



Short Note

Seismic communication in spalacids: signals in the giant root-rat and Gansu zokor

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Abstract

We analysed seismic signals in two spalacid rodents, the giant root-rat (*Tachyoryctes macrocephalus*) and Gansu zokor (*Eospalax cansus*), displaying a different degree of fossoriality. Both produced seismic signals during the peak of activity, probably as territorial advertisement. Comparison with other spalacids did not reveal a relationship between inter-pulse distance and body mass; although this relationship appeared after the giant root-rat, the largest and most fossorial species, was excluded. All hitherto studied spalacids produce seismic signals by head-thumping, which probably evolved as a ritualization of soil tampering, an interesting case of convergent evolution of communication in rodents.

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Seismic communication has been described in different animal taxa, including over 40 rodent species in 18 genera (Randall, 1993; Hill, 2008). This type of communication is advantageous, especially in situations where traditional long-range communication channels are restricted, costly or jammed. In rodents, seismic signals are used mainly as a territorial advertisement, anti-predatory signalling and for mating purposes (reviewed in Hill, 2008). This way of communication is common in two ecological groups of rodents. The first consists of epigeic species living in sparsely vegetated desert areas. In such environment, seismic signals appear to be an effective way to signalling between distant individuals (Randall, 1994). The second are rodents with a predominantly subterranean activity (Hill, 2008). For them, substrate-borne vibrations represent the only effective means of long-distance communication, since attenuation of airborne sound waves by the soil separating burrow systems makes vocalisation ineffective (e.g. Narins et al., 1992). Rodents have four ways of producing seismic signals. The most common is foot-thumping, occurring in epigeic species (Hill, 2008) and in some subterranean species (Jarvis and Bennett, 1991; Narins et al., 1992). Another is chest-beating, found in the giant molerat (*Fukomys mechowii*) (Bednářová et al., 2013). In two microtines seismic signals are produced by incisor-tapping (Giannoni et al., 1997). Finally, spalacids use head-thumping, striking their head against the tunnel ceiling (Rado et al., 1987; Li et al., 2001; Hrouzková et al., 2013). A typical seismic signal consists of pulses (strikes of the particular body part against solid substrate), which can associate in bouts (sets of pulses), and may further associate in series. The bouts can have different pulse pattern, which can be species- (Randall, 1997), sex- (Narins et al., 1992), population- or individual-specific (Randall, 1995). The thumping pattern in kangaroo rats (Dipododidae) and wood

rats (*Neotoma*) seems to be influenced by body weight. The largest species, weighting about 150g, possess the most elaborated signals, with several foot-roll sequences, whereas medium-sized ones have a rudimentary signal with only one foot-roll. Species weighting less than 60 g do not drum at all (Howe, 1978; Randall, 1997). The Spalacidae, a rodent family including blind mole rats, zokors, root-rats and bamboo rats, are extremely suitable to study seismic communication and how it relates to body mass and level of fossoriality, because both factors vary remarkably across species. We studied seismic signals in two spalacids differing in size and level of fossoriality under natural and laboratory conditions. The aim of the study was 1) to describe the physical parameters, behavioural context and daily pattern of these seismic signals, and 2) to review the data collected with those on other spalacids described in the literature to reveal if the physical characteristics of the signals were influenced by species' body mass and level of fossoriality.

The giant root-rat (*Tachyoryctes macrocephalus*, Rüppell 1842) is a large fossorial species endemic to the Bale Mountains of Ethiopia (Norris, 2017). It comes regularly to the soil surface to collect food (Vlasatá et al., 2017). The research presented here was conducted in March 2014 in the Web Valley, Bale Mountains (6°59.5' N, 39°42.1' E, 3,500 m a.s.l.). Gansu zokor (*Eospalax cansus*, Milne-Edwards 1867) is a subterranean rodent distributed across grasslands and shrublands in Gansu, Ningxia, Sichuan and Hubei, China. It lives almost entirely underground (Norris, 2017). Gansu zokors were recorded near Tianzhu field station of the Gansu Agricultural University, Tianzhu Tibetan Autonomous County, Gansu, China (6°59.505' N, 39°41.149' E, 2,900 m a.s.l.) during June and July 2015. The way of producing seismic signals was analysed in pairs of animals temporarily captured, using an artificial Perspex tunnel system with two home boxes connected by a tunnel. Interactions of both homo- and heterosexual pairs were recorded for 10 minutes using a Panasonic SDR-H69 video camera. Seismic signals were recorded in field conditions using

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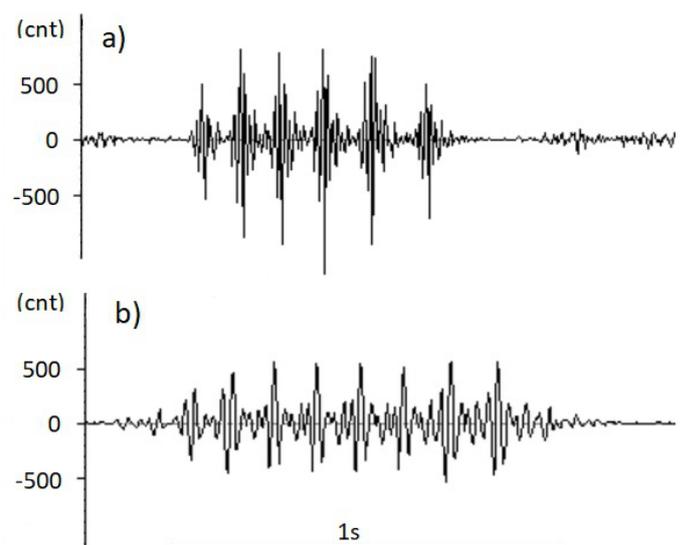
Table 1 – Characteristics of seismic signals of spalacid rodents. Means \pm SD are presented.

Species	Study type	N individuals (M:F)	Body mass (g)	Pulses per bout	Inter-pulse distance (s)	Bouts per series	Inter-bout distance (s)
<i>Tachyoryctes macrocephalus</i> ¹	Field	13(5:8)	777	5.5 \pm 1.6	0.11 \pm 0.01	2.9 \pm 1.1	1.90 \pm 0.90
male	Field	5(5:0)	858	5.70 \pm 1.28	0.11 \pm 0.01	3.0 \pm 1.3	2.09 \pm 0.93
female	Field	8(0:8)	672	5.21 \pm 1.91	0.11 \pm 0.01	2.00 \pm 0.94	1.63 \pm 0.72
<i>Eospalax cansus</i> ¹	Field	8(2:6)	190	6.90 \pm 2.33	0.13 \pm 0.01	3.80 \pm 2.21	1.90 \pm 0.86
male	Field	2(2:0)	195	6.21 \pm 2.19	0.13 \pm 0.01	6.00 \pm 4.24	2.28 \pm 1.37
female	Field	6(0:6)	183	7.11 \pm 2.35	0.12 \pm 0.01	3.46 \pm 1.81	1.78 \pm 0.63
<i>Eospalax cansus</i> (male) ²	Laboratory	4(4:0)	195	4.74 \pm 0.25	0.10 \pm 0.01		
<i>Eospalax cansus</i> (female) ²	Laboratory	4(0:4)	183	6.12 \pm 0.29	0.11 \pm 0.01		
<i>Tachyoryctes splendens</i> ³	Laboratory	6(4:2)	170	9.53 \pm 4.22	0.12 \pm 0.02	17.79 \pm 15.55	3.89 \pm 6.27
<i>Spalax galili</i> ⁴	Laboratory	24(22:2)	150	3.66 \pm 1.40	0.10 \pm 0.04	2.95 \pm 2.03	1.06 \pm 0.64
<i>Spalax galili</i> ⁵	Laboratory	14(1:13)	124 ⁷	4.01 \pm 0.56	0.09 \pm 0.01	2.60 \pm 0.77	0.79 \pm 0.11
<i>Spalax golati</i> ⁵	Laboratory	18(3:15)	143 ⁷	3.88 \pm 0.31	0.08 \pm 0.02	2.66 \pm 0.47	0.96 \pm 0.05
<i>Spalax golati</i> ⁶	Laboratory	7(4:3)	159 ⁷	2.19 \pm 0.52	0.14 \pm 0.01		0.39 \pm 0.18
<i>Spalax carmeli</i> ⁵	Laboratory	6(3:3)	129 ⁷	4.05 \pm 1.50	0.08 \pm 0.01	3.04 \pm 0.46	0.87 \pm 0.08
<i>Spalax carmeli</i> ⁶	Laboratory	6(5:1)	138 ⁷	4.06 \pm 0.46	0.12 \pm 0.01		0.44 \pm 0.30
<i>Spalax judaei</i> ⁵	Laboratory	15(8:7)	119 ⁷	6.05 \pm 0.39	0.09 \pm 0.01	2.27 \pm 0.30	0.89 \pm 0.08

¹ this study;² Li et al. (2001);³ Hrouzková et al. (2013);⁴ our unpublished data;⁵ Heth et al. (1991);⁶ Heth et al. (1987);⁷ the weights were calculated with the respect to the sex ratio in particular studies, Nevo et al. (1986).

a Vistec Gaia 3r digital data acquisition system with six seismometers ViGeo 5-1d. The seismometers were placed on the surface in two lines on above the burrows. All individuals were weighed and sexed before the recording. The position of the burrow systems were known from a concurrent radio-tracking study, or alternatively estimated based on distribution of molehills. Seismic signals were recorded from 09:00 h to 19:00 h in *T. macrocephalus*, and in irregular time intervals covering a 24 h cycle in *E. cansus*. All recordings were processed by Seismic Waves Interpretation Programme (SWIP) version 3.2.4. Statistical analysis was performed using STATISTICA StatSoft, Inc (2013) version 12. Parameters of the seismic signals analysed were the inter-pulse distance, number of pulses within each bout, and distance between bouts. Sexual differences in *T. macrocephalus* were analysed by Man-Whitney U test. Influence of body mass on inter-pulse distance and number of pulses in seven spalacid species (Table 1) was analysed by linear regression. The analysis of specificity of seismic signalling was performed on species with sufficient datasets (*Spalax galili*, *E. cansus*, *T. macrocephalus*, *T. splendens*) by Discriminant Functional Analysis (DFA) with a priori classification.

Head-thumping was observed in two dyadic tests in *T. macrocephalus*. These signals were exhibited by two large males (1,150 g and 1,164 g) when tested against other large male. No seismic communication was observed in dyadic tests in *E. cansus*. We recorded seismic signals of *T. macrocephalus* in the field in five males and eight females, out of five male and 11 female recorded (Tab. 1, Fig. 1a). Males produced more pulses per bout than females ($U=1276.5$, $p<0.01$). The most recordings were obtained between 11:00–13:00 h, with a second smaller peak around 17:00 h (Fig. 2b). We recorded two antiphonal exchanges, between two males and two females respectively. We recorded seismic signals of *E. cansus* in the field in two males and six females out of 11 male and 17 female monitored (Tab. 1, Fig. 1b). Sex differences were not evaluated due to the low number of recorded males. Zokors produced seismic signals mainly during the night (22:00–23:00 h) and during early morning (04:00–07:00 h; Fig. 2a). We recorded two antiphonal exchanges. The first one was between two females and the second between a female and a male. The comparison of physical properties of seismic communication between four species of spalacids (*S. galili*, *T. splendens*, *T. macrocephalus* and *E. cansus*) indicated that this signal could be perceived as species-specific. The best resolution was obtained in *S. galili* (Tab. 2). Body mass was pos-

**Figure 1** – Oscillogram of one bout of seismic signalling of a) *T. macrocephalus* containing six pulses, b) *E. cansus* containing nine pulses.

itively correlated with inter-pulse distance in seven spalacids only if *T. macrocephalus* was omitted (if included: $R^2=0.02$, $p=0.69$, if omitted: $R^2=0.53$, $p=0.03$). The influence of weight on number of pulses per bout was not significant ($R^2=0.02$, $p=0.7$), even after omitting *T. macrocephalus* ($R^2=0.17$, $p=0.69$).

We provide information on the physical characteristics of substrate-born vibrations in two subterranean rodents representing different spalacid genera. We studied individuals in their natural burrow systems, which is a novel approach compared to hitherto studies. In both species, period of the most frequent thumping corresponded with their highest activity; in *T. macrocephalus* for instance 90% of outside nest activity occurred between 09:00–18:00 h (Vlasatá et al., 2017), and two peaks of head-thumping in *E. cansus* corresponded with two peaks of summer activity (15:00–22:00 h and 00:00–07:00 h) (Zhou and Dou, 1990; Zhang, 2007). In *S. ehrenbergi* the seismic signals emitted in the series were used as territorial advertisement (Rado et al., 1987).

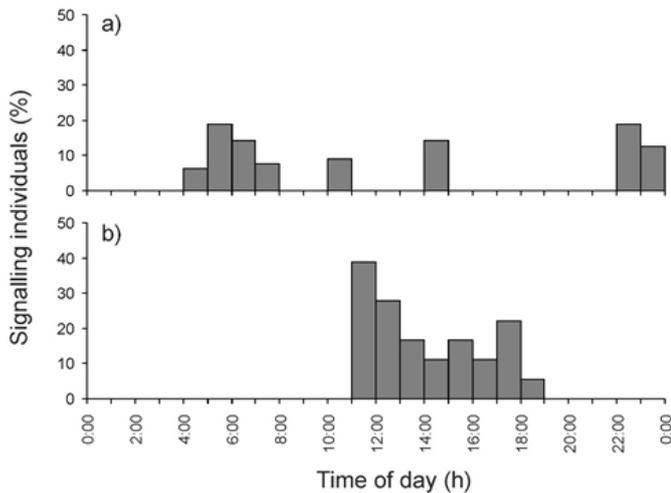


Figure 2 – Proportion of individuals producing seismic signals out of all individuals recorded in 1 h intervals of the 24 h day in a) *E. cansus* (10–20 individuals) and b) *T. macrocephalus* (8–13 individuals).

Table 2 – The success rate of classification of the signals according to DFA in spalacids, Wilk's lambda is 0.34.

	Percent correct
<i>Spalax galili</i>	86.4
<i>Tachyoryctes daemon</i>	50.0
<i>Eospalax cansus</i>	75.0
<i>Tachyoryctes macrocephalus</i>	61.5
Total	73.5

Four antiphonal exchanges recorded in our study, of which three were between individuals of the same sex, may indicate the same purpose. However, sexual differences in *T. macrocephalus* signalling suggested that these may be used in a mating context similar to that of the Cape mole-rat (*Georychus capensis*) (Narins et al., 1992). The relationship between body weight and seismic signal parameters in rodents has been studied only in kangaroo rats (Randall, 1997). The largest kangaroo rat has a complex signal (several sequences of foot-rolls with 69 foot-drums each) with the smallest inter-pulse distance (Randall, 1997). Compared to kangaroo rats, spalacids have simpler signals (2.1–9.5 thumps per bout) and their inter-pulse distance increases with body weight after excluding the largest species *T. macrocephalus*. Among mammals, head-thumping seems to be unique to spalacids, and it has only been described in three spalacid subfamilies: Spalacinae, Myospalacinae and Rhizomyinae (Rado et al., 1987; Li et al., 2001; Hrouzková et al., 2013, this study). It should be noted that we did not observe head-thumping in *E. cansus*, although this behaviour was described elsewhere (Li et al., 2001). In epigeic mammals, the origin of seismic signals is often explained as a ritualization of a conflict between fight and flight (Hill, 2008). Flight means running, so the seismic signal is usually produced by foot-thumping. The origin of using substrate-born vibration for communication purposes in subterranean mammals is probably different. Subterranean rodents need to get rid of

excavated soil, which is deposited in mounds or below ground in used burrows. Their seismic communication would seem to have evolved as a ritualization of the tampering of soil during soil removal. Interestingly, bathyergids use their hind feet to push and tamper the soil, and so they also use their hind feet for thumping (Jarvis and Bennett, 1991; Narins et al., 1992), whereas spalacids use their head for both activities (Rado et al., 1987; Li et al., 2001; Hrouzková et al., 2013). This is thus an extremely interesting case of convergent evolution of communication used for the same purposes while involving different organs. ☞

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