Functional (BOLD) MRI in zebra finch to investigate the capacity of specific brain regions to segregate meaningful auditory signals from a noisy background.

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Introduction

Background noise can be an obstacle to the successful perception of significant information in acoustic signals. In songbirds (Passeriformes: Oscines) the acoustic signals that contain significant auditory information are the songs themselves. Using fMRI in the zebra finch, we investigated the capacity of two (in)directly connected auditory regions of the telencephalon to segregate auditory signals in unfavorable auditory environments. These two regions, the primary thalamorecipient area field L and the higher auditory area caudomedial nidopallium (NCM), are part of the avian analogue of the mammalian auditory cortex.

Materials and Methods

We investigated the fMRI response in the auditory regions field L and NCM in four adult male zebra finches (*Taeniopygia guttata*) during playback of a conspecific signal (CS) mixed with different levels of white noise (WN). Table 1 shows the signal degradation values of the original CS obtained in the different stimuli. The stimulus SN-18 (signal-to-noise ratio = -18 dB) is much degraded, whereas the stimulus SN-3 (signal-to-noise ratio = -3 dB) conserves the main characteristics of CS.

Table 1

STIMULUS	CS	SN-3	SN-9	SN-18	WN
Correlation between the amplitude envelope of the stimulus and the amplitude envelope of CS	1.00	0.52	0.20	0.11	0.00
Correlation between the frequency spectrum of the stimulus and the frequency spectrum of CS	1.00	0.77	0.60	0.53	0.00
Entropy	0.00	0.81	0.96	0.98	1.00

Zebra finches were anaesthetized (ketamine + medetomidine) and immobilized in a stereotactical device. Body temperature, respiration rate and expired pCO_2 were continuously monitored. MR-imaging was performed at 300 MHz on a 7 Tesla horizontal bore NMR microscope (MR Solutions, Surrey, UK) with an actively shielded gradient-insert (Magnex Scientific Ltd, Oxfordshire, UK) having an inner diameter of 80 mm and a maximum gradient strength of 400 mT/m. Functional imaging was performed in the right hemisphere (sagittal from 0.25 to 0.75 mm lateral) with a T2*-weighted single-slice gradient-echo sequence: TR 40 ms, TE 14 ms, gradient ramp time 1000 µs, acquisition matrix 128x64, FOV 25 mm, slice thickness 0.5 mm, temporal resolution 2.56s, and spatial resolution 195x195 µm². Images were collected with a block-design paradigm consisting of 6 cycles of 8 images collected during stimulation (20 sec), and 24 images collected during rest (60 sec), resulting in 192 functional images. In all birds, five consecutive experiments were performed in random order during which the birds were exposed to the five different stimuli, all having the same mean root-mean-square power (i.e. measure for signal loudness).

Results

A significant ($P < 0.05$; $Z > 1.65$) Z-score was elicited by conspecific song in both field L and NCM, but whereas in field L the response was not reduced by added noise, in NCM the response was reduced and finally disappeared with increasing levels of noise (from SN-18) added to the song stimulus. Linear regression analysis ($P = 0.05$) with the Z-scores of the four birds as dependent variables and the three signal degradation values of Table 1 as independent factors revealed no significant correlation in field L, but indeed a significant correlation in NCM between the Z-score and the signal degradation values representing comparisons between amplitude envelopes (R^2=0.297, P=0.016), frequency spectra (R^2=0.240, P=0.033) and entropy (R^2=0.238, P=0.034). These results demonstrate that the auditory response in field L is not influenced by the CS/WN ratio of the stimulus, whereas the response in NCM decreases with higher degradation of the CS.

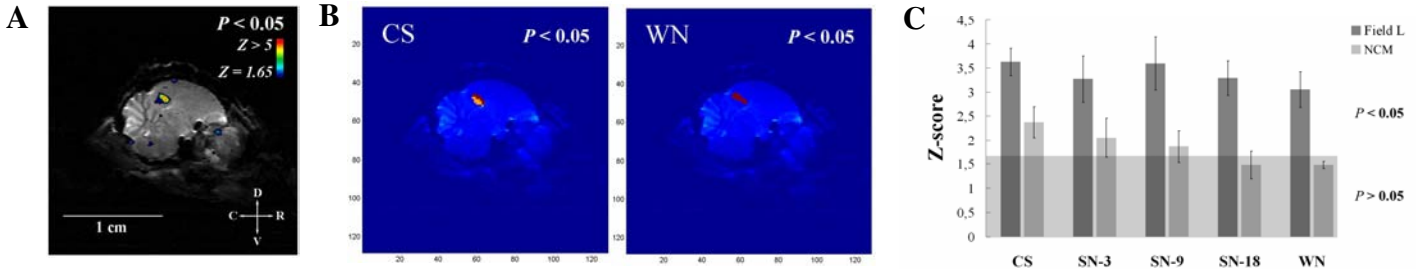

Figure 1:(A) Example of Z-score map for CS, and (B) cluster analysis maps for CS and WN illustrating two distinct brain regions (brown: field L, yellow: NCM) with a different signal time course during successive stimulation and rest periods. (C) The mean Z-score and SE (n=4) for field L and NCM to presentation of CS, SN-3, SN-9, SN-18 and WN.

Discussion

These results imply that in the songbird the capacity to segregate meaningful auditory signals in unfavorable auditory environments is not present in field L but is an emergent property of NCM. The strong similarity with IEG results in NCM (Vignal et al. (2004) *Behav Brain Res*, 153, 241-48) previously obtained with the same experimental setup demonstrates that segregation of meaningful auditory signals also takes place under anaesthesia and that fMRI can be used as an accurate in-vivo method to probe acoustically induced brain activity in the small anaesthetized zebra finch.