The effects of olfactory stimulation on the behavior of captive ring-tailed lemurs (*Lemur catta*)

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Abstract

Ring-tailed lemurs reside in many animal collections worldwide. Lemur welfare may be a cause of concern due to some captive individuals exhibiting stereotypic behavior. Despite these concerns, there has been little exploration of methods of environmental enrichment for ring-tailed lemurs. Olfactory stimulation can enhance captive animal welfare by encouraging species-typical behaviors, enhancing behavioral diversity and decreasing stereotypic behaviors. We aimed to investigate the effects of olfactory stimulation via lavender, peppermint, coconut and prey odor upon the behavior of eight captive ring-tailed lemurs. We exposed the lemurs to six individual odor conditions (odor control, novel object control, lavender, peppermint, coconut and Morio worms) and observed them for 4 hours a day for 3 days with an intervening period of 4 days between conditions. We recorded the lemurs' behavior under each condition using instantaneous scan sampling. We found significant effects of olfactory stimulation on the ring-tailed lemurs' behavior in the initial analysis but these did not survive correction for multiple testing. Overall, whilst our findings are suggestive of a general effect of olfactory stimulation on the captive ring-tailed lemurs they did not indicate a marked influence of olfactory condition. However, further investigation with a larger sample size and more biologically relevant odors may be beneficial to fully examine potential effects of olfactory stimulation in captive lemurs.

Key words: environmental enrichment, odors, zoo welfare, lemur behavior

Introduction

Ring-tailed lemurs are the most common lemur in captivity with estimated numbers of 1869-2500 ring-tailed lemurs kept in zoos around the world (Andriaholinirina et al. 2014; WAZA, n.d). Captive lemur welfare may be a cause of concern with some individuals exhibiting stress-related stereotypic behavior (Tarou, Bloomsmith & Maple, 2005). In addition, zoo visitors may cause stress in ring-tailed lemurs, with visitor presence being associated with increases in aggression and decreased grooming behavior (Chamove, Hosey & Schaetzel, 1988). The expression of stereotypic behavior in some individuals and visitor effects suggestive of stress highlights that exploring methods to enhance welfare in lemurs would be of value. Despite their popularity, and these concerns, there is minimal research into methods of enhancing welfare for captive ring-tailed lemurs, with a focus on exploring feeding enrichment in existing research (e.g. Dishman, Thomson & Karnovsky, 2009; Maloney, Meiers, White & Romano, 2006).

One common approach to enhancing welfare in captive animals is by environmental enrichment. Shepherdson (1998) defined environmental enrichment as "an animal husbandry principle that seeks to enhance the quality of captive animal care by providing the environmental stimuli necessary for optimal psychological and physiological well-being". Environmental enrichment involves providing stimuli to animals in under-stimulating captive environments in order to enhance the expression of species-appropriate behavioral and mental activities (Reinhardt & Reinhardt, 2001). There are various types of environmental enrichment including occupational, physical, social, nutritional and sensory enrichment (Young 2003).

Olfactory stimulation is a form of sensory enrichment that aims to trigger the sense of olfaction by applying a variety of non-biologically (e.g. plant matter and essential oils) and biologically relevant odors (e.g. conspecifics, heterospecifics) (Wells, 2009). One area of increasing study is the use of non-biologically relevant odors, such as essential oils, due to their ease of access and ready availability, as well as these scents being potentially appealing to keepers and visitors.

Olfactory stimulation may have positive behavioral effects in a range of captive species. Olfactory stimulation has increased activity in chimpanzees, *Pan troglodytes* (Peppermint: Struthers & Campbell, 1996), African and Asiatic lions, *Panthera leo* (Peppermint, almond and rosemary: Pearson, 2002; Powell, 1995) and African wild dogs, *Lycaon pictus* (Prey feces: Rafacz & Santymire, 2014|). Olfactory stimulation has also been found to increase foraging in Javan gibbons, *Hylobates moloch* (Ginger: Gronqvist, Kingston-Jones, May & Lehmann, 2013) and exploration in cheetahs, *Acinonyx jubatus* (prey feces: Quirke & O'Riordan 2011) and decrease stereotypic pacing in oncilla Cats, *Leopardus tigrinus* (Cinnamon: Resende et al. 2011).

Ring-tailed lemurs have highly developed scent glands and use olfactory cues extensively in their natural habitat (Drea & Scordato, 2008; Kappeler, 1998; Schilling, 1974). They use olfactory cues in a range of contexts such as territory marking, displaying dominance, and signaling reproductive status (Drea & Scordato, 2008; Jolly, 1996; Kappeler, 1990, 1998). Olfactory stimuli could therefore hold the potential to increase behavioral diversity and encourage species-typical behavior in ring-tailed lemurs in captive environments. To date, the effects of olfactory stimulation on the behavior of ring-tailed lemurs has received little attention with past research tending to focus upon the effects of feeding enrichment in captive ring-tailed lemurs. For example, the addition of browse was found to increase ring-tailed lemurs' activity levels (Dishman, Thomson & Karnovsky, 2009) and food enrichment items were found to increase playing and grooming behavior (Maloney, Meiers, White & Romano, 2006). In this study we aimed to investigate the effects of olfactory stimulation via peppermint, coconut, lavender and prey odor on the behavior of captive ring-tailed lemurs. We chose these odors as lavender has been found to have relaxant effects in dogs (Graham, Wells & Hepper, 2005) and peppermint has increased activity in captive chimpanzees (Struthers & Campbell, 1996) and African lions (Powell, 1995). Coconut has also increased exploratory behaviors in wombats, *Lasiorhinus latifrons* (Hogan et al. 2010), and prey odor has increased activity in African wild dogs (Rafacz & Santymire, 2014) and increased exploratory behaviors in cheetahs (Quirke & O'Riordan 2011).

Materials/Methods:

Study Site

Eight captive-bred ring-tailed lemurs (six females; two males) aged between 10 months and 14 years old (mean age= 47.5 months) were used within the study. All of the lemurs were housed at Birmingham Wildlife Conservation Park, Birmingham, UK. The lemurs resided in an enclosure consisting of indoor and outdoor aspects. The outside enclosure was 40m by 11m with an electrified wire barrier on three sides, and a brook as a natural barrier on the other side of the enclosure. The inside enclosure was 6m by 4.5m with the height of the inside enclosure varying from 2m to 3m. Both inside and outside enclosures contained terrestrial substrate and bark mulch as well as climbing facilities in the form of wooden logs. The lemurs' enclosure was spot cleaned once at 12:30 hours and once again at 16:30 hours. Keepers fed the lemurs once a day at 12:30 hours by scattering food between four bowls and the floor within the inside enclosure. Daily each Lemur received 40g LowFE pellets, 120g apple/cucumber/tamarind/beans, 60g root vegetables, 60g leafy vegetables or fruit, plus a protein item which varied between 40g fruit/nut mix, chickpeas, half an egg or crickets. Keepers provided a fresh supply of water at 12:30 hours and 16:30 hours.

Olfactory Conditions

The lemurs experienced six olfactory conditions: two control conditions (odor control, novel object control) and four experimental odor conditions. In the experimental conditions, we exposed the lemurs to cloths scented with the essential oils, lavender, peppermint (Naissance Ltd, UK), and coconut (Freshskin Beauty Ltd, UK) or the prey odor, Morio worms. The odor control condition provided a comparison for the effects of the odor conditions by the use of an unscented cloth, whilst the novel object control condition, where we utilized no cloth or odor, provided a control to ensure that any effects upon behavior were not due to the novel cloth stimulus within the lemurs' environment. We chose odors based on their previously reported positive effects on captive animal welfare. We provided the control conditions first (novel object control, odor control) followed by lavender, peppermint, coconut and prey odor. We randomly determined the order of exposure to experimental conditions. Due to the lemurs being group housed, we simultaneously exposed the lemurs to each olfactory condition.

Procedure

Our experimental design was based on that used in previous similar studies investigating effects of olfactory stimulation in captive animal collections (e.g. Myles & Montrose, 2015; Wells, Hepper, Coleman & Challis, 2007). For the four experimental conditions, we introduced odors (lavender, peppermint, coconut and prey) on eight sterilized 15cm x 15cm square cotton cloths. We randomly scattered the cloths around the inside enclosure, although an approximate two-meter distance was maintained between each cloth to ensure appropriate coverage of the lemurs' environment. For the lavender, peppermint and coconut conditions we impregnated the cloths with one of the odors 60 minutes before placing the cloths within the enclosure. We used twenty ml of each essential oil treatment with a 1:2 dilution of water. For the prey odor, we placed the cloths in the Morio Worms' enclosure for 60 minutes prior to placing the cloths within the lemur enclosure. We used the same scented cloths throughout all sessions in each daily condition but we provided fresh scented cloths each day for each odor. The experimenter wore plastic gloves whilst handling cloths and applying scents, and sealed cloths, post scenting, in plastic bags, to reduce risks of contamination with human and other odors. We applied the conditions over six weeks between the 13th June and 20th July 2016.

We exposed the ring-tailed lemurs to each condition from 10:30 - 16:00 hours and observed them for 4 hours a day, in two 2 hour sessions (10:30- 12:30 hours and 14:00 – 16:00 hours). Before each observation period there was a 30 minute observer habituation period (10:00-10:30 hours; 13:30-14:00 hours). This allowed the lemurs to habituate to the observer’s presence. During the observer habituation period and observations, the observer stood in the same position in the inside enclosure. We chose these time periods to allow observations to occur around the animal collection’s usual feeding and cleaning routines. The observer placed the cloths within the environment at the end of the observer habituation period in the morning (at 10:30 hours) and they remained there till the observer removed them at the end of the day’s observations (at 16:00 hours). Post placement of the cloths within the enclosure we began behavioral observations. Observations occurred three days a week (providing a total of 12 hours observations for each condition), with a four-day interval between olfactory conditions to allow time for previous odor treatments to disperse. During observation periods, the observer recorded the lemurs’ behavior every 5 minutes using instantaneous scan-sampling providing 48 observations of each lemur’s behavior per day. The observer recorded behaviors using an ethogram adapted from previous work (Table 1; Ellwanger, 2002; Meredith, 2012; Shire, 2012) and when scan-sampling the group the observer ordered this based on individual. The observer individually identified the lemurs based on their knowledge of the lemurs’ distinctive features due to their previous volunteering experience with the lemurs. Photographs of the lemurs were also available to support individual identification if required.

Table 1: Ethogram of behaviors utilized in this study (based on Ellwanger, 2002; Meredith, 2012; Shire, 2012).

Behavior	**Description**
Resting/sleeping	Putting their head down and closing their eyes. The lemur is not engaged in any other behavior (e.g. feeding, foraging, grooming) whilst resting.
Sitting	Sitting with head up and eyes open. The lemur is not engaged in any other behavior (e.g. feeding, foraging, grooming) whilst sitting.
Locomotion	Moving within or between the enclosures, climbing facilities or on the ground. This includes all forms of movements such as climbing, walking and running. The lemur is not engaged in any other behavior (e.g. feeding, foraging, grooming) whilst moving.
Feeding	Placing a food item into their mouth and chewing the food item.
Foraging	Searching for food in the enclosure either by actively moving through the enclosure or by visually searching for food items. This also involves manipulation of food items without placing them in the mouth.
Drinking	Drinking from their water source.
Mutual grooming	Grooming another individual whilst being simultaneously groomed by another individual.

One-way grooming	Grooming another individual (without being groomed by another individual).
Mating	Engaging in copulation with another individual.
Sitting in contact	Sitting in contact with another individual (e.g. bodies or limbs are in physical contact).
Stink fighting	Rubbing their tail with scent glands and directing their tail towards another individual.
Slapping	Hitting another individual with their hand.
Fighting	Engaging in an agonistic encounter with another individual where agonistic behaviors are actively reciprocated. Fighting could include aggressive behaviors such as slapping (hitting another individual with their hand), biting (sudden motion involving oral contact) and lunging (sudden aggressive movement toward another individual with the front of the body while the hindlimbs maintain their position on the substrate).
Chasing	Pursuing another individual that is simultaneously running away.
Self-grooming	Grooming self.
Scent marking	Marking an area of their environment with their scent glands.
Interaction with cloths	Interacting with the cloth for more than 5 seconds.
Sniffing cloths	Sniffing the cloth for more than 5 seconds.

Vocalizing	Opening mouth and emitting a vocalization (e.g. yap, mew, squeak, grunt, purr, squeal etc).
Vigilance	Looking intently at surroundings/into vacant space.
Pacing	Repeatedly traveling the same path.
Self-injuries	Using their claws or teeth to cause harm to themselves; such as biting, chewing or scratching.
Out of sight	Not visible to the observer.
Other	Behaviors are displayed by the focal individual not listed above.

Data Analysis

We summed the total frequency that we observed each lemur performing each behavior, providing an overall frequency count per lemur per behavior in each olfactory condition. We omitted behaviors exhibited at very low levels (mean occurrence < 1) from analysis as statistical analyses are not robust at such low levels. We used Friedman ANOVAs to determine whether olfactory condition significantly affected the ring-tailed lemurs' behavior. Where these tests found significant differences, we conducted post-hoc analysis with Wilcoxon signed-rank pair-wise tests to determine where these differences lay between olfactory conditions. We applied a Bonferroni correction to these results resulting in a Bonferroni-adjusted significance level of $P < 0.003$ to control for type I errors. We also performed Wilcoxon signed-rank tests to determine if there was a difference in lemur behavior between no-odor and odor conditions, with the former comprising a grouped mean for each behavior for both controls and the latter a grouped mean for each behavior for the four olfactory treatments. We carried out all analyses using SPSS (version 23.0, SPSS Inc. 2016).

Results

Effect of olfactory stimulation on lemur behavior

From the Friedman ANOVA tests, we found that there was a significant effect of olfactory stimulation on resting/sleeping behavior ($\chi^2(5) = 30.986$, $P < 0.001$), locomotive behavior ($\chi^2(5) = 30.735$, $P < 0.001$), sitting behavior ($\chi^2(5) = 16.884$, $P = 0.005$), foraging behavior ($\chi^2(5) = 23.590$, $P < 0.001$) and drinking behavior ($\chi^2(5) = 11.295$, $P = 0.046$). We also found a significant effect of olfactory stimulation for mutual grooming behavior ($\chi^2(5) = 24.114$, $P < 0.001$), sitting in contact behavior ($\chi^2(5) = 19.119$, $P=0.002$) and chasing behavior ($\chi^2(5) = 18.345$, $P = 0.003$). We also found a significant effect of olfactory condition on scent marking behavior ($\chi^2(5) = 16.094$, $P = 0.007$), self-grooming behavior ($\chi^2(5) = 29.797$, $P < 0.001$), vocalization behavior ($\chi^2(5) = 26.752$, $P < 0.001$) and on vigilance behavior ($\chi^2(5) = 31.843$, $P < 0.001$). However, our post hoc pairwise analysis via Wilcoxon signed-rank tests found no significant differences in any of these behaviors between olfactory conditions (Figure 1). We also found no significant effect of olfactory stimulation on feeding behavior ($\chi^2(5) = 9.065$, $P=0.107$) and one-way grooming behavior ($\chi^2(5) = 8.419$, $P = 0.135$). We observed no occurrences of pacing, self-injurious behavior, mating or stink fighting in any of the lemurs under any of the conditions, therefore we excluded this from the analysis. Slapping, fighting, sniffing cloths and cloth interaction occurred at very low levels and we omitted these behaviors from the statistical analyses.

Effect of odor versus no-odor conditions on lemur behavior

We found a significant difference between odor and no-odor conditions for resting/sleeping behavior (Z= -2.243, P= 0.025) and locomotive behavior (Z= -2.100, P= 0.036). We found higher levels of resting/sleeping behavior and locomotion in the odor condition (Figure 1).

We also found a significant difference between odor and no-odor conditions for sitting behavior (Z= -1.965, P= 0.049), foraging behavior (Z= -2.524, P= 0.012), drinking behavior (Z= -2.038, P= 0.042), self-grooming behavior (Z= -2.521, P= 0.012), mutual grooming behavior (Z= -2.371, P= 0.018) and chasing behavior (Z= -2.201, P= 0.028). We also found a significant difference between odor and no-odor conditions for scent marking behavior (Z= -2.521, P= 0.012), vocalization behavior (Z= -2.521, P= 0.012) and vigilance behavior (Z= -2.033, P= 0.042). We found higher levels of these behaviors in the no-odor condition (Figure 1).

We found no significant difference between odor and no-odor for feeding behavior (Z= -0.845, P= 0.398), one-way grooming behavior (Z= -1.053, P= 0.292) and sitting in contact behavior (Z= -0.980, P= 0.327). Again, we recorded no occurrences of pacing, self-injurious behavior, mating or stink fighting in any of the lemurs under any of the conditions, therefore we excluded this from the analysis. Slapping, fighting, sniffing cloths and cloth interaction were exhibited at very low levels and we omitted these behaviors from the statistical analyses.

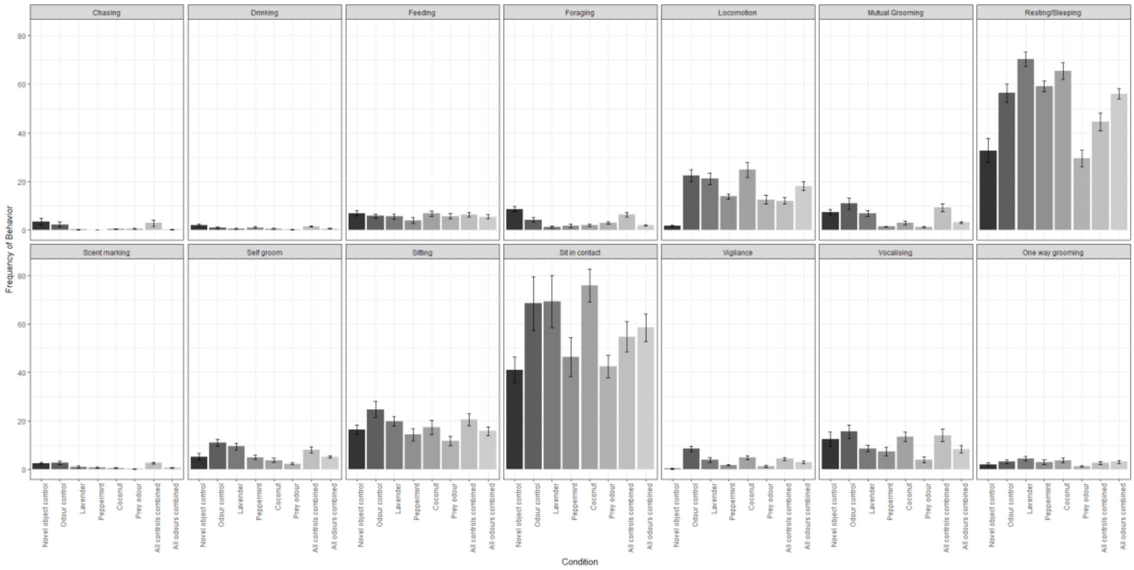

Figure 1: The mean (±S.E.) number of times the ring-tailed lemurs were recorded exhibiting each behavior during the six conditions of olfactory stimulation and the two grouped odor and no-odor conditions. The mean frequencies are presented for the three days of each olfactory condition.

Discussion

Our findings are suggestive of a general effect of olfactory stimulation on this group of captive ring-tailed lemurs but did not indicate a marked influence of olfactory condition. Whilst we found that the odor condition enhanced resting/sleeping behavior and locomotion when considered broadly against the no-odor condition, the individual odor conditions had relatively little effect on the behavior of the lemurs. Although we initially found significant effects of olfactory stimulation for many of the behaviors, these effects did not survive correction for multiple testing such that we found no significant differences in the posthoc pairwise comparisons. The relatively small sample size used in this study and risk of type II errors associated with use of the Bonferroni correction (Nakagawa, 2004; Perneger, 1998) may contribute to these findings. Whilst further research repeating this study with a larger sample size would be of value, we also need to consider other explanations for the lack of marked behavioral effects seen for the specific olfactory conditions.

Firstly, whilst the odors used in the study have been found to have beneficial effects in other species (e.g. Graham et al. 2005, Hogan et al. 2010; Rafacz & Santymire, 2014; Struthers & Campbell, 1996), the effects of olfactory stimulation are not consistent across all captive species. For instance, orange, almond, vanilla and peppermint had little effect on the behavior of Gorillas, *Gorilla gorilla gorilla* (Wells, et al. 2007) and lavender, rosemary, catnip and prey odor did not greatly influence the behavior of meerkats, *Suricata suricatta* (Myles & Montrose, 2015).

Secondly, the odors used in this study, bar the prey odor, were not biologically relevant to the lemurs. Considering lemurs' extensive use of conspecific olfactory cues (Drea & Scordato, 2008; Jolly, 1996; Kappeler, 1990, 1998), utilization of more biologically relevant cues such as fur, urine or feces from unfamiliar conspecifics may be of value in future studies. Consideration is needed though in the use of conspecific odor as this can induce anxiety under some conditions (Morgan & Tromborg, 2007), and exposure to female and male conspecific odors can result in differing behavioral effects (e.g. Descovich, Lisle, Johnston, Nicolson & Phillips, 2012; Swaisgood, Lindburg, Zhou & Owen, 2000).

Finally, the method of odor presentation may not have been appropriate for use in this context or with this species. Within the field of olfactory stimulation, studies vary in their delivery of scents, for example, through use of scent impregnated cloths (e.g. Ellis & Wells, 2010; Myles & Montrose, 2015; Wells & Egli, 2004) or via dispersed scent presentation through vaporizers or oil burners (e.g. Graham et al. 2005; Spielman, 2000; Struthers & Campbell, 1996). Dispersed scent presentation is likely to provide wider coverage for the odor than use of cloths due to fully scenting indoor enclosures (Clark & King, 2008). This may be more effective as a method of odor presentation for the lemurs. Wells et al. (2007) made similar suggestions for odor presentation in gorillas and this may be an important approach to consider in primate olfactory enrichment. There are constraints associated with scent diffusion though as this does not allow the animal to escape from the stimuli if it wishes to do so (Clark & King, 2008). Consideration could also occur of application of scents directly onto the substrate in the enclosure. This method of application could be more ecologically meaningful to the lemurs and may be an effective method of odor presentation.

Overall, our results, whilst suggestive of a general effect of olfactory stimulation on the behavior of captive lemurs in the group studied, did not indicate a marked influence of olfactory condition. However, considering lemurs' extensive use of olfactory cues in their natural environment (Drea & Scordato, 2008; Kappeler, 1990, 1998; Schilling, 1974), as well as the significant effects of olfactory stimulation found for many behaviors in the initial analysis, we believe that our findings warrant further study of the potential use of olfactory stimulation as environmental enrichment for lemurs. Future research using a larger sample size and continuous recording methods in order to enable scoring of longer duration behavioral patterns would be beneficial. In addition, further study utilizing conspecific odors and considering different methods of odor presentation may be of value.

Conclusions

1. There is a general effect of olfactory stimulation (e.g. odor versus no odor conditions) on the ring-tailed lemurs' behavior in the group studied.

2. Exposure to olfactory conditions of lavender, peppermint, coconut and prey odor affected the ring-tailed lemurs' behavior in the initial analysis but these did not survive correction for multiple testing.

3. Future research using larger sample sizes, more biologically relevant odors and different methods of odor presentation may be beneficial to fully explore the application of sensory stimulation as enrichment in this species.

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