Do complete locked-in patients fail to use a BCI because of extinction of thought?

Dr. Femke Nijboer
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ALS-BCI group in Tuebingen

Adrian Furdea
Femke Nijboer
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Carolin Ruf
Tamara Matuz
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Prof. Boris Kotchoubey

Biological Cybernetics

Jez Hill
Suzanne Martens

Prof. Andrea Kübler
Other colleagues in Tuebingen focus on:

- psychopathy
- epilepsy
- ADHD
- stroke
- musical abilities / creativity
- chronic pain

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Overview

1. **State-of-the-art BCIs for (complete) locked-in patients**
   - BCIs based on slow cortical potentials, sensorimotor rhythms and event-related potentials can be used by locked in patients
   - The case of George: BCIs for complete locked-in patients do not work?!!

2. **Extinction of goal-directed thinking in complete locked-in state**
   - Operant conditioning not possible in curarized rats (Miller, Dworkin)
   - Operant conditioning approach not possible in complete locked-in state
   - Classical conditioning approach: reflexive yes and no answers

3. **Assessing cognitive functioning in (complete) locked-in patients**
   - Cognitive test battery that does not require intact motor system
   - ERP-based test battery

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BCIs for locked-in patients?

- Communication
- Entertainment
- Internet

[ all patient pictures removed for privacy reasons ]

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free spelling with ERP-based BCI

Some patients have spelled with this over the last three years

Nijboer et al, 2008
Clin Neurophys

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Nessi: an ERP-based Internet browser

(See also Mugler et al. 2007)

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psychologisches Institut

stellenangebote am psychologischen institut

- lehre und forschung
- Promotionen
- wissenschaftliche kraftstellen
- akademische Stellplätze

E-Mail an Webmaster / © PI, Universität Tübingen / Stand: 23. Februar 2003
BCI works for....

Locked-in state (LIS)?
YES !

[ all patient pictures removed for privacy reasons ]

Complete Locked-in state (CLIS)?
NO !!

[ all patient pictures removed for privacy reasons ]

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What should a BCI for complete LIS patients do?

Give a robust and stable yes / no signal (binary switch)

Communication protocol: ‘silly questions’

“Is the capital of Italy: Rome?” vs. “Is the capital of Italy: Amsterdam?”

Communication protocol: ‘relevant questions’

“Do you have pain” vs. “Are you pain free?”
“TV on? “ vs. “TV off?”
“Go outside? vs. “Stay inside?”
Brain–computer interfaces and communication in paralysis: Extinction of goal directed thinking in completely paralysed patients?

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ABSTRACT

Objective: To investigate the relationship between physical impairment and brain–computer interface (BCI) performance.

Method: We present a meta-analysis of 29 patients with amyotrophic lateral sclerosis and six patients with other severe neurological diseases in different stages of physical impairment who were trained with a BCI. In most cases voluntary regulation of slow cortical potentials has been used as input signal for BCI-control. More recently sensorimotor rhythms and the P300 event-related brain potential were recorded.

Results: A strong correlation has been found between physical impairment and BCI performance, indicating that performance worsens as impairment increases. Seven patients were in the complete locked-in state (CLIS) with no communication possible. After removal of these patients from the analysis, the relationship between physical impairment and BCI performance disappeared. The lack of a relation between physical impairment and BCI performance was confirmed when adding BCI data of patients from other BCI research groups.

Conclusions: Basic communication (yes/no) was not restored in any of the CLIS patients with a BCI. Whether locked-in patients can transfer learned brain control to the CLIS remains an open empirical question.

Significance: Voluntary brain regulation for communication is possible in all stages of paralysis except the CLIS.

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Review: The Tübingen patients

N = 33
10 women, 23 men
28 ALS, 5 other
17 ventilated
31 SCP, 13 SMR, 12 P300

Kübler and Birbaumer, 2008
locked-in vs. completely locked-in
LIS vs. CLIS

Minor impairment

[ all patient pictures removed for privacy reasons ]

Major impairment

LIS

CLIS

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Relation between degree of impairment and BCI performance!

(Kübler & Birbaumer, Clin Neurophys, 2008)

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Kübler and Birbaumer conclude: „Operant conditioning approach fails!“

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Operant conditioning in paralyzed rats

Neal Elgar Miller

- Rockefeller University in 1966 to study physiological basis of drives
Miller‘s operant visceral learning

Change in
- Heart rate
- Colon & Gastric motility
- Gastric blood flow
- Urine output
- Uterine contractions
- Peripheral vasomotor function

By Operant Learning

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HOWEVER: Replication of this operant approach failed!
Dworkin & Miller, 1986

2,500 rats “involved”

Variation of all possible parameters
- Shock intensity
- Distribution of intertrial intervals
- Postreinforcement time-out duration
- Rate of criterion advancement
- Conditioned stimulus intensity

⇒ No effects on visceral activity
Learning of Physiological Responses:  
I. Habituation, Sensitization, and Classical Conditioning

Barry R. Dworkin and Susan Dworkin  
Department of Behavioral Science  
Pennsylvania State University College of Medicine

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Classical conditioning

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Classical conditioning terminology

Unconditioned Stimulus (US)

Conditioned Stimulus (CS)

Unconditioned Response (UR)

Conditioned Response (CR)

Finish that paper
!!!!!!!!!!!

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Development of chronically paralyzed rats

Dworkin and Dworkin, 1990

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Discrimination of Tones

Auditory Tone (CS-)
2kHz → NO Change in Visceral Activity

Shock to Tail (UCS) → Change in Visceral Activity (UCR)

Auditory Tone (CS+)
4kHz → Change in Visceral Activity (CR)

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Chance in Blood Pressure & Heart Rate
Change in EEG

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# A Comparison

<table>
<thead>
<tr>
<th>Dworkin’s Rats</th>
<th>Human complete locked-in patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracheal cannula</td>
<td></td>
</tr>
<tr>
<td>EEG electrodes</td>
<td>ECoG or EEG</td>
</tr>
<tr>
<td>Trans-urethral bladder cannula</td>
<td></td>
</tr>
<tr>
<td>Subcutaneous EKG electrodes</td>
<td>EKG monitoring</td>
</tr>
<tr>
<td>Carotid artery cannula</td>
<td>sometimes</td>
</tr>
<tr>
<td>Core-temperature probe</td>
<td>No</td>
</tr>
<tr>
<td>Bipolar EMG electrodes</td>
<td>Not needed?</td>
</tr>
<tr>
<td>Oral-gastric feeding tube</td>
<td>PEG</td>
</tr>
</tbody>
</table>
Classical conditioning in chronically paralyzed patients

If people cannot voluntarily produce two brain states through operant conditioning, is it possible to classically condition the idea of “yes” and “no” ??
Possible paradigm: noise A vs. noise B

Training phase

„Is Paris the capital of France?“

„Is Paris the capital of Germany?“

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Possible paradigm: noise A vs. noise B

„Is Paris the capital of France?“

„Is Paris the capital of Germany?“
Generalisation of CS for all preceding questions? Is the essence of yes and no stable?

Known answers
- „Is Paris the capital of Italy?“
- „Is Paris the capital of France?“
- „Is your name George?“
- „Are you in pain?“
- „Are you painfree?“

Unknown answers
- „Do you want to live?“
- „Do you want to die?“
- „emotional information“
- „personal information“
- „dynamic information“

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Thank you for your attention and the wonderful workshop!

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