Wearable EEG

What is it, why is it needed and what does it entail?

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Objectives

• We aim to:
  – Overview what we envision as wearable EEG.
  – Illustrate the motivation for its development.
  – Highlight briefly some of the research challenges.

• We will focus on epilepsy as our area of expertise, but also discuss other applications.

• The aim here it to highlight the problem and the motivation, not to present finished solutions.
Current EEG

- Inpatient EEG with time locked video is the gold standard, but:
  - Expensive.
  - Cumbersome.

Video courtesy of the NSE
Ambulatory EEG
• Ambulatory EEG is portable.
• Clinically useful in 75% of patients. [Waterhouse, 2003]
• Estimated at 50% cheaper than inpatient monitoring. [Waterhouse, 2003]
• But size still limits users acceptance.

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Image courtesy of the NSE
Limitations of AEEG

User acceptability places stringent limits on both the size and weight of devices and makes wireless operation highly desirable.

1) Electrodes need to be held in place securely.

2) Systems are bulky and can weigh up to 1 kg.

3) Wires from the head to the recording unit limit movement.

4) Long term recordings generate large amounts of data for storage on the mobile device.

5) Long term recordings generate large amounts of data to be analyzed by a neurologist.
Wearable EEG

Wearable EEG is the evolution of ambulatory EEG units from the bulky, limited lifetime devices available today to small devices present only on the head that can record the EEG for days, weeks or months at a time.
Wearable EEG solutions.
Discrete and miniature with no presence other than on the head.

1) Electrodes easy to place and replace.
2) Capable of operating for days, weeks or months at a time.
3) Lightweight, operating from small batteries.
4) No wires present other than on the head.
5) No bulky recording units to carry round.
Application areas: Epilepsy

• Affects 1% of population. [Sander, 2005]
  – Cost of €15 billion in Europe in 2004. [Pugliatti et al, 2007]

• 13 – 20% present diagnostic problems. [Binnie and Stefan, 1999]
  – 25% misdiagnosed. [Smith et al, 1999]

• Our aim is to provide additional diagnosis tools:
  – Longer temporal samples.
  – More user acceptance.
Sleep studies

• Sleep disorders affect more than 70 million people in the US.
  – 20% of serious road accidents are sleep related. [Colten and Altevogt, 2006]

• In the UK diagnosis waiting times can be up to 3 years. [Flemons et al, 2006]

• Miniaturization is key:
  – Want to enable a good nights sleep in the sleep clinic!
Brain Computer Interfaces

• BCI allows users to control computers via the EEG.
  – Changes in brain patterns can be detected and used.

• Augmented cognition aims to determine the user’s mental state and provide feedback depending on whether they are: bored, tired, stressed…

• More work is still needed on the processing algorithms.
  – But success of the field and end user acceptance will depend on the EEG unit.
User’s options

• Performed a survey of 17 neurologists at the National Hospital for Neurology and Neurosurgery and the NSE.
  – Aim is to quantify the medical need and desire for wearable EEG.

• Questionnaire procedure:
  – 6 emailed to consultants at NHNN.
  – 11 filled in after a presentation at the NSE.
Are current ambulatory recordings diagnostically useful over traditional inpatient recordings?

Yes: 12
No: 0
Don’t know: 3
Not answered: 2
Would you consider it a major improvement in your EEG practice if wearable EEG devices were available?

Yes: 13
No: 1
Don’t know: 2
Not answered: 1
Do you think that your patients would consider it a major improvement in their EEG experience if wearable EEG devices were available?

Yes: 12
No: 0
Don’t know: 3
Not answered: 2
In the future do you anticipate ambulatory recordings being:

- More common than now: 15
- Used about the same: 3
- Not answered: 1
Is the amount of EEG information produced by monitoring for weeks or months to capture rare events too much to be useful in practice?

Yes: 5
No: 5
Don’t know: 7
Not answered: 0
Would you trust automated detection or data reduction software to reduce the amount of data presented to you?

Yes: 6
No: 4
Don’t know: 7
Not answered: 0
Would you trust the automated diagnosis of disorders based upon detection software?

Yes: 1
No: 10
Don’t know: 4
Not answered: 2
Do you think that wearable EEGs would be useful for sleep studies in allowing more natural, unrestricted sleep than current sleep EEG units do?

Yes: 14
No: 1
Don’t know: 1
Not answered: 1
Are you interested in the other potential applications of wearable EEGs, such as controlling computer games or receiving feedback based upon your current awareness level?

Yes: 8
No: 4
Don’t know: 4
Not answered: 1
Do you think that wearable EEGs will be of more use to this sort of application area rather than in medical applications?

Yes: 2
No: 7
Don’t know: 7
Not answered: 1
Requirements

• New electrode technologies.
  – Easy to place.
  – Long lasting.

• Lower power consumption.
  – Average power consumption < 140 µW. [IMEC, 2007]
  – IMEC’s front-end consumes 25 µW per channel. [Yazicioglu et al, 2008].
  – Combined with the transmission power only 3 channel systems are feasible.
Wearable EEG devices are discrete, comfortable and long lasting EEG units.

There is a clear medical desire for such units for epilepsy and sleep studies.

They also have applications in Brain Computer Interfaces where the size of the EEG unit will be key to end user acceptance.

Electrodes and power consumption are the major research challenges.