to observations of bonnet monkeys in large field cages (Silk, 1991), the proportion of time the ATYPICAL infants were in contact with their mothers between 2 and 4 months of age was nearly identical to the housing in large field cages. Interestingly, the TYPICAL group was observed in direct maternal contact a greater amount of time compared to field cage housed bonnet monkeys. Comparison of time away from their mother was difficult between these two studies due to the greater size of the outdoor enclosure in the Silk study (30.5 m×70 m corral). Overall our observations of the bonnet mother–infant dyad are consistent with other laboratory observations of the bonnet monkey (Reite & Short, 1986). Were the experiences of the mother–infant dyads in the present study labeled as ATYPICAL really out of the ordinary for a macaque infant under naturalistic conditions? A number of factors may have contributed to observed differences but were not included in the data collected. For example, the mother's exchanges with other group members and the social group in general were not available since the offspring was the focal animal. TYPICAL and ATYPICAL sibling pairs might provide insights to the role of maternal style. The number of sibling pairs for which data are available is limited ($n = 5$ pairs) and preclude detailed analysis. However for these five sibling pairs, the mean percent of total time observed in proximity to their mother between 2 and 4 months of age for the ATYPICAL/ TYPICAL offspring pairs for each mother were 15.7/9.5, 20.6/5.8, 13.5/2.7, 22.5/4.2, and 8.8/5.0, respectively, for ATYPICAL/TYPICAL offspring by mother. Thus the observed differences (reduced proximity in the TYPICAL offspring) were consistent across mothers with sibling pair data available.

Do subtle and often minor challenges in the pre and postnatal period create a more fit and hardy adult? There are examples in humans that suggest early events or challenges may have positive influences on biobehavioral development. For example, in healthy populations, mild prenatal stress is associated with advanced motor development at 2 years of age (DiPietro, Novak, Costigan, Atella, & Reusing, 2006). Perhaps an environmental challenge in the

presence of adequate nutrition and medical care is not necessarily detrimental to the long-term outcome of the developing individual. Behavioral challenges in adults can produce what Neal Miller termed “toughening up” (Miller, 1980) and more recently “stress inoculation” (Lyons, Parker, Katz, & Schatzberg, 2009; Lyons & Parker, 2007; Parker et al., 2004, 2006). The latter studies are particularly germane to the present observations since they note that repeated early maternal separations of young squirrel monkeys results in adolescent behavior suggestive of improved coping and arousal regulation. Stressor and challenge experiences need not always be considered as a negative event. Certainly immune consequences of acute stressors are not uniformly negative (Fleshner & Laudenslager, 2004) and this is also a function of earlier experiences (Coe & Laudenslager, 2007).

As biological organisms, it would be a true outlier that existed in a vacuum devoid of stressors; challenge is a part of life (Lyons et al., 2009). We do not know if the consequences of ATYPICAL experiences will continue to emerge as the animals mature and become young adults. We were unable to determine if the effect is prenatal, postnatal, or due to the influences of the challenge on the mother, the offspring or both. If early experiences in fact create a more resilient individual, ATYPICAL offspring may be better adapted to challenge(s) (Lyons et al., 2009; Parker et al., 2007). These offspring form part of the core of a longitudinal study which will assess behavioral (social aggressivity and impulsivity) and physiological (hypothalamic pituitary adrenal and serotonergic system) responses to challenges as risk predictors for adolescent alcohol preferences and implications for adult alcohol abuse.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Timeline indicating birth dates and estimated ages of conception for TYPICAL (TYP, upper panel) and ATYPICAL (ATYP, lower panel) cohorts relative to relocation challenges. Note that for subjects B36 and B44 that estimated conception was close to relocation challenges. As these are estimated conception dates conception could have occurred prior to relocation. B37 was included in the ATYP group as the mother was adapting to a housing situation unlike any they had experienced previously.

Figure 2.

Mean (95% CI) nearness scores or percent of total time in contact (black bars), proximity (gray bars) and away (white bars) to mother (*upper panel*) and other group members (*lower panel*), including young monkeys, adult females, and the adult male, averaged over two to four months of age as a function of both early experience.

Figure 3.

Mean Hinde Proximity Index (95% CI) between 2 and 4 months of age for TYPICAL and ATYPICAL offspring. An Index of 0 (broken reference line) reflects equality with regard to both members of the dyad in control of proximity. An increase in the index greater than zero (broken reference line) indicates that the infant is primarily responsible for control of proximity.

Figure 4.

Differences in Mean (95% CI) Social Behavior Events (A) and States (B) presented as a function of relocation history and gender. ATYPICAL males demonstrated the greatest impact of relocation(s) challenges.