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The correlation between alopecia and temperament in rhesus macaques (*Macaca mulatta*) at four primate facilities

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Abstract

Alopecia is a ubiquitous, multifaceted problem at facilities caring for captive rhesus macaques. There is a wide range of potential etiologies for the hair loss, including compromised immune function, dermatological pathologies, and environmental factors. However, few studies have examined whether various temperamental traits affect vulnerability to develop alopecia. We examined the correlation between alopecia and temperament in 101 (51M) indoor-housed rhesus macaques at four national primate centers. We utilized a cage side version of the Human Intruder test (HIT) to assess response to four conditions: no human present (Alone), human intruder standing next to the cage without making eye contact (Profile), intruder making direct eye contact (Stare) and intruder with back turned (Back). Behavior from all videos was quantified at one facility. We used generalized linear modeling to examine the relationship between behavior on the HIT and alopecia, controlling for facility, age, and sex. There was a significant negative correlation between alopecia and various behaviors associated with an inhibited or anxious temperament, including self-directed behavior ($\beta = -0.15$, $P < 0.001$) and freeze in the Profile period ($\beta = -0.0092$, $P < 0.001$), and defensive behaviors ($\beta = -0.0094$, $P < 0.001$) and time spent in the back of the cage in the Stare period ($\beta = -0.0023$, $P = 0.015$). Individuals with an inhibited or anxious temperament had less alopecia than others. Further, there were facility differences with respect to several variables on the HIT, including defensive behavior in Stare and freeze in Profile. These results suggest that temperament can influence the development of alopecia in rhesus macaques. Our results also highlight the degree to which facility differences can affect outcomes on standardized behavioral tests.

Keywords

anxiety; hair loss; behavioral inhibition; husbandry practices

Introduction

Alopecia, or hair loss, is a common problem among rhesus monkeys (*Macaca mulatta*) in research facilities. Recent studies at large primate facilities have shown that up to 34-87 percent of the population may have alopecia at any given time [Lutz et al., 2013; Novak et al., 2014]. While the exact welfare implications of alopecia are not clear, its high prevalence is of concern to both regulatory agencies and managers of nonhuman primate colonies. As a result, the past decade or so has seen an increase in the number of studies examining the etiology of the hair loss in an effort to find treatments and/or cures [Kramer et al., 2010; Lutz et al., 2013; Novak et al., 2014; Novak and Meyer, 2009]. There are many potential causes of alopecia in nonhuman primates [see Novak and Meyer, 2009 for review]. Aging [Beisner and Isbell, 2009; Kramer et al., 2010], seasonal variations [Vessey and Morrison, 1970] and pregnancy [Beisner and Isbell, 2009] have been identified as naturally occurring reasons for hair loss. Conditions such as parasitic infections [e.g., Baker et al., 1971], nutritional deficiencies [Juan-Sallés et al., 2001], and endocrine disease [e.g., Miller et al., 1983] may cause hair loss for some individuals, although they have been ruled out in other cases [e.g., Steinmetz et al., 2005]. A recent study [Kramer et al., 2010] found chronic dermal hypersensitivity in macaques with alopecia, which may suggest immune dysregulation. Environmental factors, such as indoor housing [Steinmetz et al., 2006], high density group housing [Beisner and Isbell, 2009] and absence of substrate [Beisner and Isbell, 2008] have also been correlated with hair loss in macaques. Because there is often no pathology underlying alopecia, it is often assumed to be caused by stress. Novak and colleagues [Novak et al., 2014] found a positive correlation between hair cortisol, a measure of chronic stress, and alopecia in caged macaques, although it is not clear whether the stress caused the alopecia. Further, other studies [Sarnowski et al., 2013; Steinmetz et al., 2006] have not found this correlation. Taken together, these results suggest that there is a wide range of individual differences with respect to vulnerability to alopecia; even in the same environmental conditions, and presumably the same general stress level, some animals have significant hair loss while others do not. Finding potential risk factors for the development of alopecia is important to better understanding the condition.

One potential risk factor for the development of alopecia is personality or temperament. Temperament, defined as an individual's basic position towards environmental change and challenge [Lyons et al., 1988], can influence response to adverse or potentially adverse events, has been correlated with disease susceptibility. Certain temperamental or personality constructs, such as behavioral inhibition or an anxious temperament, have been associated with increased stress sensitivity and development of behavioral and/or health problems in humans and other species [e.g., Capitanio, 2011; Kagan, 1997; Miller et al., 1999]. For example, highly inhibited children (i.e., those who display withdrawal from or timidity towards the unfamiliar; [Kagan et al., 1988]) are at risk for developing anxiety and other psychopathologies later in life [Hirshfeld et al., 1992; Schwartz et al., 1999]. They are also more likely to develop respiratory illnesses following a stressful situation such as entering school for the first time [Boyce et al., 1995]. Socially inhibited rhesus monkeys have compromised immunological response to immunization and social relocation [Capitanio and

Mendoza, 1999; Maninger et al., 2003]. Given these relationships, it seems reasonable to hypothesize that temperament may play a role in alopecia as well.

There are at least two mechanisms by which temperament could affect the development of alopecia. First, an individual's temperament can influence the expression of specific behaviors resulting in hair loss. For example, hair loss can result from self-epilating behavior such as over-grooming (i.e., grooming oneself to excess) or hair pulling [Novak and Meyer, 2009]. In humans, hair pulling, a condition seen in the psychopathology trichotillomania, has been linked with obsessive-compulsive disorder and an anxious temperament [Christenson and Crow, 1996]. Second, certain temperamental constructs, such as behavioral inhibition, are associated with increased vulnerability to stress and its concomitant physiological measures [Kalin et al., 1998]. While the role of stress on alopecia is not clear, there is evidence to suggest that increased stress can lead to hair loss in at least some individuals by telogen effluvium [Novak and Meyer, 2009], a condition in which there is an increase in the proportion of dormant hair follicles. Further, stress has been associated with other physiological parameters such as decreased immune function, which may increase vulnerability to infections that could cause alopecia. Given this potential influence of anxious and/or inhibited temperament on alopecia, evaluating the influence of these specific temperamental traits is warranted.

Surprisingly few studies have examined the relationship between alopecia and temperament in humans and other animals. There is some evidence suggesting that people with an anxious or inhibited temperament may be more likely than others to develop alopecia [Annagur et al., 2013; Brajac et al., 2003], although this relationship has not been found in other studies [Erfan et al., 2014]. There are somewhat more studies examining the relationship between temperament and alopecia in non-human animals. Studies have found a correlation between an anxious temperament and compulsive self-grooming behavior in a variety of species, including dogs [Wynchank and Berk, 1998], cats [Moon-Fanelli et al., 1999], chinchillas [Ponzio et al., 2012] and birds [Van Zeeland et al., 2009]. For example, bird species known to have a more anxious temperament, such as cockatoos and African grey parrots, tend to engage in excessive feather-picking more than calmer species such as budgerigars [Roszkopf et al., 1986]. Cats with an anxious temperament are more likely than others to develop alopecia resulting from excessive licking and/or hair pulling [Moon-Fanelli et al., 1999]. To our knowledge, only one study has examined temperament and alopecia in nonhuman primates. Ellison et al., [2006] found that female rhesus macaques that presented with either patchy or bald patterns of alopecia were more exploratory (i.e., willing to inspect a novel object) than those with thinning hair. However, that study did not compare behavior between monkeys with and without hair loss.

In this study, we assessed the correlation between anxious temperament and alopecia across four national primate research centers. We utilized a Human Intruder test [HIT; Kalin and Shelton, 1989] to assess anxiety. This test is one of the most commonly utilized methods for assessing anxiety in macaques [Coleman and Pierre, 2014]. The HIT was designed to assess response to a potentially threatening social stimulus; an unfamiliar human both avoiding and making direct eye contact. There is a wide range of behavioral responses to these “threats”. When the human intruder avoids direct eye contact, subjects often freeze [Kalin and Shelton,

1989], an adaptive response to avoid detection by a potential threat. Conversely, an appropriate response to direct eye contact is to be vigilant and direct attention directly toward the unknown human. Subjects typically respond to direct eye contact with some degree of defensive behavior, such as threats or fear [Kalin and Shelton, 1989; Kalin et al., 1991]. While these behavioral responses are adaptive when performed in moderation, they can be problematic when performed to excess. For example, individuals that demonstrate high levels of freezing in the absence of direct eye contact may be similar to inhibited humans who exhibit excessive fear responses. There are several lines of evidence suggesting that these individuals may have a behaviorally inhibited or anxious temperament [Essex et al., 2010; Kalin et al., 1998]. If an inhibited or anxious temperament predicts hair loss, then we would expect alopecic monkeys to spend more time freezing when the human intruder is not making direct eye contact than fully haired monkeys. Further, we might also expect these alopecic monkeys to show behaviors known to indicate anxiety, including self-directed behaviors in response to an intruder [Maestripieri et al., 1992; Schino et al., 1996].

While the HIT is commonly utilized, it is often performed somewhat differently at each facility, making direct comparison across centers difficult. For example, in the studies by Kalin and others [Coleman et al., 2003; Corcoran et al., 2012; Kalin and Shelton, 1989], monkeys were tested in a novel room. Capitanio [Capitanio, 1999] modified this paradigm for use in the animal's home cage. This protocol included two no eye contact and direct eye contact conditions, one in which the intruder stands far (approximately 1m) from the cage and the other in which the intruder stands closer to the subject (approximately 0.3 m). Unlike the tests performed in a novel room, freezing behavior was rarely observed in these home cage tests. This difference was attributed to the close proximity of the intruder [Gottlieb and Capitanio, 2013], although the intruder stood the same distance from the cage in other paradigms in which freezing was a major behavioral outcome [e.g., Coleman et al., 2003; Williamson, 2003], suggesting that perhaps other factors, such as the protocol or the facility played a role. Thus, a second aim of this study is to examine outcome of the HIT across four facilities housing nonhuman primates.

Methods

Subjects

Subjects for this study were 51 male and 50 female (3-30 years, $10.8 \pm \text{SE } 5.6$ years) rhesus macaques (*Macaca mulatta*). All animals were singly housed in standard monkey cages appropriate for their size, at one of four National Primate Research Centers (New England, Oregon, Southwest or Washington, Table I). Selection of subjects differed somewhat by facility. At all facilities, subjects were selected opportunistically based on when they underwent physical exams (see below). At Facilities 1, 2 and 4, animals were chosen based on level of hair loss (i.e., either no alopecia, or appreciable hair loss), while at Facility 3, animals were selected regardless of alopecia, due to various facility constraints. Monkeys were fed standard monkey chow twice daily, and were given fresh produce or other supplemental items daily. Subjects received enrichment such as toys, foraging devices, radio and television to ensure their psychological health and well-being. Water was provided freely through automatic lixit systems. The lights were on 12 hr per day. The animal care

programs at all facilities are compliant with the laws and regulations of the United States Animal Welfare Act and are accredited by AAALAC, International. This study was approved by the Institutional Animal Care and Use Committees at each facility, and adhered to the American Society of Primatologists' Principles for the Ethical Treatment of Non Human Primates.

Alopecia Assessment

At each center, alopecia was assessed at a time during which subject was sedated for another purpose (i.e., annual or semi-annual physical exam). Sedated animals were photographed in three positions: lying on left side, lying on right side, and lying prone. A ruler was placed next to the subject to provide a common scale.

All photos were sent to the University of Massachusetts where they were analyzed for percent hair loss using Image J software (a public domain image software program, NIH). Alopecia was only measured on the dark coat of subjects. The white coat of the chest, belly, inner arms and inner legs was not assessed. See Novak et al., [2014] for details about this procedure.

Human Intruder Test

A modified, cage side version of the Human Intruder test (HIT) was performed 2-4 weeks after the photographs were taken. This test was comprised of four periods, an acclimation period and three periods in which an unfamiliar person ("intruder") was present. At the start of the test, the intruder entered the monkey's home room and placed a video camera on tripod approximately 1m in front of the monkey's cage. The intruder turned the camera on and left the room for 10 min ("Alone period"). After this time period, the intruder re-entered the room and stood approximately 0.6m from the monkey, perpendicular to the front of the cage. The intruder looked straight ahead, presenting profile and avoiding eye contact with the monkey ("Profile period"). After two min, the intruder turned her head towards the monkey, keeping her body in same position, and made continuous direct eye contact with the monkey for 2 min ("Stare period"). After this two min period, the intruder then turned around, presenting her back to the monkey for 2 min ("Back period") after which she turned off the video and left the room. The "Back period" was included to assess the subject's response once the threat had been removed (i.e., the intruder's face was not visible to the subject). The intruder kept her head down during this time period, taking care not to make eye contact with the monkeys housed on the wall opposite from the test subject. Because some NHPs respond differently to male and female caretakers, the human intruder at each facility was female, and relatively unknown (i.e., not a caretaker) to the monkey.

All videos were sent to the University of Massachusetts, where they were quantified using MPEG Streamclip. Raters had inter-observer reliability of > 90%. For consistency, behaviors from the last two minutes of the Alone period, as well as the entire Profile, Stare and Back periods were scored. Behaviors quantified included time spent in the back of the cage, amount of time freezing (a behavior in which the subject remains completely motionless except for slight movements of the eyes; Kalin and Shelton, 1989), amount of time engaged in stereotypical pacing, and self-directed behaviors (scratch, yawn). We also quantified

threat (open mouth threat and/or shaking the cage in an aggressive manner) and defensive (fear grimace, lip-smacking, teeth grinding) behaviors in response to the intruder making direct eye contact. The duration of behavior (in seconds) was calculated for each 2 minute time period.

Statistics

Correlation between behaviors on the HIT on alopecia—To quantify the relationship between HIT behaviors and alopecia, data were analyzed using a mixed effects Poisson regression model with percent alopecia as the response and HIT variables as potential covariates. Since facility, sex, and age are all known to correlate with alopecia [Lutz et al., 2013; Novak et al., 2014], sex and age were included in the model as covariates, while facility was included as a random effect. Selection of HIT variables to include in the final model was conducted using forward step-wise AIC model selection. To avoid problems with multicollinearity, the less predictive member of highly correlated pairs of HIT variables were not included in the variable selection step. Variables were included in the final model only if the decrease in AIC was at least 2 [Burnham and Anderson, 2002]. Given the large number of potential variables in the fully saturated model, additional interaction terms were not considered.

Effect of facility on HIT behaviors—A second aim of this study was to specifically examine whether behavior on the Human Intruder test differed across facilities. Because none of the data on the Human Intruder test (HIT) met the assumptions of normality, we compared behavior on the HIT across facility using separate Kruskal-Wallis analyses for each behavior. Sex demographics were not comparable between facilities. Facility 1 had only male subjects, Facility 4 had only female subjects, and Facilities 2 and 3 had both male and female subjects. Therefore, separate analyses were performed for male and female subjects. As a result, analyses on males utilized only Facilities 1, 2, and 3, while analyses on females utilized only Facilities 2, 3, and 4.

To address the multiple hypothesis testing, the false discovery rate (expected proportion of Type 1 errors among all significant findings) was controlled using the Benjamini-Hochberg procedure [Benjamini and Hochberg, 1995]. Using an ordered list of P-values generated from the individual Kruskal-Wallis tests, the Benjamini-Hochberg procedure determines which tests should be rejected in order to maintain a pre-determined false discovery rate. We only report the raw P-values from the Kruskal-Wallis test for those variables determined significant by the Benjamini-Hochberg procedure with the false discovery rate controlled at 5%.

R statistical program (R Foundation for Statistical Computing) was used for all analyses [Team RDC, 2011].

Results

Correlation Between Behavior on the HIT and Alopecia

There was a wide range of alopecia in the population (Figure 1), which ranged from 0 to 80% hair loss. The best fitting model described alopecia as a function of self-direct and

freeze in the Profile period, defensive behaviors and back of cage in the Stare period, pace in the Alone period, in addition to the subject's sex and age (Table II). Specifically, there was a significant negative correlation between alopecia and self-directed behaviors in the Profile period ($\beta = -0.15$, $P < 0.001$, Figure 2A), freeze in the Profile period ($\beta = -0.0092$, $P < 0.001$, Figure 2B), defensive behaviors in the Stare period ($\beta = -0.0094$, $P < 0.001$, Figure 2C), back of cage in the Stare period ($\beta = -0.0023$, $P = 0.015$, Figure 2D), and pace in the Alone period ($\beta = -0.023$, $P < 0.001$, Figure 2E).

Facility Differences and Behavior on the HIT

There were significant differences in how the animals responded on the Human Intruder test based on their facility. Facility differences were most prevalent when the intruder was making direct eye contact with the monkey (i.e., Stare period). There were differences with respect to the time both males and females spent in the back of the cage (Males: Kruskal Wallis $H = 11.36$, $df = 2$, $P = 0.003$; Females: $H = 9.14$, $df = 2$, $P = 0.01$, Figure 3A). Facility 1 males and Facility 4 females spent less time in the back of the cage compared to other males and females, respectively. There were also facility differences with respect to defensive behavior (Males: $H = 9.85$, $df = 2$, $P = 0.01$; Females: $H = 7.86$, $df = 2$, $P = 0.02$, Figure 3B), with Facility 1 and 4 animals engaging in these behaviors less than animals from other facilities. Interestingly, the pattern of threat behavior was similar to that of defensive behavior although the difference was not significant for females (Males: $H = 7.78$, $df = 2$, $P = 0.02$; Females: $H = 2.14$, $df = 2$, $p > 0.05$, Figure 3C). There were no significant facility differences with respect to freezing (Males: $H = 3.19$, $df = 2$, $P > 0.05$; Females: $H = 6.36$, $df = 2$, NS after Benjamini Hochberg adjustment) or self-directed behavior (Males: $H = 5.52$, $df = 2$, NS; Females: $H = 2.50$, $df = 2$, NS).

Facility also influenced the monkeys' response to the intruder in the Profile period. There were significant differences with respect to time in the back of the cage for females, although not males (Males: $H = 5.5$, $df = 2$, $P > 0.05$; Females: $H = 12.11$, $df = 2$, $P = 0.002$, Figure 4A). Freeze also differed across primate centers (Males: $H = 9.08$, $df = 2$, $P = 0.01$; Females: $H = 17.16$, $df = 2$, $P < 0.001$, Figure 4B). Both males and females from Facility 3 spent the most time freezing in this period. There was no difference in the amount of time males spent in self-directed behaviors across facilities ($H = 1.36$, $df = 2$, NS). None of the females showed any self-directed behavior during this period. Few animals expressed threat (3 females and 5 males) or defensive (2 females and 4 males) behavior during this period, thus there was not enough variation to analyze these variables.

To get a measure of non-provoked behavior (i.e., when the stranger was either absent or not a threat), we examined the amount of time animals spent pacing during the last two minutes of the Alone and Back periods. There were no facility differences in either the Alone (Males: $H = 3.24$, $df = 2$, NS; Females: $H = 0.31$, $df = 2$, NS) or Back periods (Males: $H = 2.69$, $df = 2$, NS; Females: $H = 2.13$, $df = 2$, NS).

Discussion

Behavior on the Human Intruder Test and Alopecia

This study is one of the first to examine whether temperament, as measured by the Human Intruder test (HIT), correlates with alopecia in rhesus macaques. Degree of alopecia negatively correlated with several behaviors on the HIT, including self-directed behaviors in the presence of the intruder, and freezing in the Profile period. Somewhat surprisingly, animals that engaged in these behaviors had *less* hair loss than those that did not. Additionally, alopecia was negatively correlated with defensive behaviors (e.g., lip-smacking and fear grimacing) and spending time in the back of the cage during the stare period. Taken together, these results suggest a negative relationship between alopecia and an anxious and/or inhibited temperament; anxious and/or inhibited individuals had less alopecia than others.

If an anxious temperament plays a role in the development of alopecia through a stress related mechanism (i.e., anxious animals experience high levels of stress, which can act either directly or indirectly to affect alopecia), then we might expect there to be a positive correlation between hair loss and behaviors associated with an anxious/inhibited temperament. Results from our study do not support this hypothesis. Our results are, however, consistent with the hypothesis that an individual's temperament can influence the expression of self-epilating behaviors resulting in hair loss. Hair loss in humans and other animals can be triggered by a variety of factors. Some hair loss in humans, such as that produced by trichotillomania, has been associated with anxiety and obsessive compulsive personality disorders [Christenson and Crow, 1996]. There is evidence that some macaques pick their hair in a fashion similar to that seen in patients with trichotillomania [Ellison et al., 2006]. However, this behavior often results in limited hair loss, such as small patches of alopecia, often on an arm or leg (personal observation). Thus, it is possible that the highly inhibited/anxious individuals in our study did have alopecia, but it might have presented as small localized patches, as opposed to large areas, of hair loss.

It is reasonable to think that temperament may play a role in some, but not all, etiologies of alopecia. Some individuals with small patches of hair loss might have an anxious temperament. Large amounts of hair loss, on the other hand, might have a physiological or clinical etiology, such as pregnancy, seasonal changes or dermatological condition. Thus, the pattern of alopecia (e.g., small patches of localized hair loss compared to generalized hair loss) might be an important variable, and, along with overall amount of hair loss, might provide better insight into the nature of the condition. In support of this idea, Kramer et al., [2011] found dermatological differences between animals with alopecia localized at distal forearms compared to those with generalized alopecia. Animals with localized alopecia had less inflammation than those with generalized alopecia, suggesting a psychogenic etiology for animals with small patches of hair loss [Kramer et al., 2011]. Future work should focus on the association between temperament and both the pattern and amount of alopecia.

While not a temperamental trait per se, stereotypic pacing in the Alone period negatively correlated with alopecia. Because the intruder was not present, behavior during this time period may indicate the individual's "normal" routine. Stereotypic behaviors (repetitive,

habitual behavior pattern with no obvious function; [Mason, 1991] such as pacing are commonly observed in captive nonhuman primates. Like alopecia, the etiology of pacing is unclear, but is thought to develop as a result of suboptimal environmental conditions leading to frustration and/or boredom [Mason, 1991; Wemelsfelder, 1993]. Because stereotypic animals do not necessarily have increased signs of stress compared to others [Mason and Latham, 2004; Pell and McGreevy, 1999], it has been suggested that pacing and other stereotypic behaviors may serve as a coping mechanism [Ijichi et al., in press; Koolhaas et al., 1999]. Thus, perhaps pacing reduced alopecia in some individuals. Interestingly, stereotypical pacing in the “Back” condition, in which the intruder is present, but has her back turned towards the monkey, did not correlate with alopecia. More work is needed to examine the relationship between stereotypic behavior and hair loss.

Facility Differences

The human intruder test is among the most commonly utilized tests to assess anxiety in rhesus macaques [Coleman and Pierre, 2014]. Despite its widespread use, there are few, if any, studies comparing outcomes across labs or facilities. We found significant facility differences with respect to response to a human intruder, even though the procedures were identical at each center, and the video was quantified at the same facility. Animals, particularly males, from Facility 2 were somewhat more reactive than those at other centers, displaying higher amounts of threat and defensive behavior. Conversely, monkeys at Facility 3 showed the most freezing behavior in the presence of the human intruder. Each of these behavioral profiles has been associated with an anxious or inhibited temperament [Coleman and Pierre, 2014]. Interestingly, even though males and females displayed different amounts of the behavior, the trend with respect to facility differences was comparable for both sexes.

Similar facility differences have been found with respect to amount of alopecia [Kroeker et al., in press; Lutz et al., 2013] and hair cortisol [Novak et al., 2014]. There are several potential reasons for these inter-facility differences. One potential factor is disparate housing environments. Facilities 2 and 3 have outdoor enclosures in which the subjects may have spent part of their lives, while Facilities 1 and 4 do not. Thus, the animals in Facilities 2 and 3 may have spent less time in indoor cages, which may have influenced their response to a human stranger. Early rearing, which can differ across facilities, may have influenced behavior on the Human Intruder test (HIT) as well. Several studies [Corcoran et al., 2012; Gottlieb and Capitanio, 2013] have found nursery-reared animals to be more reactive on the HIT compared to mother reared counterparts, both as infants and as adults. Another factor that could affect both behavior and alopecia is husbandry or enrichment practices. Factors such as cage material (e.g., steel or plastic) have been found to affect alopecia and the presence of barbering in rodents [Garner et al., 2004]. Even the stability and cultural attitude of the care staff towards the animals can influence behavior [Coleman, 2011]. Finally, genetic differences or country of origin (i.e., China vs India) could also cause behavioral discrepancies [e.g., Gottlieb et al., in press]. These factors should be examined further to determine the degree to which they affect behavioral responses to the Human Intruder test, as well as other behavioral tests.

This work highlights the degree to which the institution can affect outcomes on standardized behavioral tests (see Wahlsten et al., [2003] for an interesting discussion of implications of such laboratory differences), and underscores the need for cross facility studies to better determine the correlation among variables of interest. Had we performed this test in only one facility, our results may have been different, but would have been specific to that facility. Looking at multiple facilities will help elucidate the role of environmental factors such as husbandry practices on behavioral outcomes. Our results also illustrate potential difficulty in interpreting data. For example, excessive freezing is often used as a measure of inhibition [Kalin et al., 1998]. However, what constitutes “excessive” might differ at different facilities. In other words, behavior on these tests may be relative to the population, as opposed to an absolute value.

Conclusions

Alopecia is a complex, multifaceted condition, and is a common issue with captive macaques. Despite its prevalence, we know relatively little about its etiology. While often presented as a behavioral problem resulting from stress, there is little empirical evidence to suggest that this is always the case. Some individuals may be more vulnerable to hair loss than others, even in the same environmental conditions. Temperament or personality may influence an individual's vulnerability to alopecia, as it does with other disease processes. We found that monkeys with an anxious/inhibited temperament had less alopecia than other individuals. Examining different patterns of alopecia, as well as the total amount of alopecia, may provide insight into the nature of this relationship..

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Figure 1. Histogram of alopecia scores for 101 rhesus macaques from four facilities

Figure 2.

Modeled relationship between alopecia and self-directed behaviors in the Profile period (A), freeze in the Profile period (B), defensive behaviors in the Stare period (C), back of cage in the Stare period (D), and pace in the Alone period (E). Figures are calculated assuming animals are female and received average scores on all other Human Intruder test behaviors.

Figure 3.

Amount of time males and females from four facilities spent in the back of the cage (A), engaged in defensive behavior (B), and engaged in threat behavior (C) during the Stare period of the Human Intruder test. * Indicates raw $P < 0.05$, ** raw $P < 0.01$

Figure 4.

Amount of time males and females from four facilities spent in the back of the cage (A) and in freeze (B) during the Profile period of the Human Intruder test. ** Indicates raw $P < 0.01$, *** raw $P < 0.001$

Table I
Number of Male and Female Rhesus Macaques From Each Facility

Facility	Female	Male
Facility 1	0	21
Facility 2	7	8
Facility 3	26	22
Facility 4	17	0

Table II
Final Model Describing Alopecia as a Function of Human Intruder test (HIT) Variables.
Variables with negative beta (β) estimates negatively correlate with alopecia. Sex and age
were included in the model as covariates, while facility was included as a random effect

Variable	β Estimate (SE)	Lower 95% CI	Upper 95% CI	p-value
Age	-0.001 (0.008)	-0.018	0.015	0.8901
Sex (male)	-0.901 (0.106)	-1.110	-0.693	< 0.001
Pace (no one in room)	-0.023 (0.003)	-0.029	-0.017	< 0.001
Freeze (profile)	-0.009 (0.001)	-0.012	-0.006	< 0.001
Self-direct (profile)	-0.149 (0.032)	-0.212	-0.085	< 0.001
Back of cage (stare)	-0.002 (0.001)	-0.004	0.000	0.015
Defensive (stare)	-0.009 (0.002)	-0.013	-0.006	< 0.001