Multimodal Interfaces

2019

[9] Brain + Affective computing

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With inputs from Francesco Carrino, Fabien Ringeval, Bruno Dumas, and my own.

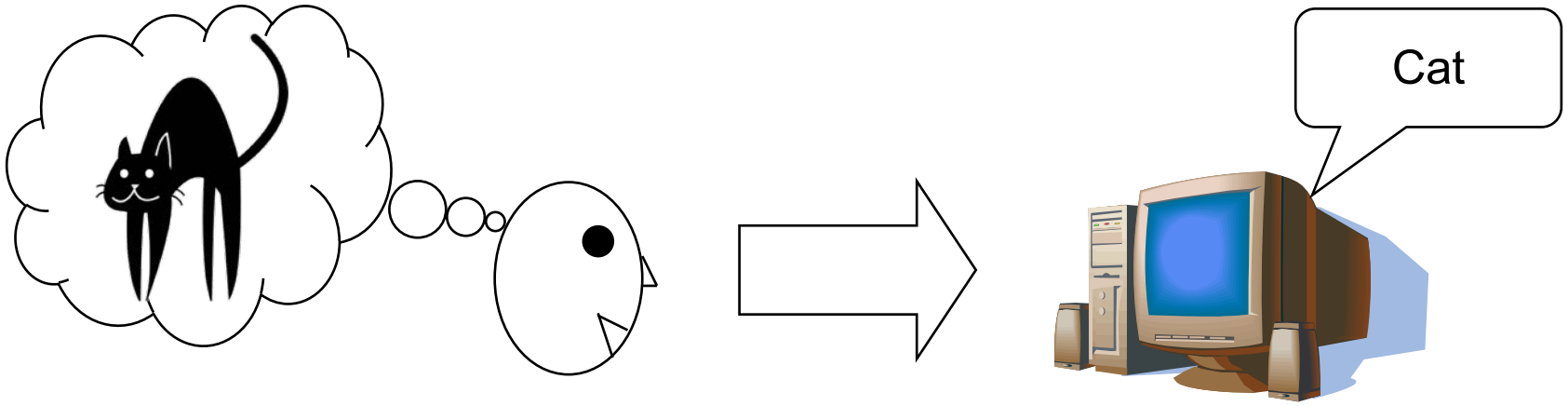
Outline

- Brain-Computer Interface (BCI)
  - Introduction and main ideas
  - BCI general schema
  - EEG & EMG
  - Prototypes & Demo
- Affective computing
  - Fundamentals on emotions
  - Models of emotions
  - Emotions recognition
  - Synthesis of emotions
  - Application examples and frameworks

[9.1] Brain Computer Interfaces

Goal

- Communication User → Computer
- No muscles involved

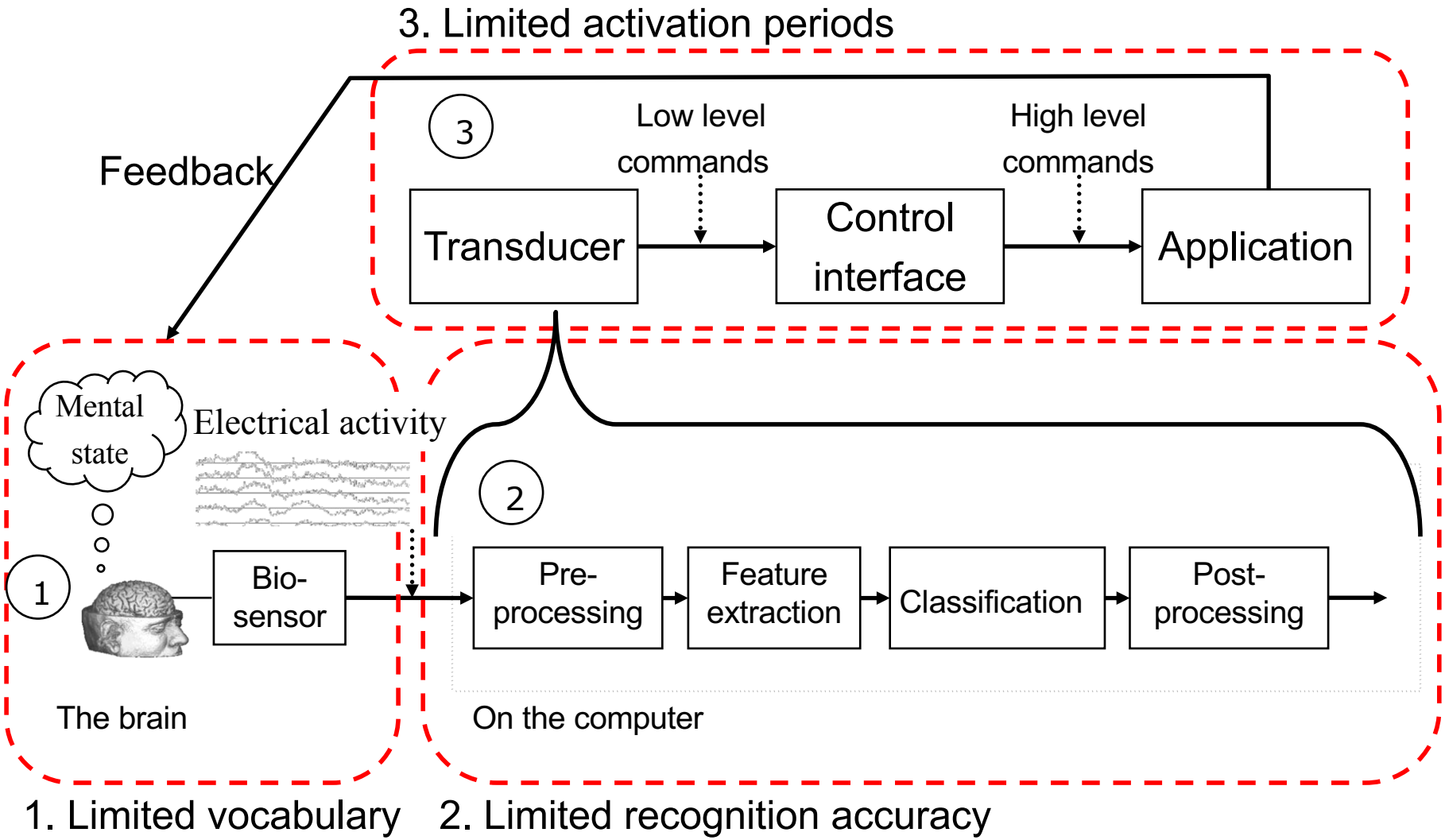


➔ Brain-Computer Interface (BCI)

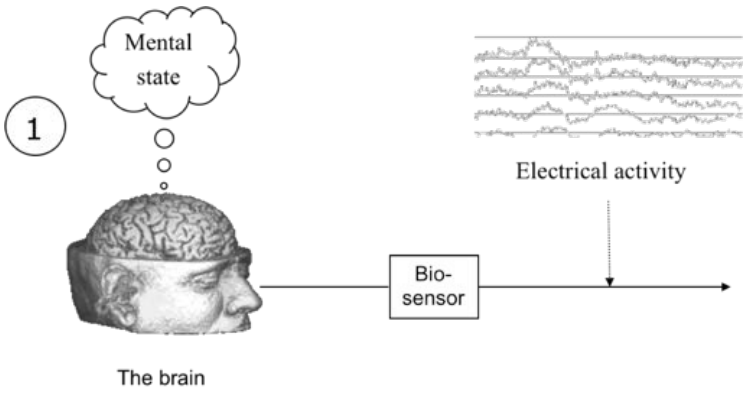
Dream vs. reality

- Dream BCI: “silent speech”
  - Think to whatever you want
  - Without recognition errors
  - Whenever you want
- Physiological problems
  - No thought sensor
  - Partial brain knowledge
  - Noisy signals
- Solutions in the BCI community (reality)
  - Limited vocabulary
  - Limited recognition accuracy
  - Limited activation/usage periods

General scheme



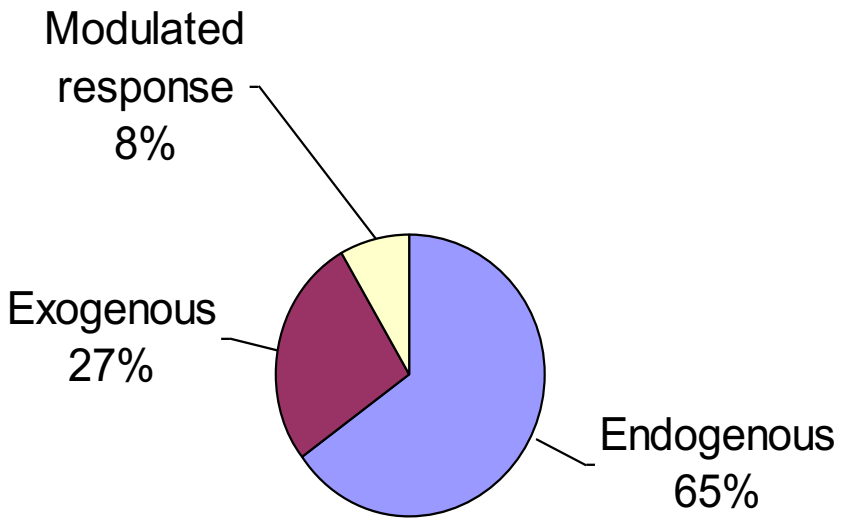
Limited vocabulary



- Physiological limitations
- Thought inference
  - Based on neuron activity
  - Neuron activity varies in time, space and frequency, non-stationary
  - Neurons can be involved in more that one thought
  - 100 billions neurons, 10^{15} connections
  - ➔ Impossible ➔ limited vocabulary
- "Thought" vocabulary must be based on
  - Well known/defined mental tasks
  - Well differentiable neuron activity

Type of mental tasks [1]

- Endogenous ("free thinking")
  - Internally modulated activity
- Exogenous (evoked potentials)
  - Driven by external stimuli
- Modulated response (biofeedback)
  - Conscious modulation of response to external stimuli

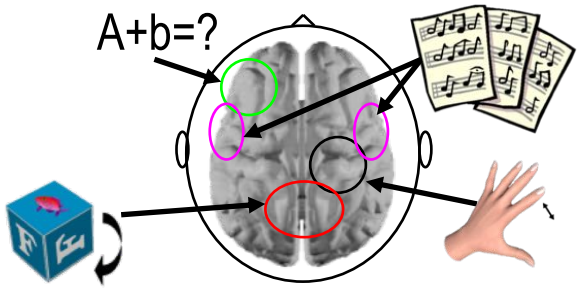


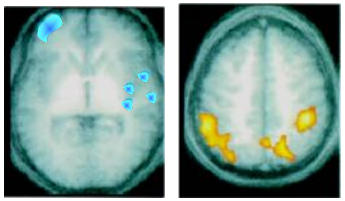
All numbers in this presentation come from Mason *et al.* paper [1] which proposes a survey of BCI design from 1977 to 2004 (about 150 publications).

Endogenous tasks

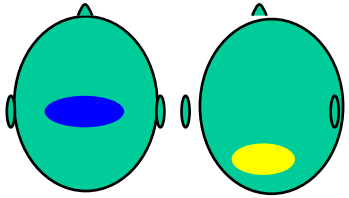
- Internally modulated activity
- Several mental tasks
- Different brain regions
- Brain activity depends on user instructions

- Imagination of movement (left/right hand, feet, tongue)
- Mental calculation
- Word association
- Mental cube rotation
- Relax
- Visual/auditory/tactile evocation
- Mentally composing a letter
- Visual counting task

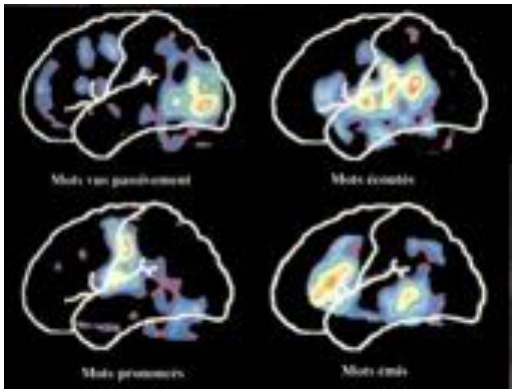




Mental calculation



Object rotation



Word tasks

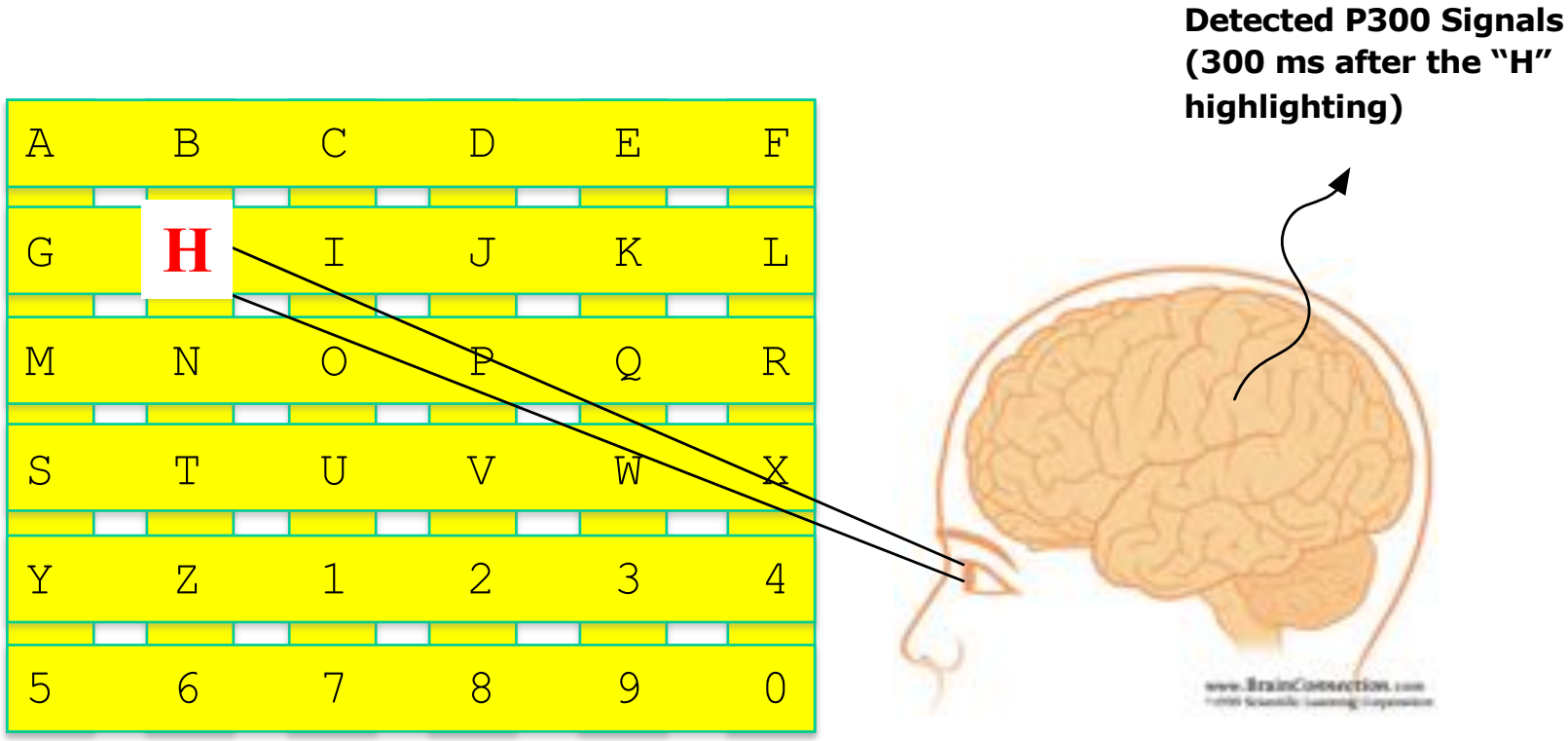
- Vocabulary limited to well known and differentiable mental tasks: ~2-6 tasks in practice*

* some experiments up to 8 tasks have been made on monkeys [7]

Exogenous tasks

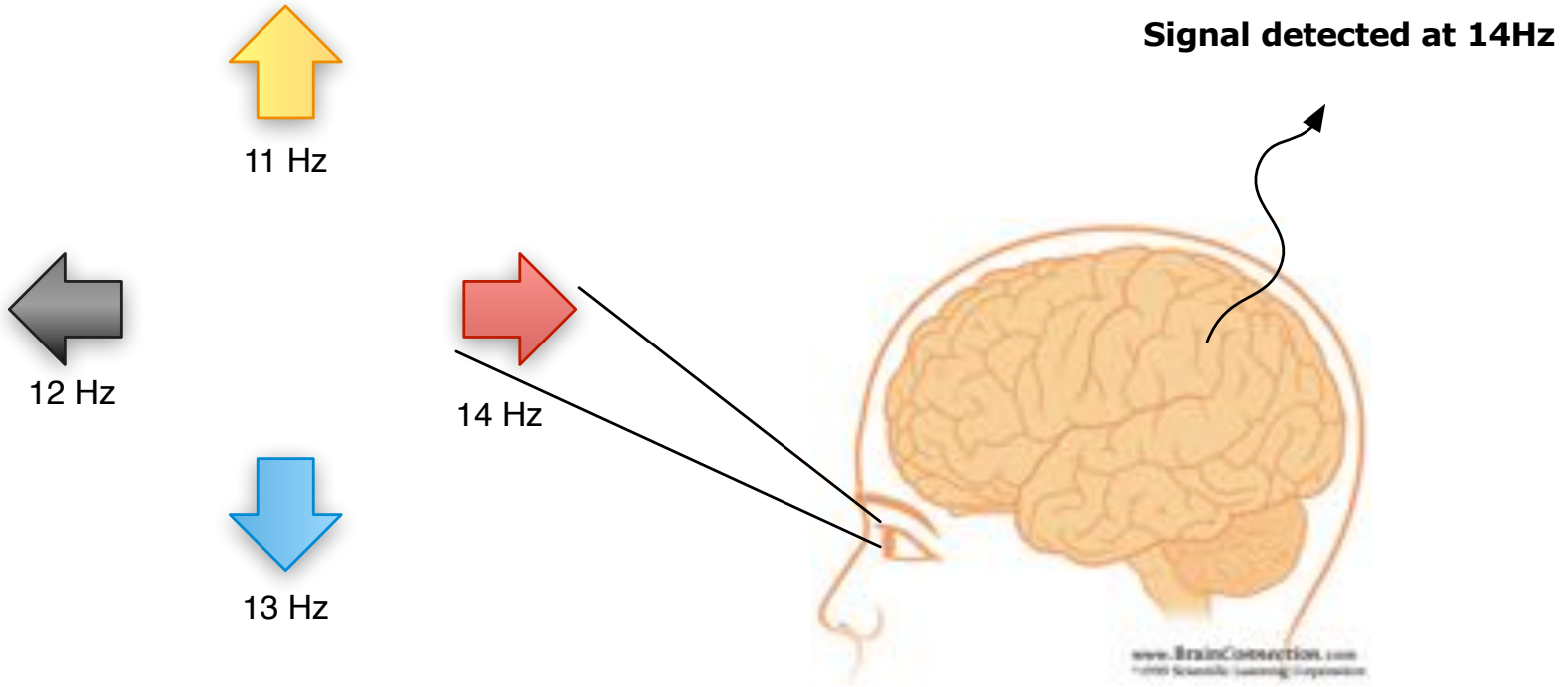
- Event-Related Potentials
  - driven by external stimulus
- Automatic brain response
- Very consistent/stable from people to people
- No training required
- P300 & SSVEP (Steady State Visually Evoked Potentials)

Exogenous tasks – P300



- P300
  - Activation appears 300 ms after a relevant and rare event
  - change amplitude proportional to event rarity
  - Video (world record)

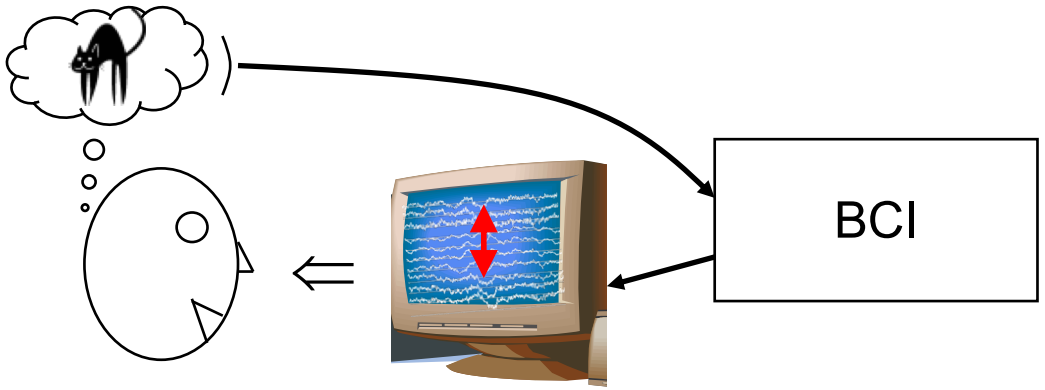
SSVEP: Steady State Visually Evoked Potentials



- Flicker stimulus
- Same frequency in occipital brain area
- Playing chess, SSVEP-based mindspeller

Modulated response

- Internally modulated from a stimulus (or operant conditioning feedback, or biofeedback)
- Brain signal = Stimulus + Feedback
- Users learn to control specific waves

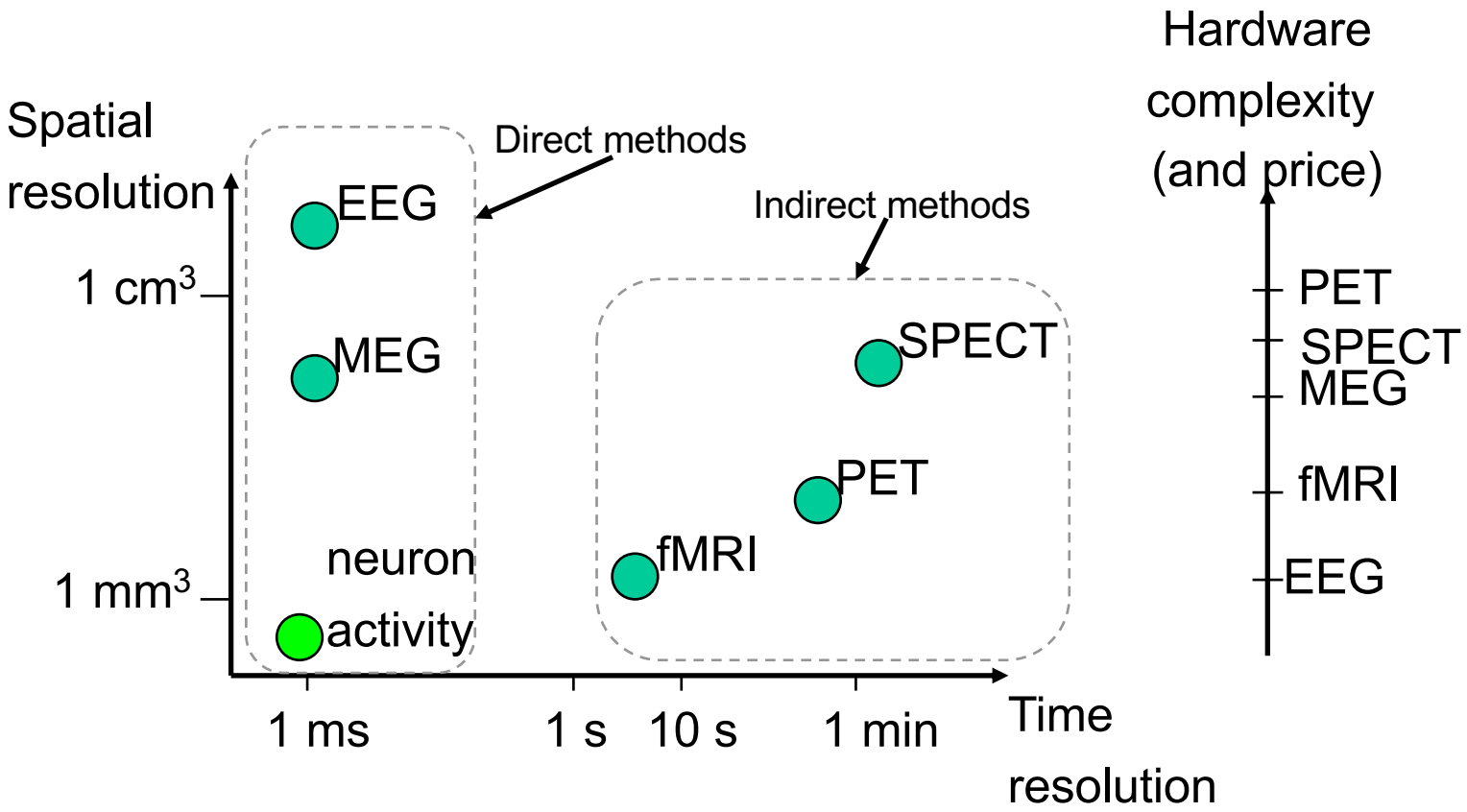


- Example: SCP*

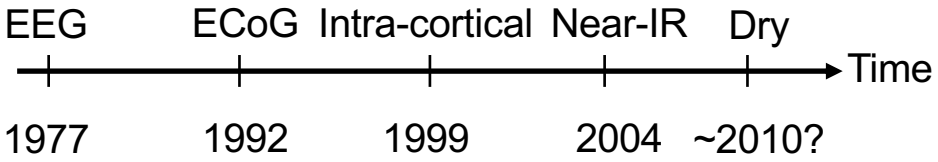
* Slow Cortical Potentials

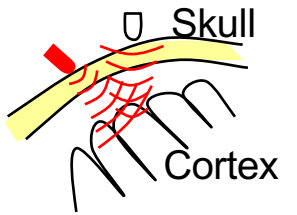
Bio-sensors

- Direct vs. Indirect methods
- Time and spatial resolution [2] [3] [4] [5]
- Hardware complexity [5]



Electrical sensors (I)



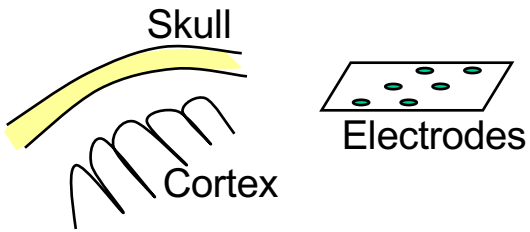


- Several types
  - EEG (Electro-Encephalo-Graphic)
  - Near-IR electrodes
  - Dry electrodes [6]

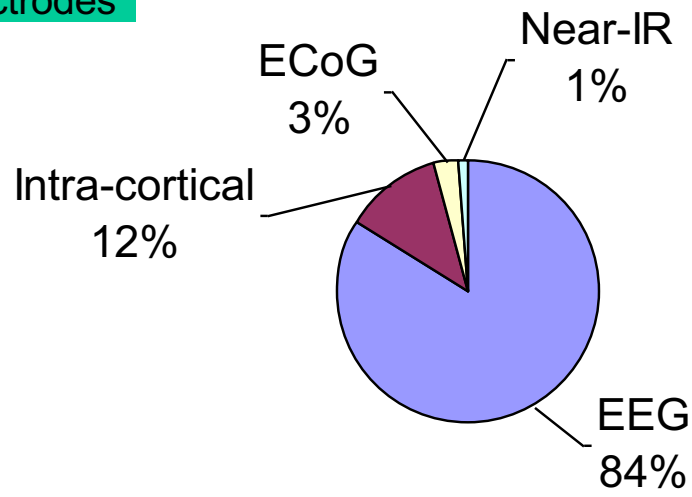
  } Surface electrodes

  - ECoG (Electro-Cortico-Graphic)
  - Intra-cortical electrodes

  } Invasive electrodes

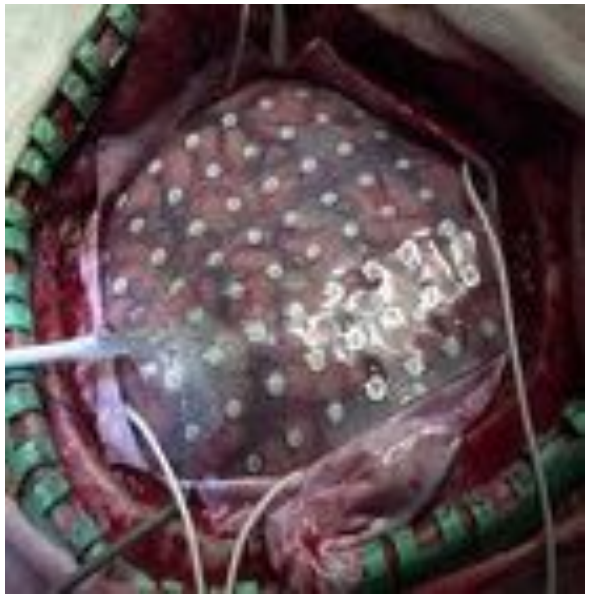


- Barriers to entry
  - Technical
  - Ethical
  - Financial



Electrical sensors (II)

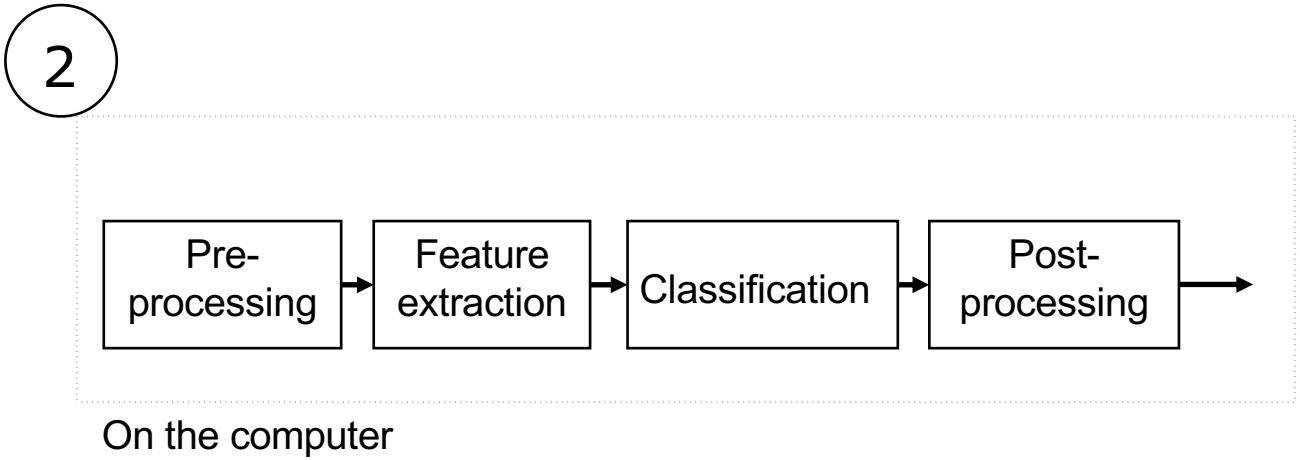
Non-invasive (EEG)



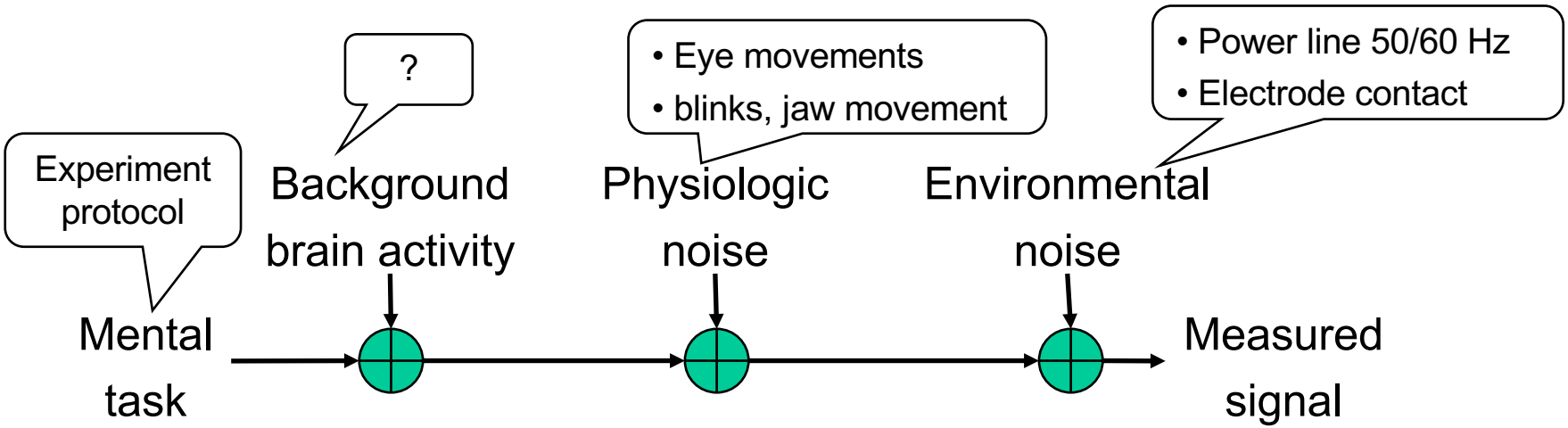
Invasive (ECoG)

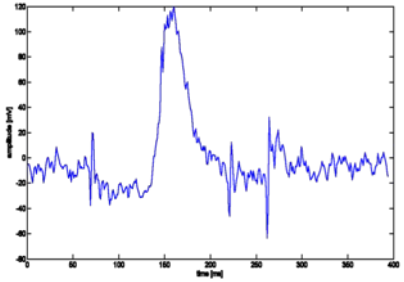
First Commercial BCI System: The ATARI Mindlink System *(1984)*

Limited recognition accuracy

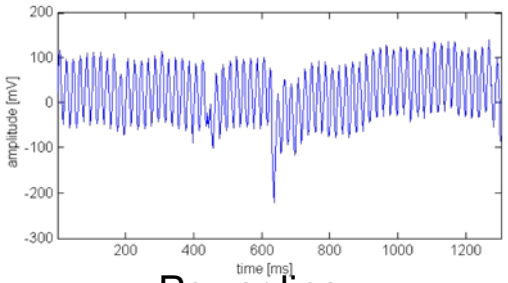


Noisy signal

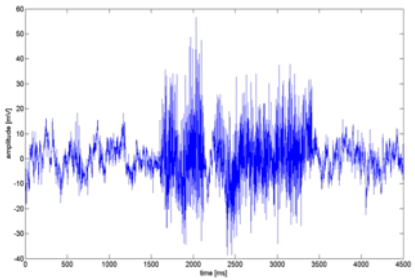




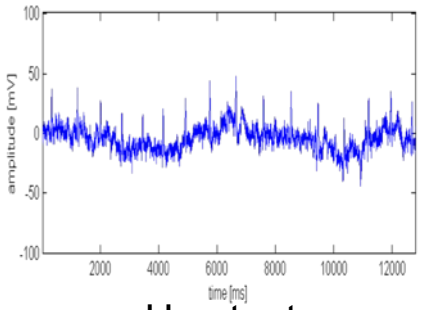
Eye blink



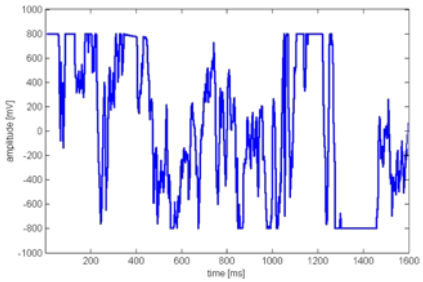
Power line



Jaw clenching



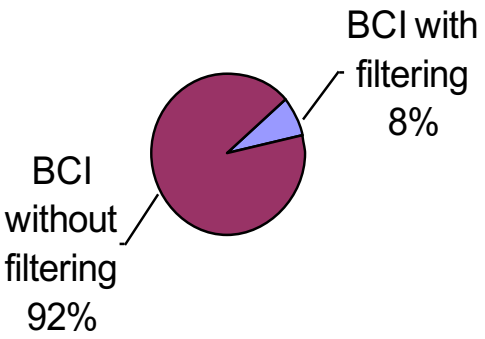
Heart rate

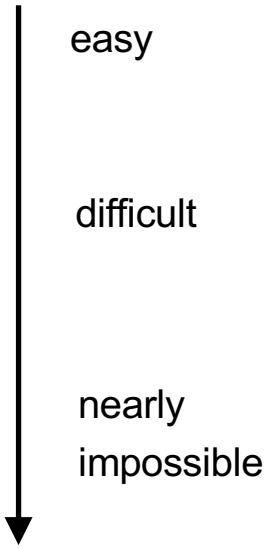


Electrode contact

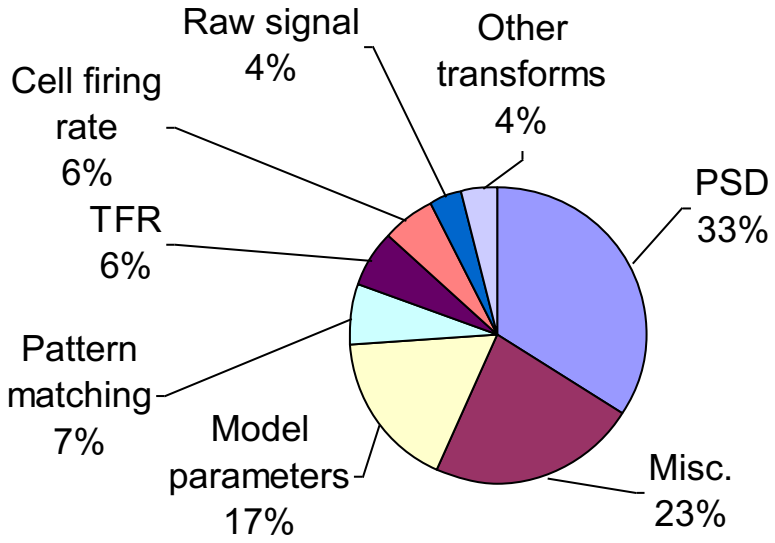
Pre-processing

- Artefact processing
  - Avoid (protocol restriction)
  - Reject
  - Tag
  - Filter
- Artefact filtering
  - Environmental
    - ✓ Power line: notch filter
    - ✓ Electrode contact: histogram outliers
  - Physiological
    - ✓ Heart rate: frequency filtering
    - ✓ Eye-blinks: ICA, PCA, AR models, frequency filtering
  - Background brain activity





Features extraction



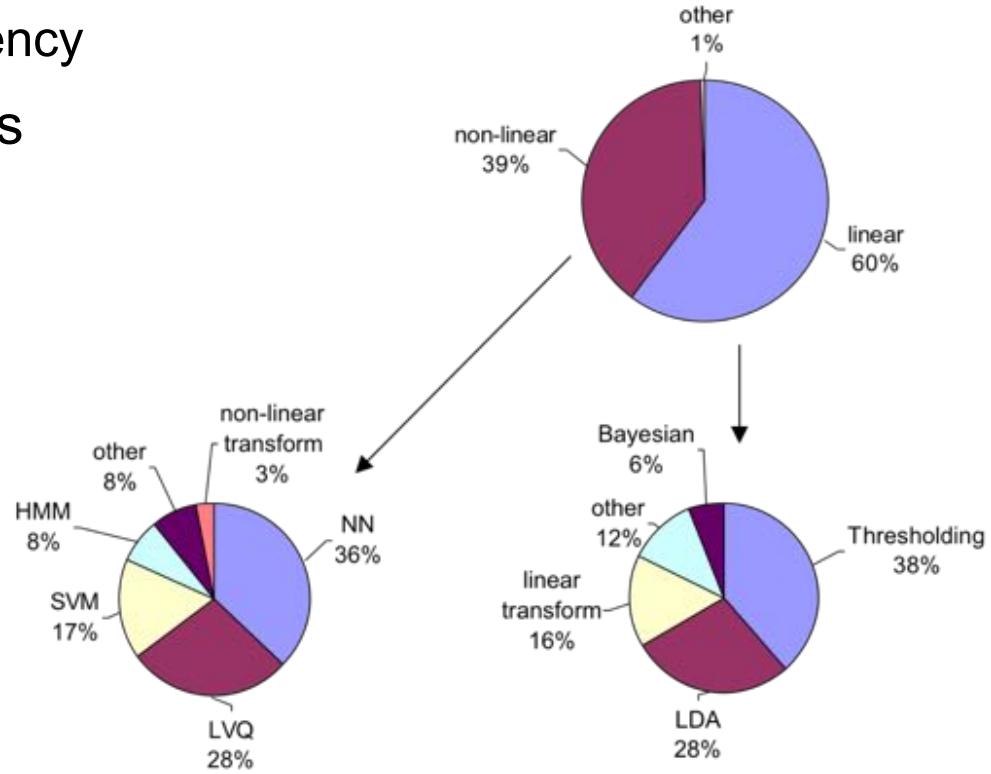
- Feature variability
  - From subject to subject
  - From session to session
- Single vs. multiple trial
- Time/space/frequency features
- Feature selection

Best features (theoretically)

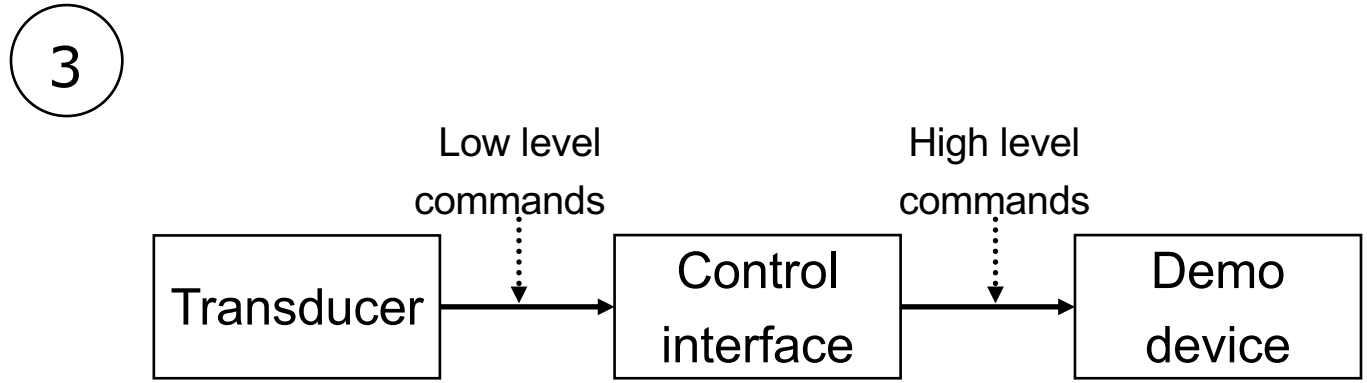
Extraction method	Time	Freq	Space	Examples
Time-Frequency Representation	✔	✔	✔	STFT, wavelet
Neuron firing rate	✔	✔	✔	-
Power Spectral Density	✗	✔	✔	Welch
Pattern matching	✔	✗	✔	Correlation
Raw signal	✔	✗	✔	Amplitude
Model parameters	✔	✗	✔	AR,AAR, Kalman
Other transforms	✔	✗	✔	ICA, PCA

Classification

- High number of training samples required
- "No-free-lunch theorem" (Wolpert)
  - Session, user, task dependency
- Linear vs. non-linear methods

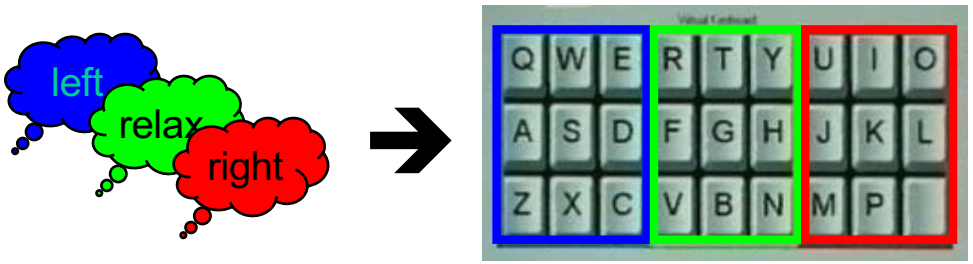


Limited activation periods



Control interface & Feedback

- Control interface =
  experiment protocol sequencer
- Increase the number of commands



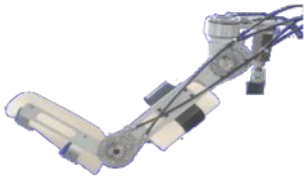
[9]

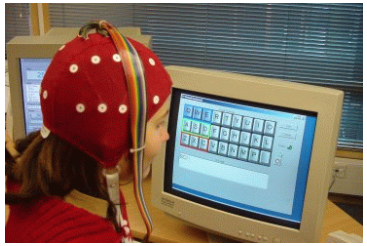
[8]

- Effect of feedback
  - Increases user motification
  - **Can** improve recognition accuracy

Applications

- Applications restricted by BCI performance
- Population: disabled vs. healthy people





[9]

Rehabilitation

Prosthesis/orthesis/FES* control
Virtual keyboard
Pointer device (1D, 2D)
Vehicle control (real or virtual)

Entertainment

Games (2D, 3D)
Multimodal interaction

[10]

- Environment:
  - Currently: inside the laboratory
  - Future: outside the laboratory

* Functional Electrical Stimulation

BCI limitation summary

- Limited vocabulary: summary
  - No thought sensor
  - Highly time and space focused brain activity
  - Limited sensor capacity
  - Vocabulary limited to well known and differentiable mental tasks
    - ✓ ~2-6 tasks in practice*
- Limited rec. accuracy: summary
  - Noise filtering is difficult
  - Feature selection is important
  - No optimal classifier
- Limited activation periods: summary
  - Control interface improves transducer output
  - Feedback improves performance
  - Rehabilitation vs. Entertainment

References

[1] S. G. Mason, A. Bashashati, M. Fatourechi, K. F. Navarro, and G. E. Birch, "A Comprehensive Survey of Brain Interface Technology Designs," *Annals of Biomedical Engineering*, 2007.

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[4] Larousse, “Larousse Médical”, Larousse-Bordas / HER, ISBN 2-03-560209-2, 2000.

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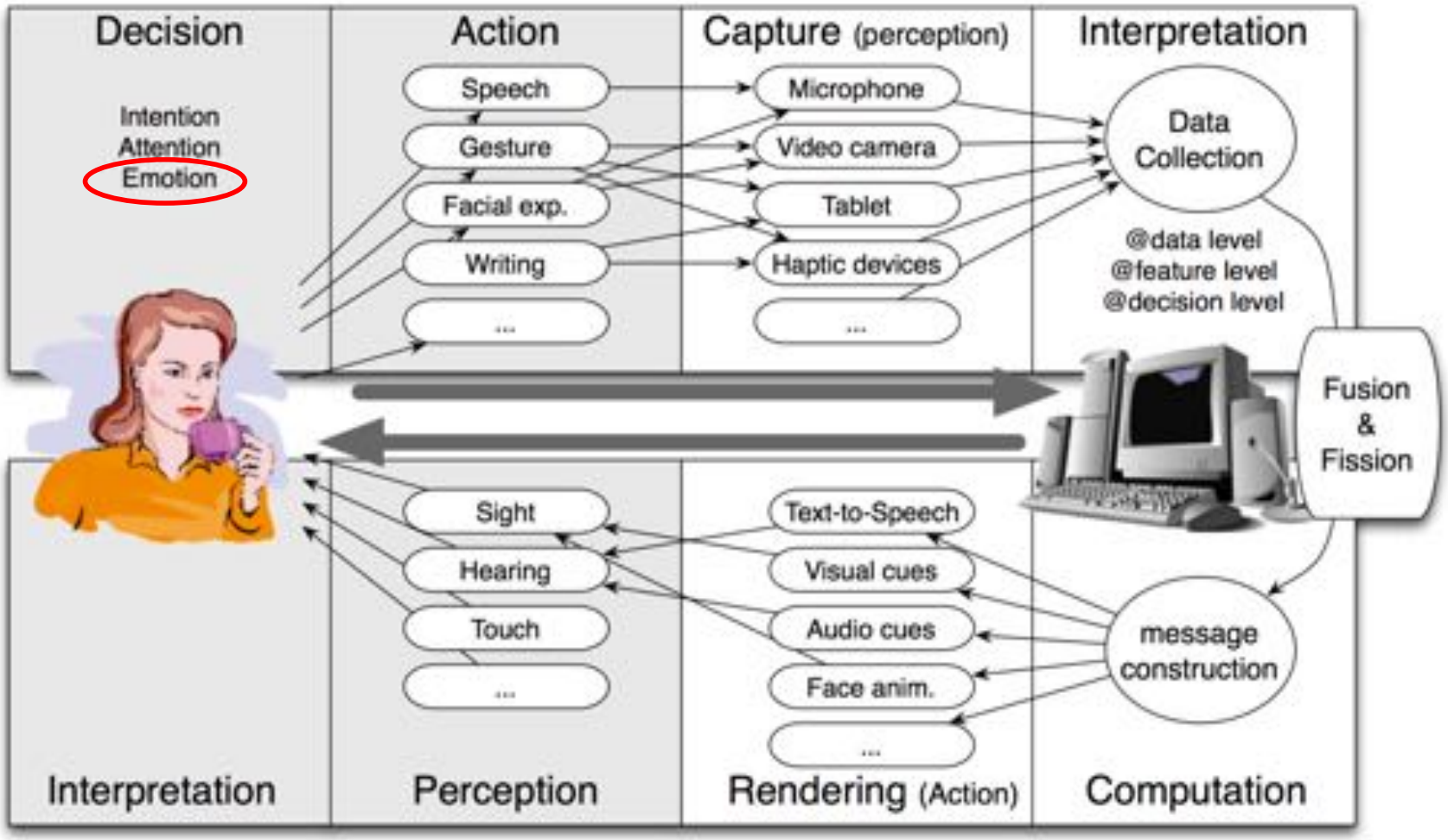
[9] Adaptive Brain Interface web site, 2002. http://sir.jrc.it/abi/

[10] J. D. Bayliss, "A Flexible Brain-Computer Interface," in *Department of Computer Science*, vol. PhD Thesis. Rochester, New York: University of Rochester, 2001.

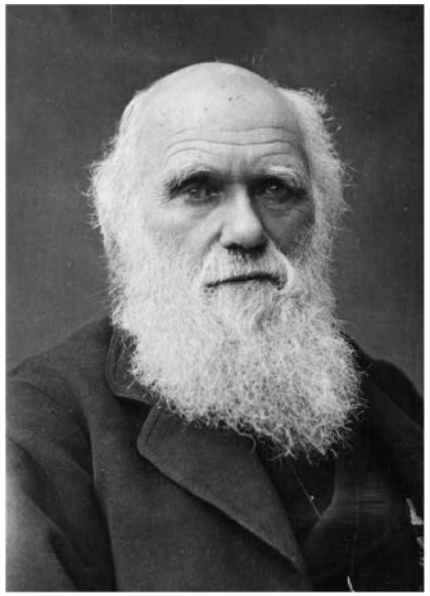
[11] R. Leeb, C. Keinrath, and G. Pfurtscheller, "BCI-based control of Virtual environment (poster)," presented at 3rd int. BCI meeting, 2005.

[9.2] Affective computing

Motivation


Decision
Action
Capture (perception)
Interpretation
Intention
Attention
Emotion
Speech
Gesture
Facial exp.
Writing
...
Microphone
Video camera
Tablet
Haptic devices
...
Data
Collection
@data level
@feature level
@decision level
Fusion
&
Fission
Sight
Hearing
Touch
...
Text-to-Speech
Visual cues
Audio cues
Face anim.
...
message
construction
Interpretation
Perception
Rendering (Action)
Computation

Research on Emotions: History



- Considered as not rational prior
  - not interesting for research
- Charles Darwin
  - "The Expression of the Emotions in Man and Animals" (1872)
- Darwin argued that emotions serve a purpose for humans
  - Communication and survival!
  - Emotions evolved through natural selection
- Following researches focussed on how to overcome emotions, e.g. for fighter pilots
- New wave of research in the 90's
  - new role: a primary communication channel

Emotions in HCI

- *Affective Computing*
  - Allowing the computer to take into account emotions from users
  - to give to machines the ability to express, recognise, synthetize and model emotions (R. Picard)
- *Affective Interaction*
  - Taking into account users emotions when designing user interfaces

- In this lesson, we will specifically focus on affective computing

What Is an Emotion?

- Emotion is a feeling
- Emotion is a state (of physiological arousal)
- A brain process that computes the value of an experience
- A word we assign to certain configuration of bodily states, thoughts, and situational factors

Definition of Emotion

- Definition of an emotion?
  - Not one definition but several ones (evolutionary, cognitive, ...)
- Working definition:
  - *Episodes of coordinated changes in several components (neurophysiological activation, motor expression, subjective feelings, action tendencies and cognitive processes) in response to external or internal events of major significance to the organism*
- External events:
  - Behaviour of others, a change in a current situation, an encounter with novel stimuli
- Internal events:
  - Thoughts, memories, sensations...

Why Study Emotions in HCI?

- Recognise them
  - Give labelled data to machine learning algorithms
  - … But what are the labels?
    - ✓ Basic emotions (Joy, Hope, Fear, ...)
    - ✓ Several categories proposed
- Predict their influence on other behaviours
  - Influence of emotion on
    - ✓ beliefs, desires, intentions, actions
    - ✓ long-term health, social interaction, collaboration
- Control them
  - Alleviate user's frustration or increase motivation
  - Self-awareness

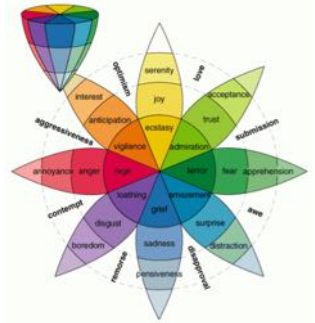
Not Every Affect Is an Emotion

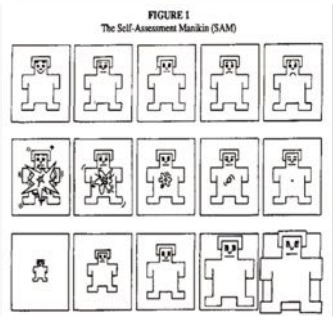
Design Features / Types of Affect	Intensity	Duration	Synchro-nization	Event focus	Appraisal elicitation	Rapidity of change	Behavior impact
Emotions: *angry, sad, joyful, fearful, ashamed, proud, elated, desperate*	●	•	●	●	●	●	●
Moods: *cheerful, gloomy, irritable, listless, depressed, buoyant*	●	●	•	•	•	●	•
Interpersonal stances: *distant, cold, warm, supportive, contemptuous*	●	●	•	●	•	●	●
Preferences/Attitudes: *liking, loving, hating, valuing, desiring*	●	●	•	•	•	•	●
Affect dispositions: *nervous, anxious, reckless, morose, hostile*	•	●	•	•	•	•	●

Scherer, Klaus R., Tanja Bänziger, and Etienne Roesch, eds. *A Blueprint for Affective Computing: A sourcebook and manual*. Oxford University Press, 2010.

Models of Emotions

- Goal of all models: emotions classification
- Two different point of views in models:
  - Emotions are discrete and different constructs
  - Emotions are characterized by dimensional values
- Presentation of 4 models used in HCI
  - Discrete models:
    - ✓ Ekman's model
  - Dimensional models:
    - ✓ Russell's model
    - ✓ Plutchik's model
    - ✓ PAD emotional state model





Ekman's Emotions Model

sadness

happiness

anger

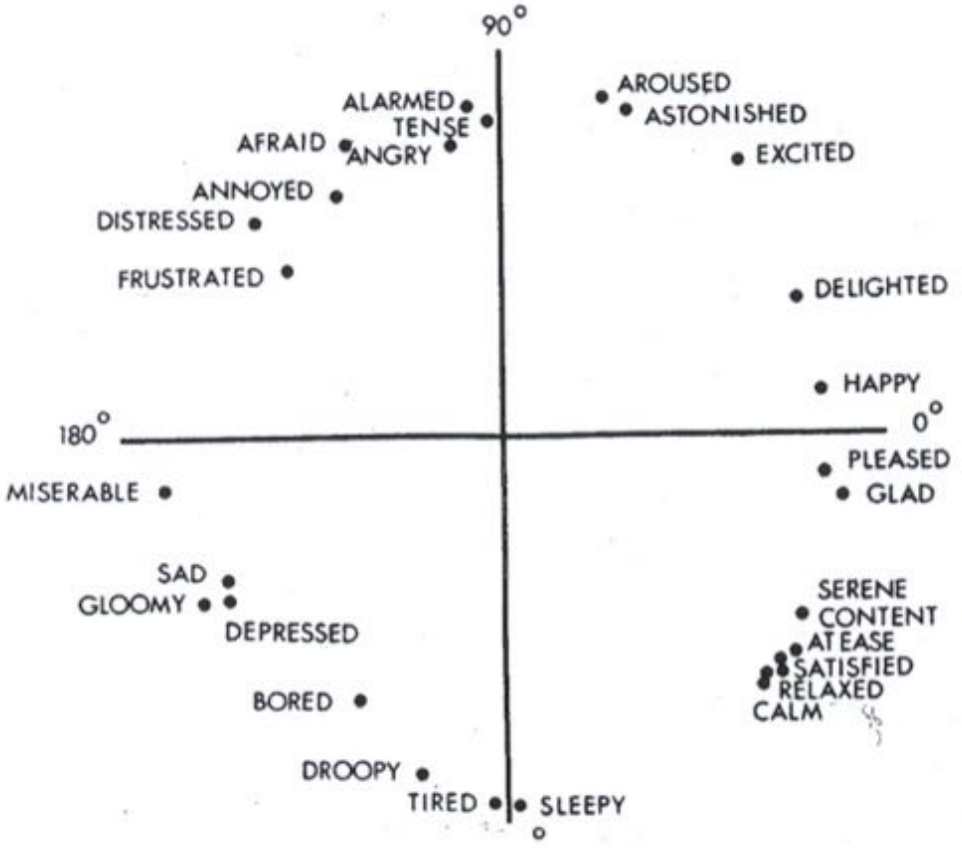
fear

disgust

surprise

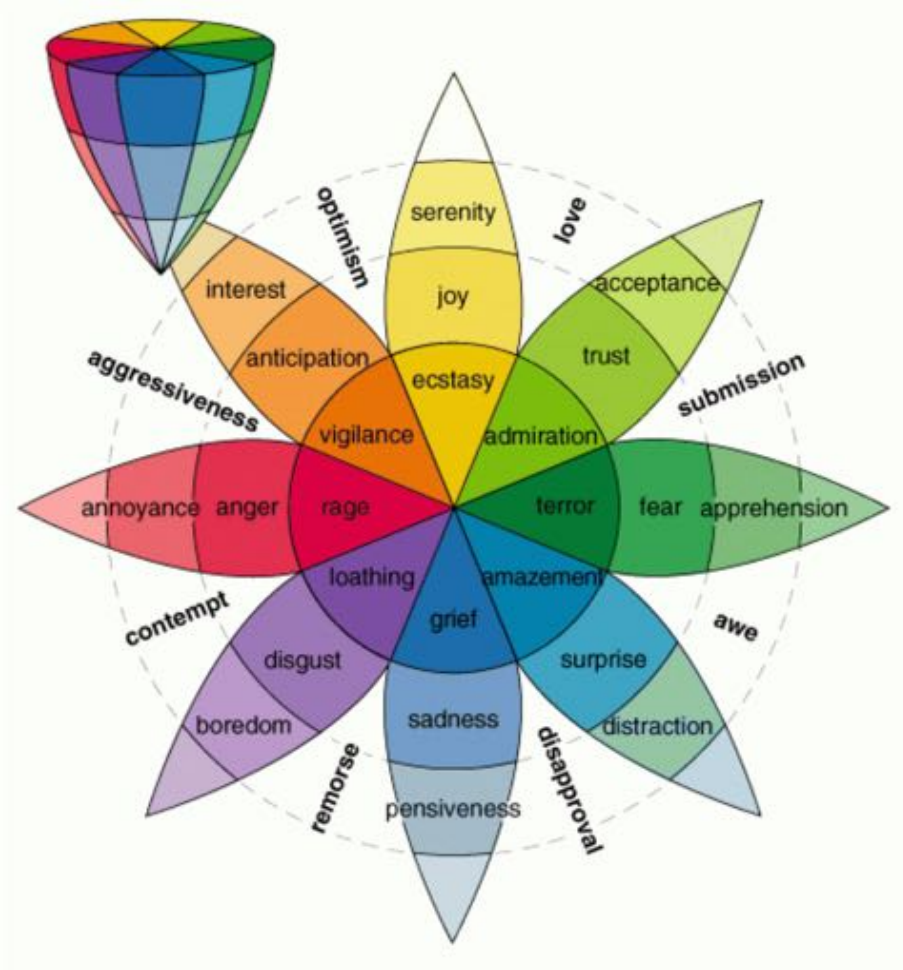
Russell's Circumplex Model of Emotions

- Dimensional Model
- Emotions are mapped on two dimensions
- X axis: valence
  - Intrinsic attractiveness or aversiveness
- Y axis: arousal
  - How much you are reactive to a stimuli



Pulchik's Dimensional Model of Emotions

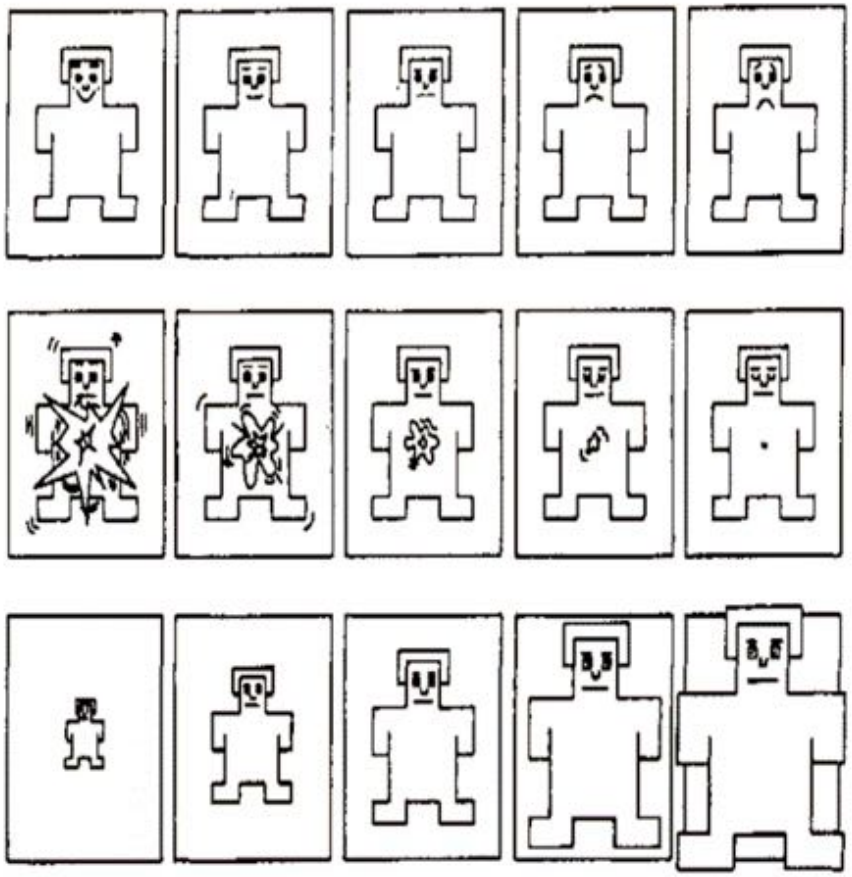
- Extension of Russell's circumplex model
- Pairs of opposite emotions
  - Joy versus sadness
  - Trust versus disgust
  - Fear versus anger
  - Anticipation versus surprise
- Concentric circles
  - Inner circles are "basic" emotions
  - Outer circles are more complex emotions
  - "blend" of basic emotions in the outer circles



PAD Dimensional Model of Emotions

- *Pleasure*, *Arousal*, *Dominance*
- Characterisation of emotional states through three numerical dimensions/scales:
  - *Pleasure-Displeasure*
  - *Arousal-Nonarousal*
  - *Dominance-Submissiveness*
- Example: anger is a quite unpleasant, quite aroused, and moderately dominant emotion

FIGURE 1
The Self-Assessment Manikin (SAM)



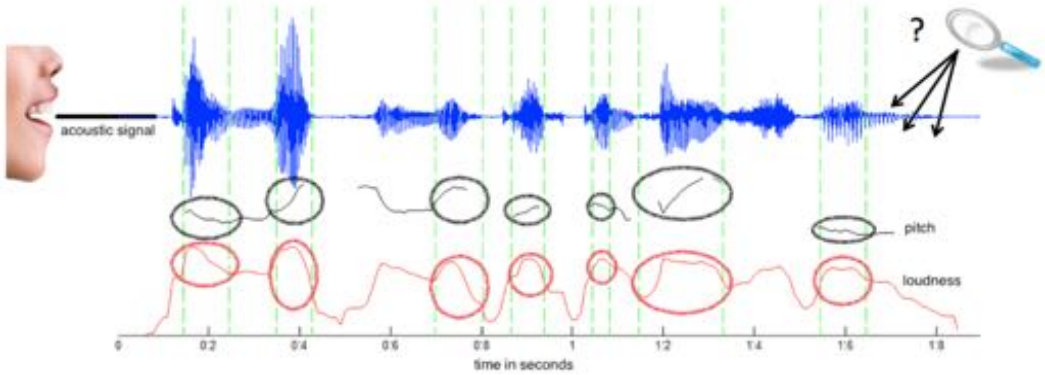
Emotions Recognition

- Emotions can manifest through very different modalities
  - Voice pitch, intonation, etc.
  - Verbal content (speech)
  - Face visual features
  - Body pose and gestures
  - Bio signals
- Artificial intelligence algorithms are in general needed for accurate recognition of emotions
- Multiple modalities -> potential for multimodal fusion
  - In this case, the role of multimodal fusion is to strengthen the accuracy of emotions recognition through the observation of multiple modalities

Recola multimodal affective database:
http://diuf.unifr.ch/diva/recola/index.html

Rec. Emotions from sound features

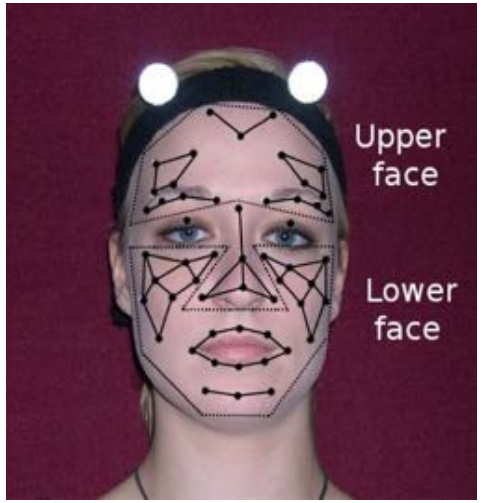
- Acoustic features are not meaningful for emotions, but rather their behaviour and evolution over time, e.g.:
  - Intonation
  - Intensity
  - Pitch
  - Duration

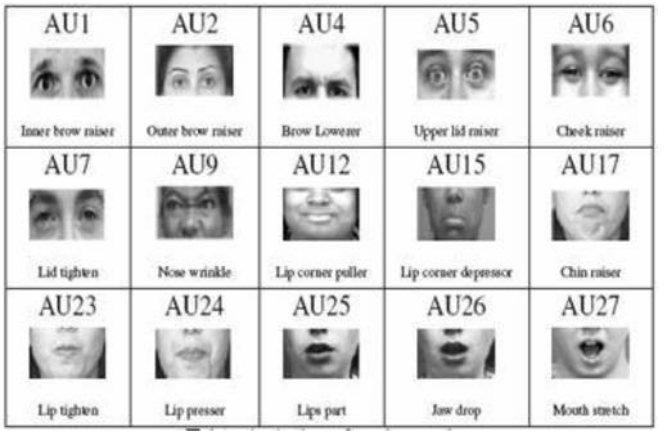


- Using speech content (e.g. speech recogniser), e.g. features :
  - Emotion dictionaries
  - Orthography (punctuation, capitalization, emoticons)
  - Wordnet
  - Syntax
  - Semantic roles
  - World knowledge

Recognising Emotions from the Face

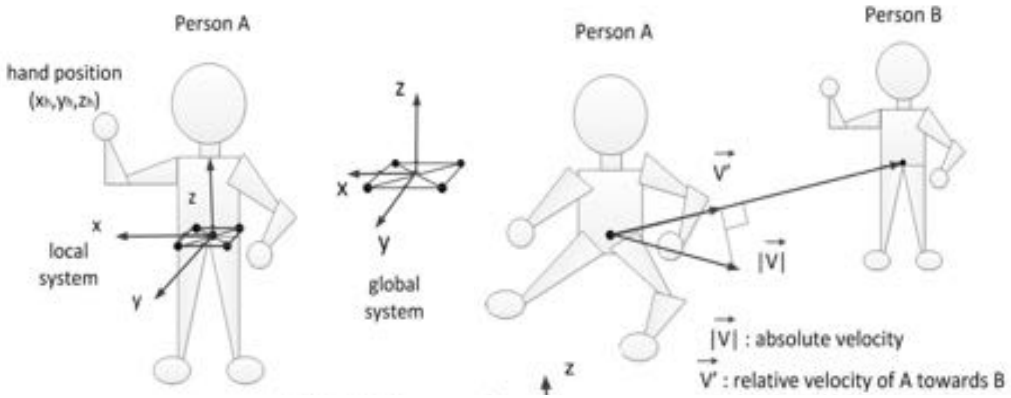
- Finding face parts
  - Using orientation, or prominent features such as the eyes/nose
  - Eigenfaces
- Extract Facial Features
  - Geometry-based, texture-based
- Classification through SVM, NN, Fuzzy logic systems, etc.
- Facial Action Coding System
  - Ekman and Friesen in 1978
  - Codes expressions from static or dynamic pictures
  - Combination of AU (action Unit) -> facial expressions
  - http://www.cs.cmu.edu/~face/facs.htm





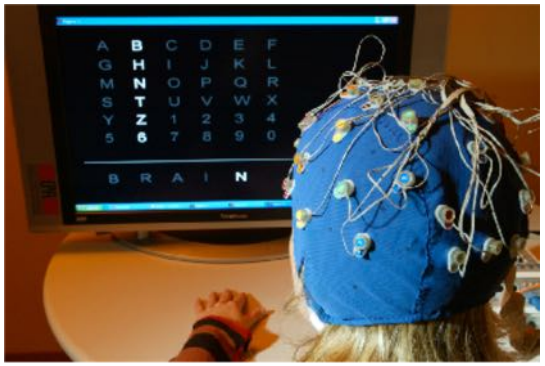
Body Expressions

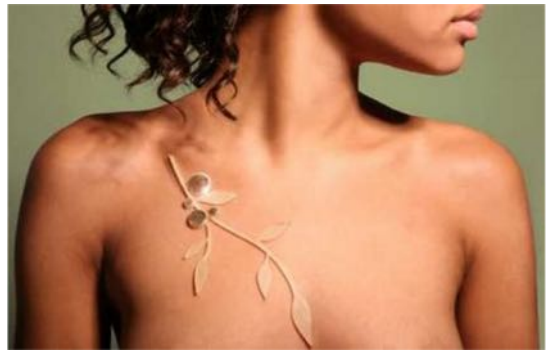
- Body language expresses rich emotional information
  - Body movement, gestures and posture
  - Behavior, e.g., approach/avoidance, looking/turning away, touching



Recognising Emotions from Bio Signals

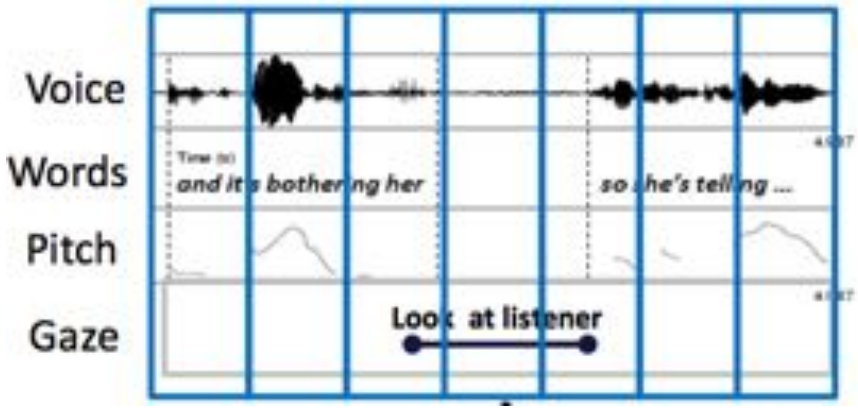
- Different emotional expressions produce different changes:
  - Anger: increased heart rate and skin temperature
  - Fear: increased heart rate, decreased skin temperature
  - Happiness: decreased heart rate, no change in skin temperature
- Pros: hard to control deliberately, continuously processed
- Cons: Intrusive – user equipped with sensors
- Challenges:
  - Creating biosensors in wearable forms
  - Every-day situations
  - Subtle and blended emotions
  - Contextual factors





Fusion for Emotion Recognition

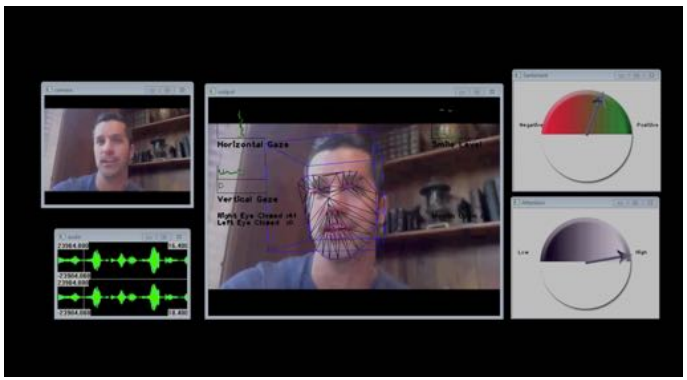
- 5 channels <-> emotional descriptors:
  - A machine learning problem



- Challenges:
  - different time scales for analysis
    - ✓ Face = still pictures
    - ✓ Voice = discrete chunks on time scale
    - ✓ Bio signals = slow, continuous variation over time
- Fusion in multimodal systems apply, with some particularities
- Feature level fusion, mostly
  - … as the modalities are closely coupled

Training Data for Emotion Recognition

- To train an emotion recognition system, training data has to be collected
- How do you make sure to have “valid” data?
  - Acted emotions: relatively easy to gather, but are they really representative?
  - Emotions collected from existing recordings: might take a long time to collect comprehensive data
  - Real-life emotions: how do you generate the emotion in the user?
- Annotate web video using Amazon’s Mechanical Turk

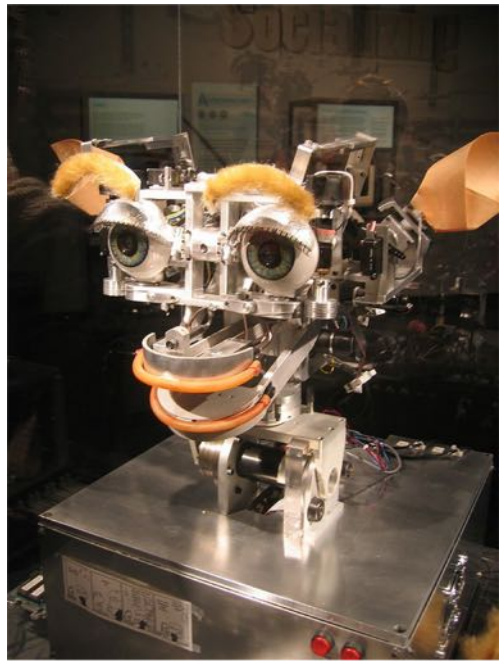


Louis-Philippe Morency, Rada Mihalcea, and Payal Doshi. 2011. Towards multimodal sentiment analysis: harvesting opinions from the web. In Proceedings of the 13th international conference on multimodal interfaces (ICMI '11). ACM, New York, NY, USA, 169-176.

Synthesis of Emotions

- Intelligent agent that supports social interactions with human users
  - In virtual reality (virtual agents)
  - In real life (robots)
- "*Characters with a brain*"
  - Reason about environment
  - Understand and express emotion
  - Communicate through speech & gesture

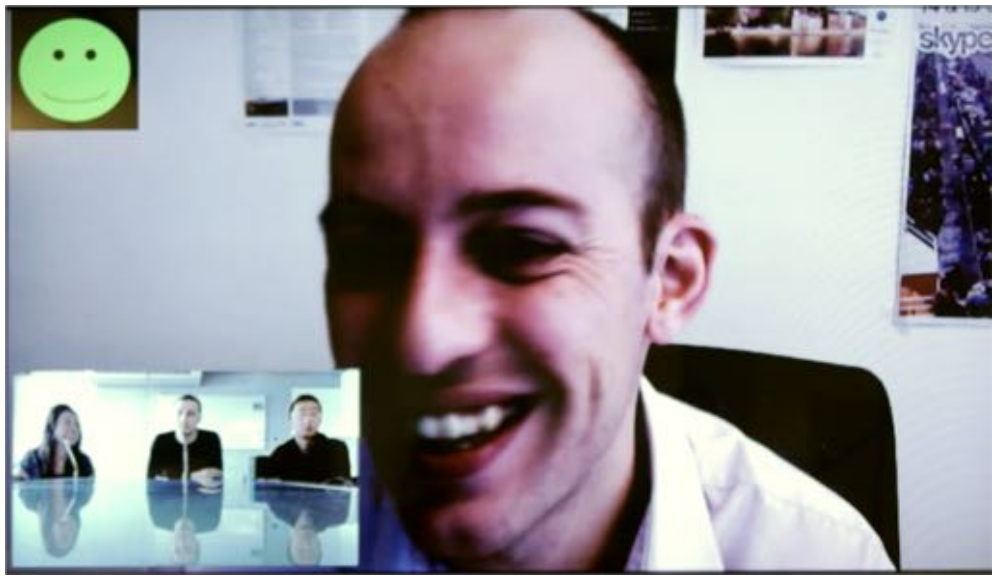
COMPAGNIE BLANCA LI, Vaison la romaine, 18.07.2014

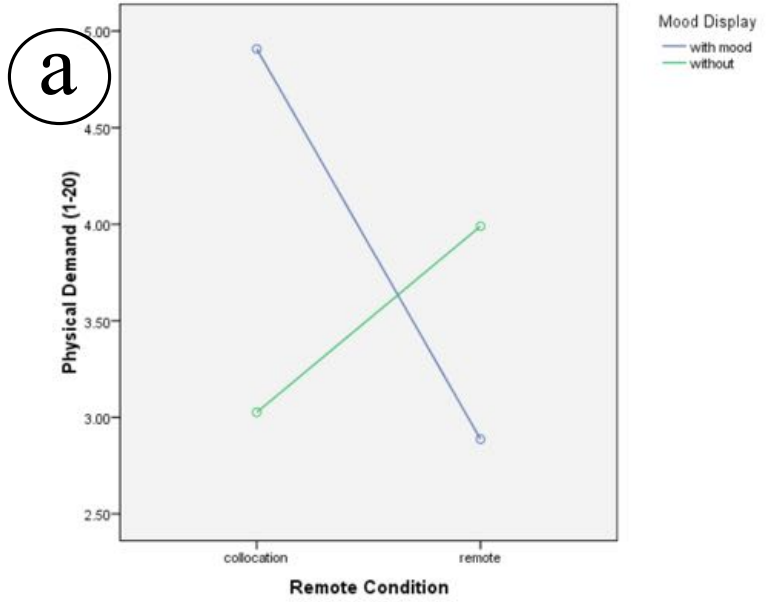


Kismet (MIT late 90's)

Effects of Agents Emotions on People

- People influenced by partner's expressions
  - E.g. Smiling yields cooperation in Trust Games





The Emotiboard: video on http://human-ist.unifr.ch

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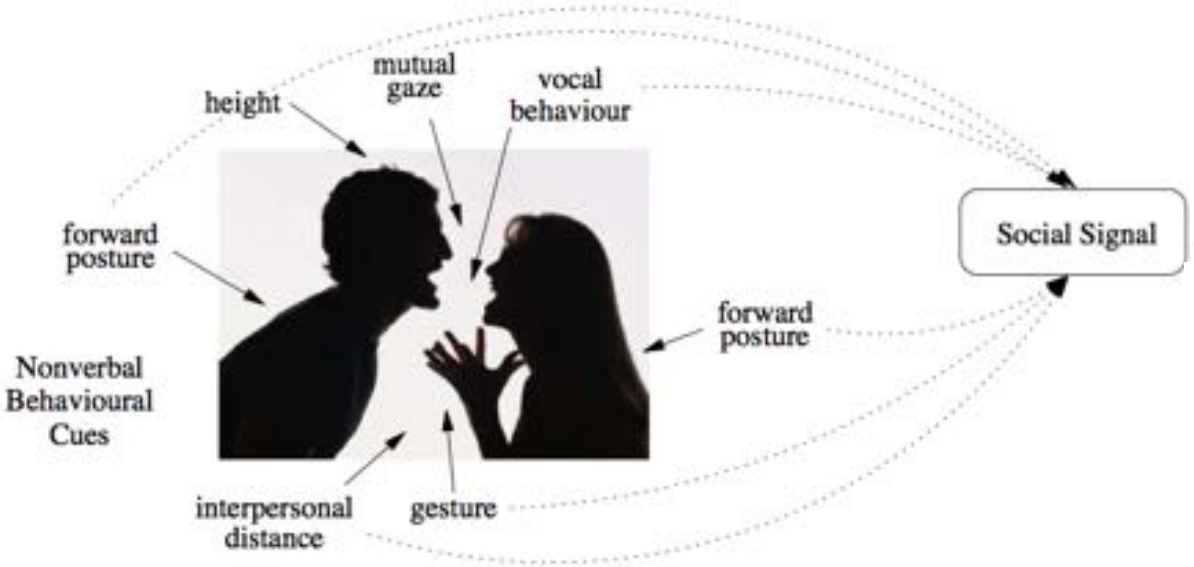
Sensors

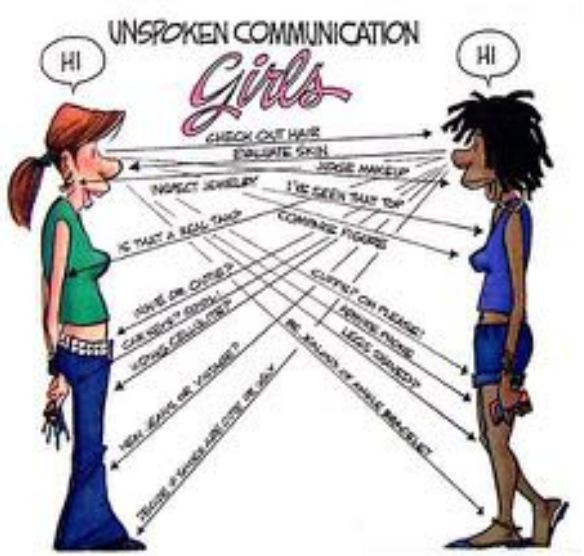
- Emotiv EPOC Neuroheadset
  - (Relatively) non invasive
  - 14 sensors
  - Integrated gyroscope
  - Wireless
  - (Relatively) low cost
  - However…
    - ✓ Sensor sensibility is average (mainly due to sensor non-invasiveness)
  - New model in 2014: Emotiv Insight
- Affectiva
  - Q sensor
  - electrodermal activity (EDA)
  - temperature and movement
  - bluetooth

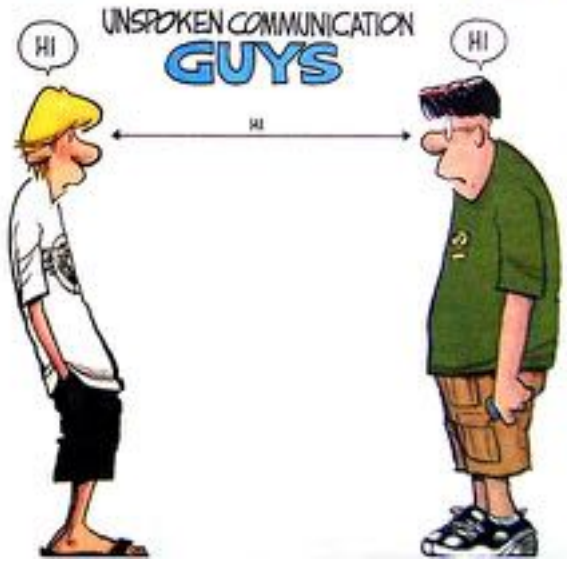
Frameworks and Librairies

- EmoVoice
  - Real-time recognition of emotions from acoustic properties of speech
  - Uses features from pitch, energy, MFCCs, duration, voice quality and spectral information
  - Uses the Open Sound Control (OSC) protocol
  - http://www.informatik.uni-augsburg.de/lehrstuehle/hcm/projects/tools/emovoice/
- open EAR using speech
  - http://openaudio.eu
- The CALLAS Framework
  - Multimodal, for artists
  - http://www.callas-newmedia.eu

Social Signal Processing







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What you should know

- Brain computer interaction (BCI)
  - Explain challenges, advantages, and drawbacks of BCI
  - General schema of a typical BCI system
  - Describe the different types of mental tasks
    - ✓ Endogenous, Exogenous, Modulated response
  - Explain the physiological problems & proposed solutions
    - ✓ Limited vocabulary, limited recognition, limited activation/usage periods
- Affective computing
  - Describe what is considered an emotion; give a definition.
  - Explain different models of emotions (discrete and dimensional).
  - Which channels can be used to recognise emotions?
  - Describe the synthesis of emotions, its goals and challenges.
  - Which channels can be used to synthesise emotions?
  - Why is affective computing interesting for HCI? Examples.