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Self adaptive BCI as Service-oriented Information System for (100 million) Patients with Communication Disabilities (NISS2010 Vol. 1, page 264)

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Expertise

- **Computational neuroscience lab** (leader: Prof. Van Hulle)
  11 researchers working on:
  - Brain Computer Interfacing (invasive & non-invasive)
  - Functional Magnetic Resonance Imaging (human + monkey)
  - Biologically-inspired computer vision
  - Single- & multi-electrode recording analysis & modeling
  - (Non-linear) signal processing, machine learning, data/text mining
- 200 scientific publications (including 2 books)
- 7 EU projects (FP5 → FP7), FWO, EF, PF, GOA, IUAP,…
- 4 patents, 4 spin-off companies founded
- Multidisciplinary: Engineering + economics + management (MBA) + psychology + law + communication degrees

Topic of today

Self adaptive Brain Computer Interaction

- *Machine learning techniques*

as Service-oriented Information System

- *Connect BCI-devices wireless to Internet*
- *Enable on line exchange of applications*
- *Use open protocols and open source*

for Patients with Communication Disabilities

- *Targetgroup: 100 million global*
- *(source: World Health Organization)*

Why: ±100.000.000 sufferers

Patients with severe motor or speech disabilities need expensive tailor-made made devices and individualized protocols to communicate.

About 1:6000 have problems with information exchange in their daily life, such as patients with ▸severe autistic disorders, and ▸Amyotrophic Lateral Sclerosis (ALS), ▸Locked-in Syndrome (LIS) and Speech and ▸Language Impaired (SLI) patients.

How: Brain-Computer Interface (BCI)

- BCI aim at creating a direct communication pathway between the brain and an external device, bypassing the need for an embodiment.
- Providing a significant improvement of the quality of life of neurologically impaired patients suffering from amyotrophic lateral sclerosis (ALS), stroke, brain/spinal cord injury, muscular dystrophy, etc.
- Can be used also for gaming, entertainment, controling, and so on.

Non-invasive BCI

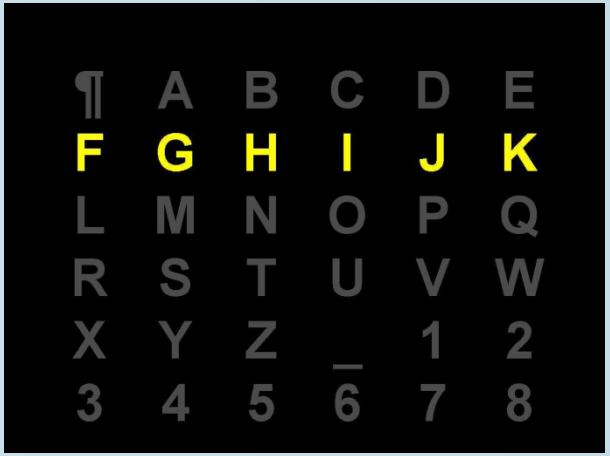
- Imagined limb movement detection
  - Can be used for cursor movement, gaming, wheelchair control and so on
- Steady-state visual evoke potential detection
  - Can be used for guiding a robot, brain-typing system, gaming and so on
- Error-potential detection
  - Can be used for correction of mistakes from other brain-computer interface systems
- P300 event-related potential detection
  - Can be used for brain-spelling system, controlling smart home environment and so on

The P300 Mind-Speller BCI

- Event Related Potential (ERP): Stereotyped electrophysiological response to an internal or external stimulus.
- Oddball paradigm: Distinction of 2 types of events, one being rarely represented.
- The rare events elicit in the EEG of the subjects an ERP consisting of an enhanced positive-going component with a latency of about 300ms: the P300 ERP.

The P300 Mind-Speller BCI

- BCI paradigm introduced by Farwell and Donchin in 1988.
- Spelling word by focusing on a visual display.
- Achieved through detection of P300 ERP.



The P300 Mind-Speller BCI

- EEG recordings are a superposition of all ongoing brain activities and noise.
- Generally, P300 component is not detectable in single trial.
- Common procedure: averaging over signals.

Repeat the round of intensifications several time for each symbol

Dramatic increase of the time taken to communicate each symbol

Mind speller: classic paradigm

→ requires multiple redisplaying + averaging (> 10 times!)

- **Disadvantages:**
  - Too slow: 2-4 characters/minute
  - Requires extensive training phase (20 mins.)
  - Needs retraining (each time electrodes are placed)
  - Very few patients tested: not for 1/3 of ALS patients (< 30 years)

Mind speller: new paradigm

- **Advantages:**
  - **5-10 times faster** than classic paradigm
  - Can be integrated with supportive text generation technology (target: 1 character/second)
  - **No training** (or retraining) → easy for patients
  - Very robust signal (usable for large corpus of patients)
  - **Very few electrodes**: 1 for ssVEP, 1 for error potential
    +
    2 ground/reference electrodes on mastoids <-> 8+2 electrodes

The new P300 'Mind Speller'® Paradigm

1. we have achieved **a superior performance**, even when using a few trials for averaging, leading to a much faster spelling rate.
2. we have **used active electrodes** (ActiCAP) which are easy to mount and comfortable to the subject (no scraping of dead skin cells required).
3. we have introduced a professional, **portable BCI device** so as to able to reach a broad range of potential customers, with a wide scale of possible applications and services.

Comparison

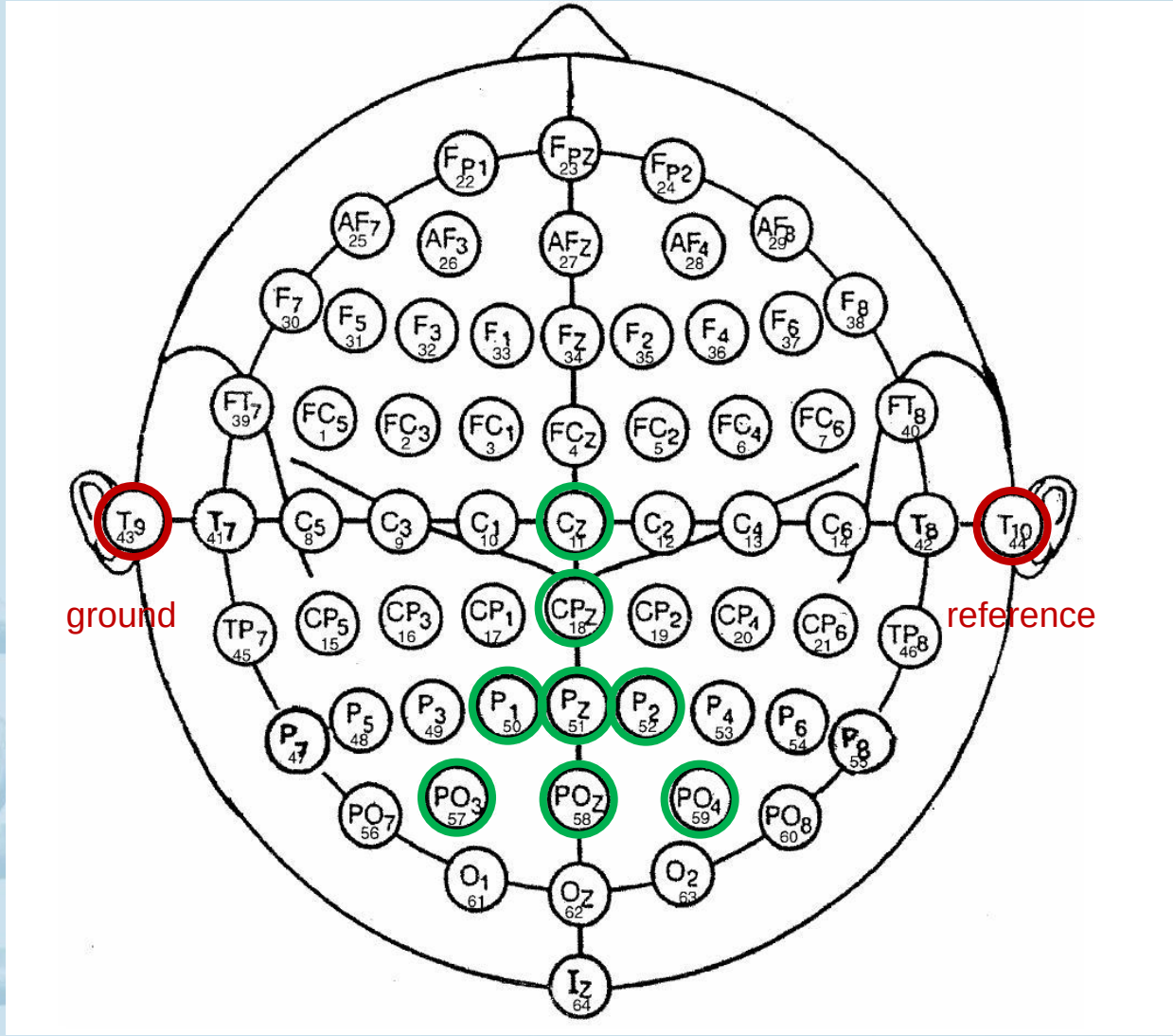
- Training accuracy
  88±6% (f-VEP) and 95±6% (c-VEP)

- Online testing accuracy
  85% (f-VEP) and 91% (c-VEP)

- ITR
  39.7±7.8 bit/min (f-VEP) and 92.8±14.1 bit/min (c-VEP)

Bin et al., 2009

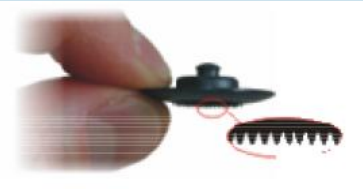
Experimental Setup



Electronics & electrodes

- Wet electrodes → **dry electrodes**

  1st step: commercial passive dry electrodes



dry spiked electrode for biopotential monitoring (Orbital Research Inc. USA)

  2nd step: active dry electrodes (better impedance)
  → IMEC's own research

- Adaptation **radio communication** protocol: id. of each individual electrode, time stamp of every sample, bidirectional control

Commercial products

MindSet (NeuroSky)

1 active dry electrode

Limited functionality: only forehead, mostly ocular activity

Price: 200$

Epoch (Emotiv)

Passive dry electrodes
Cumbersome to keep electrodes fixed on scalp

Price: 300$

Enobio (Starlab)

4 passive electrodes, limited functionality (forehead only),
Price: 3750 Euro

Commercial products

Brainquiry PET4.0 (BrainClinics)

4 active electrodes

Price: 2000 Euro

Porti (TMSI)

8 passive Ag/AgCl electrodes with shielded cables

Bluetooth

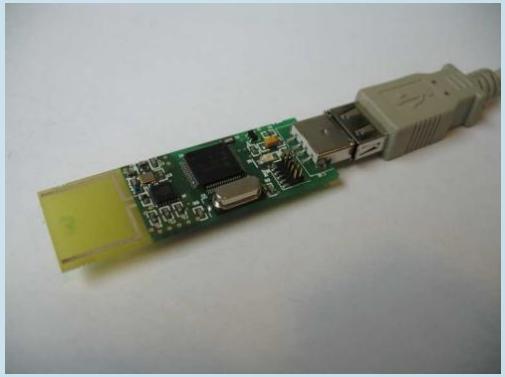
Price: 7970 Euro

g.MOBIlab+ (g.tec)

8 active Ag/AgCl electrodes

Price: 19000 Euro

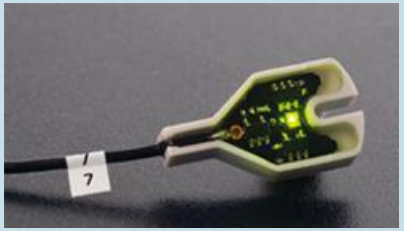
Prototype



Ultra low-power 8-channel wireless EEG amplifier

USB Bluetooth antenna

cap with 8 electrodes
(of which 2 are used)



(ActiCAP system)
active electrode

Pocket PC (PDA)

Prototype

Aim: integrate electronics + active (wet) electrodes + wires into diadem
Future: active dry electrodes

Diadem design in collaboration with Artesis school, Antwerpen

Electronics design in collaboration with IMEC, Leuven

Advantages: 1) electrodes always in right position and remain so, 2) easy to put on (by subject), 3) clean (hygiene), 4) cool design, 5) no impedance problems (active electrodes → no scratching)

Local development

www.imec.be

Prototype

Advantages:

- **Inexpensive**: mass-producible, single-chip EEG device, connected to Pocket PC via Bluetooth &
  only 2 electrodes → cheap solution
- **Easy to use**: no training, no focusing (covert attention)
- **Easy to wear**: portable, wireless, active electrodes, diadem

Proof of concept: Already tested on healthy subjects

Patient study 600/600 is started

Impact for patient

- More fluent & interactive **communication** (even voiced) with friends, caretakers, family members, bystanders
- Also for **writing** letters, community chats, online bank transactions, transport reservation, etc.
- Commands for **controlling** devices, smart homes (AAL)
- Serious games for **rehabilitation/revalidation**

⇒ Patient becomes:

- more self-reliant
- better part of social processes
- able to perform certain tasks, possibly with economical return (such as translation, legal assistance, process controlling…)

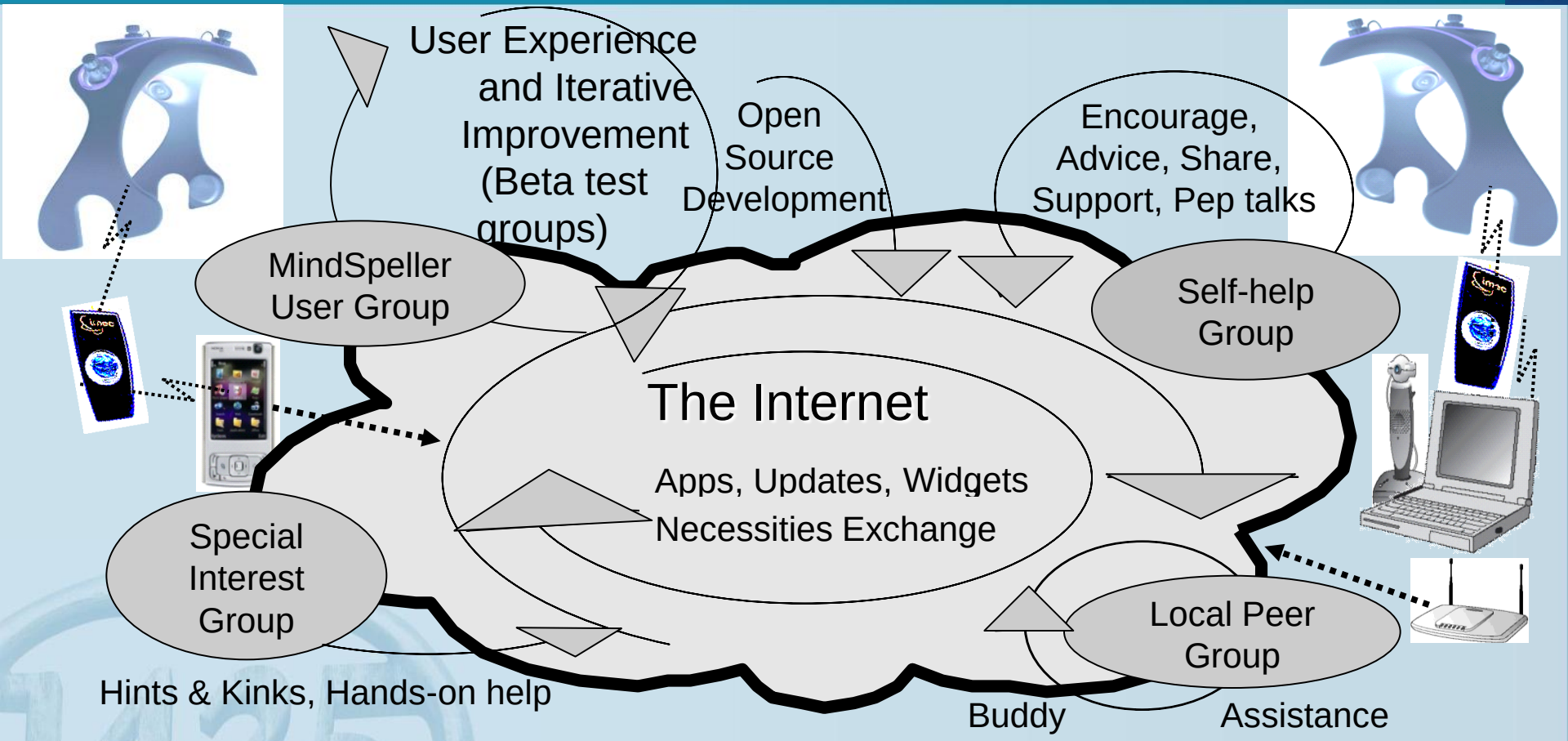
Next steps

1. Changing the wPDA for a smartphone, OS Android or so
2. Integrate all electronics and wiring in one BCI headset
3. Set up an open source community for APIs and widgets
4. Enable the online communication between Mindspellers
5. Set up the online service for communication disabled

2nd:

1. Use T9 or so for predictive text typing in the Mindspeller
2. Research the contribution of storytelling in emendation
3. Research the use of icons/ pictograms/ pictures vs text
4. Research the contribution of storytelling in ‘comic strip’
5. The integration with augmented reality in virtual worlds

Web 2.0 Services for Disabled



Services Architecture

Web 2.0 Connection, Communities, Collaboration, Conversation, Content Creation, Games, Content Sharing, Cumulative Learning, Collective Intelligence, Cheap & Fast Improvement

future non-invasive BCI development

will focus on 5 main directions:

- Word spellers BCI > characters > words > sentences
- Story tellers BCI > images > cartoon > storyboard
- Neuro robotics BCI > data > robotic motion control
- (Serious) Gaming BCI > HMI control of virtual objects
- Trauma triggers BCI > virtual environment > capturing re-experience of traumatic neurosis.

As the open standards move up, the BCI data more and more interconnects with PC platforms, PDAs and smart phones, and by that with the Internet.

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Thank you for your attention!

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