Detection of haemodynamic changes in zebra finch brain by optical and functional magnetic resonance imaging

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Introduction

Songbirds' vocal communication behaviour has been a favourite research domain for years. In order to study brain activation in response to acoustic stimuli, two different in-vivo methods that are able to assess neuronal activity based on detection of haemodynamic changes were compared within identical experimental settings.

Optical imaging (non-invasive in-vivo broadband time-resolved spectroscopy) and functional magnetic resonance imaging (Blood Oxygenation Level Dependent MRI) were both performed in zebra finch brain upon a hypercapnic challenge known to induce a standard haemodynamic response.

The use of these two methods offers the opportunity to compare their sensitivity and to correlate local variations in CBV and haemoglobin saturation level (obtained from optical data) with local BOLD signal variations (providing overall information on CBF, CBV and haemoglobin oxygenation).

Methods

Both for optical imaging and fMRI, four adult female zebra finches (*Taeniopygia guttata*) were anaesthetized with 2% isoflurane while spontaneously breathing, and immobilized in a stereotactical device equipped with essential monitoring devices. Each bird underwent three runs of 5 minutes hypercapnia (600 ml/min 7% CO₂, 21% O₂, 72% N₂), interleaved by 20 minutes normocapnia (600 ml/min 21% O₂, 79% N₂). Optical imaging was performed with an ultrafast white laser and time-resolved spectrometer. With the 95% PL (i.e. mean path length of the light detected by the camera at 95% of the measured temporal profile) at 2 spectral windows centered at 748 nm and 793 nm, we quantify respectively the haemoglobin saturation level and CBV. MR imaging was performed at 300 MHz on a 7 Tesla in-vivo NMR microscope with horizontal bore and actively shielded gradient-insert (210 mT/m).

Results

The optical imaging data demonstrated that hypercapnia induced a significant increase of the hemoglobin saturation level in run1 ($p=.01$) and run2 ($p=.01$). No significant CBV changes were observed during run1 ($p=.1$), run2 ($p=.75$) and run3 ($p=.5$). The fMRI data demonstrated the existence of significant BOLD signal changes for run1 ($p<.001$), run2 ($p<.001$) and run3 ($p<.001$).

No significant difference between the runs ($p=.950$) was detected. As it was already shown that fMRI can be used to discern auditory induced activation in the songbird brain (Van Meir et al., NeuroImage, accepted), comparison of signal intensity changes upon a standard haemodynamic challenge provides a good indication whether optical imaging could be used as an alternative in-vivo method to probe acoustically induced brain activity in the songbird brain.

Our data show that upon a 7% CO₂ challenge, fMRI is the most sensitive of the two displaying a 2.6% contrast increase as compared to the 1.2% contrast increase for optical imaging (See Figure 1).

Figure 1

Figure 1 (a) Mean 95% PL changes (reflecting respectively haemoglobin saturation level and CBV) and (b) mean percent BOLD signal changes with standard errors for four birds during the first hypercapnia run (administration of 7% CO₂ is indicated by gray area).

Conclusion

Further optimization of the optical imaging protocol will be necessary in order to use it as a probe for in-vivo brain haemodynamic changes during acoustic recognition in small zebra finch brains.