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The effects of olfactory stimulation on the behaviour of captive meerkats (*Suricata suricatta*)

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Abstract

Olfactory stimulation has been demonstrated to enhance welfare in a range of captive species through increasing behavioural diversity or decreasing frequencies of abnormal behaviours. Despite meerkats being commonly kept in many animal collections, research into methods of enrichment for captive meerkats is minimal and to date, the effects of olfactory stimulation on the behaviour of meerkats have not been explored. This study investigated the effects of olfactory stimulation on the behaviour of five meerkats (four females, one male; all captive-born) in response to five individual odour treatments: lavender, rosemary, catnip, prey odour and a no-odour control. Odours were presented individually on cloths in the animals' enclosure for a period of three days per stimulus and meerkat behaviour was recorded using a scan-sampling technique. There was no significant effect of individual olfactory stimulation on the meerkats' interaction with the cloth or general behaviour, although when odour versus no odour conditions were considered, higher levels of vigilance and eating behaviour were exhibited in the presence of olfactory stimuli. Overall, our findings suggest that olfactory stimulation in the form of odour-scented cloths does not greatly influence the behaviour of captive meerkats. However, further investigation using a larger sample size, different methods of odour presentation and more biologically relevant odours is recommended in order to fully explore the potential application of olfactory stimulation as enrichment in captive meerkats.

Introduction

Environmental enrichment can be defined as any technique designed to improve the biological functioning of a captive animal via modifications to its environment (Newberry 1995). Environmental enrichment thus seeks to enhance the quality of care in animals through providing stimuli required for optimal physiological and psychological wellbeing (Shepherdson 1998). Environmental enrichment strategies typically aim to enhance animal welfare through achieving such goals as encouraging species-typical patterns of behaviour, enhancing behavioural diversity, increasing the ability to manage challenges and positive use of the environment and decreasing frequencies of abnormal behaviour (Young 2003). When selecting the optimal environmental enrichment strategy to use, it is important to consider the species-specific characteristics of the animals being targeted (Kreger et al. 1998). Types of environmental enrichment include occupational, physical, social, nutritional and sensory (Young 2003). Sensory stimulation, which commonly uses auditory, olfactory or visual methods of enrichment, involves the provision of stimuli aimed at activating one or more of the senses and has received much recent attention in regards to its value as enrichment (e.g. Clark and King 2008; Ellis and Wells 2008; Wells 2009; Kogan et al. 2012; Ogura 2012; Robbins and Margulis 2014).

Olfactory stimulation is increasingly being considered as a method of environmental enrichment for captive animals. Olfactory stimulation aims to trigger the sense of olfaction through the application of various biologically (e.g. prey and predator odours) and/or non-biologically relevant odours (e.g. essential oils and plant matter odours) (Wells et al. 2007; Wells 2009). A number of studies have demonstrated the potential for the application of various odours to enhance captive animal welfare by increasing behavioural diversity, encouraging species-typical patterns of behaviour or decreasing frequencies of abnormal behaviours. For example, catnip, prey odour and nutmeg have been found to increase active behaviours in captive black-footed cats, *Felis nigripes* (Wells and Egli 2004). Catnip has also been found to increase the display of play-like behaviour in domestic cats, *Felis catus* (Ellis and Wells 2010) and prey odour has been shown to increase exploratory behaviours and decrease stereotypical pacing in cheetahs, *Acinonyx jubatus* (Quirke and O'Riordan 2011). Odours such as peppermint, almond and rosemary have been found to increase the activity level of captive African lions, *Panthera leo*, and Asiatic lions, *Panthera leo persica* (Powell 1995; Pearson 2002), whilst odours such as chamomile and lavender have been suggested to have relaxant effects through increased resting and decreased vocalisation in kennelled (Graham et al. 2005) and travelling dogs, *Canis lupus familiaris* (Wells 2006).

Meerkats, *Suricata suricatta*, are a species of mongoose belonging to the family Herpestidae (Dennis and Macdonald 2009) that are kept in many animal collections worldwide (van Staaden 1994). Whilst stereotypic pacing behaviour has been exhibited in some individuals, this is displayed at a low frequency (Clubb and Mason 2007). However, even if meerkats' behavioural needs are generally met in captive environments, zoos still possess a responsibility to provide animals with environmental stimulation (Young 2003). Despite being frequently exhibited in animal collections (van Staaden 1994), research into methods of enrichment for captive meerkats is minimal and tends to concentrate on foraging-based methods (e.g. Shepherdson et al. 1989). Mongooses use olfactory cues extensively in their natural environment and they play an important role in their social interactions, foraging and anti-predator behaviour (e.g. Neal 1970; Rasa 1973; Hollén and Manser 2007; Jordan 2007). Meerkats possess an acute sense of smell (Ewer 1963) and both wild and captive meerkats have been demonstrated to be capable of distinguishing between predator and non-predator olfactory cues, with greater bouts of alarm calling produced in response to olfactory contact with predator faeces (Hollén and Manser 2007). Olfactory stimuli may thus hold potential as a method of environmental enrichment for these animals by enhancing their behavioural diversity and encouraging species-typical patterns of behaviour (Young 2003). Wild meerkats spend 5–8 hours foraging a day, which involves digging to reach invertebrates (Clutton-Brock et al. 1999). Olfactory treatments using prey odour may thus be beneficial in encouraging species-typical behavioural patterns in captive meerkats by increasing foraging and digging behaviour. Wild meerkats have also been shown to be highly explorative (Thornton et al. 2008; Thornton and Samson 2012) and novel olfactory stimuli may promote exploratory behaviour and thus increase the behavioural diversity displayed by captive meerkats.

To date, the effects of olfactory stimulation on the behaviour of meerkats has been subject to little attention. The present study thus aimed to discover whether and how meerkats respond to the introduction to their environment of five individual olfactory stimuli to help evaluate the effectiveness of these different scents in stimulating meerkats' behavioural repertoire. The study would also allow us to determine the potential for the use of olfactory stimulation as environmental enrichment for meerkats.

Materials and methods

Subjects

Five meerkats (four females, one male; all captive-born) aged between 5 and 13 years were used as subjects. No evidence of abnormal behaviour or activity patterns had been noted in these meerkats prior to this study. All of the meerkats were housed together at Walford and North Shropshire College, Shropshire, UK. These facilities are used by students at the college and occasionally open to the public for animal experience days. The meerkats are housed within a purpose-built outside enclosure. No other animals were present in the meerkat enclosure during the study. The enclosure is a circular structure of 63.64 m^2 without a roof and with a surrounding 105.3 cm brick wall. Externally the enclosure is provided with a nest box, deep soil substrate, rocks and stones scattered throughout and numerous lookout opportunities through a variety of logs/branches and wooden structures. Internally it has four underground tunnels leading directly into a 4.11 m^3 concrete compartment. This underground compartment is not divided into sub-units. The meerkats are fed twice daily (morning and afternoon). This consists of a mixture of cat biscuits and fruit and vegetables such as banana and grapes. Alongside this the meerkats are also scatter-fed twice daily with invertebrates such as crickets and mealworms. None of the meerkats had been exposed to olfactory treatments prior to this study to the researchers' knowledge.

Olfactory treatments

The meerkats were exposed to five olfactory treatments; lavender, rosemary, catnip, prey (mealworm) odour and a no-odour control. Odours were chosen for their reported positive influence on the wellbeing of other captive animals such as black-footed cats, Amur leopards and dogs (e.g. Wells and Egli 2004; Graham et al. 2005; Yu et al. 2009). Predator odours were considered for inclusion but not used due to their potentially negative effects on the welfare of the animals (e.g. Buchanan-Smith et al. 1993; Zhang et al. 2008; Wells 2009). The experimental design used was based on that previously used to investigate the effects of olfactory stimulation on the behaviour of other captive species (e.g. Wells and Egli 2004; Wells et al. 2007; Ellis and Wells 2010). The odours were introduced individually into the meerkats' enclosure on five (one per meerkat) sterilised 15 cm x 15 cm square cotton cloths. Cloths were dispersed randomly around the enclosure using a haphazard scattering approach, although to ensure appropriate coverage cloths were placed at least 5 m apart. For the control condition cloths were left odourless and for lavender, rosemary and catnip, cloths were submerged into 20 g of their dried plant matter form for 24 hours prior to the start of each treatment day. For the prey odour, the cloths were placed in a mealworm enclosure for 48 hours. Usual methods of scenting cloths with prey odours involve rubbing them over the animal or contact with prey faeces (e.g. Yu et al. 2009; Ellis and Wells 2010). Use of faeces was impractical and rubbing could cause the mealworms physical trauma, thus exposure to the mealworm enclosure was used. Increased duration of exposure to the prey was used to ensure that the cloths would still be sufficiently scented despite submersion into dried matter not being feasible in this treatment. Following scenting, cloths were placed into sealed bags to prevent contamination with external odours. Plastic gloves were also worn by the researchers when handling cloths to prevent contamination with human odour.

Procedure

At the start of each olfactory treatment, cloths were placed into the meerkats' enclosure. Each study day, cloths were introduced into the meerkats' enclosure at 0930. These cloths remained in the enclosure throughout the day and were removed at the end of the last session each day at 1630. New freshly scented cloths were placed into the enclosure the following day. This procedure was conducted for three days. Following an intervening period of four days with no cloths, new cloths with a different odour were introduced. The control condition was applied first, followed by lavender, rosemary, catnip and prey odour. This order was randomly determined. This process continued for five weeks until the meerkats had been exposed to all the olfactory treatments. Behavioural observations commenced immediately following the cloths' introduction into the enclosure. Individual meerkats were identified using a combination of distinctive features and marking via a non-toxic temporary blue dye. Meerkat behaviour was recorded every 5 min using a scan-sampling technique during three sessions each day (0930–1230, 1300–1500 and 1530–1630) providing 72 observations of each meerkat's behaviour per day. These sessions occurred at these times in order to facilitate

Table 1. Description of behaviours sampled.

Behaviour	Definition
Cloth interaction	Behaviour directed towards cloth, e.g. touching, holding, rolling, sniffing
Vigilance	Standing upright on hind legs and looking at surroundings
Locomotion	Walking, climbing or running
Foraging/digging	Scratching the surface of the substrate whilst sniffing and moving slowly or using the forelimbs to dig down into the ground
Eating	Ingesting food
Drinking	Ingesting water
Playing	Social rough and tumble play and solitary playing with a non-cloth object
Grooming	Parting the fur of itself or a conspecific with its paws followed by removing particles with its mouth or paws
Inactive (resting/ sleeping)	Reclining or sitting with eyes open or shut

observation around the usual activities of the animal collection. At each of these sample points each meerkat's behavioural state was recorded using an ethogram adapted from existing work in this area (Shepherdson et al. 1989; Lincoln Park Zoo 2010; Table 1).

Data analysis

The total number of times each meerkat was observed performing each behaviour was summed in each olfactory treatment, providing an overall frequency count per meerkat per behaviour. Active and inactive behaviours were also grouped to facilitate analysis. Inactive behaviours encompassed resting and sleeping; all other behaviours were classed as active. A Friedman ANOVA was conducted for each behaviour to determine if the meerkats' behaviour was affected by the olfactory treatments. For these analyses, where significant results were found, a post hoc Wilcoxon's signed-rank test was performed on all probable paired outcomes. Subsequently, a Bonferroni correction was applied to the results, such that the criterion of significance (0.05) was divided by the number of tests conducted (10), creating a new Bonferroni adjusted significance level set at $P<0.005$ to avoid spurious positive results (Field 2013). A Friedman ANOVA was also carried out to determine whether cloth interactions decreased over the three days of exposure time. Wilcoxon signed-rank tests were performed to determine if there was a difference in meerkat behaviour between no-odour and odour conditions, with the latter comprising a grouped mean for each behaviour for all four olfactory treatments. All analyses were carried out in SPSS (version 20.0, SPSS Inc. 2011).

Results

Overview of meerkat behaviour

Meerkats spent 1.2% of the total observation time interacting with the cloths (0.3% in the control condition, and 0.9% in the experimental treatments). Meerkats' interactions with the cloths did not decrease over the course of the three days of exposure for any of the olfactory treatments (no odour: $X^2(2)=2$, $P=0.368$; lavender: $X^2(2)=1.5$, $P=0.472$; rosemary: $X^2(2)=1.5$, $P=0.472$; catnip: $X^2(2)=2$, $P=0.368$; prey odour: $X^2(2)=0.667$, $P=0.717$).

The most frequently observed behaviour throughout the study was inactivity accounting for 24.9% of observation time. Other behaviours commonly displayed included vigilance (25.7%) and foraging/digging (20.2%). The least commonly seen behaviours throughout the observation period other than cloth interaction were eating (3.1%) and drinking (0.3%).

Effect of olfactory stimulation on meerkat behaviour

There was no significant effect of olfactory stimulation on cloth interaction ($X^2(4)=9.258$, $P=0.055$), locomotion ($X^2(4)=4.640$, $P=0.326$), foraging/digging ($X^2(4)=6.309$, $P=0.177$), eating ($X^2(4)=5.505$, $P=0.239$), drinking ($X^2(4)=7.093$, $P=0.131$), playing ($X^2(4)=4.041$, $P=0.400$) or grooming ($X^2(4)=9.333$, $P=0.053$) (Table 2).

A significant effect of olfactory stimulation was found for vigilance behaviour ($X^2(4)=9.745$, $P=0.045$). A significant difference between the frequency of active behaviours ($X^2(4)=10.400$, $P=0.034$) and inactive behaviours ($X^2(4)=10.367$, $P=0.035$) dependent on odour condition was also found. Posthoc Wilcoxon signed-rank tests showed higher levels of vigilance under the rosemary olfactory condition compared to no odour, higher levels of inactivity under the no-odour condition compared to lavender and rosemary, as well as higher levels of activity under the rosemary condition compared to the no-odour and catnip conditions, and higher levels of activity under the lavender condition compared to no odour (Table 2). However, Bonferroni corrections upon the pairwise comparisons using an adjusted alpha level of 0.005 reduced these effects such that no significant differences were found between olfactory treatments (Table 3).

Effect of odour versus no-odour conditions on meerkat behaviour

No significant difference was found between odour and no-odour conditions for cloth interaction ($Z=-0.813$, $P=0.416$), locomotion ($Z=0.000$, $P=1.000$), foraging/digging ($Z=-1.355$, $P=0.176$), drinking ($Z=-1.633$, $P=0.102$), playing ($Z=-0.135$, $P=0.893$), grooming ($Z=-1.214$, $P=0.225$), inactive behaviours ($Z=-1.753$, $P=0.080$) or active

Table 2. The mean (±S.D.) number of times meerkats were recorded exhibiting each behaviour during the five conditions of olfactory stimulation and the grouped odour condition.

Behaviour	No odour	Lavender	Rosemary	Catnip	Prey odour	Odour
Cloth interaction	3 (1.225)	2.8 (2.168)	1.2 (0.837)	1.6 (0.894)	4 (2.000)	2.4 (0.994)
Vigilance	44.4 (12.915)	49.6 (17.771)	62.6 (9.529)	60 (13.946)	50.6 (13.795)	55.7 (11.005)
Locomotion	20.2 (9.680)	19.4 (12.260)	20.6 (13.050)	22.6 (14.223)	13.4 (9.127)	19 (11.484)
Foraging/ digging	40.6 (15.947)	46.4 (11.589)	43.4 (16.861)	36.6 (15.662)	51 (14.491)	44.35 (13.142)
Eating	5.6 (1.673)	8.8 (3.114)	6.2 (1.643)	6.2 (1.643)	7 (2.828)	7.05 (1.242)
Drinking	1.2 (0.837)	1 (1.000)	0.4 (0.548)	0.2 (0.447)	0.2 (0.447)	0.45 (0.371)
Playing	8 (4.950)	9 (4.301)	6.2 (3.899)	8.2 (5.541)	7.6 (4.219)	7.75 (4.054)
Grooming	12.2 (4.438)	19 (7.416)	19.6 (8.264)	10.8 (5.805)	20 (6.042)	17.35 (5.859)
Inactive	73.4 (23.870)	51.2 (19.486)	45 (25.229)	57 (32.977)	42.8 (19.318)	49 (23.666)
Active	142.6 (23.870)	164.8 (19.486)	168.8 (23.048)	153.2 (31.901)	162.8 (23.424)	162.4 (23.921)

Table 3. Post hoc comparison of olfactory treatments for vigilance, inactive and active behaviour (Z and P values arising from Wilcoxon signed-rank tests are presented).

Comparison of olfactory treatments	Vigilance		Inactive		Active	
	Z	P	Z	P	Z	P
Lavender–No odour	-1.461	0.144	-2.023	0.043	-2.023	0.043
Rosemary–No odour	-2.023	0.043	-2.032	0.042	-2.023	0.043
Catnip–No odour	-1.841	0.066	-1.084	0.279	-0.674	0.500
Prey odour–No odour	-1.625	0.104	-1.826	0.068	-1.753	0.080
Rosemary–Lavender	-1.490	0.136	-1.289	0.197	-0.962	0.336
Catnip–Lavender	-1.604	0.109	-0.674	0.500	-1.219	0.223
Prey odour–Lavender	-0.365	0.715	-1.753	0.080	0.000	1.000
Catnip–Rosemary	-0.135	0.892	-1.625	0.104	-2.023	0.043
Prey odour–Rosemary	-1.483	0.138	-0.271	0.786	-1.483	0.138
Prey odour–Catnip	-1.219	0.223	-1.753	0.080	-1.753	0.080

behaviours (Z=-1.753, P=0.080). A significant effect of odour condition was found for vigilance (Z=-2.023, P=0.043) and eating behaviours (Z=-2.023, P=0.043) with higher levels of vigilance and eating behaviours being exhibited in the odour condition (Table 2).

Discussion

The findings of this study suggest that olfactory stimulation, in the form of odour-scented cloths, does not have a marked influence upon the behaviour of captive meerkats. Whilst the odour condition was found to enhance vigilance and eating when considered broadly against the no-odour condition, the individual odour treatments had little effect on the behaviour of the meerkats. These findings cast doubts on the efficacy of the olfactory treatments used in stimulating meerkats' behavioural repertoire.

These findings were somewhat surprising, considering the acute olfactory senses of the meerkats (Ewer 1963) and mongooses' use of olfactory cues in the wild (Neal 1970; Rasa 1973; Jordan 2007). Possibly the odours used in this study were of little interest to the meerkats. The olfactory stimuli used have been demonstrated to be beneficial in some species, with species-typical patterns of behaviour and increased behavioural diversity being promoted by catnip in domestic cats (Ellis and Wells 2010), catnip and prey odour in black-footed cats (Wells and Egli 2004) and prey odour in cheetahs (Quirke and O'Riordan 2011), and relaxed behaviours being promoted by lavender in domestic dogs (Graham et al. 2005; Wells 2006). However, this is not by any means the case for all, with olfactory stimulation using scents such as orange and vanilla having little effect on the behaviour of chimpanzees, *Pan troglodytes* (Ostrower and Brent 2000) or gorillas, *Gorilla gorilla gorilla* (Wells et al. 2007). The odours explored in this study were largely biologically meaningless to the animals. Meerkats may value odour cues that possess greater biological relevance, such as body odours, or urine or faecal material from conspecifics or heterospecifics. Introduction of olfactory stimuli from natural prey has been demonstrated to be beneficial in enhancing behavioural diversity in Sumatran tigers, *Panthera tigris sumatrae* (Van Metter et al. 2008), lions (Baker et al. 1997; Schuett and Frase 2001) and African wild dogs, *Lycaon pictus* (Rafacz and Santymire 2014). Some studies have also used scents from natural predators (e.g. cotton-top tamarins, *Saguinus oedipus*: Buchanan-Smith et al. 1993; Goeldi's monkeys, *Callimico goeldii*: Boon 2003). Whilst the use of olfactory stimuli from predators is debated due to potentially detrimental effects on the welfare of the animals (Wells 2009), the vocal and behavioural responses of meerkats induced by predator faeces (Hollén and Manser 2007) does provide some potential for their use in this species. It is also important to consider that the meerkats had previously encountered the prey odour used in the study as part of their supplementary feeding. Novelty is important in a number of species in order to promote engagement with environmental enrichment (e.g. Csatádi et al. 2008; Trickett et al. 2009; Quirke and O'Riordan 2011). Novel biologically relevant odours may therefore demonstrate more benefit as olfactory enrichment in meerkats.

Alternatively, the method of odour presentation may not have been appropriate for the meerkats. The cloths, whilst functioning to provide concentrated scent provision, were themselves novel objects. Fear due to the presence of novel objects is exhibited in a range of species including rabbits, *Oryctolagus cuniculus* (Sunnucks 1998), pigs, *Sus scrofa domesticus* (Dalmau et al. 2009), horses, *Equus ferus caballus* (Forkman et al. 2007), grey foxes, *Pseudalopex griseus* (Travaini et al. 2013), birds (Forkman et al. 2007; Richard et al. 2010) and fish (Sneddon et al. 2003). Whilst meerkats often display explorative and innovative behaviour in the wild (Thornton et al. 2008; Thornton and Samson 2012), captivity can have an impact on the typical behaviours displayed (McPhee 2004; Hosey 2005; McDougall et al. 2006). It is worth noting that in this study no fearful behaviours were displayed by the meerkats and their interest and interactions with the cloths did not change over the duration of the odour treatments; nonetheless the possibility that the novel cloths provoked fear in the meerkats should be considered. Dispersed scent provision via diffusion of essential oils has been demonstrated to enhance activity in chimpanzees (Struthers and Campbell 1996) and promote relaxation in dogs (Graham et al. 2005). Diffusing scents into enclosures may be a more effective method of odour presentation for meerkats. Dispersed scent provision does not, however, provide the opportunity for individuals to avoid potentially aversive olfactory stimuli (Clark and King 2008), an important factor to bear in mind for future studies considering using this method of odour presentation.

It is also important to consider that despite meerkats' extensive use of olfactory cues, they are highly visual animals (Ewer 1963; Moran et al. 1983), as is illustrated by their vigilance behaviour (Dennis and Macdonald 2009). Meerkats also extensively use vocal communication in the coordination of their activities and have a sophisticated system of alarm calls (Manser 2001; Manser et al. 2001; Hollén and Manser 2007). Methods using visual or auditory stimulation may be more successful in enriching the environment of captive meerkats than olfactory stimulation.

These findings could be considered to indicate that olfactory stimulation does not possess much potential value as environmental enrichment for this species, but it is important to note that we did not use a no-enrichment control in our experimental design. In our control condition we introduced a scent-less cloth into the enclosure. Future studies could determine whether olfactory stimulation is of benefit as enrichment in this species by using comparison of olfactory stimulation and no-enrichment conditions. It is also important to consider that since no evidence of abnormal behaviour or activity had been observed in the meerkats prior to this study the lack of impact of the olfactory stimulation may not be due to its form but simply because the animals possessed an adequate environment. Finally it is worth noting that whilst the olfactory treatments used in this study had little effect on meerkat behaviour, when odour versus no odour was broadly considered, enhanced vigilance and eating behaviour was exhibited in the odour condition. This suggests that olfactory stimulation for meerkats does have some worth and that further study is warranted.

Overall, our results indicate that olfactory stimulation, in the form of odour scented cloths, does not markedly influence the behaviour of captive meerkats. Whilst olfactory cues are used by meerkats in a variety of different environmental and social contexts and hence olfactory stimulation may have some potential use as environmental enrichment, this study tentatively suggests that other forms of sensory stimulation may be more beneficial in enhancing behavioural diversity in meerkats. However, further investigation using a greater sample size, different odours of more biological relevance, experimental designs incorporating comparison of olfactory enrichment and no enrichment conditions, and different methods of odour presentation should be considered in order to fully explore the potential application of olfactory stimulation as enrichment in captive meerkats.

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