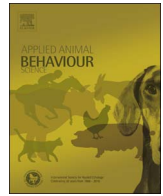




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Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

A cross-species comparison of abnormal behavior in three species of singly-housed old world monkeys

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ARTICLE INFO

Keywords:

Species differences
Behavioral assessment
Welfare

ABSTRACT

Abnormal behavior occurs in a number of captive nonhuman primate species and is often used as an indicator of welfare. However, reported levels of abnormal behavior often vary across species, making general welfare judgments difficult. The purpose of this study was to assess differences in levels of abnormal behavior and associated risk factors across three species of Old World monkeys in order to identify similarities and differences across species. The subjects were 415 (109 females) cynomolgus macaques (*Macaca fascicularis*), 365 (181 females) rhesus macaques (*Macaca mulatta*), and 331 (187 females) baboons (*Papio hamadryas*) that had been singly-housed for 30–120 days. A 5-min observation using one-zero sampling recorded the presence or absence of abnormal behavior for each animal. Macaques exhibited higher levels of abnormal behavior than baboons (29% vs. 14%; $\chi^2(1) = 24.849$, $p < 0.001$), but there was no difference between macaque species (30% vs. 28%; $\chi^2(1) = 0.263$, $p = 0.608$). Risk factors also varied. Overall, males exhibited greater levels of motor stereotypies ($b = 0.425$, $p < 0.05$), females greater levels of abnormal appetitive behavior ($b = 1.703$, $p < 0.05$), and older animals greater levels of self-directed behavior ($b = 0.065$, $p < 0.05$). However, macaques exhibited greater levels of motor stereotypy ($b = 2.527$, $p < 0.001$) and self-directed behavior ($b = 2.968$, $p < 0.005$) than did baboons. There was also a genus \times sex interaction for abnormal appetitive behavior ($b = -2.379$, $p < 0.01$) and a genus \times age interaction for motor stereotypy ($b = -0.167$, $p < 0.05$). These results demonstrate that differences in abnormal behavior exist across closely-related primate species. Therefore, a single species cannot be used generally as a model for abnormal behavior or animal welfare.

1. Introduction

Abnormal behavior has been noted in a number of captive non-human primate species including prosimians (Tarou et al., 2005; Watson et al., 2009), New World monkeys (Berkson et al., 1966; McGrogan and King, 1982), Old World monkeys (Bayne et al., 1992; Camus et al., 2013; Lutz et al., 2003, 2014), as well as lesser and greater apes (Birkett and Newton-Fisher, 2011; Nash et al., 1999; Trollope, 1977; Walsh et al., 1982) housed at both laboratories and zoos. Behavior can be considered to be abnormal if it differs in kind (i.e., qualitatively different) or by degree (i.e., quantitatively different) from those behaviors typically observed in the wild (Erwin and Deni, 1979). However, abnormal behavior is not a strict dichotomy, and the dividing line between normal and abnormal can be difficult to establish (Bayne, 1996; Mason, 1991). Although there are similarities to normal behavior, abnormal behavior is of concern because it can be an indicator of past or present compromised welfare (Mason, 1991) or altered physiological states (Tiefenbacher et al., 2004). Tiefenbacher et al. (2005) presented a “developmental-neurochemical hypothesis” theorizing that

adverse early conditions along with later stressful events result in alterations in neuropeptide and neuroendocrine systems that can lead to abnormal behavior such as self-biting. However, with the exception of pathological behaviors that may result in tissue damage (Novak et al., 2012), the extent to which levels of abnormal behaviors are an indicator of wellbeing is unclear (Mason, 1991).

Although abnormal behaviors can be uniquely individualistic, for the purpose of this paper they will be classified into four categories: *motor stereotypy*, which includes behaviors such as pacing, rocking, flipping, swinging, and head tossing (Camus et al., 2013; Fritz et al., 1992; Gottlieb et al., 2015; Hook et al., 2002; Lutz et al., 2003; Nash et al., 1999; Vandeleeest et al., 2011); *self-directed behaviors* which include hair-pulling, “saluting,” eye-covering, or digit sucking (Fritz et al., 1992; Hook et al., 2002; Jacobson et al., 2016; Lutz et al., 2003; Thierry, 1984); *abnormal appetitive behavior* which includes regurgitation, hair eating, and coprophagy (Akers and Schildkraut, 1985; Birkett and Newton-Fisher, 2011; Fritz et al., 1992; Gould and Bres, 1986; Hook et al., 2002; Jacobson et al., 2016; Nash et al., 1999; Nevill and Lutz, 2015); and *self-injurious behavior* which includes behaviors that

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<http://dx.doi.org/10.1016/j.applanim.2017.10.010>

Received 6 March 2017; Received in revised form 10 October 2017; Accepted 12 October 2017
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result in injury or have the potential for injury such as head-banging, self-biting, and self-wounding (Birkett and Newton-Fisher, 2011; Gottlieb et al., 2013; Hosey and Skyner, 2007; Lutz et al., 2003; Rommeck et al., 2009). Various factors play a role in the display of abnormal behavior. These risk factors include a number of environmental conditions such as nursery rearing, single housing, and clinical procedures (Bayne et al., 1992; Bellanca and Crockett, 2002; Crast et al., 2014; Gottlieb et al., 2013, 2015; Lutz et al., 2003; Nash et al., 1999; Rommeck et al., 2009; Vandeleest et al., 2011) as well as variables intrinsic to the animal such as the animal's species, sex, and age (Crast et al., 2014; Gottlieb et al., 2013, 2015; Lutz et al., 2003; Tarou et al., 2005; Trollope, 1977). This study focuses on intrinsic risk factors.

Surveys of zoo populations have demonstrated that levels of abnormal behavior can vary greatly across species, genera, and/or families of nonhuman primates. For example, in a survey of 108 zoos and 68 species of nonhuman primates, abnormal behavior was reported in 14% of the animals. Apes exhibited the highest percentage (40%), followed by Old World monkeys (14%), prosimians (7%), and New World monkeys (6%) (Bollen and Novak, 2000). In a smaller survey of 35 zoos, self-injurious behavior was reported in 16 species of apes, Old World monkeys, and New World monkeys, but not in prosimians (Hosey and Skyner, 2007). Similarly, an observational study conducted at twenty zoos reported that those in the families Cercopithecidae, Cebidae, Pongidae, and Hylobatidae displayed comparable levels of abnormal behavior (5.7–7.1%), while Callitrichidae, Lemuridae, and Lorisidae displayed no behavioral abnormalities (Trollope, 1977). However, a survey of 48 zoos reported that 13% of prosimians exhibited some form of abnormal behavior (Tarou et al., 2005). Differences in abnormal behavior can also be found across laboratory species. For example, studies of nonhuman primates housed singly in laboratories have reported higher levels of abnormal behavior in macaque monkeys (89–100%; Bayne et al., 1992; Camus et al., 2013; Lutz et al., 2003) and sooty mangabeys (*Cercocebus atys*) (83%; Crast et al., 2014), than in baboons (14–26%; Kessel and Brent, 2001; Lutz et al., 2014). It should be noted, however, that direct comparisons of abnormal behavior across species housed in different facilities can be confounded by variables such as differences in husbandry practices, housing conditions, as well as differences in observation or data collection methods.

In addition to overall levels, abnormal behavior can also vary in form and frequency across species; certain types of abnormal behavior are more likely to occur in some species than in others. For example, captive gorillas (*Gorilla gorilla*) are often reported to exhibit coprophagy and regurgitation/reingestion (Akers and Schildkraut, 1985; Gould and Bres, 1986), while coprophagy tends to be the most common abnormal behavior in chimpanzees (*Pan troglodytes*) (Birkett and Newton-Fisher, 2011; Jacobson et al., 2016; Nash et al., 1999; Walsh et al., 1982). Similarly, hair-pulling and hair-eating is common in baboons (Brent and Hughes, 1997; Mejido et al., 2009; Nevill and Lutz, 2015) and “wiggle digits,” a behavior that is often associated with regurgitation, appears to be limited to the baboon population (Lutz et al., 2014). In contrast, pacing, a motor stereotypy, is a behavior that is commonly performed by many species of captive nonhuman primates (Bellanca and Crockett, 2002; Crast et al., 2014; Lutz et al., 2003, 2014; McGrogan and King, 1982; Pomerantz et al., 2012, 2013; Tarou et al., 2005; Vandeleest et al., 2011). Therefore, a single species or genus may not be an accurate model of abnormal behavior for the primate order as a whole.

The role that sex plays in abnormal behavior can vary both within and between species. For example, two surveys of nonhuman primates housed at zoos assessed the impact of sex on abnormal behavior. In one survey of 630 zoo primates, significantly more males (10.2%) than females (2.7%) exhibited abnormal behavior (Trollope, 1977), while another survey of eight zoo primate species including prosimians, monkeys, and apes reported no sex difference in abnormal stereotyped behavior (Marriner and Drickamer, 1994). In macaque monkeys (e.g., *Macaca mulatta*, *M. cynomolgus*, *M. nemestrina*), when there was a sex

difference, males were reported to exhibit more abnormal behavior than were females. This was noted in all categories of abnormal behavior including motor stereotypy, self-directed, and self-injurious behavior (Bayne et al., 1995; Cross and Harlow, 1965; Gottlieb et al., 2013, 2015; Lutz et al., 2003; Novak et al., 2002; Rommeck et al., 2009; Suomi et al., 1971; Thierry, 1984; Vandeleest et al., 2011). However, studies of rhesus macaques (*Macaca mulatta*) have also reported no sex difference in some (Lutz et al., 2003, 2007) or all (Hook et al., 2002) observed abnormal behaviors. Although less is known about abnormal behavior in baboons, baboon males were also reported to be more likely to exhibit abnormal behaviors such as appetitive behaviors, self-directed behaviors and body movements (Brent and Hughes, 1997; Lutz et al., 2014). However, as with macaques, a sex difference was not reported in all behaviors (Lutz et al., 2014).

Age can also play a role in the levels of abnormal behavior displayed by nonhuman primates. Age differences in behavior may be due to factors such as the animal's physical abilities and behavioral repertoire (Mason, 1993). For example, a survey of zoos reported that younger animals (i.e., infants and juveniles) had fewer behavioral abnormalities than did older animals (Trollope, 1977). When younger animals did exhibit abnormal behavior, however, the behaviors tended to be more physically active motor stereotypies such as pacing, body flipping, and swinging (Lutz et al., 2003), and the display of these behaviors typically decreased with age (Gottlieb et al., 2013). For example, in rhesus monkeys, the display of motor stereotypic behavior increased until 6 years of age and then declined with increasing age (Gottlieb et al., 2015). Older monkeys were instead more likely to exhibit sedentary abnormal behaviors that do not require a lot of movement such as self-directed behaviors (e.g., eye poke, eye cover, hair-pull), and self-injurious behavior (Lutz et al., 2003; Thierry, 1984). However, not all studies reported an effect of age on abnormal behavior (Birkett and Newton-Fisher, 2011; Hook et al., 2002; Tarou et al., 2005) and age was reported to be negatively correlated with abnormal behavior in group-housed baboons (Brent and Hughes, 1997).

The repertoire of abnormal behavior is often highly individualistic (Pauk et al., 1977; Thierry, 1984). Because of this, displays of abnormal behavior within an individual have been described as a “behavioral fingerprint” for that individual (Bayne and McCully, 1989). However, abnormal behavior also varies across species and has the potential of being utilized as a species-specific “behavioral fingerprint.” Previous studies of species differences in abnormal behavior have often compared animals that were housed at different facilities, under varying conditions, and possibly with different observation methods. In contrast, few studies assessed abnormal behavior across species that were housed in the same facility, under similar conditions, and with the same procedures. The purpose of this study was to utilize a standardized assessment method to survey the presence of abnormal behavior in large populations of captive baboons (*Papio hamadryas*) and macaques (*Macaca mulatta*, *M. fascicularis*) and to identify species differences in abnormal behavior. In addition, the impact of intrinsic risk factors such as sex and age was assessed for comparison. Knowing these species-specific risk factors will help us to better predict vulnerable individuals for directing animal care.

2. Methods

2.1. Subjects

The subjects were 415 (109 females, 306 males) cynomolgus macaques (*Macaca fascicularis*), between the ages of 1–19 years; 365 (181 females, 184 males) rhesus macaques (*Macaca mulatta*), between the ages of 1–25 years; and 331 (187 females, 144 males) baboons (*Papio hamadryas*) consisting mainly of the subspecies olive baboon (*Papio hamadryas anubis*) and olive/yellow baboon (*Papio hamadryas cynocephalus*) crosses, along with various other crosses, between the ages of 1–22 years. All of the macaques and 290 of the baboons were mother-

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