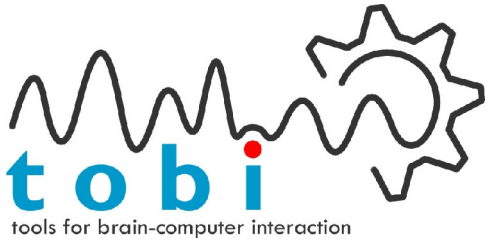
New Auditory Multiclass Paradigm for Brain-Computer Interfaces

Michael Tangermann



Outline of Talk

Event Related Potentials (ERP)

ALS Patients and ERP

New Auditory Multiclass Paradigm

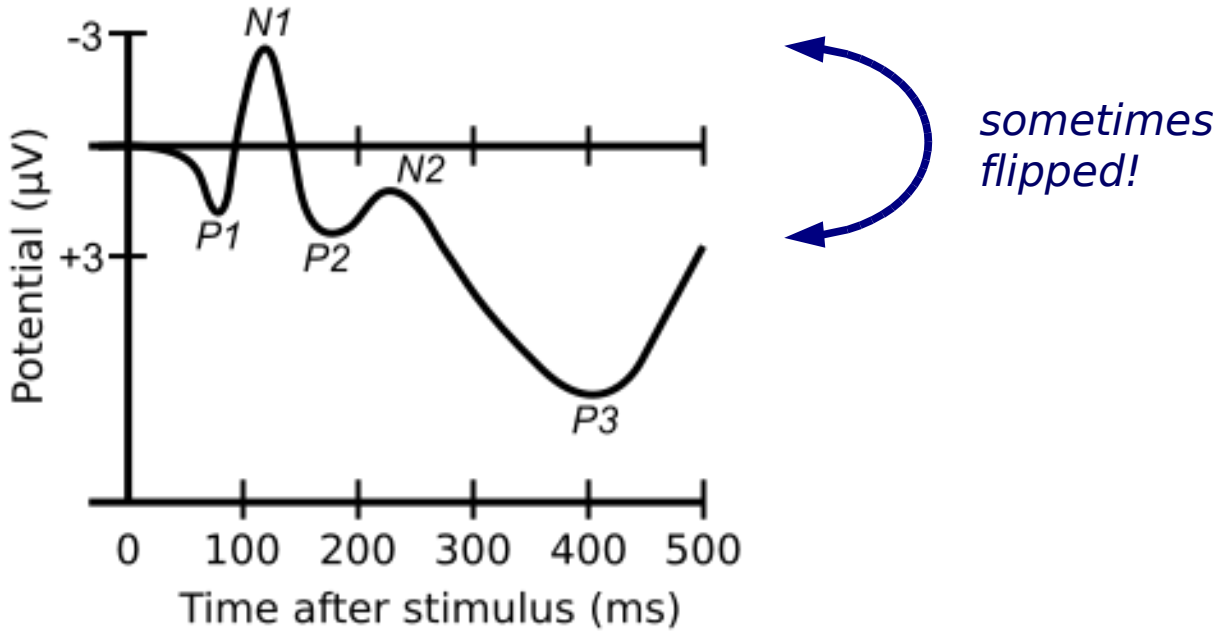
Results

Resources

Event Related Potentials (ERP)

- Electric brain response
- Time locked to internal or external event

- External sensory stimulus
- Internal events



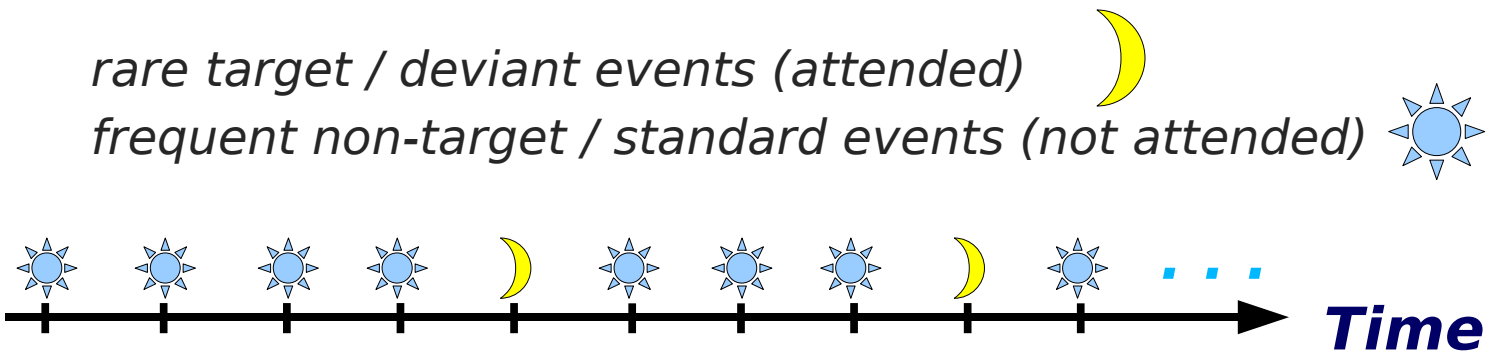
Event Related Potentials (ERP)

How do you evoke ERPs?

- Early ERPs: simply provide a stimulus.

- Late ERPs: use oddball design:

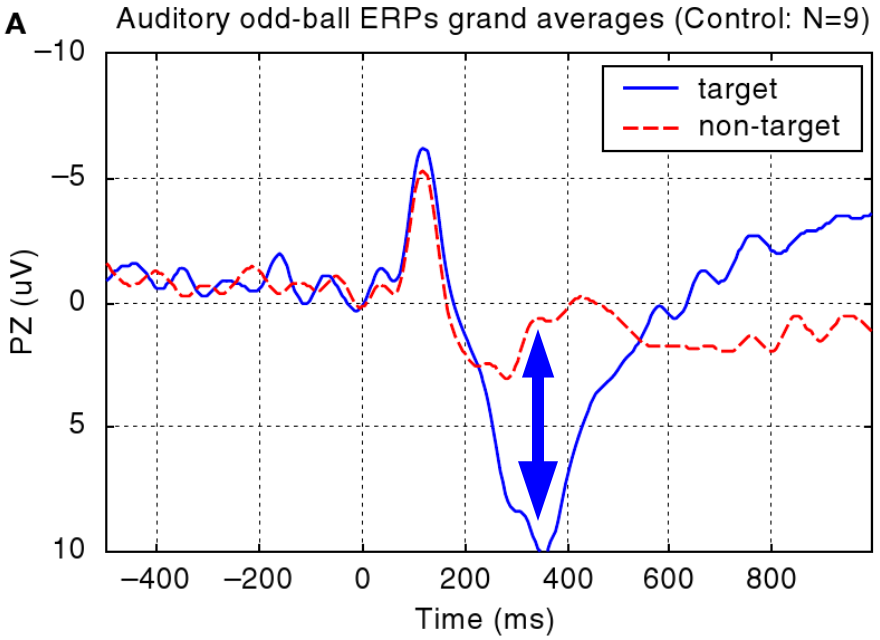
rare target / deviant events (attended)
frequent non-target / standard events (not attended)



Why ERPs for BCI?

- Time course of brain response varies with attention

[Silvoni et al. 2009]



- Rapid speed, high information transfer rates
- No user training necessary

ERP components long studied:

- auditory evoked potential (AEP) for neurophysiological screening
- visual evoked potential (VEP) for spelling, selection of symbols, control of devices

What Factors have Influence on ERP?

Variability in delay, amplitude and shape by

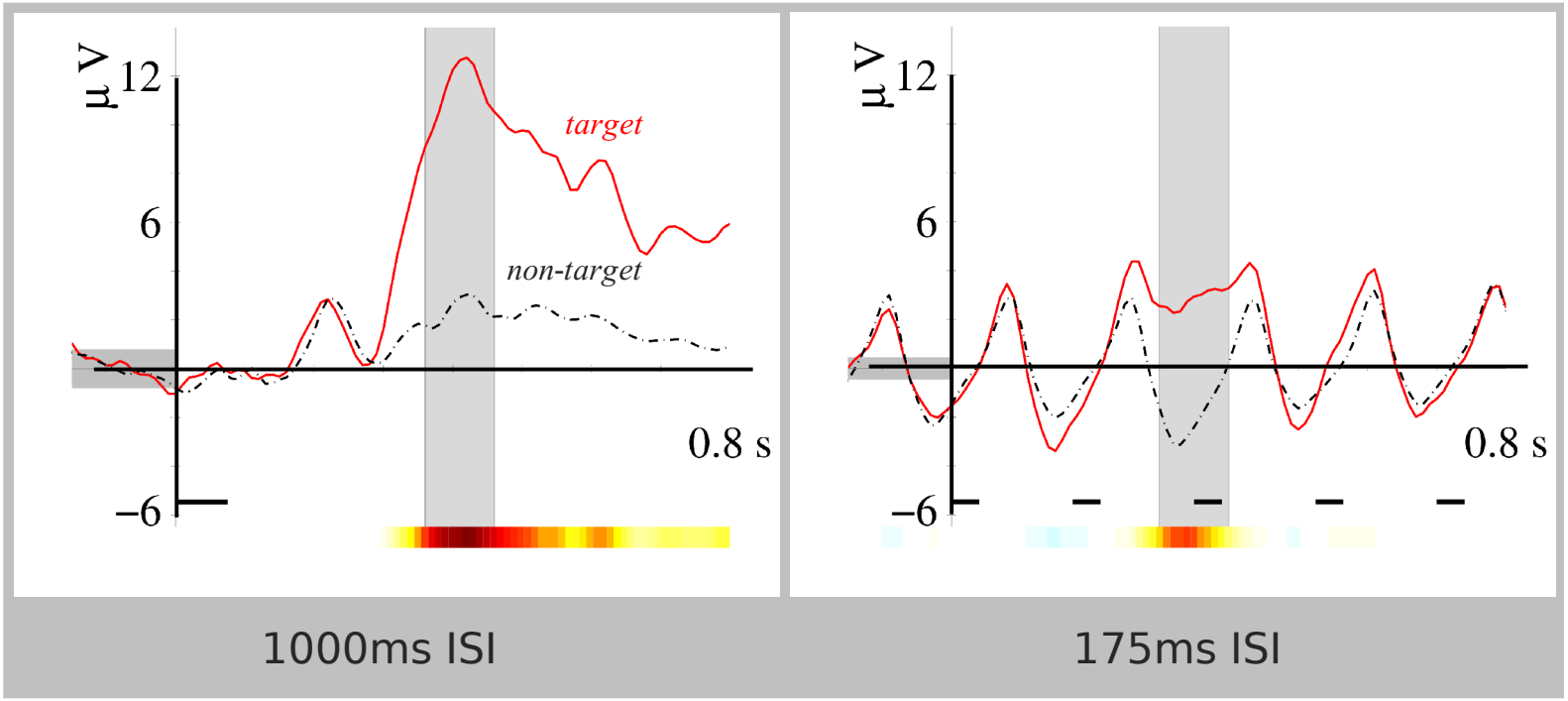
- Modality
  [Squires et al. 1977]: Auditory P300 approx. 140ms earlier that visual P300 (unclear for patients)

- Task difficulty
  e.g. stimuli close to perception threshold

- Motivation, emotion, attention
  (see next talk of Andrea Kübler and posters C09, C10)

What Factors have Influence on ERP?

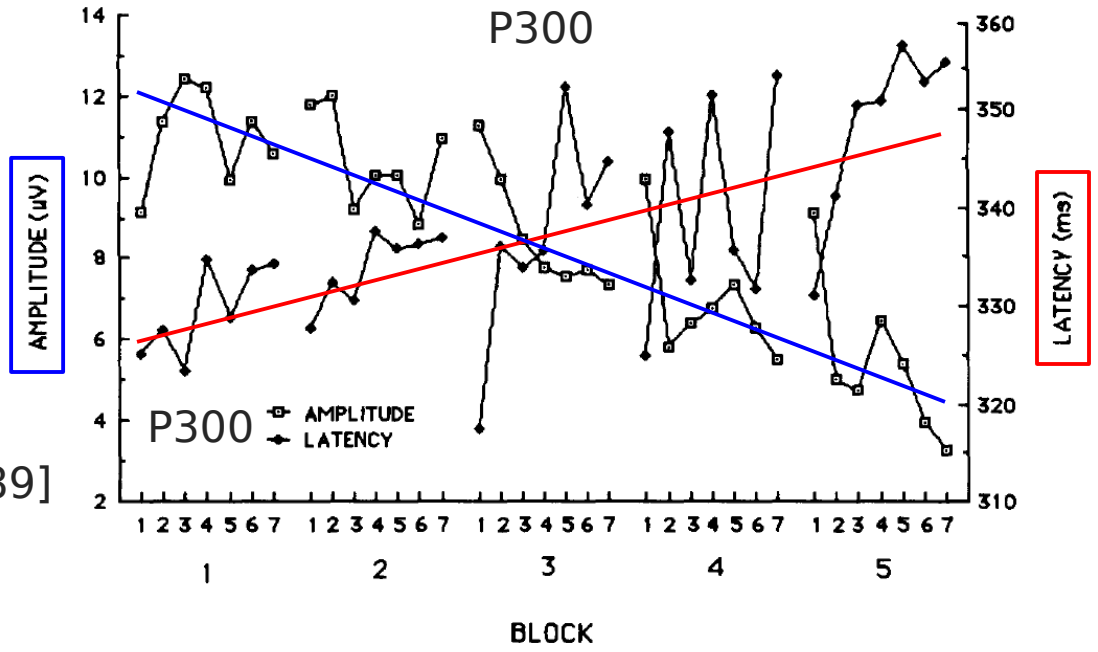
- Timing of sequences (ISI), overlap, refractory periods



What Factors have Influence on ERP?

Variability in delay, amplitude and shape by

- Habituation, block design, expected end

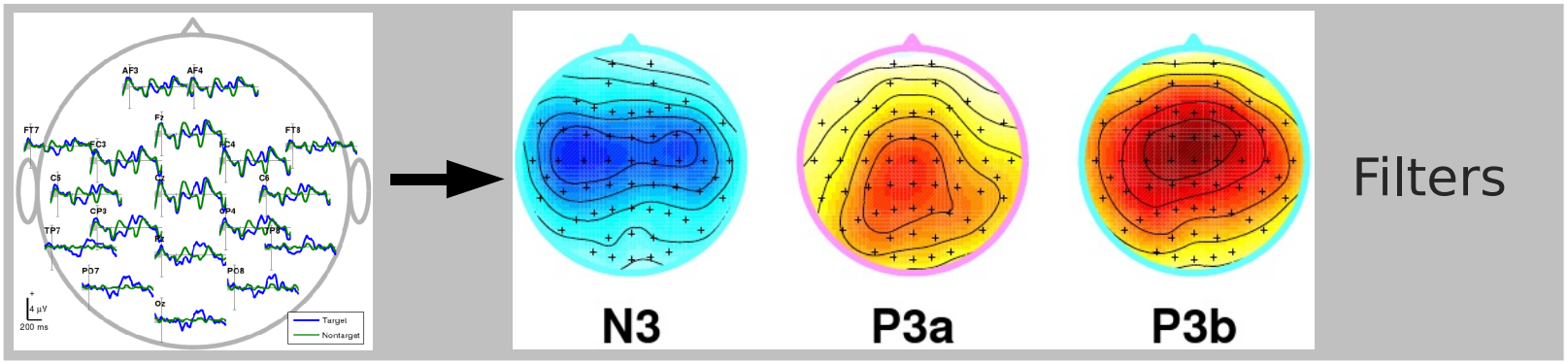


[Lammers et al. 1989]

- Age
- Neurodegenerative diseases (e.g. ALS)

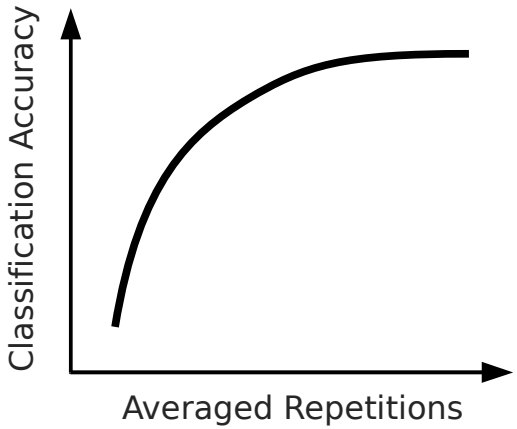
Detection of ERPs

Background EEG is strong compared to ERP amplitude:
Single trial detection quite difficult!



Algorithmic support by Machine learning:

- Spatial filtering
- Frequency filtering
- Repetitions

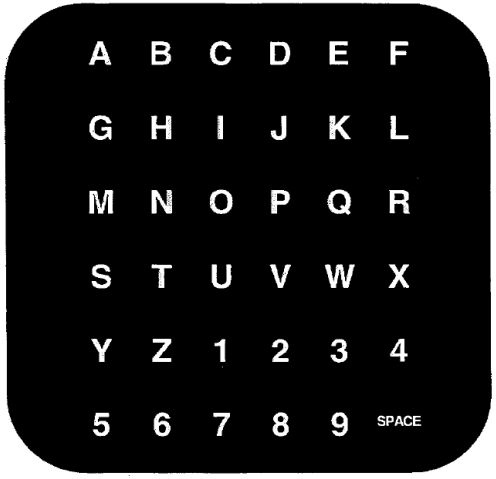


(see earlier talk by K.-R. Müller and B. Blankertz)

BCI Paradigms based on VEP

Visual P300 Speller: rapid sequence of highlighted rows and columns

[Farwell, Donchin 1988]



[Donchin et al. 2008]

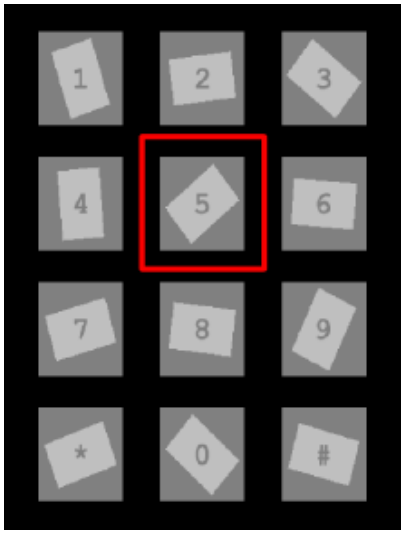
Detection of P300 target deflections after highlighting of

row #4
column #3
} "U"

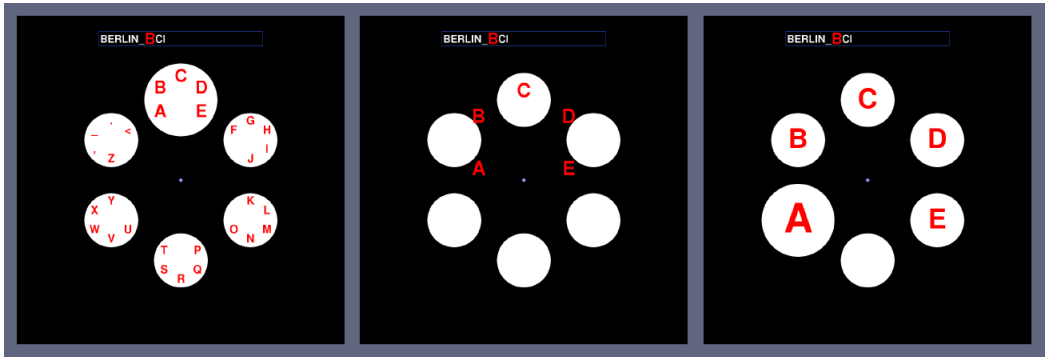
BCI Paradigms based on VEP

Pros:

- Quick spelling > 7 characters/min
- Optimized sequence codes and stimulus types
- Freedom for different layouts: home control / symbols
- Influence of matrix size and inter stimulus intervals (ISI) [Sellers et al. 2006]



[Hill et al. 2008]
[Martens et al. 2009]



[Treder et al., see poster]

Minor Impaired ALS Patients and ERPs

Early ERPs: minor differences between controls & patients
Late ERPs: delayed, decreased, partially not identifiable

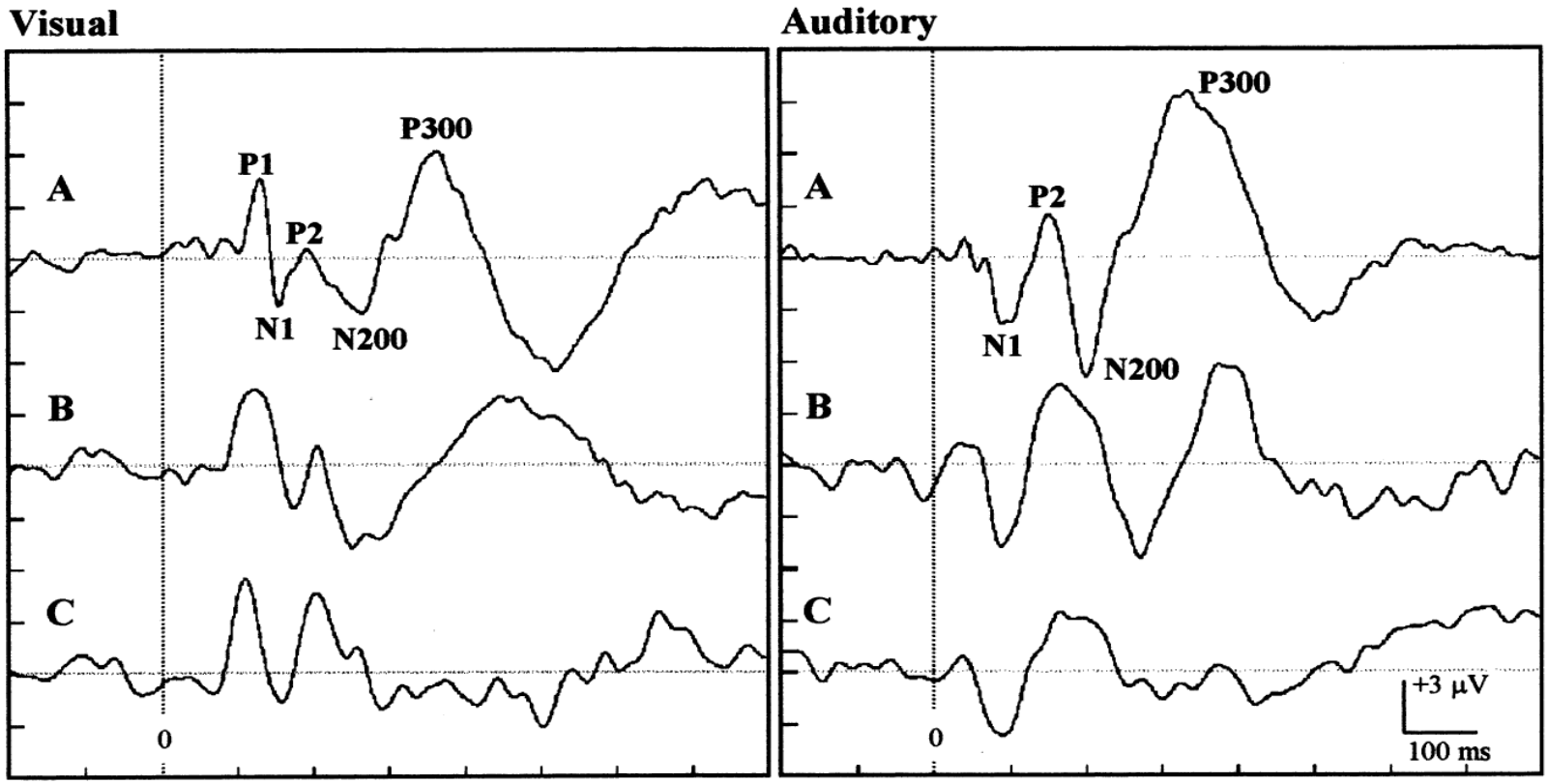
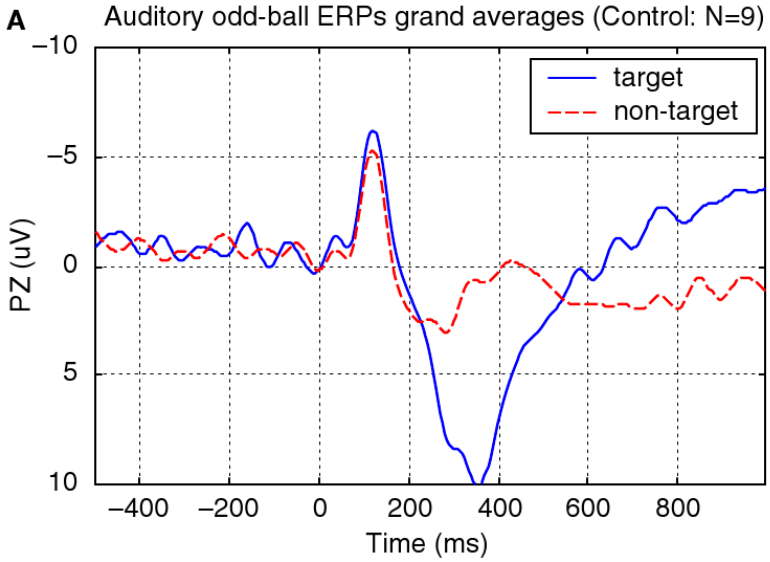


Fig. 2. Grand-averaged target visual and auditory ERPs of controls (upper trace) and ALS patients (middle and lower trace) at Cpz (visual) and Cz (auditory) electrode site. A = controls; B = delayed P300 latency, and C = not identifiable P300 in ALS patients.

Minor Impaired ALS Patients and ERPs

Similar results by [Silvoni et al. 2009], [Fabiani et al., 1987]



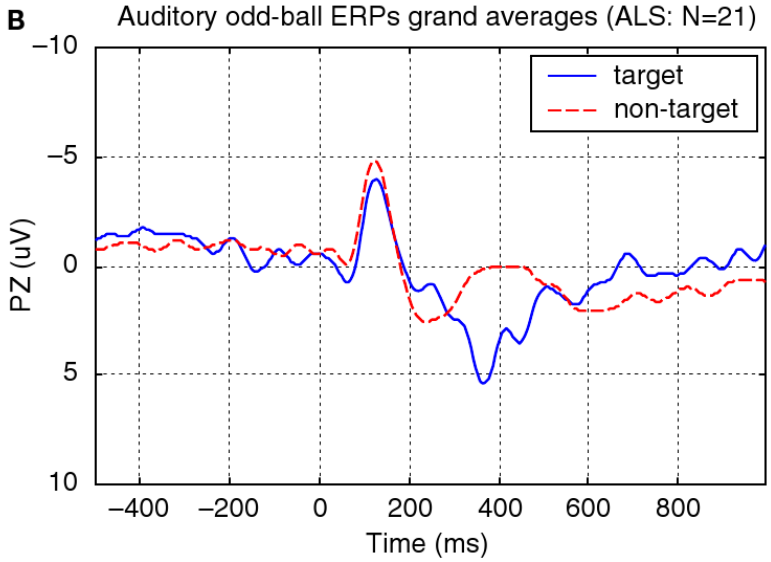
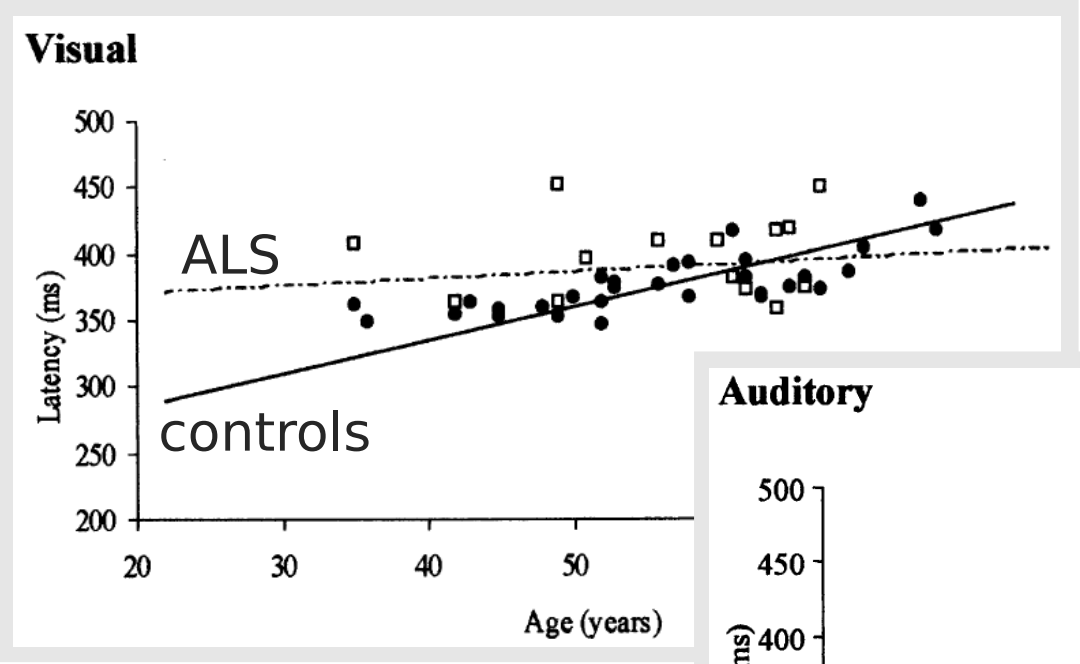
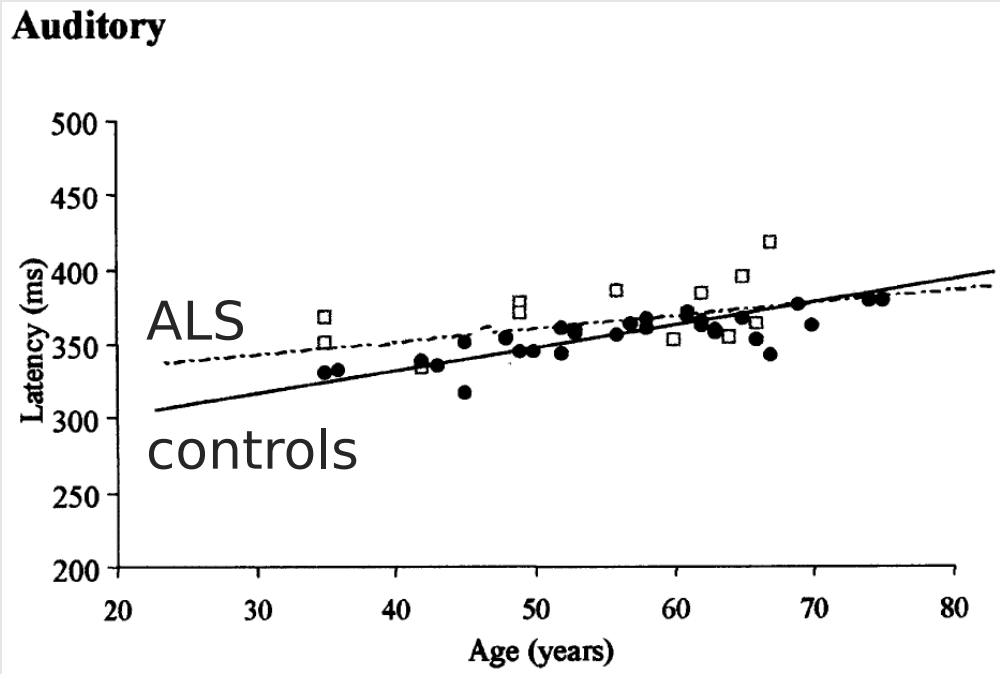


FIGURE 1 | Auditory odd-ball paradigm ERPs grand averages. (A) Control, **(B)** ALS. Mean ± SD number of target stimuli: 34 ± 9 (non-target stimuli: 168 ± 23). The auditory odd-ball paradigm was administered to each participant before the BCI training.

Minor Impaired ALS Patients: P300 and Age

P300 latency increases with age





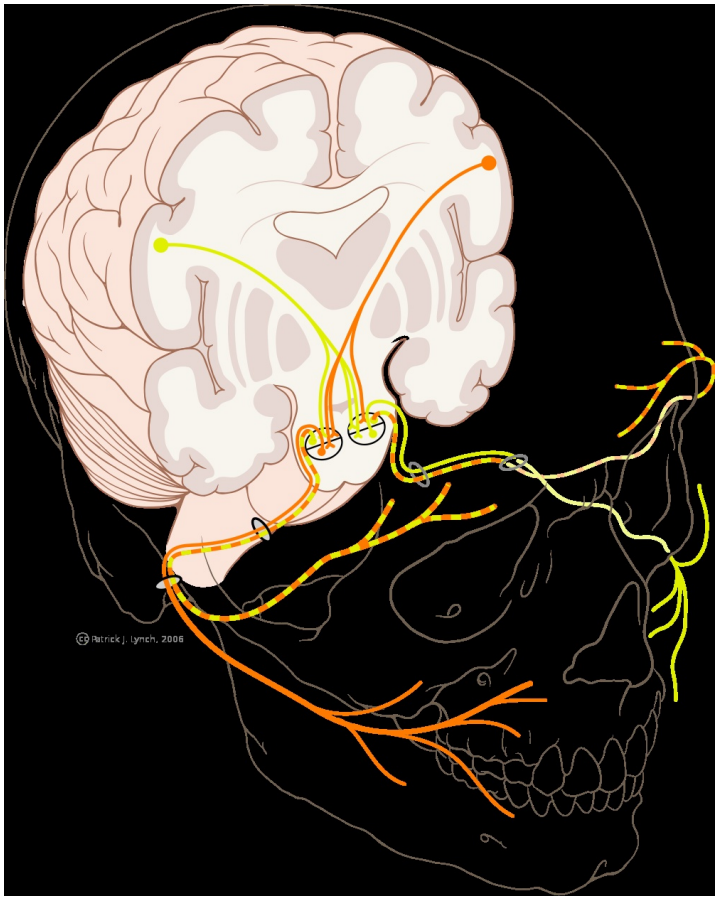
[Paulus et al. 2002]

Major Impaired ALS Patients and VEP

Progressive long-term ALS:

Degeneration of oculo-motor (3^{rd}, 4^{th}, 6^{th}) brain nerves:

- Reduced or no directed gaze
- Reduced or no gaze convergence

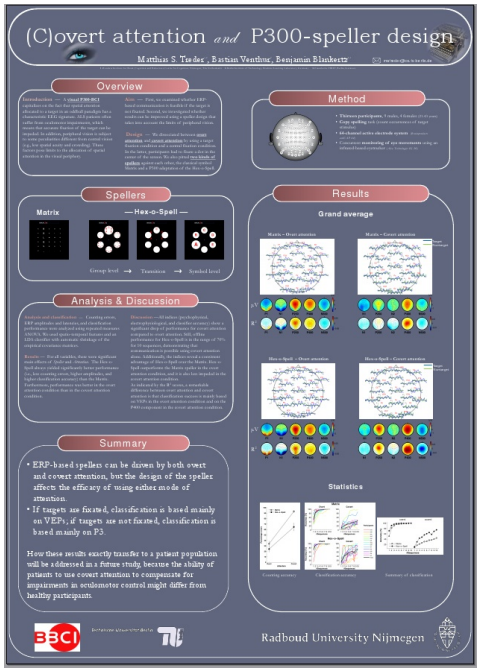


[Patrick J. Lynch, Creative Commons]

Major Impaired ALS Patients and VEP

Partial solution of the problem:

Covert attention to a stimulus located peripheral to the actual gaze direction



- VEP with covert attention
  Poster W07 by Treder et al.

- SSVEP with covert attention
  [Kelly et al. 2005], [Allison et al. 2007]

Major Impaired ALS Patients and VEP

Progressive long-term ALS:

Degeneration of 7th brain nerve:

- Reduced or no eye lid control
- Easily results in keratitis
- Loss of transmissibility

Consequences:

- Loss of sight
- VEP paradigms not feasible

What can we do for them?

Auditory Evoked Potentials (AEP)

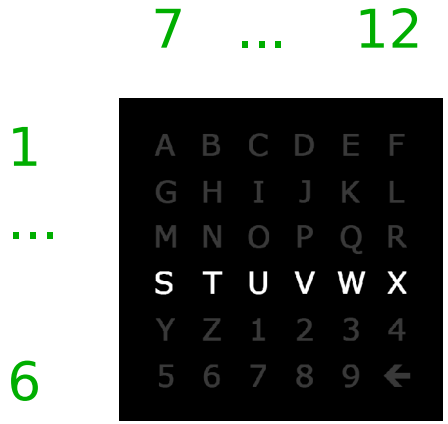
Auditory domain for

- Sight impaired (ALS) patients
- Healthy users, if control modality (AEP) shall be separated from application/content modality (typically visual)

Existing approaches:

- AEP for spelling with symbol matrix
  Sequential audio presentation of row number and column identifiers

Audio ERP: Two concurrent audio stimulation sequences
[Hill et al. 2005], Poster W09 ,[Kanoh et al. 2008]

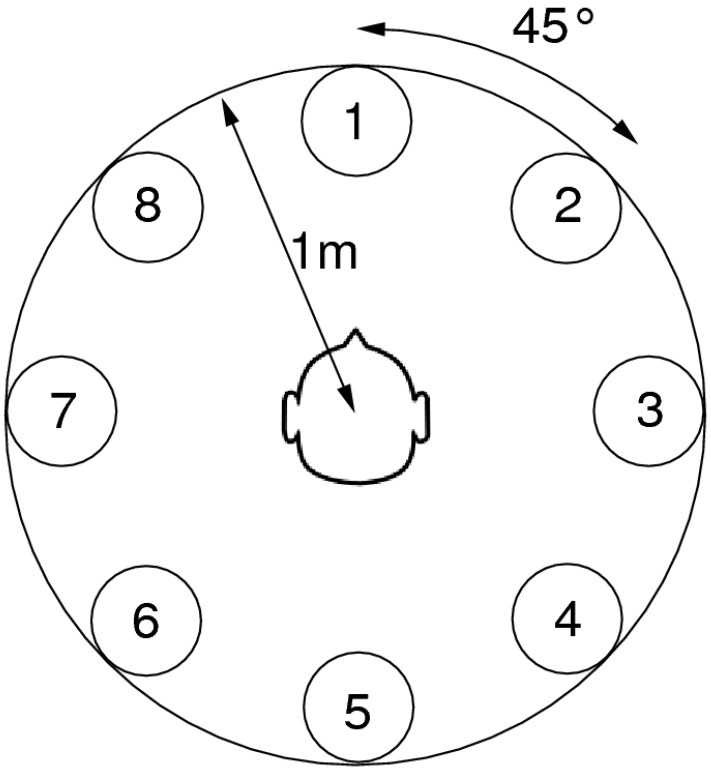


[Kübler et al. 2009]

Speedup & simple task ?

Spatially Coded AEP [Schreuder, Tangermann, Blankertz 2009]

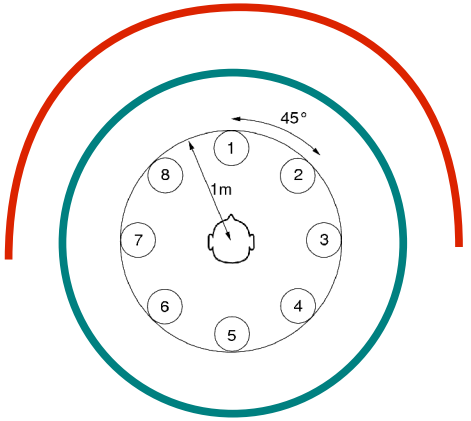
New high-speed AEP paradigm makes use of spatial hearing ability:



Spatially Coded AEP [Schreuder, Tangermann, Blankertz 2009]

New high-speed AEP paradigm makes use of spatial hearing ability:

Condition	ISI	Nr. speakers	sound
C1000	1000ms	8	noise
C300	300ms	5	noise + tone
C175	175ms	5	noise + tone



- Randomized series of brisk tones ~2500*75ms and ~3400*40ms duration
- 7 / 5 / 5 healthy subjects
- Test condition Cr: key press upon target (1000ms ISI)
- Test condition C300s: single speaker only (300ms ISI)

Results I: Perception of Directional Cues

Test condition Cr with key press reveals:

- rarely neighboring directions confused
- rarely front (1) and back (5) confused

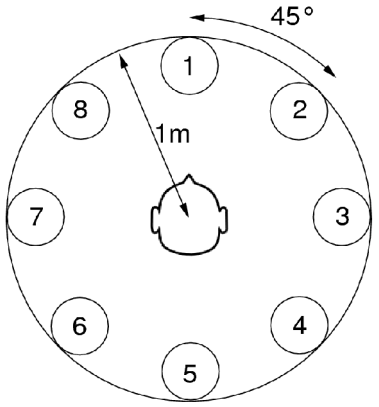
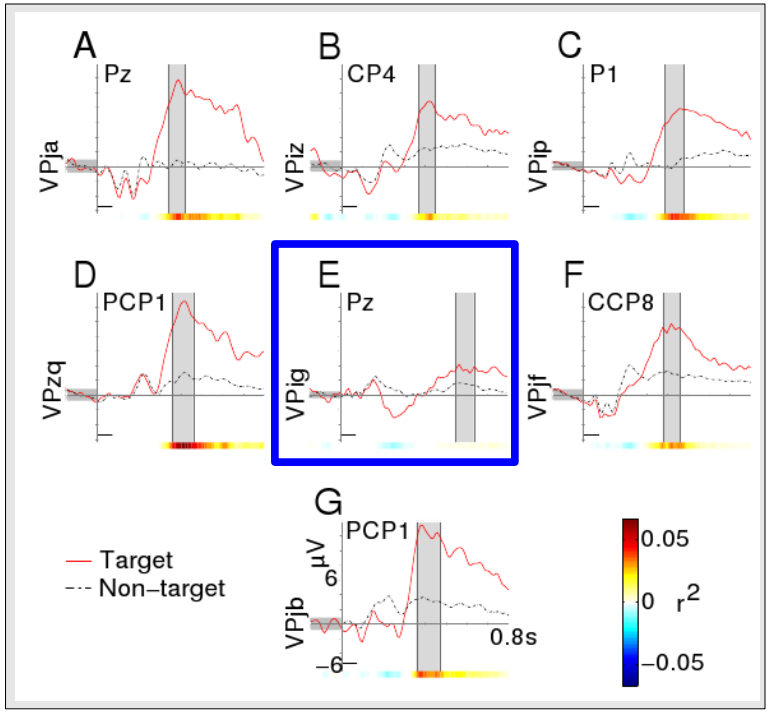


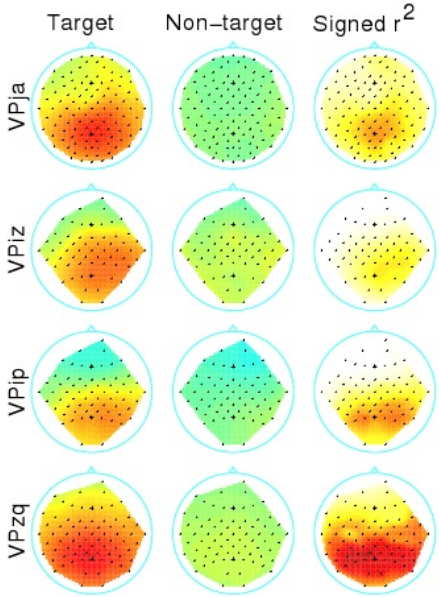
Table 5. Subject performances for the key response task

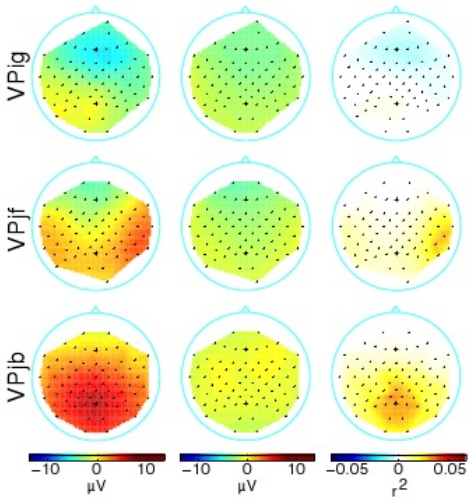
Subject	RT [ms]	Hits	False hits	Misses	Error
VPja	456 (128)	72	3	0	4%
VPiz	479 (148)	71	0	1	1.4%
VPip	507 (174)	72	1	0	1.4%
VPzq	360 (82)	71	5	1	7.8%
VPig	612 (219)	88	17	8	22.1%
VPjf	360 (131)	96	4	0	4%
VPjb	450 (113)	95	3	1	4%
Average	460.6 (142.1)	-	-	-	6.4%

Results II: Physiological Responses

Positive deflections (P300) for C1000

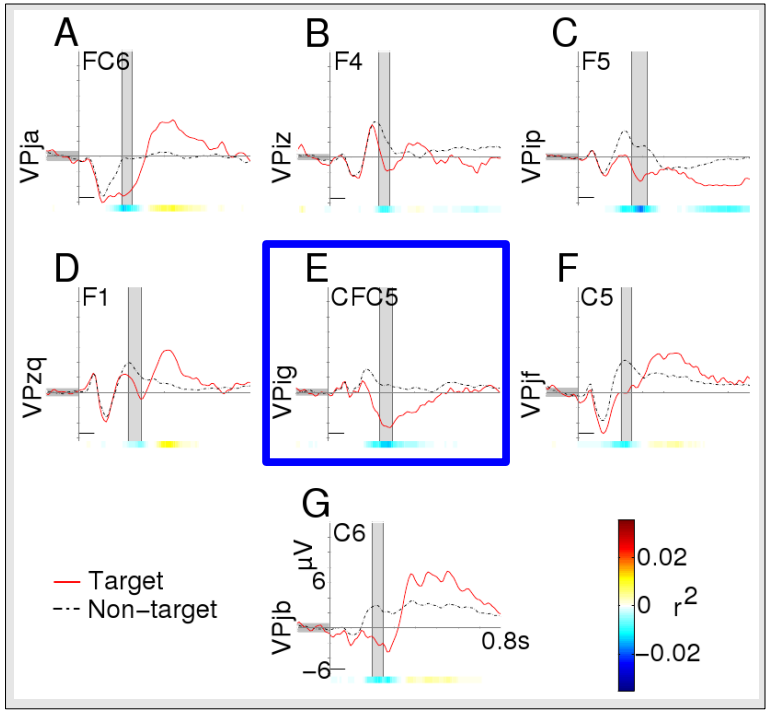


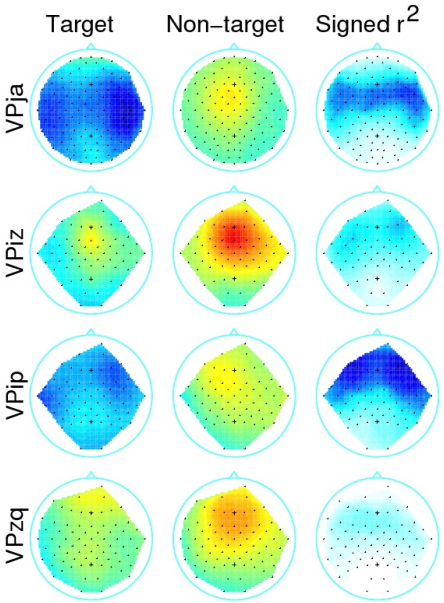


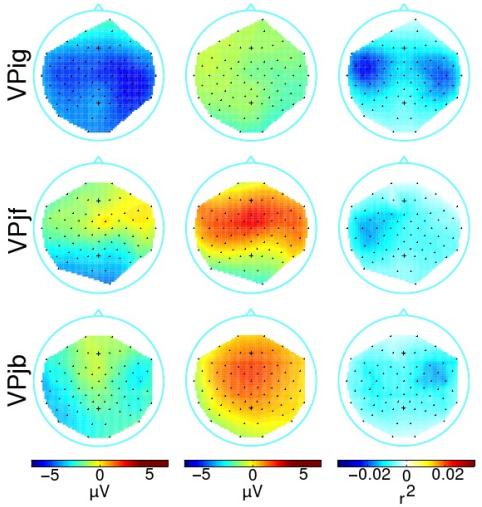


Results II: Physiological Responses

Negative deflections (N200) for C1000







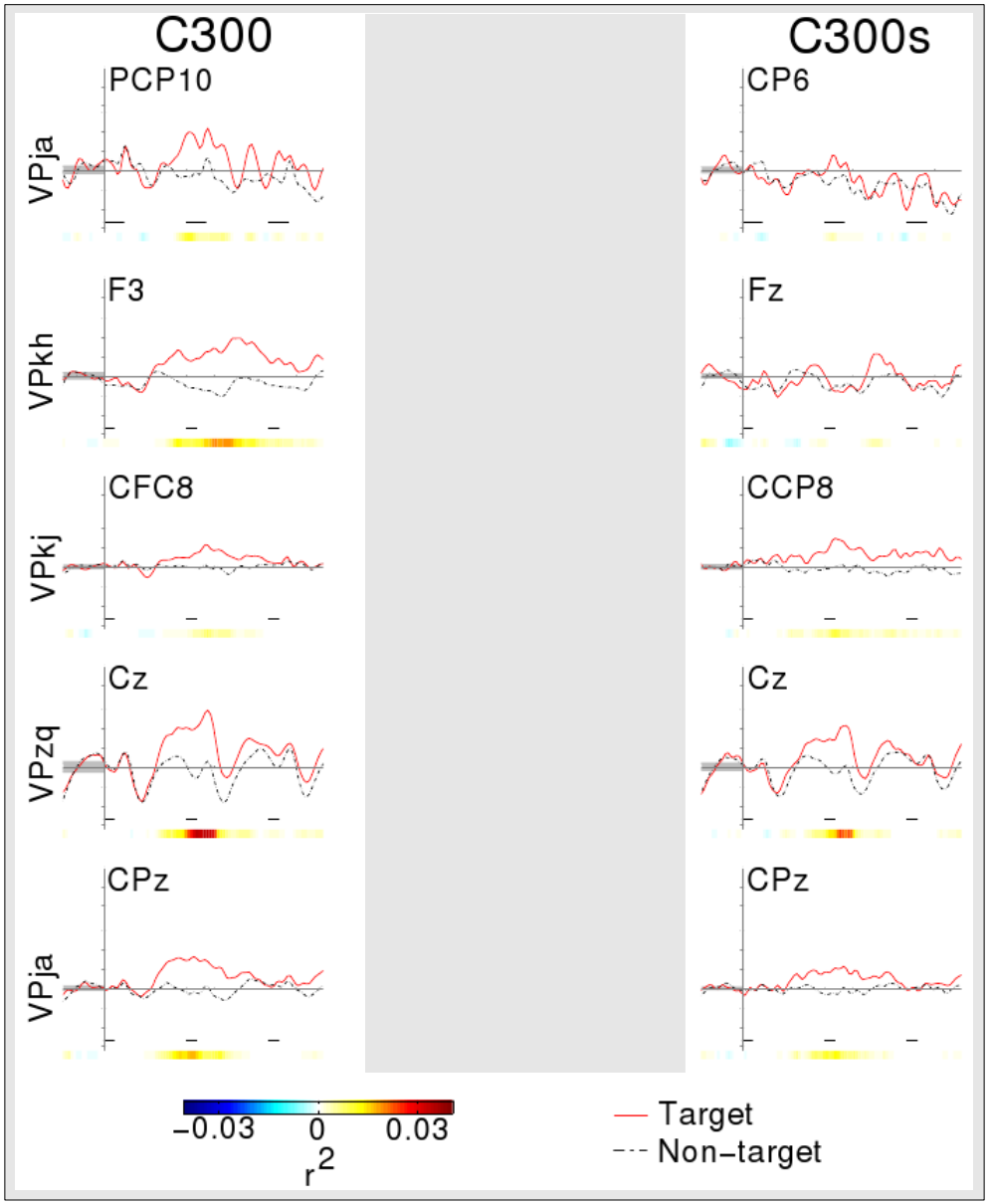
(different scales cp. to P300)

Results III: Directional Cues Useful?

Comparison of

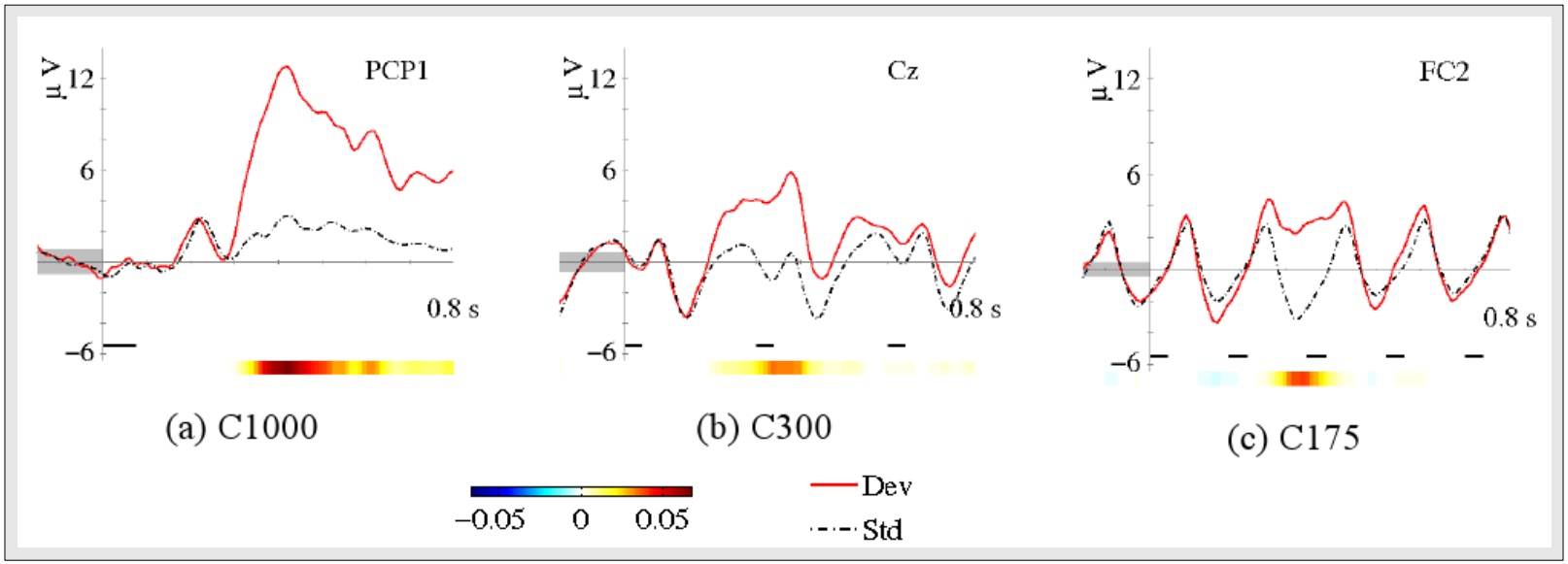
- C300 (5 speakers)
- C300s (1 speaker)

Result:
Directional coding improves ERPs



Results IV: How Quick Is Quick Enough?

Physiological response of VPzq:

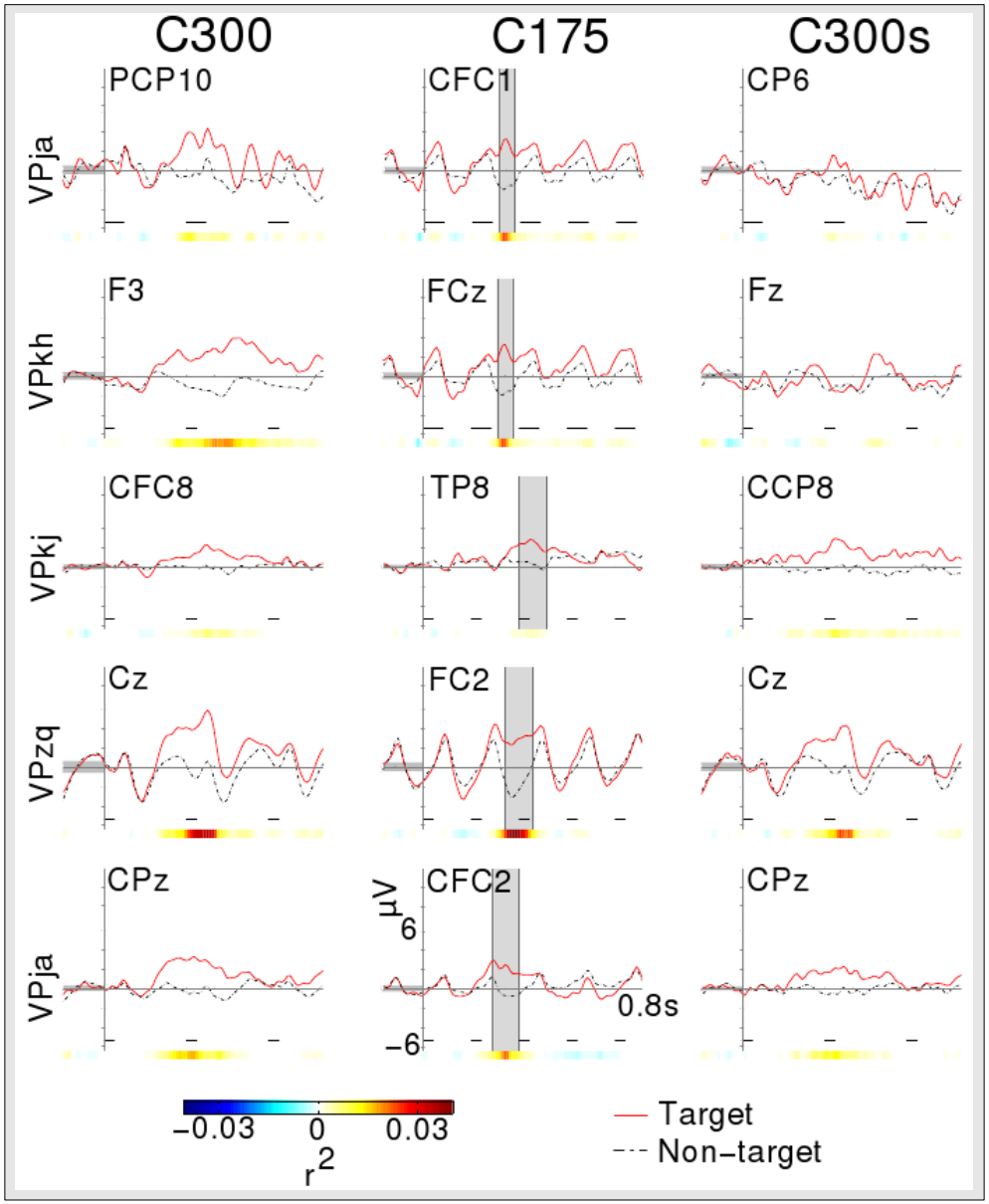


Reduction of ISI:

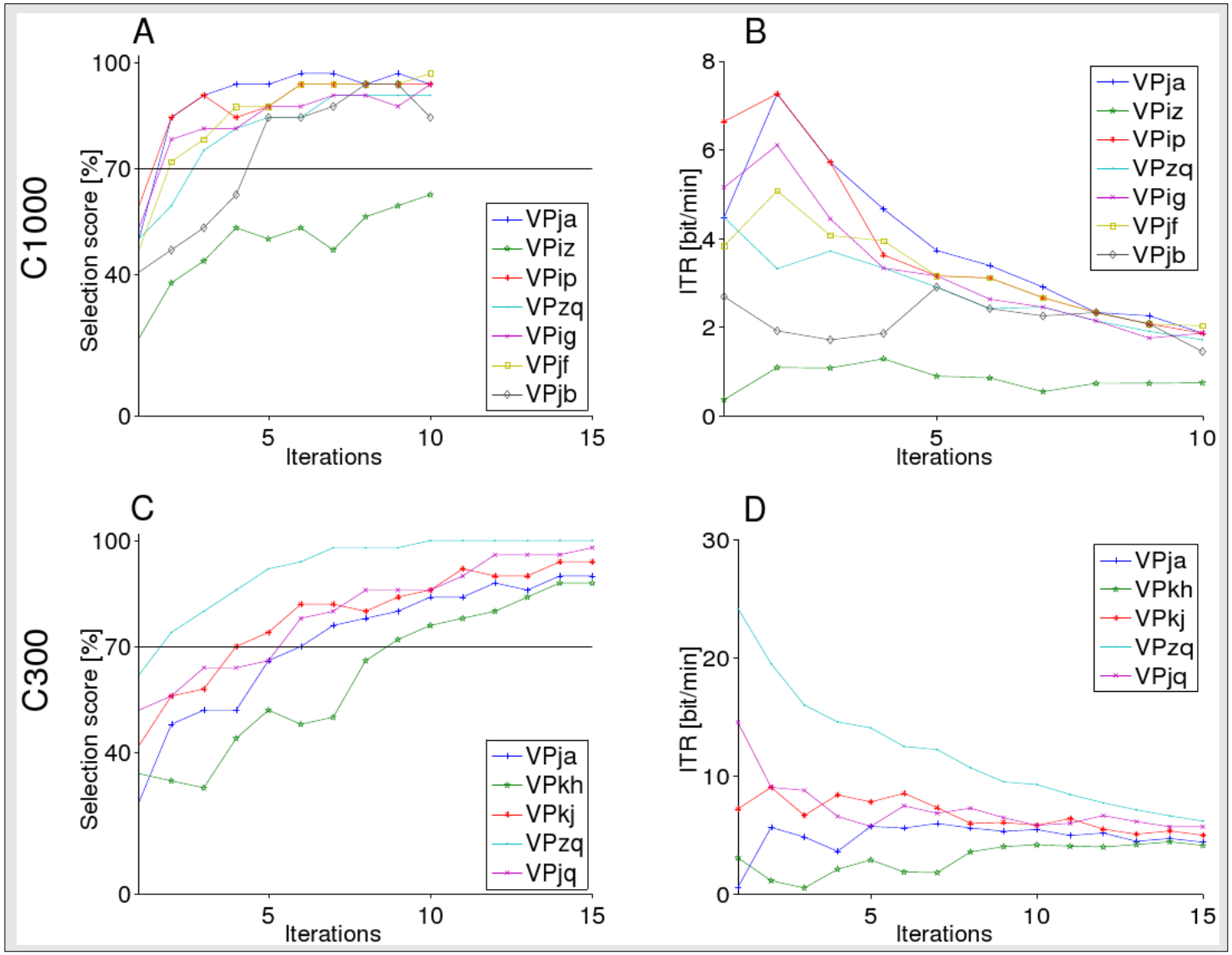
- Shorter P300
- Reduced P300 amplitude
- Early component (N200) becomes discriminative

Results IV: How Quick Is Quick Enough?

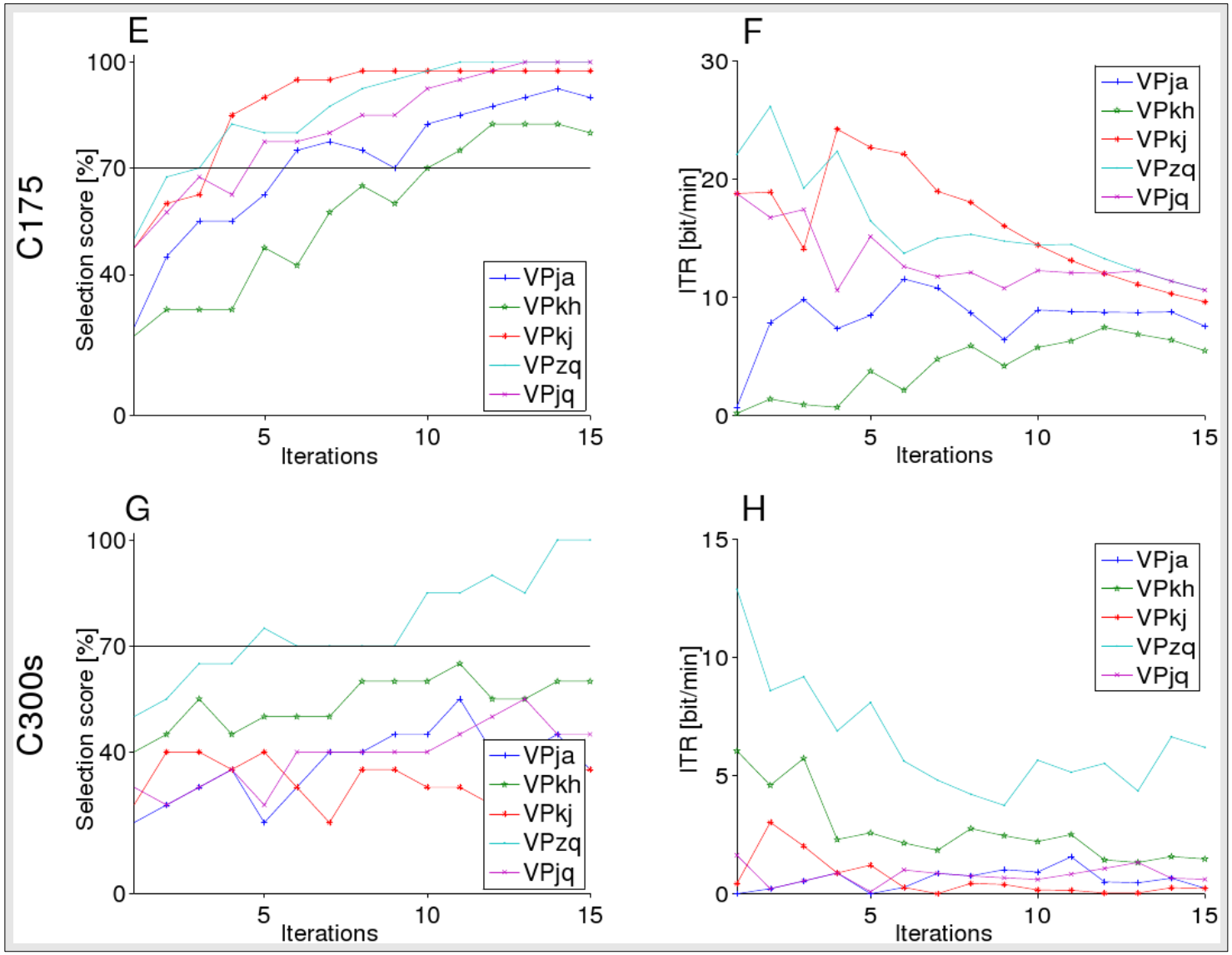
Similar response
by all subjects:



Results IV: How Quick Is Quick Enough?

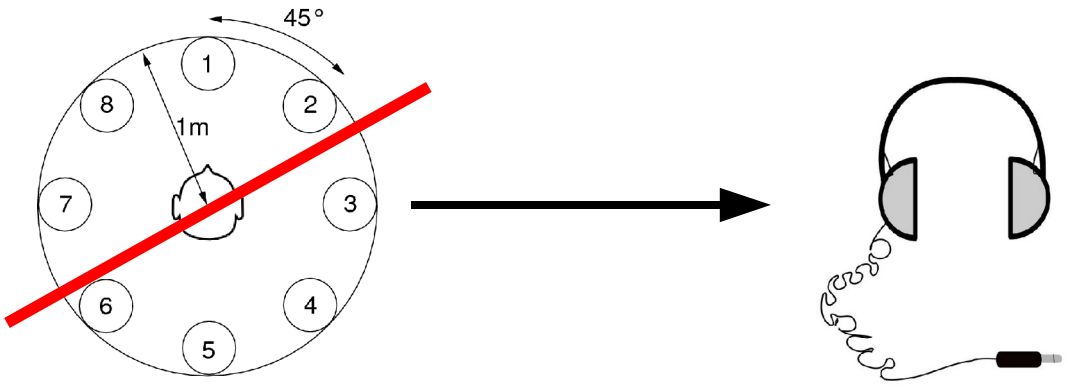


Results IV: How Quick Is Quick Enough?



Next Steps

- Currently: pilot study with patients
  ISI timing with patients?
- Parameter screening of new paradigm with feedback
- Simplification of experimental setup



Support for Your AEP Experiments

Please visit our small but growing website

http://www.bbci.de/supplementary/AEP/

Purpose:

- collect and provide materials
- exchange of hints for the use of AEP in BCI experiments

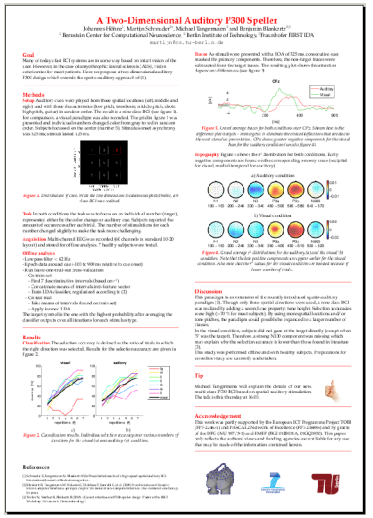
Summary

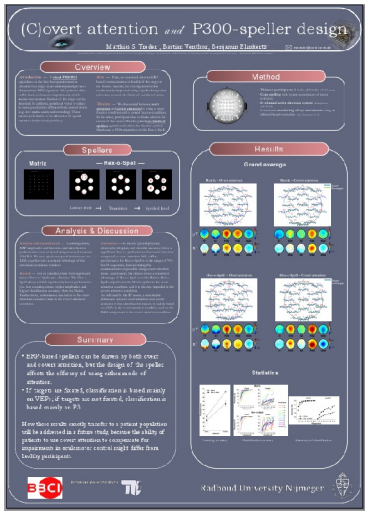
- Long-term patients raise need for new paradigms
- Visual deficits encourage the use of other modalities
- New high-speed auditory ERP (AEP) paradigm available
- Successful demonstration with healthy subjects

More “aha!“ effects?

Please visit our ERP-related posters for discussion:

- W10: A Two-Dimensional Auditory P300 Speller
  (Höhne, Schreuder, Tangermann, Blankertz)
- A02: Navigation Based on P3s Elicited by Tactile Stimulation
  (Thurlings, Brouwer, Van Erp, Werkhoven, Danóczy, Blankertz)
- W07: (C)overt attention and P300-speller design
  (Treder, Venthur, Blankertz)





Open student positions @ BBCI

Thanks to:

Martijn Schreuder

Benjamin Blankertz

Gabriel Curio

BMBF: FKZ 01 IB 001A, 01 GQ 0850
DFG: MU 987-31
EU: FP7-224631 , 216886, Pascal 2 Network

and thanks for your attention!