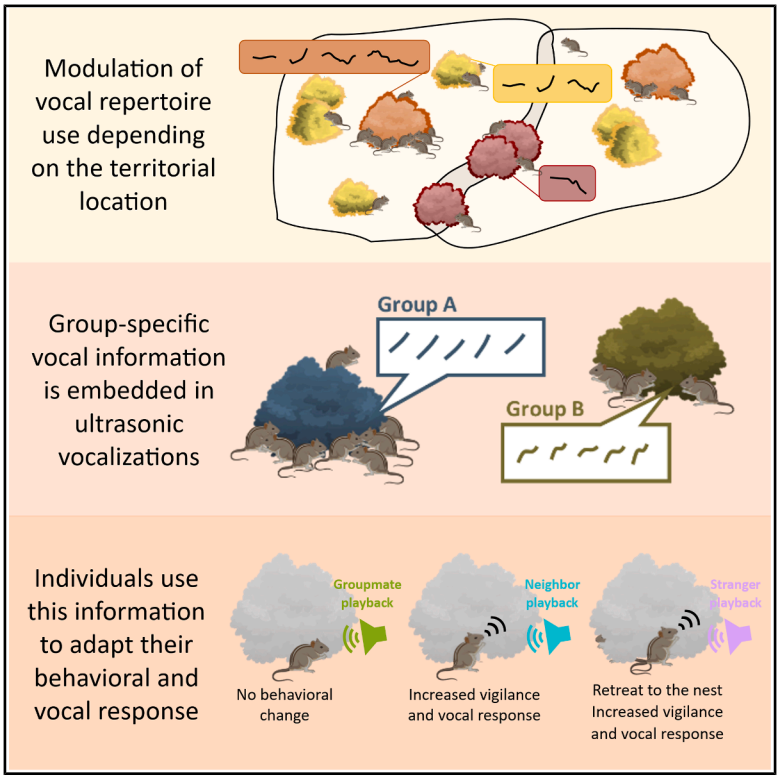
Report

Current Biology

Ultrasonic signals support a large-scale communication landscape in wild mice

Graphical abstract



Highlights

- Striped mice use different ultrasonic calls at nest, in territory, and at its border
- Ultrasonic vocalizations contain group-specific signature, encoding social identity
- Mice discriminate between groupmates, neighbors, and strangers via their calls
- Strategic vocalizing at territory edges extends the function of short-range signals

Authors

Léo Perrier, Lény Lego, Tristan Cladière, ..., Michael D. Greenfield, Nicolas Mathevon, Florence Levréro

Correspondence

leo.perrier@unine.ch

In brief

Perrier et al. show that wild African striped mice (*R. pumilio*) use short-range ultrasonic signals for large-scale communication. By vocalizing at key territorial locations, they extend the functional reach of these private signals, broadcasting group identity to differentiate between groupmates, neighbors, and strangers, mediating complex territorial dynamics.

Perrier et al., 2025, Current Biology *35*, 4837–4844
October 6, 2025
https://doi.org/10.1016/j.cub.2025.08.028

CellPress

Current Biology

CellPress

Report

Ultrasonic signals support a large-scale communication landscape in wild mice

Léo Perrier,[1,8,10,*] Lény Lego,[1,8] Tristan Cladière,[2] Martin Blanchard,[2] Lindelani Makuya,[3,4] Wiebke Berns,[1] Aurélie Pradeau,[1] Carsten Schradin,[3,4] Michael D. Greenfield,[1,5] Nicolas Mathevon,[1,6,7,9] and Florence Levréro[1,6,9]

[1]ENES Bioacoustics Research Laboratory, CRNL, CNRS, Inserm, University of Saint-Etienne, 42023 Saint-Etienne, France
[2]University of Saint-Etienne, CNRS, Institut d'Optique Graduate School, Laboratoire Hubert Curien UMR 5516, 42023 Saint-Etienne, France
[3]School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Private Bag 3, WITS, Johannesburg 2050, South Africa
[4]Université de Strasbourg, CNRS, IPHC UMR 7178, 67000 Strasbourg, France
[5]Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, KS 66045, USA
[6]Institut universitaire de France, 75231 Paris, France
[7]Ecole Pratique des Hautes Etudes - PSL, CHArt Lab, PSL University, 75014 Paris, France
[8]These authors contributed equally
[9]Senior author
[10]Lead contact
*Correspondence: leo.perrier@unine.ch
https://doi.org/10.1016/j.cub.2025.08.028

SUMMARY

Communication is central to mammalian social life, enabling group coordination and individual interactions, and often involves a trade-off between reach and privacy.[1] While signals resisting environmental attenuation reach distant audiences, they risk interception by predators or eavesdroppers; conversely, short-range signals ensure private exchanges.[2] Rodents frequently utilize ultrasonic vocalizations,[3–5] which, due to rapid environmental attenuation,[6] are generally considered a private channel for close-contact interactions within social groups.[5,7] Although laboratory studies revealed that rodents' ultrasonic vocalizations encode rich information like emotions,[5,8] identity,[9,10] sex,[11–13] and strain,[12,13] the role of these physically constrained signals in organizing broader social landscapes remains largely unexplored in the wild.[14–17] Here, we investigated the communication system of the African striped mouse (*Rhabdomys pumilio*), a highly social and territorial rodent, combining propagation experiments, passive acoustic monitoring, and playback in the field. We show that striped mice emit ultrasonic calls within family groups and at territorial boundaries, using different types of vocalizations depending on the location. Furthermore, these signals carry group-specific information, allowing mice to discriminate between group members, neighbors, and strangers. By vocalizing at key locations, striped mice extend the functional range of their short-range signals to support a large-scale communication landscape mediating complex territorial dynamics.

RESULTS

The African striped mouse is a diurnal, territorial species living in social groups.[18] Closely related to the laboratory mouse, it is an emerging model in evolutionary and ecological research, offering a bridge between lab and field studies.[19–21] A previous study has documented its vocal repertoire in captivity, showing context-dependent ultrasound emission.[22] Here, we employed a multifaceted approach in the wild, using sound propagation experiments to define the active space of signals, long-term passive acoustic monitoring with microphones across multiple territories, neural network analysis to explore vocal group identity, and field playback experiments to assess behavioral responses. We probe the paradox of using physically limited signals for potentially broad social functions by asking three core questions: are high-frequency ultrasounds restricted to private, intra-group communication or do they allow mice to interact with a broader range of individuals? Does ultrasonic signaling shift strategically with location, adapting the message to the context? And, crucially, can ultrasonic calls broadcast group identity, thereby driving neighbor-stranger discrimination and shaping territorial dynamics?

Propagation of high-frequency ultrasonic vocalizations

In animal communication, information exchange spans from private one-to-one or family-based interactions to broader public exchanges involving multiple groups[23,24] (Figure 1). Striped mouse high-frequency ultrasonic vocalizations (50–74 kHz[22]) are expected to attenuate rapidly due to their pitch.[6] Using a loudspeaker calibrated to emit mouse calls at the natural intensity (see STAR Methods), we found that vocalizations become indistinguishable from ambient noise after 2 m (Figure S1). Consequently, the active communication space for a striped mouse is confined to the bush it occupies and its immediate surroundings, suggesting a highly localized signaling system.

Spatial distribution of vocalizations

Striped mice form family groups of up to 30 individuals, including one breeding male, 2 to 4 breeding females, adult

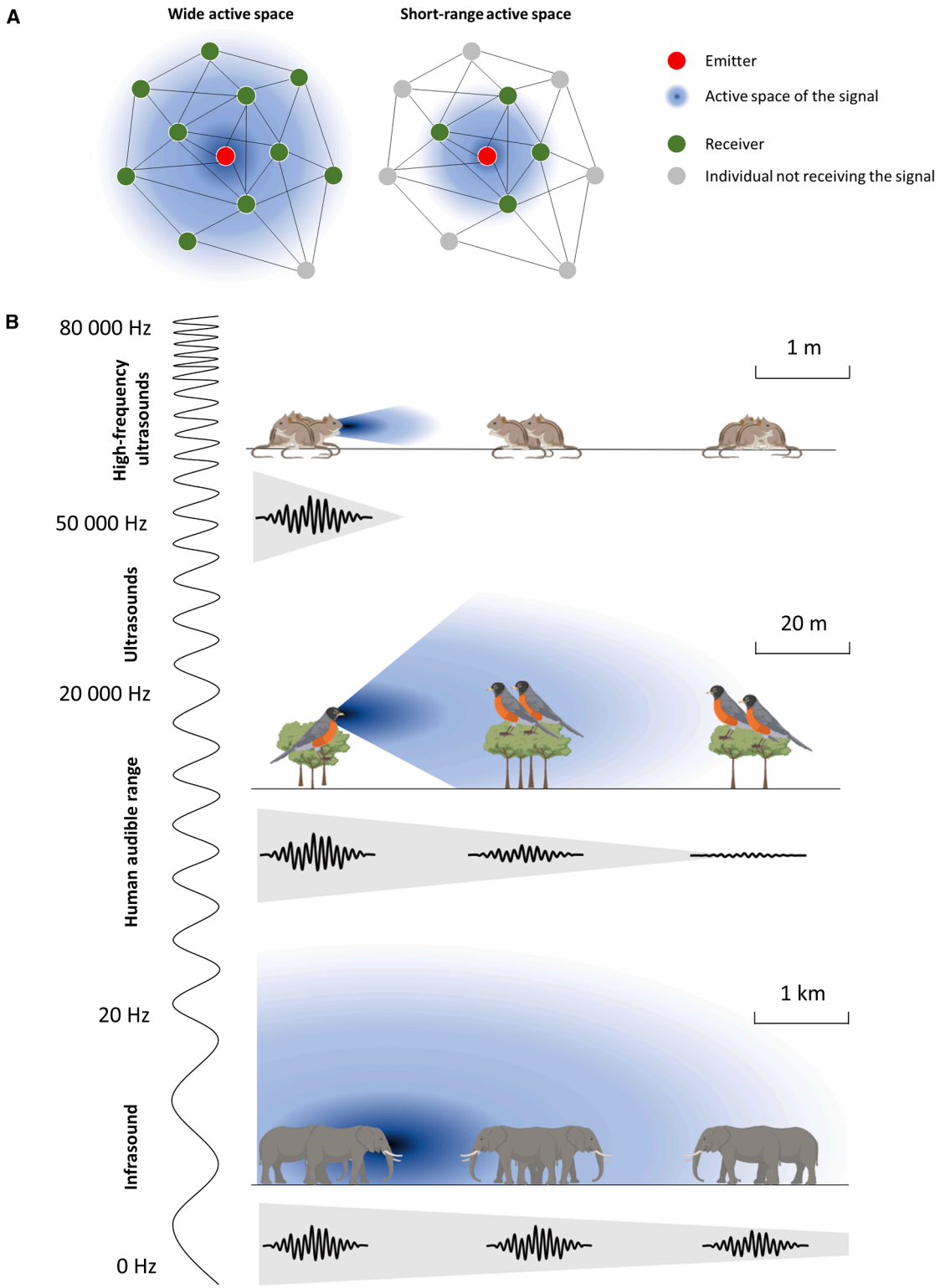


Figure 1. The use of ultrasounds as communication signals is a challenge for broad social functions

(A) The active space of a signal—the region where receivers can decode its information—depends on the signal's physical properties and the environment. Larger active spaces enable "public" communication networks among multiple individuals, whereas smaller ones support "private" exchanges.

(B) Sound frequency shapes active space: high-frequency ultrasounds (>50 kHz) attenuate quickly (see also Figure S1) and are highly directional, limiting communication to close range and hindering broader network formation. Audible frequencies (1–20 kHz) allow neighbor identification and distance estimation via sound degradation. Infrasounds (<20 Hz) travel vast distances, facilitating inter-group communication.

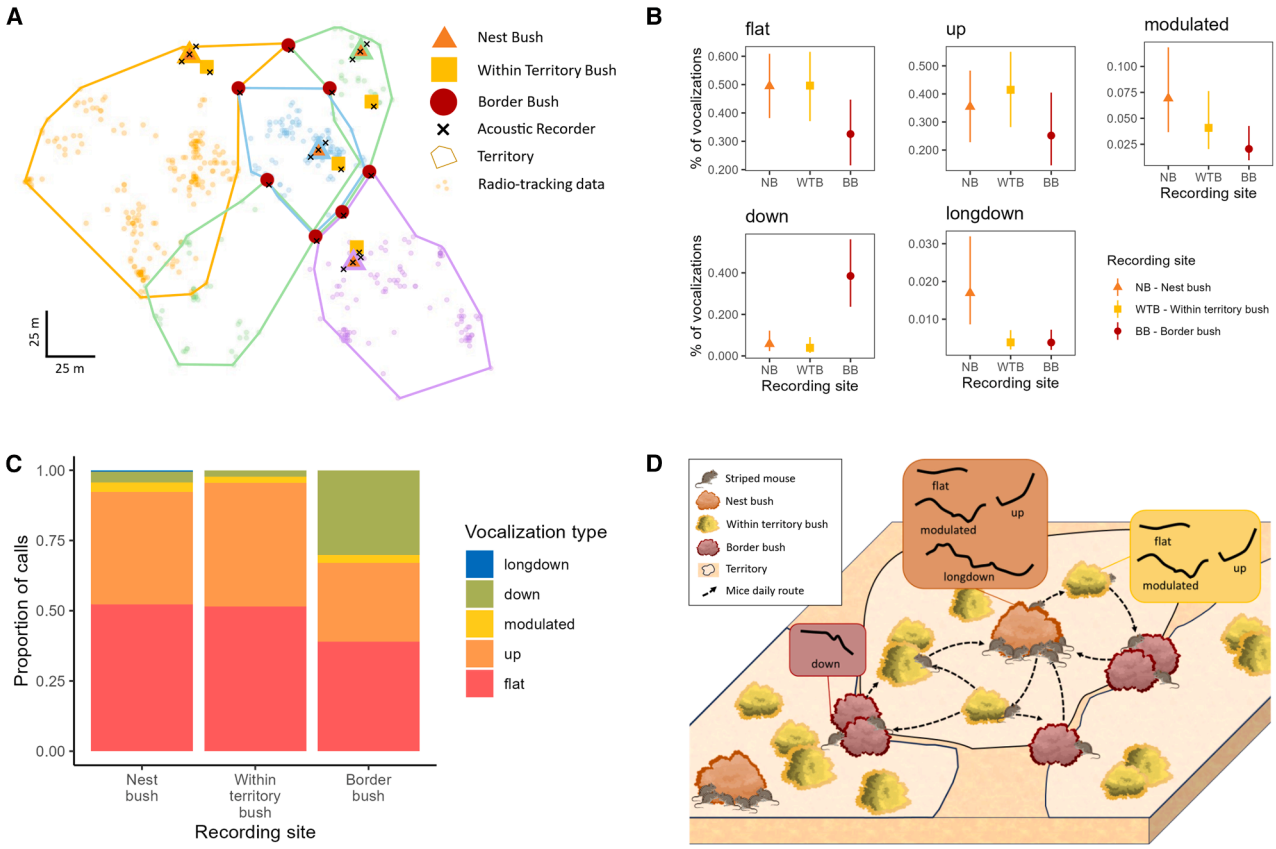


Figure 2. Location-dependent ultrasonic vocalizations in striped mice

(A) Map of the field study area showing mouse territories. Based on capture-mark-recapture, radio-tracking, and observational data, bushes were classified as: nest bushes (triangles), containing a group's communal nest; within-territory bushes (squares), used exclusively by one group; and border bushes (circles), used by at least two groups. Black crosses indicate acoustic recorder locations (see also Table S1).

(B) Mice produce a diverse repertoire of calls (mainly "flat," "up," "modulated," and "long-down") during social interactions near the bush (NB), as shown by the proportional representation of call types. In contrast, foraging within the territory (WTB) is characterized primarily by short "flat" and "up" calls. At territory borders (BB), where inter-group conflict is likely, "down" calls predominate. Solid shapes represent median of posterior distribution, with bars displaying the 95% credible interval (see also Table S2).

(C) Percentage distribution of 122,619 categorized vocalizations recorded at nest (n = 115,408), within-territory (n = 6,000), and border (n = 1,211) locations.

(D) Schematic summary of the spatial distribution of call types (stylized spectrograms).

helpers, juveniles, and pups.[18] They are highly social; individuals interact at the nest but forage alone during the day.[18] The restricted range of their ultrasonic signals raises the question of whether these signals are limited to these close-knit, intra-group interactions at or near the nest or extend across the broader territory. To address this, we mapped the territories of four striped mouse groups (comprising 8 to 23 mice) using capture-mark-recapture methods, radio-tracking, and behavioral observations (see STAR Methods).[25] Individual home-range sizes, estimated on radio-tracking data only, ranged from 220 to 1,330 square meters. We then deployed 23 autonomous recorders across these territories, targeting three bush types: nest bushes, bushes within the territory, and bushes at the borders between adjacent groups (Figure 2A; Table S1). Over 12 days, vocalizations were detected in all locations. Nest bushes exhibited the highest activity, averaging 1,956 calls/day/bush, likely reflecting greater mouse presence at night due to the high occurrence of vocalizations at sunrise and sunset. Interestingly, territory bushes averaged 115 calls/day/bush, and border bushes 25 calls/day/bush, revealing that high-frequency ultrasounds are not exclusive to the nest but are utilized throughout the territory.

Location-specific vocal repertoires

To explore whether the vocalizations depend on the type of bush in which they occur, we analyzed the composition of 122,619 recorded calls based on their frequency modulation patterns using supervised classification,[22] allowing each identified vocalization to be assigned to one of the following categories: flat, up, modulated, down, and long-down calls (Figures 2B and 2C). In nest bushes, the repertoire was notably diverse, comprising flat calls (50%), up calls (38%), modulated calls (3%), down calls (3%), and long-down calls (0.3%). Bushes within the territory mirrored this profile, though long-down calls were absent. In contrast, border bushes displayed a distinct shift: flat and up calls decreased significantly compared with nest and territory bushes (flat: −16.82%, 95% credible interval [CI]: [−30.25%; −2.77%] and −16.97%

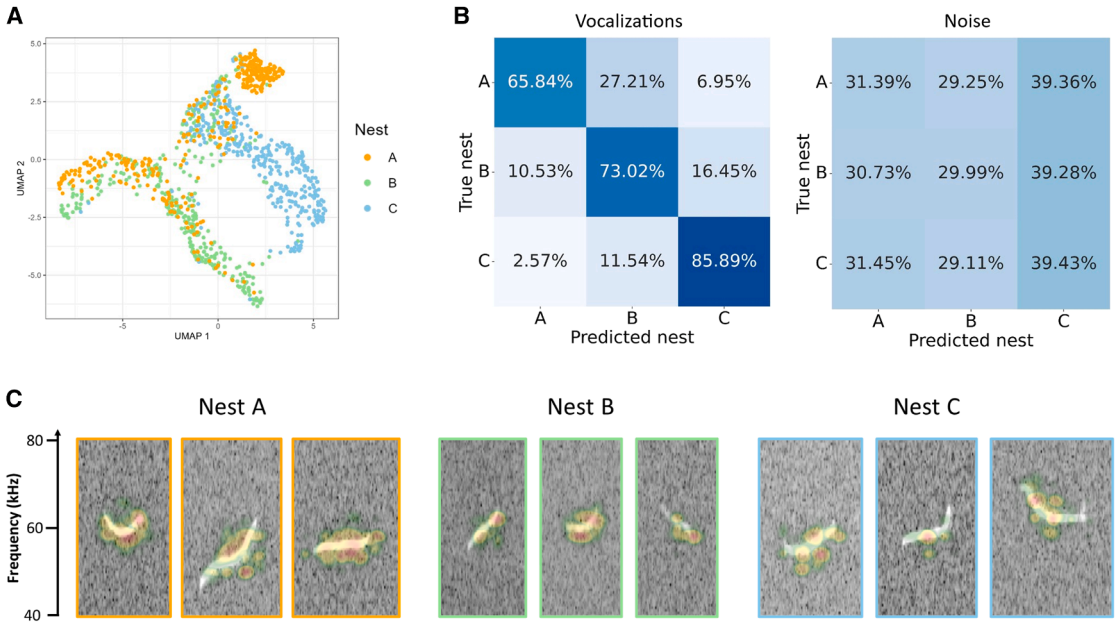


Figure 3. Group-specific vocal information in striped mouse ultrasonic calls

(A) Acoustic clustering. A two-dimensional UMAP projection of call features extracted by a neural network reveals distinct clusters corresponding to each family group, indicating group-specific vocal information in mouse vocalizations.

(B) Classification performance. Left: a confusion matrix shows the neural network's ability to correctly identify family groups from calls, with an average accuracy of 75%. Right: a confusion matrix demonstrated that the neural network performs at chance level when classifying background noise.

(C) Acoustic feature importance. Neural network activation maps highlight spectrogram regions most influential for classification, revealing that frequency modulation and pitch carry group-specific information.

[−31.36%; −2.27%]; up: −9.78% [−23.45%; −4.63%] and −15.76% [−29.79%; -0.98%], respectively), whereas down calls surged (+32.41% [19.17%; 48.12%] vs. nest; +34.26% [20.6%; 50.43%] vs. territory). This marked increase in down calls at territorial edges suggests that they play a specialized role, potentially in signaling during inter-group encounters, suggesting location-dependent vocal plasticity. In summary, a striped mouse may use its vocal repertoire differently depending on the bush it occupies within its territory (Figure 2D; Table S2).

Group-specific vocal information

We next investigated whether these vocalizations convey group identity, which could facilitate recognition of insiders vs. outsiders. We collected high-quality recordings of 18,213 calls from three distinct groups near their nests and analyzed them using a pre-trained convolutional neural network (see STAR Methods). A two-dimensional UMAP (Uniform Manifold Approximation and Projection),[26] based on call features extracted by the neural network, revealed clear clustering by group (Figure 3A), a result confirmed by a classification accuracy of 74.9% (Figure 3B). A control analysis of background noise recorded 20 ms before the vocalizations failed to classify this noise correctly, supporting the conclusion that ultrasonic vocalizations are the primary information classified by the method (Figure 3B). Additionally, neural network activation maps revealed that the spectrographic "shape" of the calls, particularly their frequency modulation, served as the primary medium for group-specific information (Figure 3C).

Behavioral responses to playback

This evidence of group-specific information suggests that ultrasonic vocalizations could serve as identifiers of social groups, potentially critical for territory dynamics. We tested this hypothesis by conducting playback experiments during the morning when the mice were basking at nest bushes (Figure 4A). We exposed 23 individuals from 3 different groups to 1-min sequences of calls from their own group, a neighboring group, a stranger group, or non-biological control sounds (noise within the mouse frequency band). Behavioral responses varied sharply by call origin (Figures 4B and 4C; Table S3; Video S1). Calls from strangers triggered retreat to the nest bush in 40% of trials (median latency 1.8 s), increased vigilance by 18.8 s ([8.9 s; 29.4 s]), and reduced basking by 20.0 s ([−30.7 s; −10.3 s]). Neighbor calls elicited a milder reaction, still increasing vigilance by 11.2 s ([2.0 s; 20.7 s]) but without promoting retreat. In contrast, group calls and control sounds provoked no significant behavioral change. Both stranger and neighbor calls stimulated heightened vocal output, with vigilance linked to increased production of down and flat calls and a reduction in up calls (Figure 4D; Table S2).

DISCUSSION

Our study reveals that short-range ultrasonic vocalizations in African striped mice differ between locations, demonstrating the ecological importance of acoustic communication both within and outside of the social group. Using a field-based experimental approach, we show that these high-frequency ultrasonic calls (50–74 kHz) carry group-specific

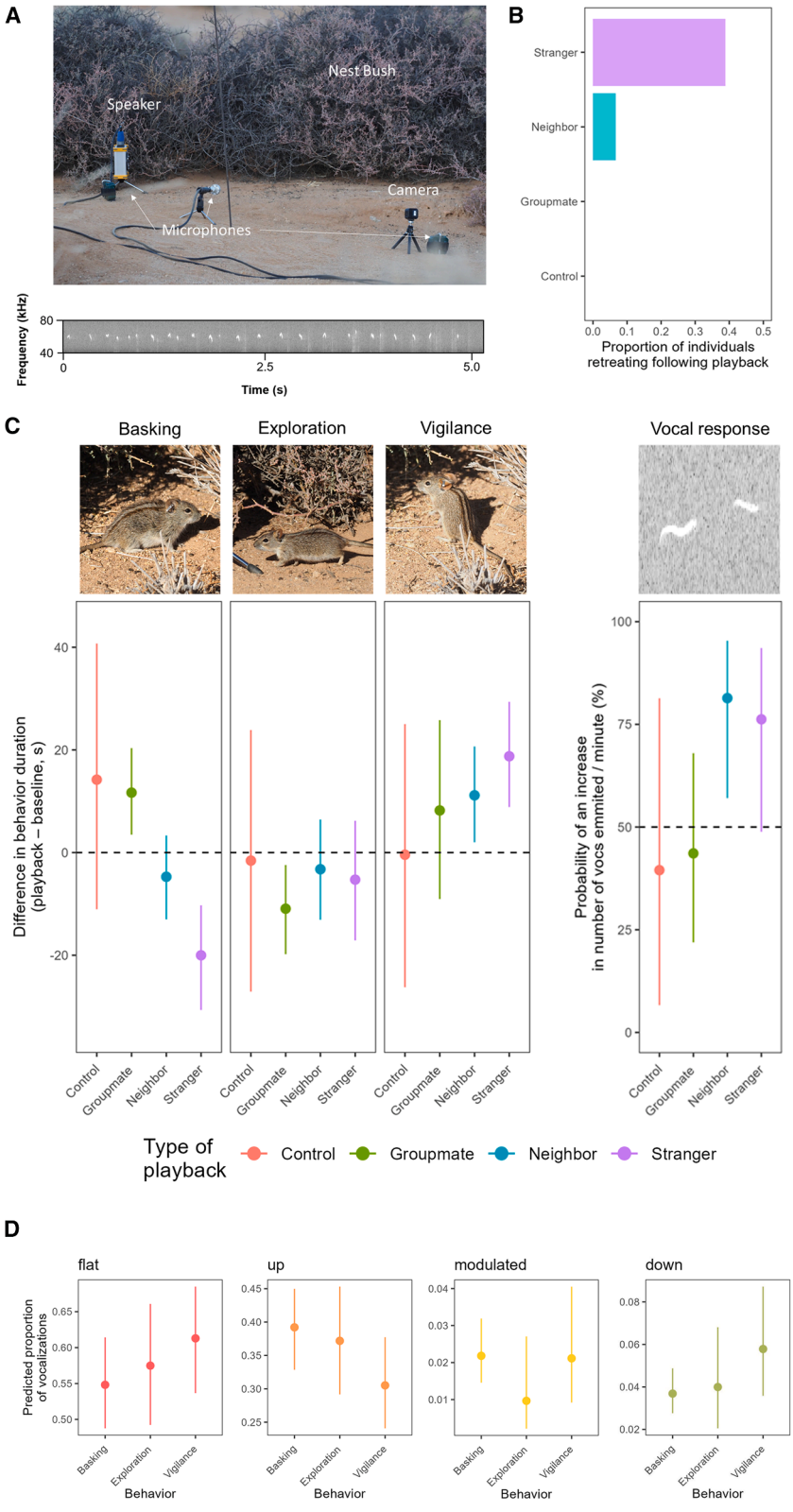


Figure 4. Ultrasonic vocalizations mediate conspecific recognition in wild striped mice

(A) Experimental setup. Equipment for ultrasonic playback is positioned near the nest bush where mice bask at dawn, enabling behavioral observations during their ~40 min gathering period. A sequence of ultrasonic calls is broadcast from the speaker.

(B) Retreat responses to playbacks. Mice exhibit greater escape behavior in response to stranger playback.

(C) Behavioral reactions to playback. Stranger ultrasounds increase vigilance and reduce basking, whereas neighbor ultrasounds elicit moderate vigilance. Calls from the mouse's own group promote basking and reduce exploratory behavior. Solid disks represent median of posterior distribution, with bars displaying the 95% credible interval (see also Video S1 and Table S3).

(D) Vocal-behavioral correlation. Vigilance is associated with increased production of "down" calls and decreased "up" calls compared with basking. Solid disks represent median of posterior distribution, with bars displaying the 95% credible interval (see also Table S2).

information, enabling mice to identify individuals from different groups. These findings provide a key step toward a better understanding of rodents' communication within natural social interactions.

The short-range propagation of mice ultrasonic vocalizations confines their active space to the emitter's immediate vicinity, such as a single bush, suggesting a role limited to "private" exchanges. However, field observations and playback experiments revealed a broader use. Mice vocalize not only at nests but also throughout their territory, including at border bushes where aggressive inter-group interactions occur[18]: breeding males are known to patrol these areas during the day,[27] therefore using calls there is likely a way to reinforce their presence. This behavior extends the reach of their short-range signals, fulfilling roles akin to the songs of territorial birds, despite the environmental constraints of open spaces between bushes in their semi-arid habitat. Calling louder or switching to lower frequency calls could enable the transmission of signals across the vast, empty space between bushes. However, this would be unnecessarily risky and would present both anatomical and energetic challenges for mice.

The mice's territories include border bushes that serve as hubs for strategic communication with neighboring groups or for dispersing strangers. By vocalizing in these socially significant locations, striped mice overcome the short range of their ultrasonic vocalizations, extending their functional role to interactions beyond the immediate family group. This communication strategy parallels chemical communication in mammals, where territorial boundaries are marked with scent.[28,29] In striped mice, acoustic signals likely complement chemical cues: ultrasounds provide immediate, "acute" information during close encounters, whereas scents serve as persistent, "chronic" territorial markers. Adapted to reduce water loss in their arid environment,[30] striped mice may rely less on urine-based chemical signaling compared with species in wetter habitats, enhancing the role of vocalizations.

Analysis of vocal activity showed context-specific call usage: diverse call types dominate at nests and within-territory bushes, while down calls prevail at borders, hinting at specialized inter-group signaling. Neural network classification of call spectrograms identified group vocal signatures, with 75% accuracy in distinguishing family groups. Mainly encoded in frequency modulation, this information enables mice to distinguish familiar individuals from strangers. Playback experiments reinforced this: stranger calls triggered strong aversive responses (e.g., retreat and vigilance), neighbor calls prompted milder vigilance, and striped mice kept on basking when hearing group calls.

Our study has several limitations that highlight directions for future research. First, our passive recording methodology prevented the identification of individual callers, so we could not assess the reliability of group vocal signatures in border-associated calls. However, given that these are predominantly highly frequency-modulated down calls, they likely carry distinct acoustic signatures relevant for inter-group encounters at territorial boundaries. A second limitation is that the stimuli representing unfamiliar individuals were recorded in captivity. Although we found no distinguishing acoustic characteristics in these signals, we cannot rule out that they differ from other stimuli in arousal level. We consider this unlikely, however, as the captive mice showed no overt signs of stress during recording. Additionally, while our experiments demonstrate a response to vocal signals alone, other cues such as odor or the physical presence of a conspecific would likely modulate this response. Finally, future research would benefit from testing a larger set of experimental groups to provide a more comprehensive understanding of the observed effects.

The emergence of group information in vocalization likely stems from an interplay between genetics[31] and learning.[32–34] On one hand, family groups, comprising related females and their offspring,[35] share genetic proximity that may shape vocal tract anatomy, producing similar call traits. Concurrently, daily interactions at the nest—a communication "hotspot"—could drive vocal convergence through learning (e.g., vocal imitation), as observed in other rodents like Mongolian gerbils.[36]

Typically, "public" communication is linked to long-range signals (e.g., loud bird songs), while "private" exchanges rely on short-range cues to avoid eavesdroppers.[2] Although our findings do not challenge this fundamental distinction, they reveal how striped mice strategically extend the functional range of short-range ultrasonic signals. By vocalizing from key locations at the boundaries of their territory, the mice effectively broaden the reach of their signals to neighboring individuals. This strategy compensates for the limited active range of their signals and extends the sender's communication network by increasing the number and quality of potential receivers of its vocalizations. This emphasizes that the scale of a communication system depends not only on signal properties but also on behavioral adaptations. In environments where long-range signaling is impractical, such strategies offer an effective alternative.

RESOURCE AVAILABILITY

Lead contact

Requests for further information and resources should be directed to and will be fulfilled by the lead contact, Léo Perrier (leoperrier97@gmail.com).

Materials availability

This study did not generate new unique reagents.

Data and code availability

All data and codes used in this paper are available on a Zenodo repository: https://zenodo.org/records/15475434. For raw data, please contact the corresponding author (L.P.).

ACKNOWLEDGMENTS

This study was made possible by the administrative and technical support of the Succulent Karoo Research Station (registered South African NPO 122-134). This study is part of the long-term Studies in Ecology and Evolution (SEE-Life) program of the CNRS. This research has been funded by the Labex CeLyA, the CNRS, the Institut Universitaire de France (F.L. and N.M.), and the University of Saint-Etienne, France.

AUTHOR CONTRIBUTIONS

L.P.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, validation, visualization, writing—original draft, and writing—review & editing. L.L.: data curation, formal analysis, investigation, methodology, visualization, and writing—original draft. T.C.: formal analysis, methodology, validation, and software. M.B.: formal analysis, methodology, validation, and software. L.M.: methodology, resources, project administration, validation, and writing—review & editing. W.B.: investigation.

A.P.: investigation and resources. C.S.: methodology, funding acquisition, resources, project administration, validation, and writing—review & editing. M.D.G.: conceptualization, methodology, and writing—review & editing. N. M.: conceptualization, methodology, project administration, funding acquisition, supervision, and writing—review & editing. F.L.: conceptualization, methodology, project administration, funding acquisition, supervision, and writing—review & editing.

DECLARATION OF INTERESTS

The authors declare no competing interests.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

- KEY RESOURCES TABLE
- EXPERIMENTAL MODEL AND SUBJECT DETAILS
  - African striped mice
  - Ethical statement
- METHOD DETAILS
  - Equipment calibration
  - Propagation experiments
  - Group monitoring
  - Monitoring of vocal repertoires
  - Extraction and classification of vocalizations
  - Group-specific vocal information recording and analysis
  - Playback experiments
- QUANTIFICATION AND STATISTICAL ANALYSIS
  - Propagation experiments
  - Monitoring of vocal repertoires
  - Group-specific vocal information recording and analysis
  - Playback experiments

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.cub.2025.08.028.

Received: May 28, 2025
Revised: July 29, 2025
Accepted: August 13, 2025
Published: September 10, 2025

REFERENCES

1. Mathevon, N. (2023). The Voices of Nature: How and Why Animals Communicate (Princeton University Press). https://doi.org/10.1515/9780691236766.
2. Larsen, O.N. (2020). To Shout or to Whisper? Strategies for Encoding Public and Private Information in Sound Signals. In Coding Strategies in Vertebrate Acoustic Communication, T. Aubin, and N. Mathevon, eds. (Springer International Publishing), pp. 11–44. https://doi.org/10.1007/978-3-030-39200-0_2.
3. Liu, H.-X., Lopatina, O., Higashida, C., Fujimoto, H., Akther, S., Inzhutova, A., Liang, M., Zhong, J., Tsuji, T., Yoshihara, T., et al. (2013). Displays of paternal mouse pup retrieval following communicative interaction with maternal mates. Nat. Commun. *4*, 1346. https://doi.org/10.1038/ncomms2336.
4. Hammerschmidt, K., Radyushkin, K., Ehrenreich, H., and Fischer, J. (2012). The Structure and Usage of Female and Male Mouse Ultrasonic Vocalizations Reveal only Minor Differences. PLoS One *7*, e41133. https://doi.org/10.1371/journal.pone.0041133.
5. Brudzynski, S.M. (2018). Handbook of Ultrasonic Vocalization: A Window into the Emotional Brain (Academic Press).
6. Griffin, D.R. (1971). The importance of atmospheric attenuation for the echolocation of bats (Chiroptera). Anim. Behav. *19*, 55–61. https://doi.org/10.1016/S0003-3472(71)80134-3.
7. Arch, V.S., and Narins, P.M. (2008). "Silent" signals: Selective forces acting on ultrasonic communication systems in terrestrial vertebrates. Anim. Behav. *76*, 1423–1428. https://doi.org/10.1016/j.anbehav.2008.05.012.
8. Saito, Y., Tachibana, R.O., and Okanoya, K. (2019). Acoustical cues for perception of emotional vocalizations in rats. Sci. Rep. *9*, 10539. https://doi.org/10.1038/s41598-019-46907-0.
9. Hoffmann, F., Musolf, K., and Penn, D.J. (2012). Spectrographic analyses reveal signals of individuality and kinship in the ultrasonic courtship vocalizations of wild house mice. Physiol. Behav. *105*, 766–771. https://doi.org/10.1016/j.physbeh.2011.10.011.
10. Marconi, M.A., Nicolakis, D., Abbasi, R., Penn, D.J., and Zala, S.M. (2020). Ultrasonic courtship vocalizations of male house mice contain distinct individual signatures. Anim. Behav. *169*, 169–197. https://doi.org/10.1016/j.anbehav.2020.09.006.
11. Zala, S.M., Reitschmidt, D., Noll, A., Balazs, P., and Penn, D.J. (2017). Sex-dependent modulation of ultrasonic vocalizations in house mice (Mus musculus musculus). PLoS One *12*, e0188647. https://doi.org/10.1371/journal.pone.0188647.
12. Ivanenko, A., Watkins, P., van Gerven, M.A.J., Hammerschmidt, K., and Englitz, B. (2020). Classifying sex and strain from mouse ultrasonic vocalizations using deep learning. PLoS Comput. Biol. *16*, e1007918. https://doi.org/10.1371/journal.pcbi.1007918.
13. Caruso, A., Marconi, M.A., Scattoni, M.L., and Ricceri, L. (2022). Ultrasonic vocalizations in laboratory mice: strain, age, and sex differences. Genes Brain Behav. *21*, e12815. https://doi.org/10.1111/gbb.12815.
14. Briggs, J.R., and Kalcounis-Rueppell, M.C. (2011). Similar acoustic structure and behavioural context of vocalizations produced by male and female California mice in the wild. Anim. Behav. *82*, 1263–1273. https://doi.org/10.1016/j.anbehav.2011.09.003.
15. Petric, R., and Kalcounis-Rueppell, M.C. (2013). Female and male adult brush mice (Peromyscus boylii) use ultrasonic vocalizations in the wild. Behaviour *150*, 1747–1766. https://doi.org/10.1163/1568539X-00003118.
16. Pasch, B., Bolker, B.M., and Phelps, S.M. (2013). Interspecific dominance via vocal interactions mediates altitudinal zonation in neotropical singing mice. Am. Nat. *182*, E161–E173. https://doi.org/10.1086/673263.
17. Jourjine, N., Goedecker, C., König, B., and Lindholm, A.K. (2025). Vocal communication is seasonal in social groups of wild, free-living house mice. Proc. Biol. Sci. *292*, 20250995. https://doi.org/10.1098/rspb.2025.0995.
18. Schradin, C., and Pillay, N. (2004). The Striped Mouse (Rhabdomys pumilio) From the Succulent Karoo, South Africa: A Territorial Group-Living Solitary Forager With Communal Breeding and Helpers at the Nest. J. Comp. Psychol. *118*, 37–47. https://doi.org/10.1037/0735-7036.118.1.37.
19. Mallarino, R., Pillay, N., Hoekstra, H.E., and Schradin, C. (2018). African striped mice. Curr. Biol. *28*, R299–R301. https://doi.org/10.1016/j.cub.2018.02.009.
20. Richardson, R., Feigin, C.Y., Bano-Otalora, B., Johnson, M.R., Allen, A.E., Park, J., McDowell, R.J., Mereby, S.A., Lin, I.-H., Lucas, R.J., et al. (2023). The genomic basis of temporal niche evolution in a diurnal rodent. Curr. Biol. *33*, 3289–3298.e6. https://doi.org/10.1016/j.cub.2023.06.068.
21. Rogers, F.D., Peña, C.J., and Mallarino, R. (2023). African striped mice (*Rhabdomys pumilio*) as a neurobehavioral model for male parental care. Horm. Behav. *152*, 105364. https://doi.org/10.1016/j.yhbeh.2023.105364.
22. Perrier, L., de Witasse Thézy, A., Pradeau, A., Schradin, C., Greenfield, M. D., Mathevon, N., and Levréro, F. (2025). A cooperatively breeding mouse shows flexible use of its vocal repertoire according to social context. Behav. Brain Res. *486*, 115575. https://doi.org/10.1016/j.bbr.2025.115575.

23. Freeberg, T.M., Dunbar, R.I.M., and Ord, T.J. (2012). Social complexity as a proximate and ultimate factor in communicative complexity. Philos. Trans. R. Soc. Lond. B Biol. Sci. *367*, 1785–1801. https://doi.org/10.1098/rstb.2011.0213.

24. McGregor, P.K., and Dabelsteen, T. (1996). 23. Communication Networks. In Ecology and Evolution of Acoustic Communication in Birds, *23*, D.E. Kroodsma, and E.H. Miller, eds. (Cornell University Press), pp. 409–425. https://doi.org/10.7591/9781501736957-032.

25. Schradin, C. (2004). Territorial defense in a group-living solitary forager: who, where, against whom? Behav. Ecol. Sociobiol. *55*, 439–446. https://doi.org/10.1007/s00265-003-0733-x.

26. McInnes, L., Healy, J., and Melville, J. (2020). UMAP: Uniform Manifold Approximation and Projection for Dimension Reduction. J. Open Source Softw. *3*, 861.

27. Schradin, C. (2006). Whole-day follows of striped mice (Rhabdomys pumilio), a diurnal murid rodent. J. Ethol. *24*, 37–43. https://doi.org/10.1007/s10164-005-0158-2.

28. Roth, J.D., Dobson, F.S., Neuhaus, P., Abebe, A., Barra, T., Boonstra, R., Edwards, P.D., Gonzalez, M.A., Hammer, T.L., Harscouet, E., et al. (2022). Territorial scent-marking effects on vigilance behavior, space use, and stress in female Columbian ground squirrels. Horm. Behav. *139*, 105111. https://doi.org/10.1016/j.yhbeh.2022.105111.

29. Biswas, S., Ghosh, K., Ghosh, S., Biswas, A., and Bhadra, A. (2025). What is in a scent? Understanding the role of scent marking in social dynamics and territoriality of free-ranging dogs. Behav. Ecol. Sociobiol. *79*, 3. https://doi.org/10.1007/s00265-024-03547-3.

30. Rimbach, R., Blanc, S., Zahariev, A., Gatta, M., Pillay, N., and Schradin, C. (2018). Seasonal variation in energy expenditure in a rodent inhabiting a winter-rainfall desert. J. Comp. Physiol. B *188*, 877–888. https://doi.org/10.1007/s00360-018-1168-z.

31. Torti, V., Bonadonna, G., De Gregorio, C., Valente, D., Randrianarison, R. M., Friard, O., Pozzi, L., Gamba, M., and Giacoma, C. (2017). An intra-population analysis of the indris' song dissimilarity in the light of genetic distance. Sci. Rep. *7*, 10140. https://doi.org/10.1038/s41598-017-10656-9.

32. Ruch, H., Zürcher, Y., and Burkart, J.M. (2018). The function and mechanism of vocal accommodation in humans and other primates. Biol. Rev. Camb. Philos. Soc. *93*, 996–1013. https://doi.org/10.1111/brv.12382.

33. Baciadonna, L., Solvi, C., Del Vecchio, F., Pilenga, C., Baracchi, D., Bandoli, F., Isaja, V., Gamba, M., and Favaro, L. (2022). Vocal accommodation in penguins (Spheniscus demersus) as a result of social environment. Proc. Biol. Sci. *289*, 20220626. https://doi.org/10.1098/rspb.2022.0626.

34. Sharp, S.P., McGowan, A., Wood, M.J., and Hatchwell, B.J. (2005). Learned kin recognition cues in a social bird. Nature *434*, 1127–1130. https://doi.org/10.1038/nature03522.

35. Schradin, C., and Lindholm, A.K. (2011). Relative fitness of alternative male reproductive tactics in a mammal varies between years. J. Anim. Ecol. *80*, 908–917. https://doi.org/10.1111/j.1365-2656.2011.01831.x.

36. Peterson, R.E., Choudhri, A., Mitelut, C., Tanelus, A., Capo-Battaglia, A., Williams, A.H., Schneider, D.M., and Sanes, D.H. (2024). Unsupervised discovery of family specific vocal usage in the Mongolian gerbil. eLife *12*, RP89892. https://doi.org/10.7554/eLife.89892.

37. Coffey, K.R., Marx, R.G., and Neumaier, J.F. (2019). DeepSqueak: a deep learning-based system for detection and analysis of ultrasonic vocalizations. Neuropsychopharmacology *44*, 859–868. https://doi.org/10.1038/s41386-018-0303-6.

38. Friard, O., and Gamba, M. (2016). BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. Methods in Ecology and Evolution *7*, 1325–1330. https://doi.org/10.1111/2041-210X.12584.

39. du Toit, N., van Vuuren, B.J., Matthee, S., and Matthee, C.A. (2012). Biome specificity of distinct genetic lineages within the four-striped mouse *Rhabdomys pumilio* (Rodentia: Muridae) from southern Africa with implications for taxonomy. Mol. Phylogenet. Evol. *65*, 75–86. https://doi.org/10.1016/j.ympev.2012.05.036.

40. Goerlitz, H.R. (2018). Weather conditions determine attenuation and speed of sound: Environmental limitations for monitoring and analyzing bat echolocation. Ecol. Evol. *8*, 5090–5100. https://doi.org/10.1002/ece3.4088.

41. Bürkner, P.-C. (2017). brms: An R Package for Bayesian Multilevel Models Using Stan. J. Stat. Software *80*, 1–28. https://doi.org/10.18637/jss.v080.i01.

STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Behavioral data	This paper	https://zenodo.org/records/15475434
Vocal data	This paper	https://zenodo.org/records/15475434
Experimental models: Organisms/strains		
African striped mice (*Rhabdomys pumilio*)	Wild animals	N/A
Software and algorithms		
R 4.4.2	R Foudation	https://www.r-project.org/
Python 3.9	Python Software Foundation	https://www.python.org/
Deepsqueak v3	Coffey et al.[37]	https://github.com/DrCoffey/DeepSqueak
Ultrasonic audio recording software Avisoft-RECORDER	Avisoft Bioacoustics	https://avisoft.com/
Audiomoth applications	Open Acoustics Device	https://www.openacousticdevices.info/applications
Audacity	Audacity	https://www.audacityteSam.org/
BORIS v8.10	Friard and Gamba[38]	https://www.boris.unito.it/
Other		
Ultrasonic microphone	Avisoft Bioacoustics	CM16/CMPA
Ultrasonic recording sound card	Avisoft Bioacoustics	UltraSoundGate 416H
Ultrasonic speaker	Avisoft Bioacoustics	Vifa speaker
Ultrasonic player sound card	Avisoft Bioacoustics	UltraSoundGate Player 216H
Video camera	GoPro	Hero 3
Audiomoths recorders	Open Acoustics Device	Version 1.1.0 with firmware 1.7.0
Radio collars	Holohil	MD-2C or PD-2C
GPS	Garmin	eTrex Venture
Sherman traps	H.B. Sherman Traps, Inc.	PLFATDG

EXPERIMENTAL MODEL AND SUBJECT DETAILS

African striped mice

The study was conducted at the Succulent Karoo Research Station within the Goegap Nature Reserve, South Africa (www.stripedmouse.com). The 1.3 ha field site featured a dry riverbed and bushes on sandy soil. The striped mouse (*Rhabdomys pumilio*), a diurnal rodent native to western South Africa,[39] lives in social groups comprising 2-4 communally breeding females, one immigrant breeding male, and up to 30 adult offspring of both sexes acting as helpers. Groups share a nest and territory but forage solitarily.[18]

Ethical statement

All experiments were approved by the Animals Research Ethics Committee of University of Witwatersrand in Johannesburg, under the clearance certificate number 2022/10/01/B.

METHOD DETAILS

Equipment calibration

To ensure playback stimuli were broadcast at a natural amplitude, we calibrated our acoustic equipment (Avisoft Vifa Speaker, CM16/CMPA microphones) using a record/playback/re-record method. First, we established a reference sound level by recording ultrasonic calls from three mice positioned 90 cm from a directional microphone. These reference recordings, termed "calibration vocalizations", were then normalized and broadcast from the speaker. The output was re-recorded using the same microphone at the identical 90 cm distance. Finally, we adjusted the speaker's output gain until the amplitude of the re-recorded playbacks precisely matched that of the original vocalizations.

Propagation experiments

White noise playback signals were broadcast at distances of 5, 10, 25, 50, 100, 150, and 200 cm using calibrated equipment (sample rate = 300 kHz, 32-bit) to study sound propagation (Figure S1). White noise was broadcast at an amplitude calibrated to match the natural sound pressure of mouse vocalizations. Specifically, the output was adjusted so that the energy within the 56-58 kHz frequency band matched that of our previously established calibration.

Group monitoring

Data on group composition and territories were collected using a combination of capture–mark–recapture methods, radiotracking, and behavioral observations. Mice were captured using Sherman traps (26 × 9 × 9 cm) baited with bran flakes, sunflower oil, and salt (total of 56 mice captured; 16, 23, 8 and 9 individuals from nests A, B, C and D, respectively). Traps were set before sunrise near potential sleeping sites identified through morning and evening observations. Each captured individual was fitted with a unique ear tag (National Band and Tag Co., Newport, KY, U.S.A.). Morning trapping sessions provided an initial assessment of group composition, as mice were typically caught immediately after leaving their nests. To obtain detailed spatial structure data, two mice per potential group were equipped with radio collars (Holohil MD-2C or PD-2C). These individuals were tracked five times per week at night to locate their nests. Once sleeping sites (nest bushes) were identified, targeted morning trapping and behavioral observations at these locations confirmed which individuals co-slept with radio-collared mice, thereby verifying group membership. Group members were then marked with nest-specific hair dye for identification. Traps were also placed around multiple bushes throughout the study area to distinguish bushes used exclusively by mice from the same nest (“within-territory” bushes) from those at territory boundaries, characterized by the presence of mice from different groups. These combined approaches enabled definitive categorization of bushes into three types: nest, within-territory, and border bush. There was no systematic difference in size or plant composition among bushes. To map home ranges of the radio-collared striped mice, they were tracked six times daily over a seven-day period (from 9:00 to 18:00, plus one session at 20:30). GPS coordinates (Garmin eTrex Venture, ±5 m accuracy) were recorded and used to calculate home ranges using the convex hull method. Group sizes ranged from 8 to 23 individuals. Territories for each group were delineated by integrating home range data from radio-collared individuals with data from individuals captured near various bushes.

Monitoring of vocal repertoires

We deployed 23 AudioMoth recorders (sampling frequency of 256 kHz, 32-bit) for 12 days across four mouse territories (Figure 1A). In each territory, three recorders were placed at the nest bush (one at the center, the two at the edges), with the remaining recorders positioned at within-territory bushes (four recorders) or border bushes between territories (seven recorders; see Table S1 and Figure 1A for details of the sampling plan). Recorders were positioned 5 cm above ground, 50 cm from bushes. Batteries and SD cards were replaced every two days.

Extraction and classification of vocalizations

Two pre-trained Deepsqueak[37] neural networks (Rat Detector YOLO R1 and Mouse Detector YOLO R2) were used to detect and classify vocalizations, with threshold set for Score (0.6) and Tonality (0.3), determined to be optimal for achieving a high detection rate with minimal false negatives. However, these less restrictive thresholds resulted in a significant number of false positives (precision of 49.63%), stemming primarily from two sources. The first source of false positives was electronic noise, present in 15 of the 23 recorders, which sometimes accounted for over 90% of false positives in a recording but was easily identifiable manually using spectrograms. The second source of false positives originated from vocalizations of other animal species, particularly the harmonics of whistling rats (*Parotomys brantsii*). To eliminate these false positives, we conducted both visual (spectrogram inspection) and auditory verification of all recordings. This process reduced the dataset from 247,089 vocalizations to a curated sample of 122,619 confirmed true positives (striped mouse vocalizations). To evaluate DeepSqueak’s detection performance after manual cleaning, we selected a 5-minute segment for each recorder, randomly choosing a day and time. Segments were required to contain at least 40 vocalizations, yielding a total of 2,123 vocalizations. We then calculated the precision (99.58% after the manual cleaning), Recall (83.79%), and F1-score (91.00%) for the entire process (Deepsqueak model + manual cleaning). Additionally, each of the 2,123 vocalizations was manually annotated by call type and compared with DeepSqueak’s unsupervised classification output.[22] The model demonstrated robust performance in accurately classifying call types within this subset, achieving an accuracy of 88.74%.

Group-specific vocal information recording and analysis

High-quality recordings (Avisoft Bioacoustics CM16/CMPA microphone, 300 kHz, 32-bit) were made during one-hour morning sessions at three nests (6 sessions from nest A, 5 from nest B, 5 from nest C), targeting marked individuals (total of 24 mice: 10 from nest A, 9 from nest B, and 5 from nest C).

Playback experiments

Playback stimuli were derived from ultrasonic vocalizations recorded in field and laboratory settings using AudioMoth recorders (firmware 1.7.0, 250 kHz, 32-bit,.wav). Field recordings were obtained during morning basking sessions, capturing one-minute sequences from identified individuals. These recordings served as the “groupmate” condition for the source group and the “neighbor” condition for adjacent groups. Laboratory recordings served as the “stranger” condition. They were obtained from individuals left

alone in their usual cages, with all their enrichment, and placed in an acoustic chamber that was also familiar to the animals. Laboratory-recorded matched field recordings in quality, with identical signal-to-noise ratio and call types. The control stimulus consisted of one-minute sequences of noise bursts (40-80 kHz, matching the frequency range of mouse vocalizations), with durations of noise bursts and intervening silences matched to the average duration of natural vocalizations and silences. These noise sequences were generated using the *seewave* R package. All stimuli were processed with noise reduction and a 40-80 kHz bandpass filter, with amplitude normalized to the natural intensity established during equipment calibration.

Playback experiments were conducted during morning basking sessions at nests A, B, and C. Each session lasted approximately one hour, timed to coincide with the mice's natural morning basking behavior. Sessions began when the first mouse emerged from the nest bush as sunlight reached it, and ended when the last mouse left to forage. Equipment was installed the previous night and experimenters positioned 5 meters away. An Avisoft Vifa speaker broadcast stimuli -control, groupmate, neighbor, or stranger- from 1 meter away, aligned with the nest to mimic a natural mouse position. Playback trials were initiated when a focal mouse remained <1 meter from the speaker, aligned with it, for >1 minute. To ensure ecological validity during groupmate playbacks, trials only began if the original caller was absent, thereby preventing an individual from hearing its own broadcasted vocalizations. These stringent criteria resulted in days with no playback events ("mock" experiments), which minimized potential habituation to the experimental setup. Behavioral responses were recorded using two GoPro Hero Session cameras: one at ground level 1m from the nest and one mounted on a metal stick (see Video S1). Vocal responses were captured with an Avisoft CM16/CMPA microphone placed 1 m from the bush, and two AudioMoth recorders (firmware 1.7.0, 256 kHz, 32-bit) served as backups, positioned near the speaker and ground camera.

To reduced disturbance, experiments were capped at six per day (average: two, range 0-6), with a minimum of three-minute interval between trials (average: six minutes, range 3-19 minutes). Only one group was tested per day, never on consecutive days. Stimuli were never repeated consecutively, and efforts were made to avoid testing the same mouse twice with the same sequence, though two individuals were retested due to technical issues. Across the three nests, control stimulus was presented 2 times, groupmate 6 times, neighbor 4-6 times, and stranger 6 times, totaling 57 experiments over five weeks. Twenty-three unique individuals were tested (nest A: 9, nest B: 9, nest C: 5). Each playback session started with 100 ms of white noise broadcast to synchronize recordings (Avisoft, AudioMoth, videos).

QUANTIFICATION AND STATISTICAL ANALYSIS

Propagation experiments

To estimate the sound intensity (dB SPL) of the playback signals, we applied a calibration procedure based on a known reference measurement. A spherical attenuation model was first implemented to account for both geometric spreading and excess attenuation of high frequencies.[6] Specifically, the attenuation was modeled as a function of distance, incorporating a frequency-dependent excess attenuation coefficient (α = 2.0 dB/m for 60 kHz[40]). A known sound source level of 44 dB SPL measured with high-precision in a laboratory setting (Thieffry et al., personal communication) served as the reference point. Using this reference, we computed the expected absolute sound levels at other distances based on the spherical model. To calibrate our experimental recordings, we measured the playback signals level dB FS (full-scale) level at each distance, between 56 and 58 kHz (mean range of striped mice USV recorded in Goegap). We also measured background noise level in the same frequency band, and corrected the level of the recorded signal with this value. We then used the model-predicted SPL at 5 cm to map the corresponding dB FS value to an absolute dB SPL level. The resulting values allowed for the generation of a calibrated attenuation curve, enabling comparison between theoretical predictions and empirical data.

Monitoring of vocal repertoires

Vocalizations recorded by the AudioMoth recorders deployed across mouse territories were extracted using DeepSqueak[37] (MATLAB 2023a) with pre-trained neural networks (Rat Detector YOLO R1, Mouse Detector YOLO R2). False positives were suppressed (tonality and network score thresholds: 0.25, 0.55), followed by supervised classification[22] and manual review, yielding 122,619 validated calls. To test whether mice varied their vocalization usage across different locations (nest bush, territory bush, border bush), we fitted a Dirichlet model with the daily proportion of call types as the response variable: *proportion of vocalizations* $\sim$ *site + (1|day)*.

Group-specific vocal information recording and analysis

Ultrasonic vocalizations recorded from 24 target individuals were extracted using Deepsqueak followed by manual review to ensure accuracy. This process generated a database of 18,210 high-quality calls: 6,256 from nest A (four sessions), 8 210 from nest B (six sessions) and 3 744 for nest C (five sessions). Spectrograms were computed as N$\times$151 pixels images, with N varying by call duration, isolated with 20 ms buffers before and after each vocalization. Pixel values were rescaled from 0 (quietest) to 255 (loudest), and black ribbons were added to standardize images to 150$\times$151 pixels. To test whether vocalizations carry group-specific information, spectrograms were classified using a pre-trained Resnet-18 Convolutional Neural Network (CNN) in Python 3.9.0 with *PyTorch* 2.2.0. Datasets were subset and balanced to 3,744 images per class, split into 70% training, 20% validation and 10% test sets. Training ran for 10 epochs (batch size: 32, learning rate: 0.001) on a NVIDIA Quadro P620 GPU, and was repeated 100 times with random subset at each iteration. Features were visualized with UMAP (using *uwot* v0.2.2 R package) and activation maps (using cv2 v4.8.1). To verify

that classification depended on vocalization shapes rather than background noise, we analyzed 6,000 random 65 ms noise samples per nest. The model failed to classify these noise samples above chance (mean accuracy: 33.73%), confirming the approach.

Playback experiments

Videos were analyzed using BORIS v8.10 to measure time spent in specific behaviors (basking, exploration, vigilance) during the minute before and during playback. Audio and video recordings were synchronized using Audacity (v3.3.2) with the *ffmpeg* library and VLC media player (v3.0.17.4).

We assessed the following responses:

- Behavioral response: A hurdle-gaussian model assessed variation in time spent on behaviors (basking, exploration, vigilance) across playback types (control, groupmate, neighbor, stranger) (*Difference in behavior duration* ~ *behavior * playback type + (1|identity)*; Figure 4C; Table S3).
- Vocal response: A binomial model evaluated whether vocalizations increased by >10% during playback (*increase* ~ *playback type + (1|identity)*; Figure 4C; Table S3).
- Vocalization type by behavior: A categorical model was used to generate probabilistic predictions of call types for each exhibited behavior (*call type* ~ *behavior + (1|identity)* Figure 4D; Table S2).

All statistical analyses were performed in R v4.3.1 using Bayesian mixed models (*brms* package v2.19.0[41]) with default priors. Results were interpreted using medians and 95% credible intervals (CIs).