Title: Unraveling computational principles for natural sound recognition through deep neuronal networks and in-vivo functional imaging.

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Proposal (250 words)

Introduction: Neuronal networks with a "deep" architecture have revolutionized the field of artificial intelligence. As the human brain, deep networks use a hierarchical architecture to process information through multiple "areas" (layers). However, when networks are trained on a specific task (e.g. sound recognition) it is not obvious that the obtained computational algorithm reflects the actual brain computations. Therefore, from a neuroscience perspective, deep networks need experimental validation. Here we connect deep networks with non-invasive measures of brain activity to advance our understanding of *natural sounds recognition*. Specifically, we aim to: 1) train a network to recognize natural sounds; 2) link this network to the brain using high resolution functional MRI and the approach of fMRI *encoding*.

Objectives: This project will: 1) validate basic computational units of deep network by comparing them to known principles of sound processing; 2) unravel higher level neuro-computational principles of sound recognition; 3) refine the deep neuronal network to a "brain inspired" one.

Setting and Methods: The candidate will work at the Maastricht Center for Systems Biology (Macsbio) and at the Department of Cognitive Neuroscience, Maastricht University. In study 1, the deep neuronal network for natural sound recognition will be trained, in study 2 the network will be linked to high-resolution fMRI responses through fMRI-encoding. In study 3, the network will be iteratively refined by using fMRI responses to constrain the training process.

Impact: This project will refine "brain-inspired" deep neuronal networks and uncover new computational principles for sound recognition.

Requirements candidate: Background in computer science, engineering, (computational) neuroscience or related fields. Good English skills (B2 or higher), being a problem solver, and good programming/ data analysis skills are required.

Keywords: neuroscience, deep learning, sound processing.

Selected publications:

1. LeCunn Y, Bengio Y, Hinton G (2015). Deep Learning. Nature (521): 436-444.
2. Santoro R, Moerel M, De Martino F, Valente G, Ugurbil K, Yacoub E, Formisano E. (2017) Reconstructing the spectrotemporal modulations of real-life sounds from fMRI response patterns. Proc Natl Acad Sci U S A 114: 4799-4804.
3. De Martino F, Yacoub E, Kemper V, Moerel M, Uludag K, De Weerd P, Ugurbil K, Goebel R, Formisano E (2017) The impact of ultra-high field MRI on cognitive and computational neuroimaging. Neuroimage. doi: 10.1016/j.neuroimage.2017.03.060.
4. Formisano, E., De Martino, F., Bonte, M., and Goebel, R. (2008). "Who" is saying "what"? Brain-based decoding of human voice and speech. *Science* 322, 970-973.
5. Santoro R, Moerel M, De Martino F, Goebel R, Ugurbil K, Yacoub E, Formisano E (2014) Encoding of Natural Sounds at Multiple Spectral and Temporal Resolutions in the Human Auditory Cortex. *Plos Computational Biology*. 10(1):e1003412.