NIH Public Access
Author Manuscript
Appl Anim Behav Sci. Author manuscript; available in PMC 2012 June 1.

Published in final edited form as:
Appl Anim Behav Sci. 2011 June 1; 132(1-2): 81–89. doi:10.1016/j.applanim.2011.02.010.

Early rearing interacts with temperament and housing to influence the risk for motor stereotypy in rhesus monkeys (*Macaca mulatta*)

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Abstract

Laboratory and zoo housed non-human primates sometimes exhibit abnormal behaviors that are thought to reflect reduced wellbeing. Previous research attempted to identify risk factors to aid in the prevention and treatment of these behaviors, and focused on demographic (e.g. sex or age) and experience-related (e.g. single housing or nursery rearing) factors. However, not all animals that display abnormal behavior possess these risk factors and some individuals that possess a risk factor do not show behavioral abnormalities. We hypothesized that other aspects of early experience and individual characteristics might identify animals that were more likely to display one specific abnormal behavior, motor stereotypy (MS). Using logistic regression we explored the influence of early rearing (involving four different types of rearing conditions), and variation in temperament, on likelihood of displaying MS while controlling for previously identified risk factors. Analyses indicated that having a greater proportion of life lived indoors, a greater proportion of life-indoors singly-housed, and a greater number of anesthesias and blood draws significantly increased the risk of displaying MS ($P < 0.001$). Rearing condition failed to independently predict the display of MS; however significant interactions indicated that single housing had a greater impact on risk for indoor-reared animals versus outdoor-reared animals, and for indoor mother-reared animals versus nursery-reared animals. There were no main effects of temperament, although interactions with rearing were evident: scoring high on Gentle or Nervous was a risk factor for indoor-reared animals but not outdoor-reared animals. The final model accounted for approximately 69.3 % of the variance in the display of MS, and correctly classified 90.6% of animals. These results indicate that previously identified risk factors may impact animals differently depending on the individual's early rearing condition. These results are also the first in non-human primates to demonstrate that individual difference factors, like temperament, could be additional tools to identify animals at highest risk for motor stereotypy.

Keywords

Temperament; abnormal behavior; early rearing; rhesus monkey; motor stereotypy

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1. Introduction

Abnormal behaviors are seen in a range of captive situations, including zoos and laboratory facilities. Among nonhuman primates these behaviors include self-stimulation, motor stereotypy, hair plucking, or self-injurious behavior, and are deemed to be abnormal in the sense that they are rarely, if ever, seen in nature. In a laboratory setting the presence of abnormal behaviors is a concern for two reasons. First, because abnormal behaviors are thought to reflect reduced psychological well-being (Erwin and Deni, 1979), animal care regulations require that primates exhibiting evidence of psychological distress must be given special attention to improve welfare (United States Department of Agriculture, Animal and Plant Health Inspection Service, 1991). Second, the presence of abnormal behavior may compromise research results. For example, self-injurious behavior (SIB) has been associated with dysregulation of the hypothalamic-pituitary-adrenal axis which has led to the suggestion that animals displaying SIB react differently to stress than do controls (rhesus macaques: Tiefenbacher et al., 2000). Because cortisol is a hormone that has widespread effects throughout the body, including effects on the cardiovascular system, immunity, metabolism, and reproductive physiology (Sapolsky et al., 2000), the altered physiological regulation could have an impact on a variety of disease-related processes.

Concerns about well-being and quality of research data have led researchers to determine the causes of abnormal behaviors in order to both prevent and treat them. Since the most commonly used non-human primate in laboratory research is the macaque (Carlsson et al, 2004), most of the studies examining the causes of abnormal behavior in non-human primates have focused on this genus. Studies examining the risk factors for abnormal behavior have found that rearing condition, specifically nursery or isolation rearing, increases the risk for abnormal behavior (pigtailed macaques: Bellanca and Crockett, 2002; rhesus macaques: Fittinghoff et al., 1974; Lutz et al., 2003; Rommeck et al., 2009). Examination of the effects of rearing condition on specific classes of abnormal behavior has shown that while rates of locomotor stereotypy did not differ between animals that were mother-reared and those that were nursery-reared, rates of non-injurious self abuse and self-stimulation were higher in nursery-reared animals (Bellanca and Crockett, 2002; Lutz et al., 2003). In addition to rearing condition, rearing location (i.e. indoors vs. outdoors) has recently been suggested to impact the risk for abnormal behaviors as well. Fontenot et al. (2006) found that outdoor housing in adulthood, regardless of whether animals were housed socially, decreased display of stereotypies and non-wounding SIB in rhesus macaques. In addition, rhesus monkeys reared outdoors with their mothers have been shown to display less self-abuse that those reared by their mothers indoors (Rommeck et al., 2009). Additional risk factors have included age, being male, being singly-housed, and experiencing a greater number of veterinary procedures or blood draws (rhesus macaques: Bayne et al., 1992; Lutz et al. 2003; Novak, 2003). These studies all suggest that there are demographic factors (e.g. sex) as well as factors relating to life experience (e.g. rearing condition, housing, or experimental/clinical procedures) that impact the risk for abnormal behaviors. Studies on the treatment of abnormal behaviors have found that although greater environmental enrichment (especially social enrichment) and larger cage size can decrease the frequency of some abnormal behaviors, in general they are resistant to treatment (rhesus macaques: Schapiro et al., 1996; Novak, 2003).

Although demographic and life history risk factors have been identified for abnormal behaviors, there is still a great deal of individual variation in risk: not all animals that possess the “usual” risk factors go on to develop abnormal behavior. Individual difference variables, specifically the characteristic ways in which an animal responds to events in its environment, may be additional risk factors. To date, however, only one study has included such data in their analysis of risk for an abnormal behavior: Novak (2003) found no relationship between the incidence of self-directed biting in rhesus monkeys and measures of impulsivity and reactivity.

As described above, “abnormal behavior” refers to a heterogeneous group of behaviors, likely having different etiologies. One type of abnormal behavior, motor stereotypy (MS), is a behavior that is seen in primate research facilities and zoo facilities, and includes any gross motor behavior that typically is repeated in a very rigid manner (crab-eating macaques: Berkson, 1968). Specific behaviors often included under the term MS include pacing, flipping, twirling, swinging, bouncing, head twisting, or rocking in non-human primates (Berkson, 1968; olive baboons: Brent et al., 2002; Lutz et al, 2003; Rommeck, et al., 2009). Our interest was in identifying risk factors specifically for MS and our hypothesized predictors included not only traditional risk factors such as rearing condition but also whether animals were reared indoors or outdoors (rearing location) and individual difference factors, specifically temperament. A better understanding of all potential contributors to this behavior could lead to the development of intervention strategies more accurately targeted at those animals that are at high risk for developing these behaviors.

2. Materials and methods

A retrospective study was conducted by combining the data from two existing research programs; a routine colony wide assessment of abnormal behavior, and a study of biobehavioral organization and temperament in infant rhesus monkeys (for methodological details see Section 2.2).

2.1 Subjects and Housing

2.1.1 Subject Selection and Housing—The final data set consisted of 202 rhesus monkeys (*Macaca mulatta*) that were living indoors at the California National Primate Research Center (CNPRC). This sample was drawn from the larger pool of animals that had been assessed for abnormal behavior if they satisfied the following criteria: 1) were participants in an infant BioBehavioral Assessment program (see section 2.2.2 for details) and 2) were housed indoors for at least 2 months (to allow for at least four abnormal behavior observations, see section 2.2.1). In addition, animals were excluded from the data set for the following reasons: 1) they exhibited other forms of abnormal behavior in the absence of MS (N = 11), 2) they only exhibited MS on one occasion (N = 27). These animals were excluded from the current analysis to ensure that animals included in the MS group reliably were displaying stereotypic behaviors and animals in the non-stereotypic group were reliably not demonstrating any form of abnormal behavior. The mean age of the animals in this data set was 3.28 years (range: 0.43–4.70 years). All procedures were approved by the University of California-Davis Institutional Animal Care and Use Committee (IACUC).

2.1.2 Rearing Condition—As infants, subjects experienced one of four rearing conditions in two rearing locations (outdoors vs. indoors). Field cage-reared infants (FR; N=128) were born to mothers living outdoors in one of 17 0.20 ha enclosures consisting of 90–150 animals with age and sex compositions similar to that in the wild. Cages contained multiple perches, climbing structures, and small shelters to provide protection from the rain and wind. Corncrib-reared infants (CR; N=22) were born to mothers living outdoors in small harem groups consisting of a single male and one to five adult females and their offspring. Cages measured approximately 4 m in diameter and contained multiple perches. Indoor mother-reared infants (IMR; N=28) were born indoors and housed in standard size laboratory caging (0.58 × 0.66 × 0.81m) with their mothers, either alone or with access to another mother-infant pair for up to 8 h each day. Nursery-reared infants (NR; N=24) were born in the field cages, removed from their mothers on the day of birth, and relocated to an indoor nursery. Once indoors, animals were placed in incubators for 28 days during which they were hand fed every 2 h and received approximately 1–1.25 h of human contact each day. After 28 days of age infants were moved to quad cages (0.46 × 0.61 × 0.69 m) and paired with one other nursery-reared age mate either intermittently (6 h per day) or continuously (for more detail see Capitanio et al., 2005).

2.2 Data Collection

2.2.1. Assessment of Temperament—At a mean of 0.3 (range: 0.25 to 0.36) years of age, all subjects were participants in an infant BioBehavioral Assessment (BBA) program at the CNPRC. The methods of this assessment are described in detail elsewhere (Capitanio et al., 2006; Golub et al., 2009). Briefly, infants were removed from their home cages, separated from their mothers and/or peers (for NR infants), and relocated to an unfamiliar indoor testing environment where they were housed individually in temporary holding cages for a period of 25 h. During this period, infants were given a battery of tests to assess behavioral and physiological reactivity. This battery included assessment of behavioral responses to the separation and relocation; interactions with novel stimuli; responses to a human intruder; responses to video playback of social stimuli; and assessment of plasma cortisol concentrations and hypothalamic-pituitary-adrenal regulation. All behavioral data were collected by trained observers who had established reliability greater than 85% agreement. At the end of the 25-h testing period infants' temperament was assessed, and infants were reunited with their mothers and/or peers and were returned to their home cages.

Data from the temperament assessment were used in the current analysis. Temperament scores were derived from adjective ratings of infant temperament, which was assessed at the end of the 25-h testing period by an observer who had worked closely with all of the animals during the entire assessment period. Thus, temperament ratings reflected not only the behavior that the technician had observed during testing, but also interactions with the animals during feeding, handling, blood sampling, and husbandry, and reflects an overall impression of the animal's functioning. Each animal was rated on a list of 16 adjectives using a 7-point Likert scale for each adjective. Assessment of inter-rater agreement and reliability for the data collection has been described (Weinstein and Capitanio, 2008). Briefly, mean inter-rater reliability for the 16 individual items, assessed using an intra-class correlation, was 0.53. Inter-rater agreement, assessed using chi-square (Lawlis and Lu, 1972), was significantly greater than chance ($P < 0.00001$) for each item, and the mean T index, a kappa-based measure indicating the magnitude of agreement (Tinsley and Weiss, 1975), was 0.64, when different observers' ratings were allowed to vary from each other by one point. Exploratory (using a promax rotation) and confirmatory factor analysis of these data (described in detail in Golub et al., 2009) yielded a four factor structure (named based on the trait with the highest positive loading): Vigilance (vigilant, not depressed, not tense, and not timid); Gentle (calm, flexible, gentle, and curious); Confidence (bold, active, confident, curious, and playful); and Nervous (fearful, nervous, timid, not calm, and not confident). Temperament factors were calculated as z-scores within each yearly cohort of the BBA assessed animals. Cronbach's alpha values for the scales ranged from 0.6 to 0.9.

2.2.2. Abnormal Behavior Assessment—All indoor-housed animals at the CNPRC were assessed for abnormal behavior by a behavioral management team to identify animals in need of special attention or treatment using twice monthly, 5-min scan sessions. The animals in the current sample were observed through this program across an average of 12.5 months (range: 2–53 months). The timing of the observations was opportunistic and thus varied across several hours of the day (Rommeck et al., 2009). Individuals that engage in motor stereotypy do so often; therefore, 5-min sessions were sufficient to detect this behavior (McCowan, unpublished data). Observations were conducted on animals in their living cage (0.58 × 0.66 × 0.81m) and under their normal living conditions (i.e. with a social partner if the animal was socially housed normally). Cages were also equipped with perches, chew toys, mirrors and coconuts as routine enrichment. All animals included in our data analysis were observed for a minimum of 2 months and animals were classified as displaying MS if at least one of the following behaviors was recorded during at least 2 separate months: pace, flip, twirl, swing, bounce, head twist, or rock (see Table 1 for definitions). All abnormal behavior data were collected by trained observers with inter-observer reliability greater than 85% agreement.

2.2.3 Additional Variables—Information relating to demographics and life history were collected from animal records and included age, sex, proportion of life spent indoors (calculated by the total number of days housed indoors divided by the animal's age in days), proportion of life indoors that the animal was singly-housed (calculated as the number of days animals were housed individually indoors divided by the total number of days in indoor housing), number of lifetime housing relocations (changes in housing location that lasted at least 24 h), number of blood draws without anesthesia, and the number of times anesthetized (typically with ketamine hydrochloride at 10 mg/kg; see Table 2 for descriptive statistics).

2.3 Data Analysis

All the variables were centered (z-scored) within this sample with the exception of temperament factor scores which were already expressed as z-scores. Our outcome measure was whether or not animals displayed motor stereotypy on at least two occasions. We selected this dichotomous measure owing to the small number of samples available for some of our subjects. Consequently, our analytic approach involved use of logistic regression to identify risk factors, and we conducted a hierarchical analysis consisting of four steps using SPSS (Version 19). In Step 1 the main effects of the demographic and experience-related predictors were entered. The effects of early rearing were tested using a set of three orthogonal contrasts; Contrast 1 tested the effects of rearing location, indoor (IMR and NR animals) versus outdoor (FR and CR animals), while Contrasts 2 (CR vs. FR) and 3 (IMR vs. NR) examined the effects of rearing condition within each rearing location. Step 2 added the interaction terms of the rearing contrasts by all of the demographic and experience related variables. For both Steps 1 and 2 backwards elimination was used to remove any terms that did not significantly improve the fit of the model (i.e. removal resulted in a non-significant change in the −2 Log Likelihood). The final two steps examined temperament as a potential risk factor for MS. Specifically, Step 3 entered the main effects of the four temperament factors and Step 4 included the interactions between the rearing contrasts and the temperament factors. Age was a variable of interest; however inclusion of age in the model resulted in evidence of multicolinearity with other variables and yielded unstable regression coefficients; consequently this variable was not included. The strength of the overall association between the predictors in the model and the outcome measure was estimated using Nagelkerke R^2 and the classification analysis, which are measures of effect size. The Nagerlkerke R^2 is a pseudo-R^2 measure (Nagelkerke, 1991), and the classification analysis compares the observed and the expected (based on the statistical model) classification of animals into the two categories of "displays MS" vs. "does not display MS." Due to the large number of predictors in the current analysis the magnitude of the odds ratios was likely inflated (Nemes et al., 2009) so effects will be discussed in relation to their direction, but not their magnitude.

3. Results

Overall 24.8% (n=50) of the sample was categorized as displaying MS on at least two separate occasions, although this varied based on rearing condition (see Table 2). The majority of animals so-categorized displayed pacing behaviors (92%), followed by bouncing (26%), swinging (26%), flipping (22%), rocking (18%), twirling (12%), and head twisting (12%). Twenty-eight percent of animals displayed only pacing while all other animals exhibited two to four different types of MS. A comparison of the specific stereotypic behaviors exhibited by animals indicated that all the animals tended to display the same behaviors with the exception of flipping behaviors which were exhibited more by IMR animals (χ^2 (3) = 15.521, P < 0.001), and swinging which was significantly more common in NR animals (χ^2 (3) = 8.831, P = 0.032; see Table 3).

3.1 Step 1: Demographic and Experience-related Predictors

The entry of all the demographic and experience-related predictors significantly increased fit from the null model (χ^2 (9) = 86.484, P < 0.001). The variables entered on this step included: the three contrasts testing the effects of rearing location and rearing condition; proportion of life lived indoors, proportion of life indoors singly-housed, total times anesthetized, number of blood draws without anesthesia, and the number of housing relocations. Data reduction was performed and resulted in the relocations variable being removed from the model because it did not significantly increase the fit of the model (χ^2 (1) = 0.968, P < 0.325). Although they were non-significant risk factors, the rearing contrasts were retained in the model due to their involvement in planned interactions in steps 2 and 4. The reduced step 1 (i.e., with relocations removed) indicated that being male, having a greater proportion of life lived indoors, having a greater proportion of indoor-life singly-housed, and a greater number of anesthesias and blood draws were risk factors for the display of MS (see full model, Table 4). Examination of the Nagelkerke R^2 indicated that these variables accounted for approximately 51% of the variance in the display of MS; classification was improved from the null (chance) model (75.2 % of cases correctly classified) to 85.6%.

3.2 Step 2: Interactions of Rearing Contrasts with Demographic and Experience-Related Variables

Step 2 of the model began with entry of the interactions between all of the variables retained in step 1 and the rearing contrasts. After data reduction, only the interactions between the rearing contrasts and the proportion of life indoors singly-housed were retained (Step: χ^2 (3) = 13.648, P < 0.003). The interactions were interpreted by comparing the odds of MS for the top and bottom tertile of the single housing variable; this was done for each rearing group separately to control for pre-existing differences in mean values. Then the odds for displaying MS were examined to determine if they differed for high and low proportions of single housing (see Table 5a) for each rearing group. These interactions indicated that both rearing location and, among the indoor-reared animals, rearing condition, interacted significantly with single housing: indoor-reared animals were affected more by single housing (odds for indoor animals were 0.55 for animals that had a low proportion of single housing vs. 2.00 for animals with a high proportion of single housing) than were outdoor-reared animals (odds were 0.11 vs. 0.32), and, of the two indoor-reared groups, IMR animals were affected more by single housing (odds were 0.29 vs. 8.00) than were NR animals (odds were 1.67 vs. 2.00). The Nagelkerke R^2 for this step increased from 0.513 to 0.576 with correct classification remaining at 85.6%.

3.3 Step 3: Main Effects of Temperament

The temperament factors were not significant predictors of MS (χ^2 (4) = 3.377, P = 0.497); however the step was retained due to the use of the temperament factors in interactions in step 4.

3.4 Step 4: Interaction Between Rearing and Temperament

The addition of the interaction terms between the four temperament factors and each of the rearing contrasts yielded a significant step (χ^2 (12) = 24.411, P = 0.018). Specifically, the interactions between the Nervous or Gentle factors and Contrast 1 (indoor versus outdoor rearing location), were significant. As was done with the interactions in step 2, these interactions were also explored by comparing the odds of MS for the top and bottom tertiles of the Gentle and Nervous factors for each rearing location separately (see Table 5b and 5c). These analyses indicated that scoring high on Gentle or Nervous was a risk factor only for indoor-reared animals. There were no significant interactions with the other rearing condition contrasts (Contrasts 2 or 3) or with the other temperament factors. The Nagelkerke R^2 for this final step was 0.693; correct classification for this final model was 90.6%. The full model is presented in Table 4.

4. Discussion

The current study aimed to expand our understanding of the risk factors that lead to the development of one class of abnormal behaviors, motor stereotypy (MS), in order to provide additional tools for the prevention of this behavior. We found that the prevalence of MS in our sample was approximately 25%, and that pacing was the most frequently seen form of MS. Using hierarchical logistic regression we found that being male, having a greater proportion of life lived indoors, having a greater proportion of life indoors singly-housed, and having a greater number of anesthesia and blood draws were risk factors for MS. In addition, the effects of single housing were most prominent in indoor- reared animals as opposed to outdoor-reared animals, and within the indoor-reared group, IMR were more strongly affected than were NR animals. Finally, although there were no main effects of temperament on the risk for MS, there were significant interactions of rearing location by temperament suggesting that the temperament factors Gentle and Nervous were risk factors for MS for indoor-reared animals only. Below, we discuss these issues.

4.1. Prevalence of Motor Stereotypy

Studies of abnormal behavior have often yielded varied prevalence levels in different study populations. The current finding that approximately one quarter of the animals studied were seen to exhibit MS is much lower than has been previously reported for this behavior (Lutz et al., 2003). However when the data were examined looking at the rearing conditions separately, the prevalence in CR (45.5%), IMR (42.9%), and NR (50%) animals in the current study is similar to the 48.9% reported by Lutz et al. (2003) in a population of animals singly-housed in a laboratory facility. This is in contrast to the 12.5% of animals displaying MS who were reared in field cages, a much lower percentage than has been previously reported for this behavior. Although the prevalence of MS differed based on early rearing, rearing condition did not emerge as a risk factor in the logistic regression model, suggesting that other factors in the model, like indoor or single housing, were likely the cause of the differences in prevalence. Also consistent with previous research, the current analysis found that pacing was the most frequently displayed form of MS (Lutz et al., 2003). Research in rodents suggests that different forms of MS have different underlying causes (Wurbel, 2006); however, due to the high comorbidity of the different forms of MS in this sample we were unable to explore this question in the current study. Very few primate studies have examined the causes of individual forms of MS; however Rommeck et al. (2009) have suggested that rocking may be dissociated from the other forms of motor stereotypy, perhaps indicating a different etiology for that behavior.

4.2 Demographic and Experience-related Predictors

In general, the demographic and experience-related predictors identified in the current study were consistent with previously reported findings. Studies of abnormal behavior have reported that being male, having lived longer in single housing, and having had a greater number of veterinary/medical procedures are risk factors for abnormal behaviors (Bellanca and Crockett, 2002; Lutz et al. 2003; Novak, 2003), and this was also supported by the current analysis. Although a greater number of blood draws has previously been found to be a risk factor for abnormal behavior (Novak, 2003), we found this to be a risk factor only in the first three steps of the model; once the temperament interactions were put into our model, number of blood draws was no longer a significant predictor. The current analysis does suggest, however, that other experimental or veterinary manipulations, like the number of anesthesia, may also influence the risk for MS. Although the number of housing relocations was predicted to be a risk factor for MS due to its association with decreased survival after simian immunodeficiency virus (SIV) inoculation (rhesus macaques: Capitanio and Lerche, 1998) and self-abuse in rhesus monkeys (Rommeck et al., 2009), it was not a significant predictor of MS in our analysis. Although this finding was contrary to our expectations, it is consistent with results reported by Novak (2003) that indicated that housing relocations did not predict SIB. In the current analysis, age was not included as a predictor of MS due to multicolinearity; however other studies suggest that this variable is related to the display of MS. Lutz and colleagues (2003) found that while increasing age was a risk factor for SIB and self-directed stereotypies, whole-body stereotypies were more common in younger animals.

The current study also provides more information on how housing condition impacts the risk for MS, and how this may differ in animals with varied early rearing experiences. First, not only was single housing a risk factor for MS, but a greater proportion of life lived indoors was also a risk factor. These findings, together with previously reported effects of outdoor housing on reducing stereotypy (Fontenot et al., 2006), suggest that earlier work demonstrating an increased risk for abnormal behaviors in singly- housed animals may be a specific instance of how a more general reduction in the social and non-social complexity of an animal’s environment may increase the risk for abnormal behaviors. Second, these findings suggest that previously reported effects of single housing on the development of abnormal behaviors may differ depending on early rearing condition and location as evidenced by the interactions between rearing history and the proportion of time indoors singly-housed. The first of the significant interactions suggests that single housing increased the risk for MS in indoor-reared animals more than in outdoor-reared animals. It is possible that outdoor-reared animals are in some way more resistant to MS when singly-housed than indoor-reared animals, possibly due to protective effects of environmental complexity early in life (mice: Powell et al., 2000). The challenges of the variable outdoor environment may also provide a form of early stress inoculation, which has been suggested to lead to greater cognitive control and emotion regulation (squirrel monkeys: Lyons and Parker, 2007), and may lead to resilience when placed in single housing later in life.

The second significant interaction indicates that although an increasing amount of time in single housing increases the risk for MS in both IMR and NR animals, the odds ratio for MS between low and high proportions of single housing is greatest in IMR animals. It is possible that early maternal experience helps buffer IMR animals only up to a point. Maternal care influences a wide range of developing systems, both behavioral and physiological (rats: Meaney and Szyf, 2005), and this maternal influence may protect their infants from developing MS under low to moderate levels of challenge. At high proportions of single housing, however, the risk in IMR animals increases dramatically. It is likely that with high proportions of single housing IMR animals may be predisposed to certain types of behaviors which may lead them to develop MS. For example, previously reported data from the BBA program indicate that IMR animals respond to separation and relocation and a human intruder challenge at 3–4 months of age with greater activity and locomotion than both NR and outdoor mother-reared animals (Capitanio et al., 2006). Perhaps after experiencing a certain amount of single housing, this early tendency toward displaying activity and locomotion becomes habitual and stereotyped. Altogether, these results suggest that the impact of single housing may be dependent of the types and the complexity of social housing early in life.

4.3 Temperament

In addition to demographic factors we also found that measures of temperament, assessed in infancy, were significant risk factors. Temperament refers to the characteristic ways in which an individual responds to the environment, and includes the intensity of the response, the threshold of responding, and the lability of mood (Allport, 1937), and in the present study was assessed by ratings of the animals by the technician based upon her full experience with the animals – while observing, handling, feeding, capturing, and blood sampling the animals during a 25-h period. The data collected during the BBA assessment appear to reflect traits that remain stable into adulthood (Sullivan et al., 2008); traits that may put some individuals at greater risk for MS.

Specifically, the Gentle and Nervous temperament factors were significant risk factors for MS above and beyond the already discussed risk factors, but only via interaction with early rearing location. Indoor-reared animals that scored high on the Gentle factor showed an increase in risk for MS while outdoor-reared animals did not show the same effect. Assessments during the BBA testing period indicate that high-Gentle indoor-reared animals respond to the challenge of a human intruder and to the BBA testing situation with low activity levels, and low levels of emotionality (Capitanio, unpublished data). These traits are similar to the traits identified in rats by Koolhaas and colleagues (1999), who suggest they are indicative of a reactive or passive coping style. In these monkeys, a predisposition to cope with the challenges of a novel or indoor environment in a passive fashion seems to put them at greater risk for displaying MS later in life.

The Nervous temperament factor reflects an animal that was rated as more fearful, nervous, and timid, but less calm and confident. Our analysis indicates that nervous temperament was a risk factor for MS primarily for indoor-reared monkeys, with high-Nervous animals at greater risk than low-Nervous animals. Nervous temperament in infant monkeys has been associated with a tendency to respond to challenge with negative emotional behaviors (rhesus monkeys: Capitanio et al., 2011), and in this sample, high-Nervous indoor-reared animals tended to respond to the challenge of a human intruder with more fearful behavior (fear grimace, scream). As animals age and are exposed to the daily challenges of indoor living, MS may develop in high-Nervous animals as a mechanism to cope with their continued arousal. In fact, it’s possible that the MS displayed by these animals still contains other elements of negative emotionality, such as threats or cage shakes; unfortunately, the data collection for the abnormal behavior scans did not involve recording this information.

Our results suggest that there are multiple pathways by which temperament can influence development of motor stereotypy, but that these pathways are specific to particular types of early experiences. The common link may be that development of a particular temperament profile in the context of a specific set of early life experiences may result in difficulty coping with challenge; high-Nervous indoor-reared animals tend to respond with negative affect, and high-Gentle indoor-reared animals seem to seem to respond in a passive fashion, with reduced activity and emotionality. Nevertheless, both temperament styles appear to be associated with a greater tendency to displaying MS. While the only other study to examine individual difference factors such as these failed to find a relationship between impulsivity or reactivity and SIB (Novak, 2003), we reiterate that the etiologies of SIB and MS may be quite different. Nevertheless, the exploration of the role played by individual difference factors in the development of abnormal behavior remains in its infancy; consequently, we consider our results and interpretations as provisional until other studies can add to this perspective.

5. Conclusion

Altogether, these data suggest that response patterns that are measurable in infancy can be considered risk factors for the development of abnormal behaviors up to several years later. In addition, the knowledge that different response patterns are predictive of MS depending on the animal's early rearing environment can be potentially useful in targeting prevention strategies to animals. While we await confirmation and extension of these initial results, we believe they support the idea that an individual-differences approach to understanding development of abnormal behavior may hold great promise in improving prediction and treatment, and represents a novel approach to animal welfare.

Acknowledgments

We thank L. DelRosso, L. Calonder, E. Lowe, and S. Kang for contributions to this project. This research was supported by NIH grants #Rr000169 and Rr019970.

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Table 1

Motor Stereotypy: Behavioral Definitions

Behavior	**Definition**
Pace[ab]	Repetitive, undirected walking or running in the same pattern– three or more repetitions.
Flip[a]	Three or more repeated forward or backwards somersaults.
Twirl[a]	Three or more repeated horizontal turns of the body.
Swing[a]	Grasping a part of the cage with one or more hands or feet while moving in the exact same pattern – either back and forth or in a circular pattern - for three or more repetitions.
Bounce[a]	Jumping up and down for three or more repetitions using a rigid posture. This behavior did not include cage shaking which can often involve brief bouncing.
Head Twist[b]	Moving, lifting, or twisting the head in an exaggerated way (can co-occur with pacing).
Rock[ab]	A rhythmic movement either side to side or forward and backward for at least three repetitions (can co-occur with self-clasping).

[a]Berkson (1968);

[b]Brent et al. (2002)

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Table 2

Descriptive statistics for potential predictors of motor stereotypy by rearing condition

	NR (N = 24)	**IMR (N = 28)**	**CR (N = 22)**	**FR (N = 128)**	**Overall**
Motor Stereotypy Present	50.0%	42.9%	45.5%	12.5%	24.8%
Sex (% Male)	54.2%	50.0%	68.2%	54.7%	55.4%
	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)
Life lived indoors (proportion)	0.703 (0.35 – 1.0)	0.830 (0.35 – 1.0)	0.435 (0.11 – 0.79)	0.283 (0.05 – 0.79)	0.425 (0.05 – 1.0)
Life indoors, singly-housed (proportion)	0.313 (0.04 – 0.62)	0.168 (0 – 0.79)	0.431 (0.01 – 1.0)	0.249 (0 – 1.0)	0.265 (0 – 1.0)
Housing relocations	18.88 (6 – 62)	11.25 (3 – 26)	12.41 (5 – 27)	9.49 (4 – 28)	11.17 (3 – 62)
Blood draws	3.46 (0 – 9)	4.43 (0 – 36)	4.45 (2 – 40)	3.89 (0 – 37)	3.98 (0 – 40)
Anesthesia	20.29 (0 – 44)	25.32 (0 – 56)	26.64 (3 – 53)	17.9 (0 – 51)	20.16 (0 – 56)

Nursery-reared (NR); Indoor mother-reared (IMR); Corncrib-reared (CR); Field cage-reared (FR)

Table 3

The prevalence of each type of motor stereotypy, by rearing condition

Stereotypic Behavior	NR (N = 12)	IMR (N = 12)	CR (N = 10)	FR (N = 16)	Total (N = 50)
Pacing	91.7%	100.0%	80.0%	93.8%	92.0%
Swinging	58.3%[a]	16.7%	10.0%	18.8%	26.0%
Bouncing	25.0%	16.7%	30.0%	31.3%	26.0%
Flipping	41.7%	50.0%[a]	0.0%	0.0%	22.0%
Rocking	25.0%	0.0%	30.0%	18.8%	18.0%
Twirling	25.0%	8.3%	10.0%	6.3%	12.0%
Head Twisting	8.3%	25.0%	20.0%	0.0%	12.0%

[a] χ^2 at $P < 0.05$ indicated significantly more animals than expected displaying the behavior.

Nursery-reared (NR); Indoor mother-reared (IMR); Corncrib-reared (CR); Field cage-reared (FR)

Table 4

Risk factors for motor stereotypy in the final model

Predictor	Coefficient	P	OR	CI at 95%
Step 1				
Contrast 1 (Indoor vs. outdoor reared)	0.453	n.s.	1.573	0.167 – 14.782
Contrast 2 (CR vs. FR)	0.069	n.s.	1.071	0.092 – 12.459
Contrast 3 (NR vs. IMR)	−0.479	n.s.	0.620	0.022 – 17.293
Sex (male = 1)	2.253	0.002	9.519	2.216 – 40.895
Life Lived Indoors	1.686	0.001	5.396	2.032 – 14.324
Life indoors, singly-housed	1.905	< 0.001	6.720	2.413 – 18.714
Blood draws	1.281	n.s.	3.601	0.904 – 14.342
Anesthesia	0.858	0.009	2.359	1.242 – 4.480
Step 2				
Contrast 1 X Single housing	2.280	0.023	9.780	1.379 – 69.379
Contrast 2 X Single housing	1.228	n.s.	3.413	0.709 – 16.424
Contrast 3 X Single housing	−4.411	0.017	0.012	0.000 – 0.453
Step 3				
Vigilant	−0.765	n.s.	0.465	0.105 – 2.066
Gentle	−0.032	n.s.	0.968	0.265 – 3.534
Confident	−0.001	n.s.	0.999	0.342 – 2.922
Nervous	−0.247	n.s.	0.781	0.146 – 4.188
Step 4				
Contrast 1 X Vigilant	2.422	n.s.	11.266	0.600 – 211.387
Contrast 2 X Vigilant	−2.366	n.s.	0.094	0.002 – 5.751
Contrast 3 X Vigilant	0.499	n.s.	1.646	0.024 – 113.345
Contrast 1 X Gentle	2.764	0.042	15.867	1.104 – 228.011
Contrast 2 X Gentle	−3.206	n.s.	0.041	0.001 – 2.567
Contrast 3 X Gentle	−0.701	n.s.	0.496	0.025 – 9.929
Contrast 1 X Confident	1.551	n.s.	4.716	0.502 – 44.294
Contrast 2 X Confident	−0.585	n.s.	0.557	0.027 – 11.331
Contrast 3 X Confident	−2.941	n.s.	0.053	0.002 – 1.221
Contrast 1 X Nervous	5.142	0.004	171.057	5.141 – 5691.266
Contrast 2 X Nervous	−4.272	n.s.	0.014	0.000 – 3.611
Contrast 3 X Nervous	−2.568	n.s.	0.077	0.002 – 3.518
Constant	−3.423	< 0.001	0.033	

Model χ^2 (27) = 126.952, P < 0.001. Nagelkerke R^2 = 0.693. Classification = 90.6%.

Logistic regression coefficient, significance level, odds ratios (OR), and confidence intervals (CI) for the final model are presented, including those for the factors that were non-significant (n.s.). Nursery-reared (NR); Indoor mother-reared (IMR); Corncrib-reared (CR); Field cage-reared (FR).

Table 5

The odds of displaying motor stereotypy for the top and bottom tertiles of the predictors that interact significantly with rearing history

		Outdoor Reared	Indoor Reared	IMR	NR
a.	Low Proportion Single Housing	0.11	0.55	0.29	1.67
	High Proportion Single Housing	0.32	2.00	8.00	2.00
b.	Low-Gentle	0.21	0.89		
	High-Gentle	0.21	1.00		
c.	Low-Nervous	0.25	0.55		
	High-Nervous	0.21	1.00		

IMR: Indoor mother-reared; NR: Nursery-reared.