AN INVESTIGATION INTO THE EFFECTS OF AUDITORY ENRICHMENT ON ZOO-HOUSED MEERKATS (*SURICATA SURICATTA*)

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ABSTRACT

Environmental enrichment is now a staple practice in animal husbandry that plays an important role in providing the highest level of welfare for animals in captivity. It involves enhancing animals' environments to allow them to perform diverse, species-specific behaviours, thus improving the animals' physical, mental and social wellbeing. This study investigates auditory enrichment. Natural sounds were played to four zoo-housed meerkats, and their behaviours were monitored using instantaneous scan sampling and their sentry behaviour was timed. The sounds played were meerkat calls, predator calls and savannah sounds; these were tested against a control of no additional sound played to the meerkats' environment but the enclosures' standard background sound of rainforest noise that was played continuously through tests. All three sound manipulations significantly increased total positive behaviours (such as movement, foraging and socialising) and increased the meerkats' time spent on sentry duty, and significantly decreased occurrence of stereotypical behaviours (repetitive actions such as pacing) and inactivity. These results are a positive step in research of enrichment for meerkats, contributing to a growing body of evidence showing the beneficial effects of auditory enrichment on a wide variety of captive animals, including zoo-housed elephants and shelter dogs.

INTRODUCTION

The welfare of captive animals is an issue of huge importance in the world today. With thousands of zoo and aquarium facilities worldwide holding millions of animals (Williams, Hoppitt and Grant, 2017), research is always advancing to better understand the needs of animals in captivity. In 1991, an amendment was made to the US Animal Welfare Act that required captive non-human primates to be provided with adequate enrichment to stimulate them psychologically (Kulpa-Eddy, Taylor and Adams, 2005). This was the first law anywhere in the world requiring the implementation of environmental enrichment. The UK Animal Welfare Act 2006 now requires all kinds of captive animals to be provided with an adequate level of care that meets their necessary physical, mental and social welfare needs (Legislation.gov.uk, 2011). Despite these improvements in legislation, one issue that has persisted in captive animals is stereotypical behaviours (Newberry, 1995); these are abnormal, repetitive actions without any apparent function (Mason, 1991), with some examples being pacing in repetitive patterns, head-bobbing, hair pulling and plucking feathers (Shyne, 2006). Mason et al. (2007) estimated that at least 10,000 captive wild animals show some kind of stereotypy, but the figure is likely far higher due to increasing numbers and sizes of animal collections.

Stereotypical behaviours are often a controversial subject in the zookeeping and zoo research community (Shepherdson, Mellen and Hutchins, 1999), as there is evidence that stereotyping is induced by stress, and is therefore a welfare concern (Young, 2007). Conversely, there is an argument that stereotypical behaviours can be comforting and reduce stress by allowing the animal to cope with a potential stressor (Shepherdson, Mellen and Hutchins, 1999). Until recently, behavioural studies have focussed on reviewing and reducing stereotypical behaviours rather than measuring stress levels (Moberg and Mench, 2007), although more studies are now investigating the latter with success. The treatment of stereotypic behaviours has proven difficult; no stereotypy (the performance of a stereotypical behaviour) has ever been completely abolished through environmental enrichment and only around 50% of attempts effectively reduce stereotyping (Swaisgood and Shepherdson, 2005).

Environmental enrichment is the enhancement of a captive animal's environment to improve their physical and psychological wellbeing (Hoy, Murray and Tribe, 2009). Zoo keepers regularly create inventive new ways of providing enrichment for the animals in their care, including making their enclosures more interesting and interactive, for example with toys and climbing opportunities, puzzle feeders and scented materials (Shyne, 2006, Young, 2007, Myles and Montrose, 2015). Auditory enrichment is the use of sounds to provide stimulation for animals. It can be cost-effective and easy to implement (Newberry, 1995); little time and effort is required to provide a positive experience for the animal (Shyne, 2006). This is a relatively understudied and underused form of enrichment in zoos, with the few studies carried out so far mostly focussing on music genres due to their noted effects on humans, laboratory animals and shelter dogs (Alworth and Buerkle, 2013; Amaya, Paterson and Phillips, 2020). In zoo settings, classical music has been found to reduce stereotyping in Asian elephants (*Elephas maximus*) and increased preening in psittacines (members of the parrot family) showing it can have positive effects (Wells and Irwin, 2008; Williams, Hoppitt and Grant, 2017). However, classical music was also found to increase stereotypical behaviour in Western lowland gorillas (*gorilla gorilla gorilla*) and decrease calm vocalisations in psittacines (Robbins and Margulis, 2014; Williams, Hoppitt and Grant, 2017), so positive effects are not universal across species or individuals. A different approach to auditory enrichment instead of music can be 'natural' sounds. Although most animals currently in zoos are captive-born and have never lived in the wild to experience what is considered natural noise, it is important to explore this option for enrichment and its potential impact on behaviour and benefits for animals. Initial studies have indicated the value of this research area, for example, in the aforementioned study of Western lowland gorillas, naturalistic sounds were also tested and decreased stereotypic behaviours (Robbins and Margulis, 2014), and in the psittacines there was an increase in preening when rainforest sounds and parrot calls were played (Williams, Hoppitt and Grant, 2017). Zoo visitors can also benefit from enrichment, it can help keepers educate the public on animals' natural habitats and may encourage animals to display natural species-specific behaviours (Sherwen et al., 2014).

As many zoo animals are born into captivity, there is understandable debate as to whether playing sounds such as rainforest soundtracks or predator calls can be deemed 'natural sounds' to an animal which has lived their whole life in captivity and never previously experienced such a thing (Mason et al., 2007). A study by Hollén and Manser (2007) investigated alarm call behaviour in captive-born meerkats by exposing them to predator and non-predator scents. They found that the captive-born meerkats gave a very similar response to wild meerkats and were able to distinguish between the two scents. They also displayed a very similar range of alarm calls when compared to wild meerkats. This strongly suggests that experience of interaction with predators is not necessary to perform species-specific anti-predator behaviours. Therefore, it can be argued that the same concept can be applied to auditory treatments, and the use of 'natural' sounds can be a valid form of enrichment for captive-born zoo animals.

The meerkat, *Suricata suricatta*, is a small member of the mongoose family *Herpestidae* and is found across southern Africa (IUCN S.S.C.S., 2015). They live in large family groups, called 'mobs', who are closely bonded and take on a variety of necessary roles such as hunting, caring for young and sentry duty to keep watch for threats from predators (Grzimek et al., 2003). Their natural predators include snakes, jackals and birds of prey such as goshawks (Grzimek et al., 2003), and they use vision and hearing to detect threats (Rauber and Manser, 2018).

Meerkats are particularly common in zoos despite being categorised as 'least concern' for extinction on the International Union for Conservation of Nature (IUCN) Red List (IUCN S.S.C.S., 2015). They are kept in most zoos, animal parks and even aquariums throughout the UK (Sherwen et al., 2014), yet there are relatively few studies focussed on meerkat enrichment. This could be because meerkats appear to be well suited to captive life (Scott, 2014). Captive meerkats make good candidates for many different styles of enrichment. They have good eyesight and a keen sense of smell and hearing (Grzimek et al., 2003), meaning many forms of sensory stimulation could be potentially effective sources of enrichment. They are explorative and inquisitive by nature, unlikely to be scared by the introduction of novel items to their enclosure where some more naturally wary species can struggle. Meerkats have a varied diet which allows for trying different kinds of feeders as enrichment. All of these factors mean there is every chance that environmental enrichment can improve their welfare in some way.

Some studies have found that meerkats stereotype less than many other species in zoo environments (Lowe, 2013), but there are still instances of stereotyping within the species. One study on meerkat enrichment looked into the effects of a slow feeder toy on behaviour, and found that it created some positive changes in behaviour, but did not significantly reduce the pacing behaviour the mob had been displaying (Shepherdson, Brownback and James, 2007). Therefore, it is important that other forms of enrichment are explored, including the auditory enrichment tested in this study.

Study Aims

It has been observed by the head keeper at Calderglen Zoo (Personal communication) that some unwanted behaviours are performed by the mob that this study focusses on, specifically running towards keepers and zoo staff in anticipation of food, often paired with pawing at the glass walls of the enclosure, and pacing. Within this experiment, these are the three behaviours considered as stereotypes. It was also expressed these meerkats are often lazy, so an increase in activity and sentry behaviour would be desirable.

The aim of this study was to investigate the effects of different auditory enrichment treatments on the behaviour of captive meerkats, with the additional aim of increasing positive behaviours, defined as sentry, locomotion (any movement; walking, running, climbing etc.), digging/foraging, grooming, and socialising, and reducing negative behaviours; defined as stereotypical behaviours and inactivity. The three auditory enrichments selected were 1) meerkat calls, 2) predator calls, and 3) savannah sounds. These will be referred to as the 'sound manipulations', meaning the changes made in the experiment to test against the control which is where no additional sound is played to the meerkats. For each of the sound manipulations tested, it was hypothesised:

Meerkat calls would cause an increase in positive behaviours and decreased negative behaviours.

Predator calls would increase some positive behaviours such as sentry duty, but may also cause an increase in negative behaviours if they induce stress.

Savannah sound would increase positive behaviours, but may also increase negative behaviours such as inactivity.

MATERIALS & METHODS

Subjects & Husbandry

The subjects for this study were four male meerkats, all captive-born. They are housed at Calderglen Zoo in Calderglen Country Park, East Kilbride, Scotland and have been together all their lives; 3 brothers all 6 years old and their father at 8 years old. They have an indoor enclosure measuring approximately 30m^2. The enclosure, pictured in Figure 1, has a thick layer of sand substrate with multiple hides, logs, cacti and high platforms. The enclosure is not shared with any other species and is kept on a temperature cycle between 24°C and 32°C throughout the day. The meerkats are fed three times a day with their food scattered throughout their enclosure. Their diet consists of a variety of fruit and vegetables, invertebrates, ferret biscuits and chicks. Feeding times were restricted to around 9am, 12pm and 3pm to allow data collection to work around feeding.

Figure 1. A photograph of the meerkats' enclosure.

Pilot Study

The title, authors' names, paper processing dates and abstract are included in the first section of the document (i.e. before the Introduction, above), which is in a single-column format.

Before the study, the keepers determined that marking the meerkats to identify them individually would not be possible as the markings did not last long enough to allow reliable

identification. There were no clear individual differences to tell the meerkats apart, so all measures were taken of group behaviour. A pilot study was conducted over two days along with research of similar experiments to decide on a specific experimental procedure (Myles and Montrose, 2015; Shepherdson, Brownback and James, 2007). To determine all possible behaviours displayed by the meerkats, an ethogram was constructed, seen in Table 1. An ethogram is a table of all possible behaviours that will be seen during the experiment that the observer can use to accurately categorise anything they see, keeping results consistent. The pilot study was also used to determine the length of the observation period, which was decided as 10 minutes to allow multiple observations to be made over a substantial length of time and not so long that it would become difficult for the observer to continuously take accurate recordings. Instantaneous scan sampling was used to observe the meerkats – this method involves the observer taking note of the behaviours performed at predetermined intervals through the total observation period, rather than trying to keep track of every change in behaviour. Here the interval time was decided at 30 seconds, this timing allowed a reliable representation of the meerkat behaviours to be recorded, whilst also ensuring that the observer could record sentry duty timings. The three sound manipulations were decided on through research of relevant sounds (Hollén and Manser, 2007; Grzimek et al., 2003). It was confirmed with the head zookeeper that predator sounds were safe and ethical to use.

Auditory Treatments

Three manipulations were chosen for testing; meerkat calls, predator calls and ambient savannah sound. The meerkat calls were sourced from YouTube (ESL and Popular Culture, 2018) and consisted of a variety of alarm calls, chatters and barks between meerkats. They were spaced out randomly, but with roughly a 5-10 second pause between calls and the full recording was played throughout the observation period. The predator calls were sourced from two different YouTube videos (Audio Raptor, n.d.; Travell, 2020) and consisted of a variety of different calls from jackals and goshawks; natural predators of meerkats. They were also spaced out randomly with roughly a 5-10 second pause between calls and alternating between the two animals, and the full recording was played throughout the observation period. The ambient savannah sound was sourced from YouTube (OpenYourMind, 2017) and consisted of a mixture of environmental sounds such as wind blowing and rustling of grass along with animal sounds including non-predatory bird calls, elephant sounds and insect chirps. It was played consistently without pauses. The noise level was not measured, but was deemed clearly audible at far sides of the enclosure without being loud enough to be harmful by the observer. There was a background soundtrack of rainforest noise and bird calls played continuously in all tests.

Experimental Procedure

Observation sessions were conducted throughout November and December 2020. Each sound manipulation was tested over two consecutive days where 10 observation sessions were conducted, with a five-day rest period between the different sound manipulations being tested to avoid carry over effects. The total time spent showing sentry behaviour by any meerkat in the mob was recorded with a stopwatch throughout each observation period whilst simultaneously recording behaviours from the ethogram (Table 1) using instantaneous scan sampling. The control (where no additional sound was played) was carried out by taking scan samples of the behaviour of each meerkat every 30 seconds for a total of 10 minutes. Total sentry time performed by any individual meerkat was timed on a stopwatch. All sound manipulations were played over the top of the background noise. For the manipulations, the speaker was placed in the same location and the selected sound was played for one minute to allow the meerkats to adjust to the noise level. It was then continuously played while observations were taken every 30 seconds for the following 10 minutes via instantaneous scan sampling and again total sentry time performed by any individual was timed on a stopwatch. The same observer performed all tests.

Data Analysis

All results were recorded using Microsoft Excel version 2019, R (version 4.0.2) and R Studio (version 1.3.1093) were used to create all graphs and run statistical analyses. To visualise the results, boxplot graphs of total positive behaviour, sentry time, stereotyping and inactivity per observation session were plotted against sound manipulation. The results were fitted to models such as Linear Models (LMs) and Generalized Linear Models

Table 1. Ethogram of meerkat behaviours recorded during the study.

Behaviour	Description
Locomotion	Walking, running or climbing around the enclosure
Inactive	Sitting or lying down, doing no other activities
Sentry	Standing on hind legs or sitting upright and alert, watching surroundings
Digging/Foraging	Scratching substrate with forelimbs, smelling and collecting any food
Grooming	Looking through own fur with paws or mouth
Socialising	Active with other meerkat(s); playing, play fighting, grooming others
Stereotyping	Pacing, digging into glass, running towards keepers when they are visible
Eating	Consuming food
Drinking	Consuming water
Interacting with the Observer or Sound	Looking and moving towards the observer and speaker
Interacting with Visitor	Looking and moving towards a visitor
Out of Sight	Not visible to the observer

(GLMs) to allow us to plot graphs and run statistical analyses, and these different models are used to find the best 'fit' for that specific set of data and gain more accurate analyses. A GLM and an F-test were used to assess total positive behaviour occurrence against sound manipulation to check for any significant differences, and Tukey's Test was run to check for more specific differences in the meerkat's responses to the individual sounds. These tests allow us to check for statistical significance; that is, to check that any differences or trends in the results are not random or chance, but are in fact caused by the manipulation, in this case the new sounds being played. Similar processes were followed for the other results; a LM was ran with F-test for sentry time occurrence, a GLM and an F-test were ran for analysis of stereotyping occurrence and a GLM and a Likelihood Ratio Test were run for inactivity occurrence. Again, Tukey's Test was run for all three sets of results. The number of observation sessions, or 'run', was then included into each of these models to determine any change in response over time exposed to each sound.

RESULTS

Total Positive Behaviour

In order to view the overall effect of the sound manipulations on positive behaviours, the occurrences of these were used to produce Figure 2.

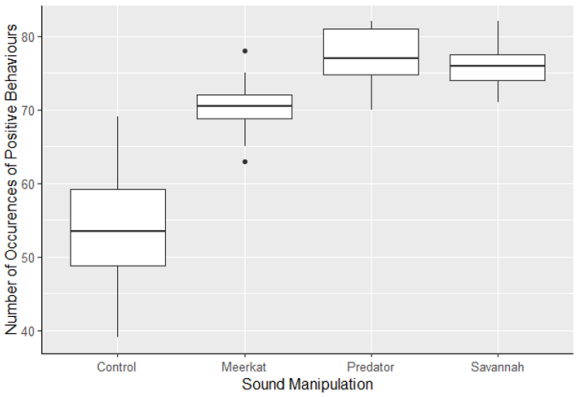

Figure 2. Boxplot displaying the number of positive behaviours displayed by the meerkats during observation sessions including the control observation and sound manipulations (meerkat calls, predator calls and savannah sounds).

The thick line in the middle of each box represents the mean average of the data, the top and bottom lines of the box itself indicate the 1st and 3rd quartile ranges of the data, the extending lines or 'whiskers' represent the maximum and minimum in the data and any dots represent outlier data; that which is most different to the rest collected. Figure 2 displays a clear increase in the occurrence of positive behaviours performed for all three sound manipulations compared to the control. This was found to be a significant difference ($F_{3,76} = 94.76$, $P < 0.001$), with an average of 63.87% of the mobs' time spent on positive behaviours during control conditions, increasing to 83.87%, 92.08% and 90.64% during meerkat calls, predator calls and savannah sounds respectively. Tukey's test showed that there was a significant increase in the total occurrence of positive behaviours shown during meerkat calls, predator calls and savannah sound compared to the control of no auditory enrichment, seen in Table 2 by the values in the 'Adjusted p-value' column being less than 0.05. Both predator and savannah sound also saw a significant increase in positive behaviours compared to meerkat calls. In summary, all three sound manipulations resulted in significant increases in occurrences of positive behaviours compared to control observations with predator and savannah sounds also having significantly greater increases in positive behaviours over the meerkat calls.

Table 2. Results of Tukey's test showing changes in occurrence of positive behaviours for the control and all 3 sound manipulations.

Comparison (Positive Behaviour)	Difference in Mean	Lower Confidence Interval	Upper Confidence Interval	Adjusted p-value
Meerkat-Control	16.80	12.83	20.77	**<2.2e-16**
Predator-Control	23.70	19.73	27.67	**<2.2e-16**
Savannah-Control	22.50	18.53	26.47	**<2.2e-16**
Predator-Meerkat	6.90	2.93	10.87	**0.00011**
Savannah-Meerkat	5.70	1.73	9.67	**0.0018**
Savannah-Predator	-1.20	-5.17	2.77	0.86

Sentry Time

The total time spent on sentry behaviour was recorded for all observation sessions, the results of which are displayed in Figure 3. Although there is more variation within this data set than seen in Figure 2, indicated by the boxes on the plot being taller so more spread along the y-axis, there is still an increase in total time spent performing sentry behaviour for all manipulations compared to the control, and this difference was significant ($F_{3,76} = 4.79$, $P = 0.004$). During control conditions the mob spent an average of 208.5 seconds on sentry duty – 34.75% of the time observed. The meerkat sound manipulation increased this to 315.5 seconds – 52.58% of the time observed, and predator calls saw the most sentry time at 317.6 seconds – 52.93% of the time observed. The savannah sound also saw an increase in sentry time compared to the control with an average of 314.3 seconds and 52.38% of the mob's time spent on sentry behaviour. The significance of each sound manipulation's effect on sentry time can be seen in Table 3 which shows the results of Tukey's test. All three sound manipulations were statistically significant when compared to the control conditions, and this time there was no significant difference when comparing each manipulation to one another when looking at time spent on sentry duty.

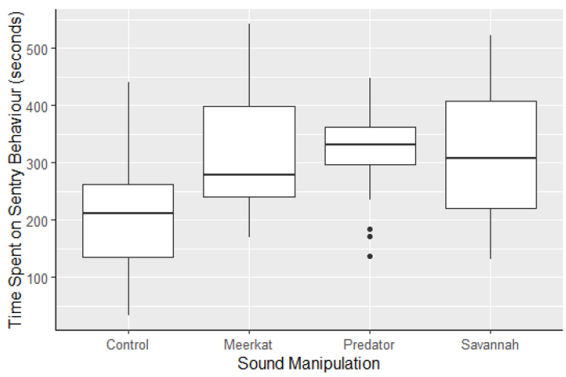

Figure 3. Boxplot displaying the time spent on sentry time, in seconds, displayed by the meerkats during observation sessions including the control observation and sound manipulations (meerkat calls, predator calls and savannah sounds).

Table 3. Results of Tukey's test showing changes in sentry time for the control and all 3 sound manipulations.

Comparison (Sentry Time)	Difference in Mean	Lower Confidence Interval	Upper Confidence Interval	Adjusted p-value
Meerkat-Control	107.00	15.94	198.06	**0.015**
Predator-Control	109.10	18.04	200.16	**0.012**
Savannah-Control	105.80	14.74	196.86	**0.016**
Predator-Meerkat	2.10	-88.96	93.16	0.99
Savannah-Meerkat	-1.20	-92.26	89.86	0.99
Savannah-Predator	-3.30	-94.36	87.76	0.99

Stereotyping

The results for the first of the negative behaviours reviewed (stereotyping) are depicted in Figure 4. During control conditions the number of occurrences of stereotypical behaviours had an average value of 3.35, while the meerkat sound manipulation reduced this to 1.1 occurrences. Predator calls saw this drop even further to 0.85 occurrences and finally

the savannah sound manipulation produced an average of only 0.45 occurrences of stereotyping. This decrease in stereotyping was found to be significant ($F_{3,76} = 10.48$, $P < 0.001$). The significance of each sound manipulation's effect on occurrence of stereotyping can be seen in Table 4 which shows the results of Tukey's test. It indicated that all three sound manipulations caused a significant decrease in occurrence of stereotypical behaviour when compared to control conditions, but there was no statistical difference in effect between the sound manipulations.

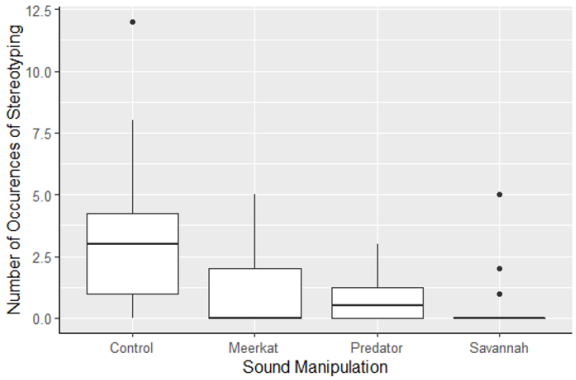

Figure 4. Boxplot displaying the occurrences of stereotyping displayed by the meerkats during observation sessions including the control observation and sound manipulations (meerkat calls, predator calls and savannah sounds).

Table 4. Results of Tukey's test showing changes in stereotyping for the control and all 3 sound manipulations.

Comparison (Stereotyping)	Difference in Mean	Lower Confidence Interval	Upper Confidence Interval	Adjusted p-value
Meerkat-Control	-2.25	-3.79	-0.70	**0.0015**
Predator-Control	-2.50	-4.05	-0.95	**0.00035**
Savannah-Control	-2.90	-4.45	-1.35	**0.000029**
Predator-Meerkat	-0.25	-1.79	1.29	0.97
Savannah-Meerkat	-0.65	-2.19	0.89	0.69
Savannah-Predator	-0.40	-1.95	1.15	0.90

Inactivity

The second negative behaviour recorded was inactivity, which displayed a similar trend to that seen in stereotypical behaviours, depicted in Figure 5. During control conditions inactivity was at its highest, with the mob spending 21.49% of their time inactive. This decreased significantly during all three sound manipulations; meerkat calls dropped inactivity to 7.86% of the observed time. Predator calls saw a further decrease so only 4.11% of the meerkat's time was spent inactive. Finally, the mob was inactive for an average of 5.12% of the time when savannah sound was played. This decrease in inactivity from all three sound manipulations was found to be significant ($LRT_{3,76} = 297.76$, $P < 0.001$). The significance of each sound manipulation's effect on the occurrence of inactivity can be seen in Table 5 which shows the results of Tukey's test. When looking at the effect of sound manipulations on occurrence of inactivity, the Tukey's test shows that all three sound manipulations caused a significant decrease in occurrence when compared to control conditions. Both predator and savannah sound also saw a further significant decrease in inactivity compared to meerkat calls.

Habituation

In order to evaluate any changes in the effectiveness of the sound enrichment over time, the 'run' (the repetition of the sound being played) was added into the models so that the first time the meerkats experienced each sound could be compared to the final time after 20 repetitions. This would allow us to visualise any habituation: a possible effect where the changes in behaviour induced by the enrichment lessen or disappear when it is used repeatedly.

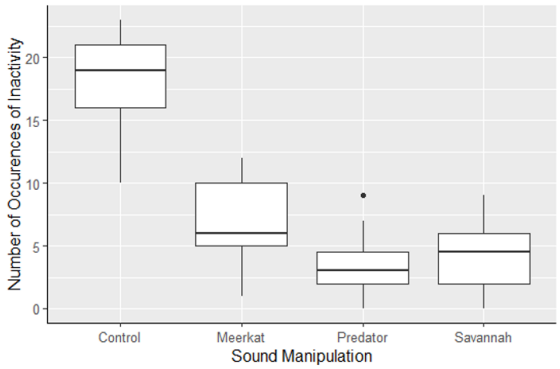

Figure 5. Boxplot displaying the occurrences of inactivity displayed by the meerkats during observation sessions including the control observation and sound manipulations (meerkat calls, predator calls and savannah sounds).

Table 5. Results of Tukey's test showing changes in inactivity for the control and all 3 sound manipulations.

Comparison (Inactivity)	Difference in Mean	Lower Confidence Interval	Upper Confidence Interval	Adjusted p-value
Meerkat-Control	-11.45	-13.99	-8.90	**<2.2e-16**
Predator-Control	-14.60	-17.15	-12.05	**<2.2e-16**
Savannah-Control	-13.75	-16.29	-11.20	**<2.2e-16**
Predator-Meerkat	-3.15	-5.69	-0.60	**0.0092**
Savannah-Meerkat	-2.30	-4.85	0.25	**0.091**
Savannah-Predator	0.85	-1.69	3.39	0.82

To look at this for the meerkat's total positive behaviour over time, run was included in the original model, and the results can be seen in Table 6. All four results here were statistically significant as the values in the 'p-value' column are less than 0.05. All three sound manipulations saw a slight increase in positive behaviour as run increased, indicated by the positive values in the 'Estimate' column. Therefore the number of repetitions of observation sessions caused a slight but significant increase in occurrence of positive behaviours for all 3 sound manipulations, and no habituation occurred.

Table 6. Effect on occurrence of positive behaviour when 'run' is added into the original model to assess change in behaviours over time.

Comparison (Positive Behaviour)	Estimate	Standard Error	t-value	p-value
Control:Run	-0.0091	0.0032	-2.87	**0.0053**
Meerkat:Run	0.0089	0.0042	2.10	**0.039**
Predator:Run	0.0094	0.0041	2.28	**0.026**
Savannah:Run	0.0086	0.0042	2.07	**0.042**

When run was included to look at sentry time, we see the following results in Table 7. Here, the only significant difference was during the savannah sound manipulation, where sentry time increased as more observations were carried out. This means there was no significant change in sentry time as more observation sessions occurred during the control conditions or during the meerkat call and predator call manipulations.

Table 7. Effect on sentry time when 'run' is added into the original model to assess change in behaviours over time.

Comparison (Sentry Time)	Estimate	Standard Error	t-value	p-value
Control:Run	-4.43	4.07	-1.09	0.28
Meerkat:Run	-1.66	5.75	-0.29	0.77
Predator:Run	3.05	5.75	0.53	0.59
Savannah:Run	15.53	5.75	2.69	**0.0087**

Table 8 shows the stereotyping behaviour model when run was included. Here there were no significant values as none of the p-values are less than 0.05, so there was no significant change in stereotypical behaviours over time during control conditions and all three sound manipulations.

Table 8. Effect on occurrence of stereotyping when 'run' is added into the original model to assess change in behaviours over time.

Comparison (Stereotyping)	Estimate	Standard Error	t-value	p-value
Control:Run	-0.016	0.032	-0.51	0.61
Meerkat:Run	-0.014	0.065	-0.21	0.83
Predator:Run	-0.029	0.073	-0.40	0.69
Savannah:Run	-0.11	0.11	-1.00	0.32

When looking at the effect of run in the inactivity model shown in Table 9, we see the only significant result is in the meerkat calls manipulation. Here as run increased, inactivity slightly decreased, indicated by the negative 'Estimate' value. This means the decrease in inactivity, a positive change, continued as the meerkat calls were played more so no habituation occurred.

Table 9. Effect on inactivity when 'run' is added into the original model to assess change in behaviours over time.

Comparison (Inactivity)	Estimate	Standard Error	t-value	p-value
Control:Run	0.010	0.0091	1.11	0.27
Meerkat:Run	-0.049	0.018	-2.75	**0.0060**
Predator:Run	0.0045	0.023	0.19	0.84
Savannah:Run	-0.013	0.021	-0.62	0.53

Many of the results in tables 6 to 9 are not significant, which indicates that there was very little difference in the behaviours between the first and last time they experienced a sound and any behavioural changes that did occur stayed at that change throughout the experiment.

Limitations

This study had some limitations similar to many other studies in this field. Firstly, a sample size of four meerkats is small, and because there was no way to identify them individually all measures had to be taken of the group as a whole. The level of detail in which you can observe animal behaviour is always important in behavioural studies. In a sound enrichment study on Western lowland gorillas, playing a rainforest soundtrack reduced stereotyping such as hair-plucking and regurgitation and reingestion of food in all three gorillas observed, although neither of these effects were statistically significant (Robbins and Margulis, 2014). Much like the current study, Robbins & Margulis had a similarly small sample size, but were able to record behaviours on an individual level – something this study could have benefitted from to assess levels of stereotypy and improvement per individual. It would be desirable if more individuals could be observed across a range of zoos to assess if the positive effects found in this study can be more generally applied to captive meerkats. This appears to be a common limitation in enrichment studies: they frequently have fewer individuals observed than desired, and rarely test on more than one group of animals or in more than one zoo. This is likely due to time and cost restraints; most zoos are likely to be focussed on the improvement of wellbeing for a range of their own animals than one specific species. Observing individual meerkats would be necessary to ensure all individuals are benefiting from the enrichment, and that none are being impacted negatively but hidden within overall positive group data (Swaisgood and Shepherdson, 2005). This could be done by using video footage and tracking the meerkats, but this is a more costly and time-consuming method than that used in the current study. A further limitation of the current study was the measurement of stereotypical behaviours. The most commonly observed stereotypy was the unwanted running towards keepers, but the appearance of keepers could not be controlled for, so will have occurred different numbers of times during different observation periods as the keepers went about their daily tasks.

DISCUSSION

The findings of this study suggest that natural sounds are an effective form of auditory enrichment for improving the behaviour and wellbeing of a mob of captive meerkats. All three sound manipulations tested: meerkat calls, predator calls and savannah sound, caused a significant increase in total positive behaviours and time spent on sentry duty, as well as a significant decrease in stereotyping and inactivity. Similar effects in meerkats have previously been achieved through other forms of enrichment. For instance, a mealworm dispenser was used as enrichment and caused a significant increase in digging/foraging, and a significant decrease in inactivity (Shepherdson, Brownback and James, 2007). Another study looked at olfactory enrichment in meerkats (Myles and Montrose, 2015), and found that scents such as rosemary and lavender increased sentry behaviour and activity levels. These studies together prove that meerkats' behaviours can be altered by a range of enrichments in a way that improves their welfare.

This study makes an important contribution to the growing evidence for the positive effects of sound enrichment. Wells and Irwin (2008) attempted to apply the calming effect of classical music in humans to a group of zoo-housed Asian elephants. They found all four individuals observed reduced stereotypical behaviours in response to classical music. Wells and Irwin also looked at the elephant's behaviour over the length of the study, and found that their response to enrichment did not change over time, suggesting that they did not habituate to the sounds played. Habituation is when an animal becomes used to an enrichment that is repeatedly used and it no longer provides positive behavioural changes, and is something to ideally avoid as much as possible. The current study found similar results when 'run' was analysed; increases in positive behaviours and sentry time stayed at increased levels for all runs, and decreases in negative behaviours also stayed low through all runs. This suggests there was no habituation in the meerkats. Longevity and reusability of enrichment is invaluable as it allows those using it to be able to rely on that enrichment for a period of time without its effect wearing off too quickly (Young, 2007).

Another point worth considering with auditory enrichment is whether an animal is reacting to the sound itself, or if the sound being played is simply masking a more distressing or uncomfortable sound such as construction equipment or traffic noise (Williams et al., 2021). Many studies have found significant differences in effect based on different sounds played, which is unlikely to be the case if the sound was simply hiding other unwanted sounds. The current study found some significant variation between the different sound manipulations; both predator calls and savannah sound caused a significantly greater increase in positive behaviours and a greater decrease in inactivity displayed than meerkat calls. This further supports the idea that it is the sound itself causing changes in behaviour and not simply the masking of other sounds.

Many environmental enrichment techniques have been used on a huge variety of captive animal species with differing levels of success. This current study has contributed to the research of auditory enrichment finding that three natural sounds tested increased positive behaviours and decreased negative behaviours in zoo-housed meerkats. An interesting next step could be an investigation into any changes in stress hormones associated with enrichment as well as behaviour. This could give good insight into physiological change instead of just behavioural, and could develop knowledge of the links between stress and stereotypical behaviours. Stress levels have been measured in meerkats by looking at levels of glucocorticoid metabolites (the products of stress hormones that can indicate how much stress was experienced) in faeces (Braga Goncalves et al., 2016). A recent study found that an increase in group size significantly decreased faecal glucocorticoids and hence stress levels. Meanwhile, increasing visitor numbers significantly increased stress levels (Scott et al., 2017). Cortisol (a stress hormone, often measured directly from blood samples) studies around enrichment have had success in other species too; captive leopards (*Felis bengalensis*) showed significantly lower cortisol levels when moved from a barren enclosure to one with dense vegetation providing shelter (Carlstead, Brown and Seidensticker, 1993). Studies such as this are crucial in the improvement of welfare for captive animals by allowing us to

understand how to effectively reduce their stress levels, and adaptations could easily be made to this experimental procedure to examine stress level changes as a result of auditory enrichment.

Overall, there needs to be more balance in the species and groups of animals for which enrichment is investigated. The vast majority of enrichment studies to date have focussed on large mammals (Shyne, 2006), particularly primates, big cats and bears. This could be because these are not only animals found in many zoos, but also are known to commonly suffer from stereotypical behaviours and poor welfare historically (Hoy, Murray and Tribe, 2009). Now that certain animal groups have been extensively covered and a solid knowledge of enrichment methods has been achieved, it may be time to focus more on the less studied groups, such as smaller mammals, reptiles and invertebrates, which have equal need for a high standard of welfare (Eagan, 2018) and which can, as this study as demonstrated, benefit substantially from enrichment.

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