



Data Article

Spontaneous long-term and urethane induced hippocampal EEG power, activity and temperature data from mice lacking the $Ca_v3.2$ voltage-gated Ca^{2+} channel



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ARTICLE INFO

Article history:

Received 4 March 2021

Revised 26 March 2021

Accepted 29 March 2021

Available online 1 April 2021

Keywords:

Activity

CA1

EEG

Hippocampus

Mouse

Power

Telemetry

Urethane

ABSTRACT

This article provides raw relative electroencephalographic (EEG) power, temperature and activity data from controls and $Ca_v3.2$ deficient mice. Radiotransmitter implantation was carried out in male experimental mice under ketamine/xylazine narcosis. Following a recovery period, radiotelemetric EEG recordings from the hippocampal CA1 region were obtained under spontaneous 24 h long-term conditions and post urethane injection. Relative EEG power values (%) for 2 s epochs were analysed for the following frequency ranges: delta 1 (δ_1 , 0.5–4 Hz), delta 2 (δ_2 , 1–4 Hz), theta 1 (θ_1 , 4–8 Hz), theta 2 (θ_2 , 4–12 Hz), alpha (α , 8–12 Hz), sigma (σ , 12–16 Hz), beta 1 (β_1 , 12–30 Hz), beta 2 (β_2 , 16–24 Hz), beta 3 (β_3 , 16–30 Hz), gamma low (γ_{low} , 30–50 Hz), gamma mid (γ_{mid} , 50–70 Hz), gamma high (γ_{high} , 70–100 Hz), gamma rip-

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ples ($\gamma_{ripples}$, 80–200 Hz), and gamma fast ripples ($\gamma_{fast\ ripples}$, 200–500 Hz). In addition, subcutaneous temperature and relative activity data were analysed for both the light and dark cycle of two long-term recordings. The same type of data was obtained post urethane injection. Detailed information is provided for the age and body weight of the experimental animals, the technical specifications of the radiofrequency transmitter, the stereotaxic coordinates for the intracerebral, deep and epidural, surface EEG electrodes, the electrode features, the filtering and sampling characteristics, the analysed EEG frequency bands and the data acquisition parameters. EEG power data, temperature and activity data are available at MENDELEY DATA (doi:10.17632/x53km5sby6.1, URL: <http://dx.doi.org/10.17632/x53km5sby6.1>). Raw EEG data are available at zenodo (<https://zenodo.org/>).

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Specifications Table

Subject	Biology
Specific subject area	Power analysis from radiotelemetric CA1 EEG recordings
Type of data	External Excel (xls.) files External ASCII (ascii.) files
How data were acquired	EEG radiotelemetry setup (TA10ETAF20 transmitter, DATAquest ART acquisition software, DSI, USA), EEG relative power, activity and temperature analysis using Neuroscore software (DSI, USA)
Data format	Analyzed data (primary EEG power data from EEG recordings, as xls.-files) Raw EEG data (from hippocampal CA1 recordings, as ascii.-files)
Parameters for data collection	Relative EEG power data were obtained from the CA1 region of the hippocampus from male control and $Ca_v3.2^{-/-}$ mice for two 24 h long-term recordings (12 h / 12 h, light / dark cycle) and following two urethane (800 mg/kg i.p.) injections. Recordings were carried out under non-restraining conditions in ventilated cabinets (under controlled environmental parameters).
Description of data collection	Hippocampal EEG data from the CA1 region were obtained using deep epoxytite coated tungsten electrodes. EEGs were sampled at a nominal sampling rate of 1000 Hz. Data were Fast Fourier Transformation (FFT) based analysed for relative power of the different frequency bands including delta 1 (δ_1 , 0.5–4 Hz), delta 2 (δ_2 , 1–4 Hz), theta 1 (θ_1 , 4–8 Hz), theta 2 (θ_2 , 4–12 Hz), alpha (α , 8–12 Hz), sigma (σ , 12–16 Hz), beta 1 (β_1 , 12–30 Hz), beta 2 (β_2 , 16–24 Hz), beta 3 (β_3 , 16–30 Hz), gamma low (γ_{low} , 30–50 Hz), gamma mid (γ_{mid} , 50–70 Hz), gamma high (γ_{high} , 70–100 Hz), gamma ripples ($\gamma_{ripples}$, 80–200 Hz), and gamma fast ripples ($\gamma_{fast\ ripples}$, 200–500 Hz). Relative power values are provided for 2 s epochs. Activity data represent relative values, temperature values are provided in °C. Raw EEG data were exported as ascii.-files in 1 h epochs.
Data source location	Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte, BfArM), Kurt-Georg-Kiesinger Allee 3, 53175 Bonn, Germany The primary data sources are hippocampal EEG recordings. The primary data are located as indicated above.
Data accessibility	For EEG power data: Repository name: MENDELEY DATA Data identification number: 10.17632/x53km5sby6.1 Direct URL to data: http://dx.doi.org/10.17632/x53km5sby6.1 For EEG raw data: Repository name: Zenodo Data identification numbers: doi:10.5281/zenodo.4557037; doi:10.5281/zenodo.4557942; doi:10.5281/zenodo.4558201; doi:10.5281/zenodo.4561604; doi:10.5281/zenodo.4561641;

(continued on next page)

doi:10.5281/zenodo.4561655; doi:10.5281/zenodo.4561657;
doi:10.5281/zenodo.4561663; doi:10.5281/zenodo.4561667;
doi:10.5281/zenodo.4561672; doi:10.5281/zenodo.4561674;
doi:10.5281/zenodo.4561676; doi:10.5281/zenodo.4561682;
doi:10.5281/zenodo.4561686; doi:10.5281/zenodo.4561695;
doi:10.5281/zenodo.4561702

Related research article

Arshaad, M.E. Siwek, C. Henseler, J. Daubner, D. Ehninger, J. Hescheler, A. Sachinidis, K. Broich, A. Papazoglou, M. Weiergräber, Enhanced hippocampal type II theta activity and altered theta architecture in mice lacking the Ca_v3.2 T-type voltage-gated calcium channel, *Sci. Rep.*, 11(1):1099. [1]

Value of the Data

- These data provide resources for the investigation of EEG power characteristics of various EEG frequency bands up to 500 Hz from the hippocampal CA1 region of control and Ca_v3.2^{-/-} mice. This data collection provides the basis for EEG power analysis under unrestrained long-term recording conditions, followed by pharmacological administration of urethane to specifically induce type II theta oscillations.
- These data are of value for scientists who want to get further insight into the frequency characteristics of the hippocampal CA1 region and their dependency on circadian rhythmicity and activity.
- Data are provided in a standardized format to ease access and use for multiple purposes.
- The publication of this dataset will enable users to benchmark their results for comparison with radiotelemetric EEG power data on other voltage-gated Ca²⁺ channels and to postulate novel hypotheses on the role of Ca_v3.2 in hippocampal rhythmicity. Strain, line and temporal specificities need to be considered upon comparison.

1. Data Description

Male controls and Ca_v3.2^{-/-} mice were anesthetized using ketamine/xylazine and implanted with a radiofrequency transmitter. Hippocampal CA1 EEG recordings were recorded using a radiotelemetry set-up (DSI, USA). EEG frequency bands were analyzed for relative power (%) using an FFT based approach via a DSI specific software (Neuroscore, DSI, USA). As the Neuroscore raw EEG data file format requires the related software, which is not freely available, the raw EEG data were exported as *asci*-files in 1 h epochs and are available at Zenodo (<https://zenodo.org/>). Importantly, these raw EEG data were not filtered and no artefact detection or artefact elimination had been carried out. When uploading the *asci*-files, also note that the left column represents the time scale (*x*-axis in *sec*, 1 ms steps according to 1 kHz sampling rate) and the right column provides the EEG voltage values (in mV). For the activity related *asci*-files, the left column displays time values in 1 s steps and the right column represents relative activity values (see also description below).

The relative power data (including temperature and relative activity) following artefact elimination using Neuroscore were exported as Excel file (*.xls*) format and are accessible at MENDELEY DATA (doi: 10.17632/x53km5sby6.1, URL: <http://dx.doi.org/10.17632/x53km5sby6.1>).

In total, data from eight control mice (control #1-control #8 with the internal numbering) and eight Ca_v3.2 deficient animals (Ca_v3.2^{-/-} #1 - Ca_v3.2^{-/-} #8 with the internal numbering) are accessible at MENDELEY DATA (for relative power data) and at Zenodo (for raw EEG data).

At Mendeley, six Excel files are available for each animal containing relative power values, activity and temperature from:

- Baseline recording 1 (R1) for the dark cycle (Mouse ID_Baseline Rec 1_DC)
- Baseline recording 1 (R1) for the light cycle (Mouse ID_Baseline Rec 1_LC)

- Baseline recording 2 (R2) for the dark cycle (Mouse ID_Baseline Rec 2_DC)
- Baseline recording 2 (R2) for the light cycle (Mouse ID_Baseline Rec 2_LC)
- Post urethane recording 1 (U1) (Mouse ID_Urethane 1_6 h)
- Post urethane recording 2 (U2) (Mouse ID_Urethane 2_6 h)

At Zenodo, eight zip.-folders for the $\text{Ca}_v3.2^{+/+}$ mice (<https://doi.org/10.5281/zenodo.4557037>; <https://doi.org/10.5281/zenodo.4557942>; <https://doi.org/10.5281/zenodo.4558201>; <https://doi.org/10.5281/zenodo.4561604>; <https://doi.org/10.5281/zenodo.4561641>; <https://doi.org/10.5281/zenodo.4561655>; <https://doi.org/10.5281/zenodo.4561657>; <https://doi.org/10.5281/zenodo.4561663>) and eight folders for the $\text{Ca}_v3.2^{-/-}$ mice (<https://doi.org/10.5281/zenodo.4561667>; <https://doi.org/10.5281/zenodo.4561672>; <https://doi.org/10.5281/zenodo.4561674>; <https://doi.org/10.5281/zenodo.4561676>; <https://doi.org/10.5281/zenodo.4561682>; <https://doi.org/10.5281/zenodo.4561686>; <https://doi.org/10.5281/zenodo.4561695>; <https://doi.org/10.5281/zenodo.4561702>) containing raw EEG data are available.

2. Experimental Design, Materials and Methods

2.1. Study animals

$\text{Ca}_v3.2^{+/-}$ embryos (provided by Kevin Campbell via MMRCC-Mutant Mouse Resource & Research Centers) were re-derived with C57BL/6 J mice. Controls and $\text{Ca}_v3.2^{-/-}$ mice were obtained using random intra-strain mating. Eight $\text{Ca}_v3.2^{+/+}$ control mice (mean age: 124 ± 1 days, all ♂) and eight $\text{Ca}_v3.2^{-/-}$ animals (mean age: 129 ± 4 days, all ♂) were analyzed electroencephalographically. Experimental mice were housed in clear Macrolon cages type II in groups of 3,4 with *ad libitum* access to drinking water and standard food pellets. Mice were maintained under controlled environmental conditions using ventilated cabinet Model 9AV125P (Tecniplast, Germany) and UniProtect cabinet (Bioscape, Germany) with the following settings: ambient temperature 21 ± 2 °C, relative humidity 50–60%, and conventional 12 h/12 h light/dark cycle starting at 5:00 a.m.

2.2. Pre-surgical management of experimental animals and transmitter implantation

For pre-surgical preparation of experimental animals including selection of mouse lines, age and gender, anesthesia, temperature support, pain management, etc. please refer to our detailed protocols [2–4].

In brief, mice were anesthetised by ketamine/xylazine (100/10 mg/kg, i.p.). Subsequently, a longitudinal incision was made at the scalp of the animal down to the neck. Subsequently, the transmitter was inserted into a subcutaneous pouch on the back of the animal. Details on the transmitter implantation are also provided in [2,3,5].

2.3. Intrahippocampal electrode placement for electrohippocampal CA1 recordings

For intracerebral, deep EEG recordings from the hippocampal CA1 region, the TA10ETA-F20 transmitter (DSI, USA) with the following technical specifications was used: weight 3.9 g, volume 1.9 cc, input voltage range ± 2.5 mV, channel bandwidth (B) 1 - 200 Hz, nominal sampling rate (f) 1000 Hz ($f = 5$ B), warranted battery life 4 months, on-off mechanism magnetically actuated.

The differential electrode targeting the CA1 region was positioned at the following stereotaxic coordinates: (+)-lead, caudal -2 mm, lateral of bregma 1.5 mm (right hemisphere), and dorsoventral (depth) 1.5 mm. The epidural reference electrode was positioned on the surface of the cerebellar cortex at the following stereotaxic coordinates: (-)-lead, bregma -6 mm and lateral of bregma 1 mm (right hemisphere). For intracerebral recordings, the sensing lead of the

transmitter was mechanically clipped to the deep electrode [2,3,5]. The deep tungsten electrodes (FHC, USA; shank diameter of 250 μm) are encapsulated with epoxy with an impedance of 50–100 $\text{k}\Omega$ (measured at 1000 Hz). Epidural and intracerebral electrodes were fixed using glass ionomer cement (Kent Dental, Kent Express Ltd., UK) and the scalp was closed using over-and-over sutures (Ethilon, 6–0). Based on the body surface/body volume ratio, mice are highly susceptible to hypothermia. Therefore, supplemental warmth was given to the mice during the entire period of anesthesia/surgical procedure and the first two days post implantation using a heating pad. A detailed description of the stereotaxic EEG electrode placement and transmitter implantation was previously provided by Weiergräber and colleagues [2–4]. For peri- and post-operative pain management, carprofen (5 mg/kg, Rimadyl, Parke-Davis/Pfizer, Germany) was injected subcutaneously. Note that mice were given 10 days to fully recover after surgery. This recovery period was determined by the finding that no alterations in basic physiological/behavioral parameters such as water and food uptake, locomotion, surface and body core temperature, etc. could be detected between radiotransmitter-implanted, non-implanted, and sham-operated mice 10 days post surgery [6].

2.4. Verification of EEG electrode placement

To confirm that electrodes were placed correctly in the exact CA1 target area, brains were extirpated *post mortem* and fixed in 4% formaldehyde solution. Next, 60 μm brain coronal slices were cut using a Vibroslice Tissue Cutter EMS 5000-MZ (Campden Instruments Limited, UK). Subsequently, slices were stained with hematoxylin/eosin to visualize the branch canal. Experimental animals in which EEG electrodes were not placed correctly in the defined target region were removed from the subsequent analysis.

2.5. Radiotelemetric EEG data acquisition

For each experimental animal, two 24 h spontaneous long-term EEG recordings from the CA1 hippocampal region (electrohippocampogram) were performed: the first 24 h recording (R1) at day 10 post surgery, the second 24 h recording (R2) one week later at day 17 post implantation.

Note that the 10 day recovery period is based on the observation that 10 days post surgery no differences in physiological parameters between transmitter implanted, non-implanted, and sham-operated animals could be detected [6,7]. The second 24 h long-term baseline recording (R2) was conducted at day 17 post implantation to check whether relative EEG power frequency values for the different frequency bands are robust over time [8–10]. In addition, at day 18 and 25 post implantation two EEG recordings were carried out following urethane injections (U1, U2) with 800 mg/kg i.p. each (Sigma, Germany, urethane freshly dissolved in 0.9% NaCl).

CA1 intrahippocampal EEG data were acquired using the Dataquest ART 4.2 software (DSI, USA). EEG data were sampled at a nominal rate of 1000 Hz with no *a priori* filter cutoffs. Based on the Shannon-Nyquist theorem and limit, EEG frequency analysis was carried out up to 500 Hz (upper gamma range) [11].

Apart from biopotentials (such as EEG), the TA10ETA-F20 transmitter also provides temperature and activity data. As the radiofrequency transmitter was placed in a subcutaneous pouch on the back of the experimental animals in our setting, the recorded subcutaneous temperature values do not represent body core values. Importantly, subcutaneous temperature data were shown to correlate with body core temperature under environmentally controlled conditions and can thus be compared within and between the individual genotypes [2,3,5,12,13].

The activity data are provided by the telemetry system in relative values (relative activity). These relative data represent activity in the horizontal plane and integrate trip distance, velocity and acceleration. If the experimental animal is inactive, relative activity is 0. For the active state, relative activity values are > 0 . For details see also Lundt et al. [2].

2.6. Relative EEG power from electrohippocampal EEG recordings

EEG data were exported to Neuroscore version 3.2 (DSI, USA) for further FFT based frequency analysis in the range of 0.5–500 Hz, including the following distinctive frequency bands: delta 1 (δ_1 , 0.5–4 Hz), delta 2 (δ_2 , 1–4 Hz), theta 1 (θ_1 , 4–8 Hz), theta 2 (θ_2 , 4–12 Hz), alpha (α , 8–12 Hz), sigma (σ , 12–16 Hz), beta 1 (β_1 , 12–30 Hz), beta 2 (β_2 , 16–24 Hz), beta 3 (β_3 , 16–30 Hz), gamma low (γ_{low} , 30–50 Hz), gamma mid (γ_{mid} , 50–70 Hz), gamma high (γ_{high} , 70–100 Hz), gamma ripples ($\gamma_{ripples}$, 80–200 Hz), and gamma fast ripples ($\gamma_{fast\ ripples}$, 200–500 Hz) [2,3,5]. Note that a broader theta frequency band (theta-alpha band, θ_2) is included, based on the complex functional interdependence of hippocampal oscillatory activity [14–18].

For FFT based analysis, the duration of the individual EEG epochs was determined as 2 s [2,3,5]. Mean relative EEG power (%) for the individual frequency ranges was calculated for the individual circadian stages, i.e. two dark cycles (DC1, DC2, 12 h each) and two light cycles (LC1, LC2, 12 h each), and 6 h post urethane 1 and 2 injection phases (U1, U2). Potential EEG artefacts were identified by both manual inspection of the EEG and the automated artefact detection tool of Neuroscore® and were eliminated from the EEG relative power data [2–4].

Relative activity counts and temperature data were also analyzed for baseline (R1, R2) and post urethane recordings (U1, U2). Importantly, activity data (active state, i.e. activity units > 0) or inactive state (activity units = 0) during the conventional 12 h/12 h light/dark cycle (starting at 5:00 a.m.) were exported together with the relative EEG power of the individual frequency bands from the hippocampal CA1 deflection.

Ethics Statement

All animal experiments were carried out in accordance with the guidelines of the German council on animal care and experimental protocols were approved by the local institutional and national committee on animal care (State Agency for Nature, Environment and Consumer Protection, Landesamt für Natur, Umwelt und Verbraucherschutz, LANUV, Germany, AZ-Nr. 87–51.04.2010.A321). All animal experimentation was further conducted in line with the ARRIVE guidelines, the National Institute of Health Guide for the Care and Use of Laboratory Animals (NIH Publications No. 8023, revised 1978) revised 1996 or the UK Animals (Scientific Procedures) Act 1986 and associated guidelines, or the European Communities Council Directive of 24 November 1986 (86/609/EEC) and September 22nd, 2010 (2010/63/EU). Specific effort was made to reduce the number of experimental animals and their suffering (3R strategy).

CRediT Author Statement

Anna Papazoglou: Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing Review and Editing; **Muhammad Imran Arshaad:** Data curation, Formal analysis, Software, Writing - Original draft; **Magdalena Elisabeth Siwek:** Data curation, Methodology, Writing - Review & Editing; **Christina Henseler:** Data curation, Formal analysis, Methodology, Software, Writing Review & Editing; **Johanna Daubner:** Investigation, Methodology, Software, Writing - Review & Editing; **Dan Ehninger:** Methodology, Resources, Software, Writing - Review & Editing; **Jürgen Hescheler:** Methodology, Resources, Software, Writing - Review & Editing; **Karl Broich:** Funding acquisition, Methodology, Resources, Software, Writing - Review & Editing; **Marco Weiergräber:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - Original draft, Writing - Review & Editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

Acknowledgments

The authors would like to thank Dr. Robert Stark and Dr. Christina Kolb (both German Center for Neurodegenerative Diseases, DZNE, Bonn) for assistance in animal breeding and animal health care.

References

- [1] M.I. Arshaad, M.E. Siwek, C. Henseler, J. Daubner, D. Ehninger, J. Hescheler, A. Sachinidis, K. Broich, A. Papazoglou, M. Weiergraber, Enhanced hippocampal type II theta activity AND altered theta architecture in mice lacking the $Ca_v3.2$ T-type voltage-gated calcium channel, *Sci. Rep.* 11 (2021) 1099, doi:[10.1038/s41598-020-79763-4](https://doi.org/10.1038/s41598-020-79763-4).
- [2] A. Lundt, C. Wormuth, M.E. Siwek, R. Muller, D. Ehninger, C. Henseler, K. Broich, A. Papazoglou, M. Weiergraber, EEG radiotelemetry in small laboratory rodents: a powerful state-of-the art approach in neuropsychiatric, neurodegenerative, and epilepsy research, *Neural Plast.* (2016) 8213878 2016, doi:[10.1155/2016/8213878](https://doi.org/10.1155/2016/8213878).
- [3] A. Papazoglou, A. Lundt, C. Wormuth, D. Ehninger, C. Henseler, J. Soos, K. Broich, M. Weiergraber, Non-restraining EEG radiotelemetry: epidural and deep intracerebral stereotaxic EEG electrode placement, *J. Vis. Exp.* (2016), doi:[10.3791/54216](https://doi.org/10.3791/54216).
- [4] M. Weiergraber, M. Henry, J. Hescheler, N. Smyth, T. Schneider, Electrocorticographic and deep intracerebral EEG recording in mice using a telemetry system, *Brain Res. Protoc.* 14 (2005) 154–164, doi:[10.1016/j.brainresprot.2004.12.006](https://doi.org/10.1016/j.brainresprot.2004.12.006).
- [5] R. Muller, A. Papazoglou, J. Soos, A. Lundt, C. Wormuth, C. Henseler, D. Ehninger, K. Broich, M. Weiergraber, Automatic detection of highly organized theta oscillations in the murine EEG, *J. Vis. Exp.* (2017), doi:[10.3791/55089](https://doi.org/10.3791/55089).
- [6] K. Kramer, L.B. Kinter, Evaluation and applications of radiotelemetry in small laboratory animals, *Physiol. Genom.* 13 (2003) 197–205, doi:[10.1152/physiolgenomics.00164.2002](https://doi.org/10.1152/physiolgenomics.00164.2002).
- [7] K. Kramer, L. Kinter, B.P. Brockway, H.P. Voss, R. Remie, B.L. Van Zutphen, The use of radiotelemetry in small laboratory animals: recent advances, *Contemp. Top. Lab. Anim. Sci.* 40 (2001) 8–16.
- [8] N. Rensing, B. Moy, J.L. Friedman, R. Galindo, M. Wong, Longitudinal analysis of developmental changes in electroencephalography patterns and sleep-wake states of the neonatal mouse, *PLOS ONE* 13 (2018) e0207031, doi:[10.1371/journal.pone.0207031](https://doi.org/10.1371/journal.pone.0207031).
- [9] T.H. Wen, J.W. Lovelace, I.M. Ethell, D.K. Binder, K.A. Razak, Developmental changes in EEG phenotypes in a mouse model of fragile X syndrome, *Neuroscience* 398 (2019) 126–143, doi:[10.1016/j.neuroscience.2018.11.047](https://doi.org/10.1016/j.neuroscience.2018.11.047).
- [10] A. Papazoglou, J. Soos, A. Lundt, C. Wormuth, V.R. Ginde, R. Muller, C. Henseler, K. Broich, K. Xie, B. Haenisch, et al., Motor cortex theta and gamma architecture in young adult APPswePS1dE9 alzheimer mice, *PLOS ONE* 12 (2017) e0169654, doi:[10.1371/journal.pone.0169654](https://doi.org/10.1371/journal.pone.0169654).
- [11] M. Weiergraber, A. Papazoglou, K. Broich, R. Muller, Sampling rate, signal bandwidth and related pitfalls in EEG analysis, *J. Neurosci. Method.* 268 (2016) 53–55, doi:[10.1016/j.jneumeth.2016.05.010](https://doi.org/10.1016/j.jneumeth.2016.05.010).
- [12] C.P. Moons, K. Hermans, R. Remie, L. Duchateau, F.O. Odberg, Intraperitoneal versus subcutaneous telemetry devices in young Mongolian gerbils (*Meriones unguiculatus*), *Lab. Anim.* 41 (2007) 262–269, doi:[10.1258/002367707780378177](https://doi.org/10.1258/002367707780378177).
- [13] D.J. McCafferty, S.G. & A Nord, Challenges of measuring body temperatures of free-ranging birds and mammals, *Anim. Biotelemetry* 3 (2015) 10.
- [14] G. Buzsaki, Theta oscillations in the hippocampus, *Neuron* 33 (2002) 325–340.
- [15] G. Buzsaki, D.L. Buhl, K.D. Harris, J. Csicsvari, B. Czeh, A. Morozov, Hippocampal network patterns of activity in the mouse, *Neuroscience* 116 (2003) 201–211.
- [16] R.G. Munn, S.M. Tyree, N. McNaughton, D.K. Bilkey, The frequency of hippocampal theta rhythm is modulated on a circadian period and is entrained by food availability, *Front Behav. Neurosci.* 9 (2015) 61, doi:[10.3389/fnbeh.2015.00061](https://doi.org/10.3389/fnbeh.2015.00061).
- [17] V.J. Lopez-Madrona, E. Perez-Montoyo, E. Alvarez-Salvado, D. Moratal, O. Herreras, E. Pereda, C.R. Mirasso, S. Canals, Different theta frameworks coexist in the rat hippocampus and are coordinated during memory-guided and novelty tasks, *Elife* 9 (2020), doi:[10.7554/eLife.57313](https://doi.org/10.7554/eLife.57313).
- [18] A. Goyal, J. Miller, S.E. Qasim, A.J. Watrous, H. Zhang, J.M. Stein, C.S. Inman, R.E. Gross, J.T. Willie, B. Lega, et al., Functionally distinct high and low theta oscillations in the human hippocampus, *Nat. Commun.* 11 (2020) 2469, doi:[10.1038/s41467-020-15670-6](https://doi.org/10.1038/s41467-020-15670-6).