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A Tinbergian review of self-injurious behaviors in laboratory rhesus macaques

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ABSTRACT

Self-injurious behaviors (SIBs) are a welfare and practical concern in laboratory rhesus macaques (*Macaca mulatta*), and may share a similar etiology to human SIBs. This review uses a Tinbergian perspective to investigate why rhesus monkeys perform SIBs. In addition to reviewing research specifically focused on rhesus macaque SIBs, this paper reports data on human SIBs to help explain the behavior in non-human primates. This review is broken into four distinct sections based on Tinbergen's 'four whys' of behavior: phylogeny, ontogeny, causation, and function. The first section, phylogeny, presents a few studies that link SIBs to monoamine-related genes. Phylogeny of SIBs as a whole, however, is insufficiently researched in non-human primates, as data are scarce on at-risk primate species and heritable factors. The developmental section attributes SIBs to rearing experiences (*e.g.*, isolation housing and surrogate rearing), history of stressful experiences (*e.g.*, husbandry and research protocols), and at-risk life stages (*e.g.*, adolescence). Together these two sections help explain the origin of SIB-vulnerable phenotypes. Next, the causation section looks at potential internal mechanisms (*e.g.*, neurotransmitters, neuropeptides, hormones, and affective states), behavioral and psychological correlates of SIBs (*e.g.*, stereotypic behaviors, floating limb syndrome, and cognitive inflexibility), and external stimuli (*e.g.*, individual housing, outdoor housing, and environmental enrichment). Lastly, the function section utilizes data on human self-report to consider putative benefits of SIBs such as self-stimulation and coping with stress and/or perhaps neuropathic pain. It addition, this section considers how these behaviors may alternatively represent brain dysfunction. In the final discussion and conclusion, treatment implications inspired by each of the four whys are considered, as well as the merits of using Tinbergen's approach to study abnormal behaviors.

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1. Introduction

Laboratory rhesus macaques (*Macaca mulatta*) are at risk for developing self-injurious behaviors (SIBs), with reports of 5–25% of certain populations affected (Bayne et al., 1995; Lutz et al., 2003; Novak, 2003). Reported SIBs include self-slapping, head-banging, and more injurious forms such as self-biting (Gluck and Sackett, 1974). Self-biting, the most common SIB observed (Tiefenbacher et al., 2000), is often performed repeatedly (within a bout or in isolated, single bites, Reinhardt, 1999; Tiefenbacher et al., 2000), can occur daily (Tiefenbacher et al., 2000), and can cause wounding (although most bites do not, Novak, 2003), which in extreme cases can lead to euthanasia (Gottlieb et al., 2013). As such, SIBs are a welfare concern in laboratory primates.

This review uses Tinbergen's (1963) ethological framework to discuss why SIBs are prevalent in captive rhesus macaques. Tinbergen's (1963) ethological framework uses four complementary levels to explain behavior: phylogeny, ontogeny, causation, and function. Phylogenetic explanations look at the behavior's evolutionary history and its genetic contributions through species comparisons, genetic and heritability research. Ontogenetic explanations investigate how a behavior develops in an individual by focusing on age, stage of development, and early experiences. Causal explanations focus on internal and external factors that initiate, maintain, and/or terminate behavior. Functional explanations consider the current, 'proximate' benefits of the behavior, as well as its likelihood of improving the animal's fitness (ultimate fitness). Tinbergen (1963) argued that these four aspects, sometimes called 'the four whys', are equally important and together provide a comprehensive explanation. This is significant as SIB studies may focus on only one or two aspects, therefore overlooking other contributing key variables. Here these four questions comprehensively explore how and why SIBs exist in captive rhesus macaques.

As well as synthesizing rhesus macaque research, this paper reviews relevant human literature on non-suicidal SIBs. SIBs in captive primates appear similar to self-mutilation acts seen in humans, however unlike non-human primates, human subjects can verbally self-report motives for SIBs. Forms of SIBs exhibited in humans vary by population; SIBs seen in individuals with intellectual and developmental disabilities include self-biting, head-banging, and head-slapping (Symons and Thompson, 1997), while self-hitting (plus self-cutting and self-burning, clearly absent in macaques) are more common in general and psychiatric populations (Briere and Gil, 1998; Klonsky, 2009).

This review begins by describing the species and individuals most at risk, and their genetic and developmental predispositions (where known). This paper then describes the causes and possible functions of such behaviors. Lastly, the discussion looks at the treatment implications of each of the four whys, provides an integrated overview of SIBs, highlights future research needs, and ends by reconsidering the merit of Tinbergen's approach when studying abnormal behaviors.

2. Phylogeny

This section is the least researched and most poorly understood aspect of rhesus macaque SIBs. Thus, where data permits, this section reviews how rhesus macaques compare to other primates in their SIBs; how within-species genetic actors might contribute; and relate this to genetic predispositions in humans.

2.1. Species differences and other taxonomic effects

SIBs occur in diverse laboratory primates including squirrel monkeys (*Saimiri sciureus*, McGrogan and King, 1982), chimpanzees (*Pan troglodytes*, Walsh et al., 1982), lar gibbons (*Hylobates lar*, Bernstein et al., 1963), small-eared bushbabies (*Otolemur garnetti*, Watson et al., 2009), as well as macaques (Sackett et al., 1981). However, only one of these non-macaque studies report the prevalence of affected subjects, with 4% of their chimpanzee sample displaying SIBs (Walsh et al., 1982), which is similar to the prevalence of rhesus macaques in one study (*e.g.*, 5%: Bayne et al., 1995; but see also Lutz et al., 2003 and Novak, 2003; who report 11–25% of single-housed rhesus macaques displaying SIBs). As well, only one study has directly compared rhesus abnormal behaviors with other macaque species (pigtailed [*Macaca nemestrina*] and long-tailed [*Macaca fascicularis*]) in identical environments, and in isolation-reared subjects. Rhesus monkeys displayed "isolation syndrome" (a suite of atypical behaviors including stereotypic behaviors [SBs] and SIBs) for approximately 50% of total observations, while long-tailed monkeys displayed them for approximately 25%, and pigtailed monkeys for less than 5% (Sackett et al., 1981). Propensities for isolation-induced abnormal behaviors including SIBs thus vary by taxon, with rhesus macaques being more at risk than related species. However, this study did not specifically evaluate species differences in SIBs. Turning to zoo primates, although Hosey and Skyner (2007) argue that SIBs are not a significant issue here, researchers have recorded SIBs in Old World monkeys, New World Monkeys, apes and prosimians (Novak and Bollen, 2006; Hosey and Skyner, 2007). Nevertheless, prevalences are low (*e.g.*, 2.2–3.7%: Hosey and Skyner, 2007; Novak and Bollen, 2006), and similar across these taxonomic groups.

Species differences are worth investigating, however, because they may reflect differences in evolved species-typical behaviors (Mason, 2010). For example, Pomerantz and collegues, using a phylogenetic comparative approach to zoo primate SB, report that