Translational Neural Engineering: Accelerated medical device design for treatment of neuro-psychiatric disorders and brain injury

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Medical Device Design Lab

- ~50 concurrent projects. Bioengineers + local network of other engineering specialists and biomedical scientists
- ~200 clinical partner trial sites. US and international

**HD-tDCS**
Brain-stimulation cap for epilepsy treatment

**WiPOX**
Wireless hand-help intraoperative sensor

**Toddler-Cane**
Brain-stimulation cap for epilepsy treatment
Translational Medical Device Design

Device Design
New Technology

Scientific Hypothesis
Cellular / behavioral mechanism

Manufacturing
Commercial medical

Regulatory
Device / trial side

New Treatment
Reducing human suffering

Pre-Clinical Testing
Animal Models

Intellectual Property
Licensing

Clinical Trial
Case...Pivotal

Design as a continuum. Bioengineers supporting specialist network
Contract Research for Industry

- From biomedical start-up to market leader. Consumer products.
- Services: bench testing, preclinical, IP prosecution / licensing, regulatory, clinical trial, and design

- HD-tDCS: Brain-stimulation cap for epilepsy treatment
- Spinal Cord Stimulation: Technology verification and pre-clinical
- Galvanic Spa: Consumer / medical regulatory

Catheter Tractor Simulation design
Model driven design

- Simulate before any experimental design steps
- Model precision supports better design
- Device / tissue interactions
- Animal-human translation
Epilepsy: Seizures of hyper-active neurons
- Treatments decrease excitability
- More electrical stimulation increase activity
- Cathodal Direct Current Stimulation can decrease activity: control seizures

1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models
HD-tDCS
Non-invasive brain stimulation

Direct Current Stimulation

1995-2000 Pre-clinical experiments: **Direct Current Stimulation on epilepsy animal models**
2009 HD-tDCS
Non-invasive brain stimulation

Animal model of seizures

1995-2000 Pre-clinical experiments: **Direct Current Stimulation on epilepsy animal models**

Hyper-polarize soma = decrease excitability
HD-tDCS
Non-invasive brain stimulation

1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models

Depolarize soma = increase excitability

Animal model of seizures
Suppression and Control of Epileptiform Activity by Electrical Stimulation: A Review

DOMINIQUE M. DURAND, MEMBER, IEEE, AND MAROM BIKSON

Dominique M. Durand (Member, IEEE) was born in Monbazillac, France, in 1951. He received the Eng. degree from Ecole Nationale Superieure d’Electronique, Hydraulique, Informatique et Automatique de Toulouse, France, in 1973, the M.S. degree in Biomedical Engineering from Case Reserve University, Cleveland, OH, in 1974, and the Ph.D. degree in electrical engineering from the Institute of Biomedical Engineering, University of Toronto, Canada, in 1982.

Marom Bikson was born in Tel-Aviv, Israel, in 1975. He received the B.S. degree in biomedical engineering from Johns Hopkins University, and the Ph.D. in biomedical engineering from Case Western Reserve University in 2001.

He worked at Sontra Medical, Cambridge, MA. He is currently a post-doctoral fellow in the Department of Neurophysiology, Division of Neuroscience, University of Birmingham, U.K. His research interests include non-synaptic interactions in the CNS and the effects of

1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models

Solid biomedical science + engineering. No translation.

HD-tDSC Non-invasive brain stimulation
2000 **Transcranial Direct Current Stimulation**

1995-2000 Pre-clinical experiments: **Direct Current Stimulation on epilepsy animal models**

**HD-tDCS** Non-invasive brain stimulation
1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models

2000 Transcranial Direct Current Stimulation

2009 HD-tDCCS
Non-invasive brain stimulation

Diffuse Current with regions of excitation
2009 HD-tDCS
Non-invasive brain stimulation

1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models

Scalp
Brain

Targeted inhibition

High-Definition Transcranial Direct Current Stimulation (tDCS)
Gyri-precise head model of transcranial direct current stimulation: Improved spatial focality using a ring electrode versus conventional rectangular pad

Model workflow preserves anatomy precision of MRI

High-Definition Transcranial Direct Current Stimulation (tDCS)

1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models
2009 HD-tDCS
Non-invasive brain stimulation

HD-tDCS
High-Definition Transcranial Direct Current Stimulation (tDCS)

1995-2000 Pre-clinical experiments: Direct Current Stimulation on epilepsy animal models
- tDCS with two large electrodes stimulates most of the brain
- High-Definition tDCS (HD-tDCS) used arrays of small electrodes
- Controlling the current at each HD electrode allows steering of stimulation to brain targets

High-Definition Transcranial Direct Current Stimulation (tDCS)

1995-2000 Pre-clinical experiments: **Direct Current Stimulation on epilepsy animal models**
HD-tDCS
Non-invasive brain stimulation

Product design implement HD-tDCS + reduce regulatory hurdle, reduce cost, simplify set-up.

FDA Regulatory  Phase-1 Trials  Clinical Trials  EU Regulatory

2009 2015

ISO 13485, New York City
HD-tDCS
Non-invasive brain stimulation

Product design implement HD-tDCS + reduce regulatory hurdle, reduce cost, simplify set-up.

2009
HD-tDCS

Non-invasive brain stimulation

FDA Regulatory
Phase-1 Trials
EU Regulatory

Product Design
Clinical Trials

2015
ISO 13485, New York City

Soterix Medical
HD-tDCS
Non-invasive brain stimulation

Soterix Medical
ISO 13485, New York City

2009

FDA Regulatory
Phase-1 Trials
EU Regulatory

Product Design
Clinical Trials
2015

Figure 1. Photos of the HD-tDCS device and interface, and example of the electrode configuration used in the present study.

The Journal of Pain, Vol 13, No 2 (February), 2012: pp 112-120
Available online at www.sciencedirect.com
HD-tDCS
Non-invasive brain stimulation

Combining HD-tDCS with EEG mapping of brain
”Read and write the brain”

2009
FDA Regulatory
Phase-1 Trials
EU Regulatory

2015
Product Design
Clinical Trials
ISO 13485, New York City
HD-tDCS
Non-invasive brain stimulation

Clinically Effective Treatment of Fibromyalgia Pain With High-Definition Transcranial Direct Current Stimulation: Phase II Open-Label Dose Optimization

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FDA Regulatory  Phase-1 Trials  EU Regulatory

2009  Soterix Medical  Product Design  Clinical Trials  2015

ISO 13485, New York City
HD-tDCS in an infant customized to inhibit brain targets identified by EEG.

Translational medical device design: Hypothesis is the design.

- Trial design: March 30, 2015
- Dose design: Regulatory: Israel Ministry of Health
- Device customization: March 20, 2016. First Treatment

Patient LB