$$d'_{A-B} = 2(R_A - R_B)/\sqrt{(\sigma_A^2 + \sigma_B^2)}$$

where R is the difference between the firing rate during presentation of a given stimulus and that during the baseline period, and σ^2 is its variance. A d' value of 0 signifies an absence of selectivity, i.e. equivalent responses to both stimuli. As most multiunits and single units exhibited an increase in the firing rate over baseline levels in response to any call stimulus, a positive d' value signifies a response bias to stimulus A while a negative values a response bias to stimulus *B*. As discussed by Nealen & Schmidt (2006), because the d' metric is symmetric about zero, i.e., may vary in either the positive or negative direction, a population-level description of auditory selectivity is best revealed by comparing observed indices to 0. A d' value of $> +1$ or < -1 was used as the criterion for identifying a cell as highly selective. We ensured that all single units with a $d'_{\mathrm{A-B}}$ value of $> +1$ were significantly more driven by stimulus A than by stimulus B: all these neurons showed a higher firing rate during stimulus A than during stimulus B (all $P < 0.001$). To examine whether auditory experience affected the selectivity of NCM neurons, we compared the number of highly selective cells using a χ^2-test.

Analysis of response habituation

We also examined whether firing-rate habituation differed between call stimuli. Auditory responses to a stimulus in the NCM are initially vigorous, but habituate rapidly when the stimulus, a song or a call, is repeated (Chew *et al.*, 1995; Stripling *et al.*, 1997, 2001; Phan *et al.*, 2006). The habituation rate was calculated at each electrode site for each call stimulus by performing a trial-by-trial analysis of responses (raw spike rate) to 50 call stimulus presentations. To evaluate the statistical significance of any interaction between repetition and call identity, a repeated-measures ANOVA was performed. When responses (raw spike rate) are plotted against presentation number, the slope of the linear portion of the resulting function is the habituation rate. We computed a linear regression for the responses to the 45 last presentations in order to further compare regression slopes between call stimuli.

Analysis of amount of information

To investigate whether social experience with the calls of individual males affected the auditory properties of NCM neurons, we quantified the amount of transmitted information in the neuronal responses. The method, described by Schnupp *et al.* (2006), consists of evaluating how well the responses of a neuron differentiate between different call stimuli by calculating the mutual information between call stimuli and neural spike trains. As a first step, peristimulus time histograms (PSTHs; 10-ms bin width) were created on a neuron-by-neuron and trial-by-trial basis. Three time intervals following call onset (100, 200 or 300 ms) were considered. Each response pattern, i.e. each spike train, was converted into a list of spike count values; these can be thought of as a vector in a multidimensional space and one can quantify how similar two response patterns are by calculating the Euclidean distance between these two responses in this space. Each response in turn was picked as a test pattern and was assigned to the call stimulus that was the closest in terms of Euclidean distance. The accuracy of the classification by the decoder algorithm, i.e. the proportion of assignments to the correct call stimulus, was then calculated. In short, if the response patterns are reproducibly similar among repeated presentations of the same stimulus and reproducibly different from patterns evoked by other stimuli, the response patterns will form distinct clusters in the response space and most patterns will be correctly assigned. However, if the responses lack reproducible and distinctive patterns then the assignment will essentially be random. This procedure was repeated until each trial of a neuron was considered as a test pattern and until each time interval was taken into account. A confusion matrix allowed an estimation of the mutual information (MI) between the response and stimulus class, depending on the time interval selected. The MI (in bits) is given by Shannon's formula:

$$\mathrm{MI} = \sum_{x,y} p(x,y) \cdot \log_2(p(x,y)/p(x).p(y))$$

where x and y are the values obtained by the random variables 'presented stimulus class' and 'assigned stimulus class' (x, $y \in \{1, 2, 3\}$) and one adopts the convention where 0.log(0) equals 0. The *a priori* probability, $p(x)$, of any one stimulus evoking any one particular response is 1/3. The probability of a response being assigned to any one stimulus class, $p(y)$, and the joint probability of observing a particular combination of stimulus and response assignments, $p(x,y)$, were estimated from the observed frequency distributions in the confusion matrix. We also estimated the expected magnitude of a bias by calculating MI values for 'shuffled' data, in which the response patterns had been randomly reassigned to stimulus classes. The shuffling was repeated 20 times and the mean MI estimate for the 20 shuffled datasets was used as an estimator for the bias. Bias estimates varied little from unit to unit: the median bias was 0.10 bits per response and it did not exceed 0.19 bits per response. All MI values reported below are 'bias-corrected,' i.e. the bias estimate obtained for each unit was subtracted from the original MI estimate. These computations were performed using a CUSTOM software in the R environment.

Statistical methods

The normality of the population was first assessed with the Liliefors test with $P < 0.05$ (Statistica v8.0; StatSoft, Inc.). Auditory response data were mostly analysed with parametric statistics. However, when data did not meet the assumption of a normal distribution we used nonparametric tests. Responses to call stimuli were appraised by the use of repeated-measures ANOVAs or the Friedman test, which is the nonparametric equivalent. We tested the effects of two factors (call identity and group) and their interactions on RS values in a linear mixed model. Distributions of data were analysed using a χ^2-test. All comparisons were two-tailed ($P < 0.05$).

Histology

At the end of each experiment, the animal was killed with a lethal dose of pentobarbital and the brain quickly removed from the skull and placed in a fixative solution (4% paraformaldehyde). Brains were subsequently immersed in 20% sucrose in PBS solution for cryoprotection. Sections (30 μm) were cut on a freezing microtome and processed for Cresyl violet staining. They were examined for electrode penetration tracks and the electrolytic lesions made to indicate recording sites (Fig. 3).

Results

Awake mated females

To examine the neural correlates of call-based recognition, we measured the auditory responses of NCM neurons in awake mated