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Experimental Evidence for Cross-modal Impacts of Anthropogenic Noise on Information Use

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Figure S1. Additional Responses of Dwarf Mongooses to Predator and Herbivore (Control) Faeces During Ambient-Noise and Road-Noise Playback
(A) Vigilance post-detection of the faeces was affected by the interaction between faecal type and sound treatment. During ambient-noise playback, the mongooses were more likely to be vigilant in response to predator cues cf. herbivore cues (Wilcoxon signed ranks test: $Z = 2.366$, $n = 7$, $p = 0.018$), but there was no such difference in road-noise playback ($Z = 1.690$, $n = 7$, $p = 0.091$); road-noise playback caused an increase in vigilance such that there was no difference in response to predator cues between the two sound treatments ($Z = 0.105$, $n = 7$, $p = 0.917$). (B) Time spent at the burrow before departing for foraging was also affected by the interaction between faecal type and sound treatment. The mongooses spent significantly less time at the burrow after detecting predator faeces when there was road-noise playback cf. ambient-noise playback ($Z = 2.028$, $n = 7$, $p = 0.043$), which is the opposite relative response to that exhibited following detection of the control faeces ($Z = 1.992$, $n = 7$, $p = 0.046$). Shown in both panels are results for each mongoose group separately (dotted lines; $n = 7$, although data values for some groups are the same, thus the number of dotted lines can appear less than 7) and the overall treatment mean (solid squares) ± SE. Values for trials in ambient-noise playback are given in blue and those for trials in road-noise playback are given in red.
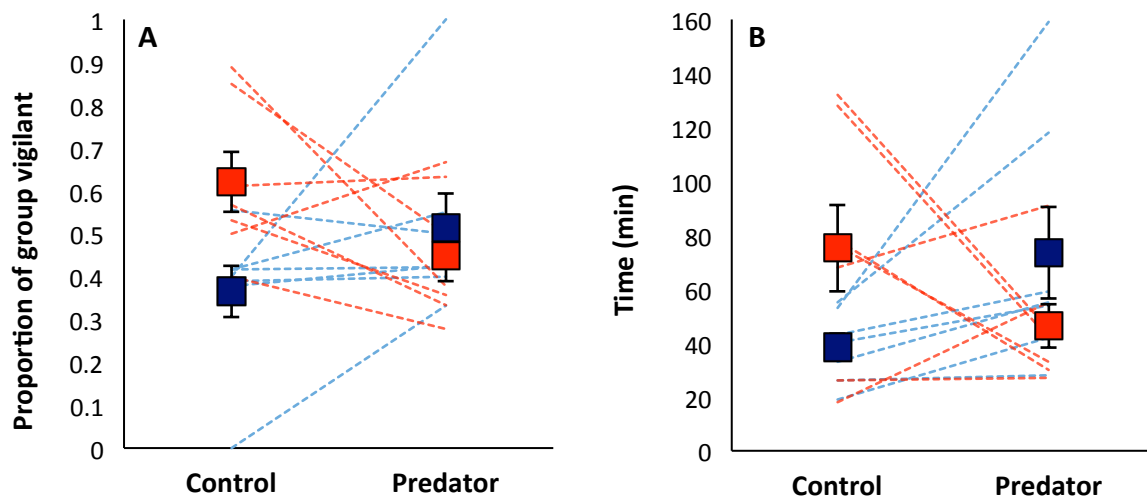
Table S1. Output from linear mixed models (LMMs) and generalised linear mixed models (GLMMs) investigating: (a) time until the first mongoose approached the faecal presentation (LMM); (b) total number of approaches elicited by the faecal presentation (LMM); (c) number of approaches that elicited sniffing behaviour (GLMM); (d) number of approaches that elicited over-marking (GLMM); (e) average proportion of adult group members vigilant in scans conducted during the 6-min period after the first mongoose had approached the faeces (LMM); and (f) total time spent at the sleeping burrow (LMM). Significant fixed terms shown in bold; variance (±SD) reported for random terms (in italics).

Fixed effect	χ^2	df	p	Effect ± SE
Time to first approach				
Age of faeces	1.229	1	0.268	-0.297 ± 0.261
Group size	0.534	1	0.465	0.729 ± 0.963
Noise	3.672	1	0.055	9.395 ± 4.806
Faeces	0.205	1	0.651	2.120 ± 4.668
Intercept				23.525 ± 4.163
Group ID				*40.480 ± 6.362*
Number of approaches				
Age of faeces	0.300	1	0.584	-0.006 ± 0.011
Group size	0.216	1	0.643	0.017 ± 0.035
Noise:Faeces	**6.910**	**1**	**0.009**	**-1.104 ± 0.417**
Noise				0.116 ± 0.295
Faeces				1.112 ± 0.295
Intercept				1.155 ± 0.217
Group ID				*0.024 ± 0.153*
Number of approaches that elicited sniffing				
Age of faeces	2.249	1	0.134	-0.028 ± 0.019
Group size	0.002	1	0.968	-0.002 ± 0.051
Noise:Faeces	**5.487**	**1**	**0.019**	**-1.063 ± 0.452**
Noise				0.154 ± 0.391
Faeces				1.720 ± 0.312
Intercept				0.494 ± 0.310
Group ID				*0.088 ± 0.297*
Number of approaches that elicited over-marking				
Age of faeces	0.016	1	0.899	0.003 ± 0.027
Group size	1.190	1	0.275	-0.078 ± 0.077
Noise:Faeces	**5.675**	**1**	**0.017**	**-1.691 ± 0.710**
Noise				0.406 ± 0.638
Faeces				2.464 ± 0.515
Intercept				-0.665 ± 0.530
Group ID				*0.223 ± 0.472*
Proportion vigilant				
Age of faeces	1.392	1	0.238	0.004 ± 0.004
Group size	1.339	1	0.247	-0.012 ± 0.010
Noise:Faeces	**5.733**	**1**	**0.017**	**-0.325 ± 0.139**
Noise				0.256 ± 0.099
Faeces				0.154 ± 0.099
Intercept				0.365 ± 0.070
Group ID				*<0.001 ± 0.001*
Time at burrow				
Age of faeces	0.848	1	0.357	0.004 ± 0.004
Group size	2.210	1	0.137	0.029 ± 0.019
Noise:Faeces	**8.517**	**1**	**0.004**	**-0.392 ± 0.131**
Noise				0.227 ± 0.092
Faeces				0.237 ± 0.092
Intercept				1.559 ± 0.922
Group ID				*0.029 ± 0.172*

Supplemental Experimental Procedures

Study site and population
Data were collected in January–July 2015 from seven groups (mean ± SE group size: 12.0 ± 1.3, range: 6–15) of wild dwarf mongooses on Sorabi Rock Lodge, Limpopo Province, South Africa (24° 11'S, 30° 46'E). Groups were habituated to close human presence (<5 m), with individuals identifiable from small blonde dye marks (Wella UK Ltd, Surrey, UK) or distinctive physical markings [S1–S3]. Dwarf mongooses are cooperatively breeding diurnal carnivores that live in large (5–30 individuals) mixed-sex groups. Owing to their small size (<300 g), they are subject to intense predation, with terrestrial predators at the study site including black-backed jackals (*Canis mesomelas*), side-striped jackals (*Canis adustus*), honey badgers (*Mellivora capensis*), African civets (*Civettictis civetta*), serval (*Felis serval*), African wildcats (*Felis lybica*), caracals (*Caracal caracal*) and slender mongooses (*Galerella sanguinea*), along with a number of reptilian species [S4, S5]. A busy tar road (R530) runs adjacent to several of the study territories.

Experimental faecal stimuli
As secondary predator cues, serval and domestic cat (*Felis catus*) faeces were used. The aim was to use faeces from servals, since they are a sympatric predator. However, fresh serval faeces were not always available when required, so cat faeces were used too. Cat faeces have been used in this regard in other mongoose studies [S6, S7], and a pilot study indicated no qualitative difference in response by dwarf mongooses to the two types of faeces [S8]. To ensure a matched design, the same predator-cue type (serval or cat) of a similar age (serval faeces: mean ± SE = 4.5 ± 0.9 days, range = 2−6 days, n = 4; cat faeces: mean ± SE = 4.9 ± 0.6 days, range = 2−7 days, n = 10) was used for the two predator presentations to a given group. Fresh predator faeces were collected in Ziploc plastic bags and frozen at -20°C; they were defrosted shortly before use (always within 1 week of freezing). The entire faecal deposit was presented, with samples visually size matched. Fresh giraffe (*Giraffa camelopardalis*) faeces of a similar size, collected and stored in the same way, were used as a control cue.

Experimental playback tracks
All sound recordings were made with a Marantz PMD660 professional solid-state recorder (Marantz, Mahwah, NJ, USA) and a handheld ME66 short-gun directional microphone (Sennheiser, High Wycombe, UK) with a Rycote Softie windshield (Rycote Microphone Windshields, Stroud, UK). Sound files were stored on a Transcend compact flash card (Transcend, Taipei, Taiwan). Ambient noise was recorded from the centre of each group's territory when weather conditions were calm and no dwarf mongooses were present. Recordings of the R530 were made from 10 m when vehicles were passing as part of another study [S9]. To standardise playbacks, natural peak amplitudes were measured (ambient noise, using a Mastech MS6700 sound meter (YunXia, ShanDong, China): 40–45 dB at 1 m; road noise, using a HandyMAN TEK1345 sound meter (Metrel UK Ltd., Normanton, UK): 65–70 dB at 10 m).

Playback tracks were produced in Praat 5.3.55 (Phonetic Sciences, Amsterdam, The Netherlands). Ambient-noise recordings were cut to a period of 15 min and any loud extraneous noise (for instance, air traffic and heterospecific alarm calls) was removed. Road-noise tracks were modified to contain the same number of vehicles as one another, with a combination of different vehicle types that related to the frequency they were observed on the road (determined from 10 1-h traffic counts conducted randomly between 6 am and 6 pm in March–April 2015). Unique ambient-noise and road-noise tracks were used for trials to each mongoose group, but the same tracks were used for the two relevant trials to a given group.

Experimental protocol
The order of the four treatments was counterbalanced between the seven groups, with trials to the same group separated by 1–3 days. All trials to a group were conducted under calm weather conditions, at the same type of sleeping burrow (termite mounds), and in similar habitat types (dense habitats with >60% ground cover were not used). Before the first mongoose emerged in the morning, the faecal sample was placed 30 cm from the latrine site at the burrow if this location was known (from previous monitoring of the group as part of the long-term study [S10]), otherwise 1 m from the main burrow entrance. A SME-AFS portable field speaker (Saul Mineroff Electronics Inc., New York, USA) was hidden from view and adjusted to the relevant playback volume (see above). The relevant playback track was started as soon as the first mongoose emerged and played on loop from an mp3 device (Kubic Evo EV8B, ARC UK) until 50% of the group had left the burrow to start foraging. Trials were filmed with a HD Panasonic DMC-XS3EB-R video camera (Panasonic House, Berkshire, UK) mounted on a tripod 2 m from the faecal sample. If a natural predator was encountered after the group had

emerged, or any other major disturbance took place (e.g. an inter-group interaction), the trial was abandoned and repeated on another day (n = 5 trials).

Data were collected only from adults, since juveniles may respond inappropriately to secondary predator cues [S11, S12]. During trials, timings of the following were noted: emergence of the first mongoose from the burrow; first approach by a mongoose within 30 cm of the faecal deposit [S10]; and when 50% of the group had left the burrow area to start foraging. Data for the remaining response variables were extracted from video recordings: scans every 2 min for 6 min after the first mongoose approached the faeces, noting the number of visible adults that were vigilant (scanning the surroundings from ground level or acting as a sentinel [S1]); and event sampling of all approaches to the faeces, documenting whether sniffing and over-marking (urinating, defecating, anal-gland marking and cheek-gland marking) behaviour was exhibited.

Data analysis
Statistical tests were carried out in R (version 3.2.2, 2015-08-14). Parametric tests were conducted where data fitted the relevant assumptions of normality and homogeneity of variance. Logarithmic and square-root transformations were conducted to achieve normality of errors in some cases (details below), otherwise non-parametric tests were used. Linear mixed models (LMMs) or generalised linear mixed models (GLMMs) were conducted accordingly (package: lme4 [S13]). Mixed models incorporate fixed and random effects, the latter accounting for the repeated trials to the same group. Random-effects models with a common subject slope but different intercepts were used, since observations were not replicated [S14].

All potential explanatory terms and two-way interactions of interest were included in the maximal model. Likelihood Ratio Tests comparing the change in deviance on removal of a term (ANOVA model comparison, Chi-squared test), along with the Akaike Information Criterion, were used to determine the minimal model [S15]. Fixed effects were dropped in order of least significance until removal of a term resulted in a poorer fit of the model. Consequently, only terms that explained significant variation in the data remained in the minimal model. Non-significant terms were individually added back to the minimal model to obtain significance levels. Values for a significant term were acquired by either comparing the term with a null model or by comparing the full minimal model with each term removed individually. Significance levels and corresponding effect sizes ± SE are shown in model tables, with only significant interactions presented. All quoted p-values are two-tailed and were considered significant below an alpha level of 0.05.

To examine whether sound treatment affected initial faecal detection, the square-root-transformed time between emergence of the first mongoose and first approach of the faecal deposit by a mongoose was analysed using a LMM. To assess subsequent interactions with the faeces, three analyses were conducted. A LMM was used on the log-transformed total number of approaches elicited by the faecal stimulus, and two GLMMs with a Poisson error structure and log-link function were used on the number of approaches that resulted in sniffing and over-marking behaviour respectively. To investigate vigilance behaviour after faecal detection, the average proportion of adult group members that were vigilant in the scan samples conducted in the 6-min period post-detection was analysed using a LMM. To consider the duration of time spent near the safety of the sleeping burrow, the log-transformed duration of time between the first faecal approach and 50% of the group leaving the burrow was analysed using a LMM. In all models, sound treatment (ambient noise, road noise), faecal type (predator, control), and the interaction between sound treatment and faecal type, along with group size and the age of the faecal deposit, were included as fixed effects; group identity was included as a random term.

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Author Contributions

A.M, J.M.K. and A.N.R. conceived and designed the study; A.M. collected the data; A.M. analysed the data with advice from J.M.K. and A.N.R.; A.N.R. wrote the first draft of the manuscript, and A.M. and J.M.K. contributed to revisions.