Comparing Sensorimotor Rhythms, Slow Cortical Potentials, and P300 for Brain-Computer Interface (BCI) use by ALS patients – a within subjects design

F Nijboer[1], U Mochty[1], J Mellinger[1], T Matuz[1], E Sellers[2], TM Vaughan[2], DJ McFarland[2], G Schalk[2], JR Wolpaw[2], N Birbaumer[1,3], A Kübler[1]

E-mail: femke.nijboer@uni-tuebingen.de

[1] Institute of Medical Psychology and Behavioral Neurobiology, University of Tübingen, Germany.

[2] Wadsworth Center, New York State Department of Health, Albany, NY, USA.

[3] Center of Cognitive Sciences, University of Trento, Italy.

Introduction

- Severely paralyzed people often need communication tools that do not depend on muscle control. Brain-computer interfaces (BCIs) measure specific features of brain activity and translate them into device commands. Most current noninvasive BCIs use sensorimotor rhythms (SMR), slow cortical potentials (SCPs), or the event-related P300 potential. We are comparing BCI use with these features in people with amyotrophic lateral sclerosis (ALS) in a within subject design.
- We are also assessing the interaction of psychological variables (i.e., current mood, motivation, quality of life, depression) and BCI use.

Patients

Subject	Age	Sex	ALS type	Time Since Diagnosis	Artificial		Limb Function	Speech
					Nutrition	Ventilation		
A	67	M	Bulbar	17 months	yes	no	Yes	No
B	47	F	Spinal	2 years	yes	yes	Minimal	Slow
C	56	M	Spinal	9 months	yes	yes	None	Slow
D	53	M	Spinal	4 years	no	no	Weak	Yes
E	49	F	Spinal	1 year	no	no	Yes	Slow
F	39	M	Spinal	3 years	yes	no	Minimal	Slow
G	46	M	Spinal	10 years	yes	yes	None	No

Slow Cortical Potentials

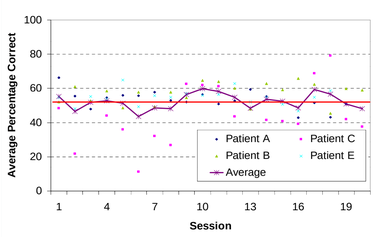
Methods

During each trial in the SCP training the patient was presented with an active target at either the top or the bottom of a computer screen. A cursor moved steadily across the screen, with its vertical movement controlled by SCP amplitude. The patients task was to hit the target. Successful SCP regulation was reinforced by an animated smiling face and a chime.

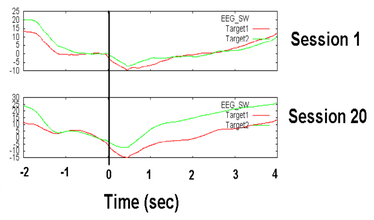
Study Design:

- N = 4 patients completed, 8 patients in final study
- 20 sessions

Results



Average learning curve over sessions for four patients.



Patient B: SCP for top target (red line) and bottom target (green line). A bigger differentiation can be seen comparing session 1 to session 20

- None of the patients learned to successfully hit the targets.
- Some patients did learn to make a differentiation between negative and positive SCPs.

Sensorimotor rhythms

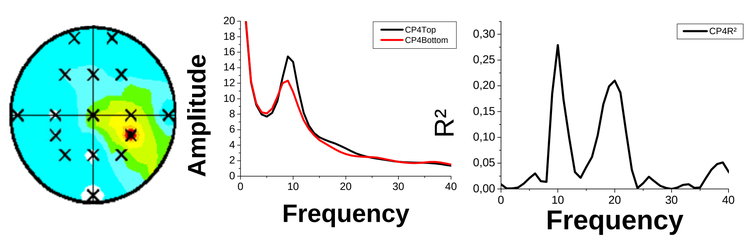
Methods

During each trial of the SMR training, the patient was presented with a target consisting of a red vertical bar that occupied the top or bottom half of the right edge of the screen and a cursor on the left edge. The cursor moved steadily across the screen, with its vertical movement controlled by SMR amplitude. The subject's task was to hit the target

Study Design:

- N = 4 patients completed (Kübler et al, 2005), 8 patients in final study
- 20 sessions

Results



Patient C: Scalp topography (nose at top), amplitude spectra at the control location (CP4), and the corresponding r^2 spectrum.

- All patients successfully learned to hit the targets with an accuracy above 75 %.
- Two patients used a beta (18-25 Hz) rhythm recorded from CP3.
- One patient used a mu (8-12 Hz) rhythm recorded from CP4
- One patient used a beta rhythm recorded from Cz

P300

Methods

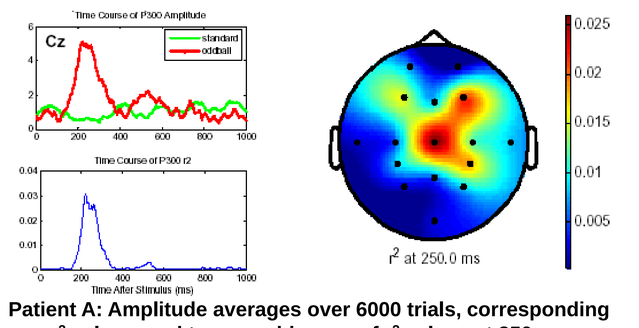
During each trial of the P300 training the patient was presented with a matrix containing the alphabet. Rows and columns flashed randomly and sequentially, and the participant was asked to count the number of times a certain target symbol (e.g the letter 'P'). Target flashes elicit a large P300 response while non target flashes do not.

Study Design:

N = 7 patients completed, 7 in final study

- 10 sessions

Results



Patient A: Amplitude averages over 6000 trials, corresponding r^2 values, and topographic map of r^2 values at 250ms.

- Four patients were successful with accuracies in the last training session ranging from 13,5 % to 86,6 % (with 2,77 % expected by chance).
- After ongoing training two patients achieved accuracies up to 100 %.

Psychological variables

Objectives:

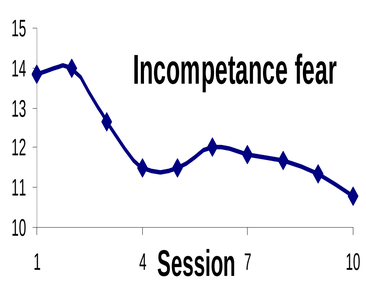
To elucidate the interaction between psychological factors and BCI use.

Methods:

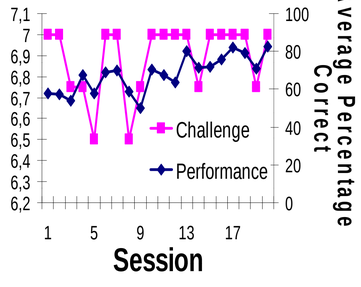
Before and after each training block QoL and depression were measured using questionnaires. Before each training session mood and motivation were measured.

Results:

Psychological factors appear to influence BCI use, but in an individual manner. E.g:



Average score of all patients on 'Incompetence Fear' over the course of P300 training. Fear that the training will result in failure decreases over P300 as well as SMR training (figure not shown)



Average score on 'Challenge' patient A sees in the training and performance over all sessions of the SMR training. Performance is related to 'Challenge'

Conclusions

- These initial results suggest that SMRs provide the best overall performance across patients with ALS.
- SMR seems to be more reliable over time than P300.
- In addition, although P300 based BCI has an apparent advantage in that it requires no initial user training, it appears to be effective for some users only.
- SCP use seems to be more difficult and may require more training.
- Psychological variables appear to affect performance. This suggests that their evaluation could help improve BCI training protocols and help to establish the practical value of BCI applications. E.g.:
  - The interaction between psychological factors and BCI use differs between patients. In patient A for example, there challenge the patient saw in the training session was related to his performance.
  - An overall finding shows that 'Fear of Incompetence' declines over P300 and SMR training session, but is not related to performance.

Future Plans

- With six of the patients from this study, we plan ongoing training. Our aim is to work towards a clinical application.
- We would like to develop and test a complete auditory BCI in ALS patient

References

Kübler, A., Nijboer, F., Mellinger, J., Vaughan, T.M., Pawelzik, H., Schalk, G., McFarland, D.J., Birbaumer, N., Wolpaw, J.R. (2005). Patients with ALS can use sensorimotor rhythms to operate a brain-computer interface. *Neurology*, vol.. 64, p. 1775 – 1777

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