APPLICATIONS OF REAL TIME FMRI: PAIN TREATMENT AND SUBSTANCE ABUSE TREATMENT

MARCH 2007

THIS WORK SUPPORTED BY NIH:

MH067290-01
Applications of Real Time fMRI

NS050642-03
Applications of Real Time fMRI - Phase II

DA-4-7748
Virtual Reality and Real Time fMRI

DA-4-7748
Virtual Reality and Real Time fMRI - Phase II

NS049673-01
Novel Methods for Functional Brain Imaging

DA021877-01A1
Measurement and Control of Patterned Brain Activation

SPECIAL THANKS FOR HELP AND GUIDANCE
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Ro Nemeth, NIDA
Dave Thomas, NIDA
Larry Stanford, NIDA
Linda Porter, NINDS
<table>
<thead>
<tr>
<th>COLLABORATIVE TEAM</th>
<th>AFFILIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHRISTOPHER DECHARMS</strong></td>
<td>Omneuron</td>
</tr>
</tbody>
</table>
| – Chloe Hutton  
| – Susan Landau  
| – Brett Mensh  
| – Kristen Lutomski  
| – Saxon MacLeod  
| – Debbie Scacco  
| – Dave Hagewood |
| **SEAN MACKEY** | STANFORD |
| – Axel Lucca  
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| – Fumiko Maeda  
| – Alison Adcock |
| **GARY GLOVER** | STANFORD |
| **JOHN PAULY** | STANFORD |
TALK OUTLINE

OVERVIEW OF REAL TIME FMRI

LEARNED CONTROL OVER BRAIN ACTIVATION AND PAIN

RTFMRI IN CHRONIC PAIN

SUBSTANCE ABUSE - PRELIMINARY EXPERIENCES
DESCARTES VIEW OF BRAIN, AND PAIN
IS IT POSSIBLE TO VISUALIZE THE MECHANISMS UNDERLYING PERCEPTION IN REAL TIME?
CAN MRI BECOME A THERAPEUTIC MODALITY?

Diagnostic Radiology

DIAGNOSTIC
• MRI provides answer
• Very broad application

Today

3T MRI
CAN MRI BECOME A THERAPEUTIC MODALITY?

Diagnostic Radiology

DIAGNOSTIC
• MRI provides answer
• Very broad application

Today

Neuroimaging Therapy

THERAPEUTIC
• MRI provides patient improvement
• Application in areas of severe need

Tomorrow?
RTFMRI AS A POTENTIAL NEW INTERFACE TO THE NERVOUS SYSTEM

- **Cochlear implant**
  - Wires
  - • Restore hearing through direct stimulation of the nervous system in the profoundly deaf
  - • Potential to move on to vision as well

- **Deep brain stimulation**
  - Wires
  - • Drive centers in the brain that control global functioning in order to remediate disease
  - • Currently applied in Parkinson’s disease, efforts underway in others

- **EEG-based measurement**
  - Wires
  - • Used in epilepsy and elsewhere
  - • EEG Neurofeedback
  - • Control of screen cursor demonstrated in people

- **Multi-electrode recording**
  - Wires
  - • Control of screen cursor demonstrated in monkeys
  - • Potential to control prosthetics
**RTFMRI AS A POTENTIAL NEW INTERFACE TO THE NERVOUS SYSTEM**

- **Cochlear implant**
  - Restore hearing through direct stimulation of the nervous system in the profoundly deaf
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- **Deep brain stimulation**
  - Drive centers in the brain that control global functioning in order to remediate disease
  - Currently applied in Parkinson’s disease, efforts underway in others

- **EEG-based measurement**
  - Used in epilepsy and elsewhere
  - Used in anesthesia monitoring
  - Control of screen cursor demonstrated in people

- **Multi-electrode recording**
  - Control of screen cursor demonstrated in monkeys
  - Potential to control prosthetics

- **Neuroimaging/Cognitive**
  - Non-Invasive
  - No tissue damage
  - Reasonable localization
OBLIQUE SLICES

Slice Thickness
e.g., 6 mm

Number of Slices
e.g., 10

Consecutive Slices Through SPACE

MRI: IMAGES OF ANATOMY – PHYSICAL STRUCTURE

Consecutive

Slices

Through

SPACE
fMRI: IMAGES OF PHYSIOLOGY – FUNCTION

fMRI FUNCTIONAL IMAGES ARE DERIVED FROM CHANGES IN T2*-SENSITIVE LOW-RESOLUTION IMAGES OVER TIME

Same Spatial Slice Followed Through TIME

10 min of data collection
fMRI functional images are derived from deviations in low-resolution anatomical images.

Same spatial slice followed through time.

Condition 1

Condition 2

~2s

10 min of data collection

Hours/days of analysis

Statistical map superimposed on anatomical MRI image.
fMRI functional images are derived from deviations in low-resolution anatomical images.

Same spatial slice followed through time.

Condition 1

Condition 2

Region of interest (ROI)

Statistical map superimposed on anatomical MRI image.

Hours/days of analysis

10 min of data collection

~2s
fMRI functional images are derived from deviations in low-resolution anatomical images

Condition 1

Condition 2

Same spatial slice followed through time

ROI time course

Region of interest (ROI)

10 min of data collection

10 min of data collection

Statistical map superimposed on anatomical MRI image
OVERVIEW OF METHOD

MRI acquires real time fMRI data (spiral or EPI)

Real time fMRI analysis
• Motion correction
• Temporal filtering
• Spatial filtering
• Event-related averages
• Pattern comparison

Subjects (or patients or clinicians) watch their cognitive processes unfold ‘live’, depicted as simulated displays

Image from story courtesy
The Boston Globe
RTFMRI SETUP
RTFMRI-BASED TRAINING – A MORE PRECISE, ANATAMICALLY TARGETED MEASURE THAN TRADITIONAL AUTONOMIC ‘BIOFEEDBACK’

<table>
<thead>
<tr>
<th>MEASURES</th>
<th>CONSEQUENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>60’s</strong></td>
<td><strong>AUTONOMIC FUNCTION</strong></td>
</tr>
<tr>
<td>Heart Rate</td>
<td>Predominantly measures of global arousal.</td>
</tr>
<tr>
<td>Breath Rate</td>
<td>Most useful if you want to teach relaxation</td>
</tr>
<tr>
<td>Skin Conductance</td>
<td></td>
</tr>
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<td>Skin Temperature</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>TODAY</th>
<th><strong>BRAIN FUNCTION</strong></th>
<th>Can measure the very specific neurophysiological functions associated with the &gt;100 individual brain areas.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Can measure patterns of activation evolving across multiple brain areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential to train subjects to produce very specific neurophysiological effects.</td>
</tr>
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</table>
### Challenges with fMRI as a Measure of Brain Function

<table>
<thead>
<tr>
<th>TIMESCALE</th>
<th>PROBLEM</th>
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<tr>
<td>Neural activation is on a msec timescale, diseases lead to long-term changes in brain function. fMRI signals evolve over a few seconds.</td>
<td>Cognitive processing is closer to the seconds timescale. We'll use better temporal methods as soon as they come along.</td>
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<th>SPATIAL SCALE</th>
<th>PROBLEM</th>
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<tr>
<td>There may be $\sim 10^7$ neurons in the areas that fMRI is measuring – that’s no way to measure the code.</td>
<td>It may not be necessary to control individual neurons to achieve important applications: eg drugs, deep brain stimulation.</td>
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<td>Isn’t MRI way too expensive to really be practical?</td>
<td>Patient care costs can easily run into $100k/yr/patient for many CNS diseases. Invasive CNS procedures can easily cost this much for a single procedure.</td>
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*“Neurophysiologist reaction”*
### CHALLENGES WITH fMRI AS A MEASURE OF BRAIN FUNCTION

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**OVER TIME, IMAGING TECHNOLOGY WILL EVOLVE TO NEW USES:**
### RTfMRI AND COGNITIVE TRAINING TAKE-HOME EXERCISE

<table>
<thead>
<tr>
<th>POSSIBLE CREDIT</th>
<th>ASSIGNMENT</th>
<th>DUE DATE</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Produce 1% modulation in rACC activation</td>
<td>Next Wed</td>
</tr>
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</table>
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<td></td>
<td>Take control over your own reward and endorphin systems…</td>
<td>??</td>
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<td>??</td>
</tr>
<tr>
<td></td>
<td>Decrease pain and suffering</td>
<td>Future</td>
</tr>
</tbody>
</table>
Learned regulation of spatially localized brain activation using real-time fMRI. 


deCharms, R. C., Christoff, K., Glover, G. H., Pauly, J. M., Whitfield, S., and Gabrieli, J. D.
IMPACT OF RTFMRI TRAINING ON BRAIN ACTIVATION

A) Pre-Training BOLD Individual

B) Post-Training BOLD Individual

C) Average

D) Average

E) Concurrent EMG

% signal Δ

0 60 120 180 240s

Time (s)

mV

0 1 2 3 4 5 6

0 0.2 0.4 0.6

0 60s
TIME COURSE OF TRAINING EFFECT AND CONTROLS

- **Training, ROI**
- **Whole brain control**
- **Sham Training, ROI**
- **Motor Task, ROI**
- **Post-Training Test, ROI**

% signal Δ

- **A)**
- **B)**
- **C)**
- **D)**
- **E)**

Sessions: Session I, Session II, Session III

Feedback: + Feedback, - Feedback
CAN THIS APPROACH BE USED IN CLINICALLY IMPORTANT AREAS?
TRANSLATING BASIC RESEARCH IN PAIN INTO A NEW POTENTIAL THERAPEUTIC APPLICATION AREA: NEUROIMAGING

BASIC RESEARCH

Pain can be powerfully modulated by cognitive processes including attention, placebo effect, hypnosis, and many others involving a matrix of brain regions.

There are large individual differences in pain perception...

...and subjects with different pain sensitivities show differences in a similar group of brain regions.

Pain, and brain, can be changed substantially by mechanisms of plasticity.

APPLIED QUESTION

CAN SUBJECTS BE TRAINED TO MORE EFFECTIVELY COGNITIVELY CONTROL PAIN?

CAN SUBJECTS SHIFT THEIR PAIN TOLERANCE OR PERCEPTION?

CAN NEURAL PLASTICITY BE ANATOMICALLY TARGETED?
POTENTIAL TARGETS IN THE PAIN CONTROL SYSTEM

- **Thalamus VPL/VPM**
- **SI/SII**
- **DCN**
- **MI/SMA**
- **Insula**
- **Amygdala**
- **Anterior Cingulate Rostral ACC**
- **Lateral Orbito-Frontal**
- **Periaqueductal Gray**
  - **Pons/Parabrachial nucleus**
  - **Rostral Ventromedial Medulla**
  - **Spinal Cord Dorsal Horn**

**Internal capsule**

**Ascending Pain Perception System**

**Descending Pain Control System**

Invasive Electrical Neurostimulation Provides Pain Relief

Potential Target
**RTFMRI TRAINING PROTOCOL IN HEALTHY SUBJECTS**

**BLOCK DESIGN**

<table>
<thead>
<tr>
<th>Cycle (3 blocks, 150s total)</th>
<th>Rest 30s</th>
<th>Increase 60s</th>
<th>Decrease 60s</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Pain</td>
<td>Pain</td>
<td></td>
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Control over brain activation and pain learned by using real-time functional MRI. *Proceedings of the National Academy of Sciences* (2005)  
*deCharms, R. C., Maeda, F., Glover, G. H., Ludlow, D., Pauly, J. M., Soneji, D., Gabrieli, J. D., and Mackey, S. C.*
Control over brain activation and pain learned by using real-time functional MRI.

*Proceedings of the National Academy of Sciences (2005)*

RTFMRI TRAINING PROTOCOL IN HEALTHY SUBJECTS

BLOCK DESIGN

CYCLE, (3 blocks, 150s total)

Rest 30s  Increase 60s  Decrease 60s

Pain  Pain

Cycle 1  150s  Cycle 2  150s  Cycle 3  150s  Cycle 4  150s  Cycle 5  150s  After Scan Ratings

RUN, (5 cycles + ratings, 13min), 1-5 RUNS per TRAINING DAY

Briefing  Pre-Tests  Anatomicals  Debrief

ROI TARGET: rostral Anterior Cingulate Cortex
RTFMRI TRAINING PROTOCOL IN HEALTHY SUBJECTS

**BLOCK DESIGN**

- **CYCLE**: (3 blocks, 150s total)
  - Rest 30s
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**ROI TARGET**: rostral Anterior Cingulate Cortex

**SUBJECT INSTRUCTIONS**: Written text describing cognitive modulation of pain

- Attend to pain vs. attend away
- Perceive the pain as more intense vs. less intense
- Perceive the pain as harmful vs. only a tactile sensation
RTFMRI TRAINING PROTOCOL IN HEALTHY SUBJECTS

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<table>
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<tr>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
<th>Cycle 5</th>
<th>After Scan Ratings</th>
<th>Debrief</th>
</tr>
</thead>
<tbody>
<tr>
<td>150s</td>
<td>150s</td>
<td>150s</td>
<td>150s</td>
<td>150s</td>
<td></td>
<td></td>
</tr>
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<td>Pain</td>
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<td>Pain</td>
<td>Pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
<td>Increase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60s</td>
<td>60s</td>
<td>60s</td>
<td>60s</td>
<td>60s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td>Rest</td>
<td>Rest</td>
<td>Rest</td>
<td>Rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30s</td>
<td>30s</td>
<td>30s</td>
<td>30s</td>
<td>30s</td>
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RUN, (5 cycles + ratings, 13min). 1-5 RUNS per TRAINING DAY

ROI TARGET: rostral Anterior Cingulate Cortex

SUBJECT INSTRUCTIONS: Written text describing cognitive modulation of pain

• Attend to pain vs. attend away
• Perceive the pain as more intense vs. less intense
• Perceive the pain as harmful vs. only a tactile sensation

SUBJECT DISPLAYS
rtfMRI-BASED TRAINING LEADS TO SPATIALLY-SPECIFIC CHANGES IN BRAIN ACTIVATION

MEASURE: Thresholded T-statistic,
(INCREASE – DECREASE) last run VS. (INCREASE – DECREASE) first run
HEALTHY SUBJECTS LEARN INCREASED CONTROL OVER BRAIN ACTIVATION THROUGH THE COURSE OF TRAINING

MEASURE: Brain Activation, BOLD % Signal Change, (Increase Period – Decrease Period) from each pair of blocks, Averaged over N=8 Subjects
HEALTHY SUBJECTS LEARN INCREASED CONTROL OVER PAIN THROUGH THE COURSE OF TRAINING

MEASURE: Pain Intensity Rating % Difference, 
(Increase Period Rating – Decrease Period Rating)/Average from each pair of blocks, 
Averaged over N=8 Subjects
THE TIMECOURSE OF LEARNING OF CONTROL OVER BRAIN ACTIVATION MIRRORS THE TIME COURSE FOR CONTROL OVER PAIN

---

**Graph 1:**
- **y-axis:** rACC activation (BOLD)
- **x-axis:** Training run 1, Training run 2, Training run 3, Final test run 4
- **Legend:**
  - *: Significant difference
  - †: Trend towards significance

**Graph 2:**
- **y-axis:** Pain intensity rating (% difference)
- **x-axis:** Training run 1, Training run 2, Training run 3, Final test run 4
- **Legend:**
  - *: Significant difference
  - †: Trend towards significance
LEARNED CONTROL OVER BRAIN ACTIVATION IN RACC LEADS TO CORRESPONDING CHANGES IN PAIN INTENSITY RATINGS FOR A CONCURRENT THERMAL STIMULUS

\[ y = 28.167x + 7.013 \]

\[ R = 0.368 \quad p < 0.00076 \]
FOUR CONTROL GROUPS WERE TRAINED USING SIMILAR OR IDENTICAL PROCEDURES BUT IN THE ABSENCE OF RACC RTFMRI INFORMATION

<table>
<thead>
<tr>
<th>GROUP I</th>
<th>Received purely behavioral training for twice as long as the experimental group, but they had no rtfMRI feedback. They were additionally instructed to focus attention on the thermal stimuli during “increase” periods.</th>
<th>Control for effects of extended attention training</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP II</td>
<td>Received identical instructions to the experimental group, and the same period of training, but with no rtfMRI information, to test the effect of identical practice alone.</td>
<td>Control for identical training without rtfMRI</td>
</tr>
<tr>
<td>GROUP III</td>
<td>Received identical training to the experimental group, but using rtfMRI information derived from a posterior cingulate cortex region not involved in pain processing, to examine spatial and physiological specificity.</td>
<td>BLIND CONTROL Control for spatial and physiological specificity</td>
</tr>
<tr>
<td>GROUP IV</td>
<td>Received identical training to the experimental group, but unknown to them the rtfMRI displays that they saw corresponded to activation from a previously-tested experimental subject’s rACC, rather than their own rACC.</td>
<td>BLIND CONTROL Control for cognitive effects.</td>
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THE LEARNED CONTROL OVER PAIN REQUIRES SPATIALLY-SPECIFIC RTFMRI INFORMATION
THE LEARNED CONTROL OVER PAIN REQUIRES SPATIALLY-SPECIFIC RTFMRI INFORMATION

- Pain Intensity
  - † † p<.01
  - † † † p<.001
  - * p<.05 vs. experimental
  - ** p<.01 vs. experimental
  - *** p<.001 vs. experimental

- Change in pain rating (% difference)
  - CONTROL GROUPS, NO EFFECT
  - EFFECT

- rACC exper. group
- Attention control group I
- rtfMRI control group II
- PCC control group III
- Yoked control group IV
THE LEARNED CONTROL OVER PAIN REQUIRES SPATIALLY-SPECIFIC RTFMRI INFORMATION

- Pain Intensity
- Unpleasantness

† † p<.01
† † † p<.001
* p<.05 vs. experimental
** p<.01 vs. experimental
*** p<.001 vs. experimental
CAN THE PICTURES OF YOUR HEAD PROVIDE RELIEF?
RTFMRI TRAINING PROTOCOL IN PAIN PATIENTS

BLOCK DESIGN

CYCLE, (3 blocks, 150s total)

Rest 30s  Increase 60s  Decrease 60s

NO PAINFUL EXTERNAL STIMULI

Briefing Pre-Tests Anatomicals

Cycle 1 150s  Cycle 2 150s  Cycle 3 150s  Cycle 4 150s  Cycle 5 150s  After Scan Ratings  Debrief

RUN, (5 cycles + ratings, 13min). 1-5 RUNS per TRAINING DAY

ROI TARGET: rostral Anterior Cingulate Cortex

SUBJECT INSTRUCTIONS: Written text describing cognitive modulation of pain

• Attend to pain vs. attend away
• Perceive the pain as more intense vs. less intense
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SUBJECT DISPLAYS

fMRI BOLD difference

0 50 100s
PATIENT REPORT OF PAIN MEASURES

PRIOR TO SCANNING

Pain Rating Index

<table>
<thead>
<tr>
<th>Type of Pain</th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throbbing</td>
<td>1</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Shooting</td>
<td>1</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Stabbing</td>
<td>1</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Sharp</td>
<td>1</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Cramping</td>
<td>✓</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Gnawing</td>
<td>✓</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Hot-Burning</td>
<td>✓</td>
<td>2</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Aching</td>
<td>✓</td>
<td>2</td>
<td>✓</td>
<td>3</td>
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<tr>
<td>Heavy</td>
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<td>Tender</td>
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<tr>
<td>Splitting</td>
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<td>✓</td>
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<td>Tiring/Exhausting</td>
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<td>✓</td>
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<td>Sickening</td>
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<tr>
<td>Punishing/Cruel</td>
<td>✓</td>
<td>2</td>
<td>✓</td>
<td>3</td>
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Present Pain Intensity (PPI) – Visual Analog Scale (VAS). Tick along scale below for pain:

No pain

Worst possible pain
**PATIENT REPORT OF PAIN MEASURES**

**PRIOR TO SCANNING**

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**AFTER SCANNING**

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**II. Present Pain Intensity (PPI)–Visual Analog Scale (VAS).** Tick along scale below for pain:

- No pain
- Worst possible pain

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**II. Present Pain Intensity (PPI)–Visual Analog Scale (VAS).** Tick along scale below for pain:

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CHANGE IN PAIN RATINGS FOLLOWING RTFMRI TRAINING IN CHRONIC PAIN PATIENTS

MPQ
VAS

p<.001

rACC rtfMRI experimental group

Change in pain rating (%)
PATIENTS WHO LEARNED TO CONTROL RACC ACTIVATION SHOWED A CHANGE IN PAIN, OTHERS DID NOT

Change in MPQ (%) vs. rACC change in activation (BOLD)

\[ y = 0.376x + 0.392, \quad R = 0.9173, \quad p < 0.01 \]

Change in VAS (%) vs. rACC change in activation (BOLD)

\[ y = 0.422x + 0.085, \quad R = 0.9170, \quad p < 0.01 \]
A CONTROL GROUP, TRAINED USING AUTONOMIC BIOFEEDBACK, DID NOT SHOW THE SAME CHANGES IN PAIN
## MOTIVATIONS FOR NEUROIMAGING THERAPY IN CHRONIC PAIN TREATMENT

<table>
<thead>
<tr>
<th>NON-PHARMACOLOGIC</th>
<th>IMPLICATION</th>
<th>RATIONALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uses endogenous physiological, neurotransmitter systems</td>
<td>No drug-related side effects.</td>
</tr>
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</table>

<table>
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<tr>
<th>REVERSIBLE</th>
<th>Can be terminated if unsuccessful.</th>
<th>Potentially low risk.</th>
</tr>
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<tr>
<th>NON-INVASIVE</th>
<th>No physical intervention required.</th>
<th>No surgery.</th>
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</table>

| PHYSICIAN’S OFFICE IMAGING MAY BECOME FEASIBLE | Less expensive | Technology grows to meet need: |
CAN THIS APPROACH COOL THE FIRES OF CHRONIC PAIN?
A Better View of Brain Disorders
Science 313, 1377-1379 (8 Sept, 2006)
Miller, G
CAN REAL TIME FMRI LEAD TO A NEW, MECHANISTICALLY-BASED, COMPUTER GUIDED FORM OF COGNITIVE INTERVENTION?
ONGOING STUDY: LONG-TERM RTFMRI TRAINING PROTOCOL IN PAIN PATIENTS

BLOCK DESIGN

NO PAINFUL EXTERNAL STIMULI

Briefing
Pre-Tests
Anatomicals

RUN, (5 cycles + ratings, 13min). 1-5 RUNS per TRAINING DAY

ROI TARGETS: (Two groups)
1. rostral Anterior Cingulate Cortex
2. Training using rACC and bilateral insula

PROTOCOL: Training over 6 consecutive sessions, approximately 6 weeks

SUBJECT DISPLAY
WILL NEUROIMAGING THERAPY PRODUCE LONG-TERM DECREASES IN CHRONIC PAIN?

Training Group (N=21)
21% decrease
Decrease seen in 16/21

NOTE: Preliminary, Unpublished Data!
No Control Group to Date
Placebo Effects Are Likely
WILL NEUROIMAGING THERAPY PRODUCE LONG-TERM DECREASES IN CHRONIC PAIN?

Training Group (N=21)
21% decrease
Decrease seen in 16/21

Waiting List Control (N=24)
5% decrease

NOTE:
Preliminary, Unpublished Data!
No Control Group to Date
Placebo Effects Are Likely
COMPARISON OF EFFECT ACROSS TWO TRAINING SITES/SCANNERS

Comparison Across Training Sites (N=10/11)

Training Week

VAS Pain Rating

NOTE:
Preliminary, Unpublished Data!
No Control Group to Date
Placebo Effects Are Likely
## CAN RTFMR-BASED TRAINING BE USED IN SUBSTANCE ABUSE?

### PROTOCOL DETAIL

#### OVERVIEW OF DISPLAY TO SUBJECTS

<table>
<thead>
<tr>
<th></th>
<th>INCREASE 30s</th>
<th>RATE 20s</th>
<th>REST 30s</th>
<th>DECREASE 30s</th>
<th>RATE 20s</th>
<th>REST 30s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RTFMRI TRAINING TASK</strong></td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
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The table above represents the protocol detail for a study using RTFMRI-based training in substance abuse. The task includes stimulus-induced craving, self-induced craving, and RTFMRI training. The display to subjects includes various stages such as increase craving, decrease craving, rate, and rest. The images illustrate the graphical representation of these stages.
WE ARE ACTIVELY ENROLLING CHRONIC PAIN PATIENTS FOR OUR CURRENT TRIAL

THANK YOU...

SOME REFERENCES

