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brains, behaviour, organisations

Scientific and Technical Breakthrough of the Year: Using 3D Printing for in vivo Neurophysiology

Shane O'Mara November 10, 2013

3D printing, Boston, Boston University, Brown University, Christopher I. Moore, Cognitive science, Electrode, electrode array, electrophysiology, free behavior, Massachusetts Institute of Technology, McKinsey & Company, microdrive, multi-site, National College of Art and Design, neuroscience, optogenetics, Royal Hibernian Academy, United States, Wilson, Yamamoto

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English: Stereolithography (3D printing) :: the

The annual awards season is upon us. The various journals will nominate their scientific and technical breakthroughs of the year. There are lab awards too: well done TCIN for nominations in two categories.

3d printing is regarded by many as being the basis of the next industrial revolution (e.g. McKinsey & Company, 2013). I first encountered 3d printing in an non-

inner ear of a fossil baboon (2.8millions year) initially 2cm enlarged to 22cm. ::Specimen of of Anthropology Molecular and Imaging Synthesis of Toulouse. Français : Stéréolithographie :: Oreille interne d'un fossile de babouin (2.8millions d'année) initialement de 2cm agrandie à 22cm. ::Exemplaire du Laboratoire d'Anthropologie Moléculaire et Imagerie de Synthèse de Toulouse. (Photo credit: Wikipedia)

industrial context through the work of the artist Andrew Folan of the NCAD for a Royal Hibernian Academy exhibition. My technical breakthrough of the year is straightforward is both straightforward and revolutionary: a superb case of lateral thinking – the application of 3d fabrication and 3d printing to in vivo neurophysiology to produce the *flexdrive* (see abstract below).

English: Photograph of the Royal Hibernian Academy building in Ely Place, Dublin, Ireland. Taken by me 20 January 2009. (Photo credit: Wikipedia)

The *in vivo* application of 3d printing is based around an open-source collaborative platform which allows one to print novel electrophysiological recording hyperdrives with up to 64 channels. The original hyperdrive designs (see this for an early example; see Yamamoto and Wilson, 2008 for review), while providing great data yield in terms of numbers of units recorded, were and are heavy (>40 grams) and physically cumbersome, often requiring counterbalanced weights and pulleys to be attached to the headstage (presenting difficulties for movement). By contrast, 3d printed flexDrives are c. 4-5 g (fully loaded) and present few postoperative implantation problems and can be combined with cannulae that allow optogenetic control of neural circuits (a technique most assuredly deserving the hype). At last, here is the promise of a cheap and innovative methodology allowing high-density recording to be combined easily with other techniques to allow the fine-grained dissection of neural circuits to understand their role in supporting cognition and behaviour. These applications are a novel technological approach to the exploration of brain function and will over time materially assist in the development of personalised medicine.

UPDATE: I should add that we print our flexDrives in the laboratory of Professor

Martin Hegner in CRANN (Trinity College's Nanoscience Institute). The 3d printing system we use is an EDEN250, with an axial resolution of 40µm (x); 80µm (y) and 16µm (z). There is certainly a 'scales falling from eyes' moment here for me, as the customisations possible are limited only by imagination, miniaturisation, practicality and good sense now. Multiplanar, multiconcentric arrays of differing, shapes, sizes and densities are now feasible.

Voigts J, Siegle JH, Pritchett DL and Moore CI (2013).

The flexDrive: an ultra-light implant for optical control and highly parallel chronic recording of neuronal ensembles in freely moving mice.

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Electrophysiological recordings from ensembles of neurons in behaving mice are a central tool in the study of neural circuits. Despite the widespread use of chronic electrophysiology, the precise positioning of recording electrodes required for high-quality recordings remains a challenge, especially in behaving mice. The complexity of available drive mechanisms, combined with restrictions on implant weight tolerated by mice, limits current methods to recordings from no more than 4–8 electrodes in a single target area. We developed a highly miniaturized yet simple drive design that can be used to independently position 16 electrodes with up to 64 channels in a package that weighs ~2 g. This advance over current designs is achieved by a novel spring-based drive mechanism that reduces implant weight and complexity. The device is easy to build and accommodates arbitrary spatial arrangements of electrodes. Multiple optical fibers can be integrated into the recording array and independently manipulated in depth. Thus, our novel design enables precise

optogenetic control and highly parallel chronic recordings of identified single neurons throughout neural circuits in mice.

Keywords: electrophysiology, microdrive, electrode array, optogenetics, multi-site, free behavior

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