

Biosignals as an Advanced Man-Machine Interface

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Position of this presentation

- The paper concerns the classification of biosignals.
- This presentation is complementary to it
 - background
 - examples
 - data gathering
- More info on processing the biosignals?
 - Biosignals 2009: next Saturday, Parallel session 10

Outline

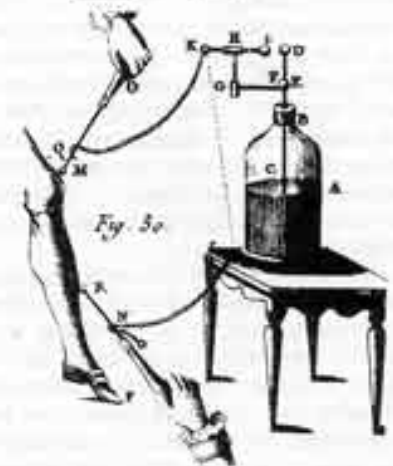
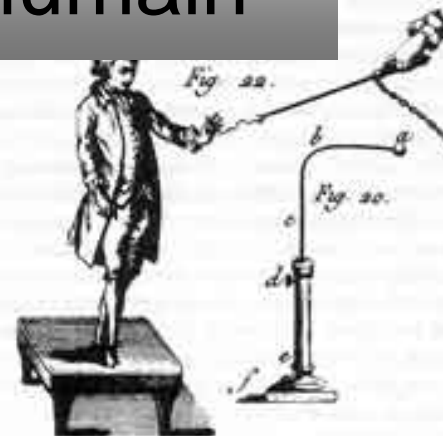
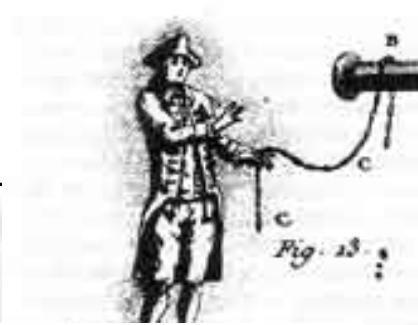
Envisioning the not so far future of consumer products

1. General introduction: emotions for Man-Machine Interfaces
2. Research on biosignals revealing emotions
3. Classification of biosignals that express emotions

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General introduction

Bertholon, 1786. De L'electrice du corps humain



That men are machines (whatever else they may be) has long been suspected; but not till our generation have men fairly felt in concrete just what wonderful psycho-neuro-physical mechanisms they are.*

William James (1842 - 1910)

* James, W. (1893). Review: La pathologie des emotions by Ch. Fere. *The Philosophical Review*, 2(3):333-336.

Why biosignals?

- and not ...
 - Facial expressions through computer vision
 - Speech
 - Brain imaging techniques
- 1. Hard to manipulate / no social masking!
- 2. Relatively good signal-to-noise ratio
- 3. Getting less and less obtrusive

Table 1: An overview of common physiological signals and features used in ASP.

Physiology (source)	Features	Unit	Remark
Cardiovascular activity through ECG or BVP (Berntson et al., 1997)	Heart rate (HR)	beats / min	
	SD IBIs	s	HRV index
	RMSSD IBIs	s	HRV index
	LF power (0.05Hz - 0.15Hz)	ms^2	Sympathetic activity
	HF power (0.15Hz - 0.40Hz)	ms^2	Parasympathetic activity
	VLF power (< 0.05Hz)	ms^2	
	LF/HF		
Electrodermal Activity (EDA) (Boucsein, 1992)	Pulse Transit Time (PTT)	ms	
	Mean, SD SCL	μS	Tonic Sympathetic Activity
	Nr of SCRs		Rate Phasic Activity
	SCR amplitude	μS	Phasic Activity
	SCR 1/2 recovery time	s	
Skin temperature (ST)	SCR rise time	s	
	Mean, SD temp	$^{\circ}C$	
Respiration (Grossman and Taylor, 2007)	Respiration rate		
	Amplitude Resps		
Muscle activity through EMG (Reaz et al., 2006) (Westerink et al., 2008b)	Mean, SD corrugator supercilii	μV	Frowning
	Mean, SD zygomaticus major	μV	Smiling
	Mean, SD upper trapezius	μV	
	Mean, SD inter-blink interval	ms	

Notes. SD: Standard deviation; RMSSD: Root Mean Sum of Square Differences; IBI: Inter-beat interval; LF: Low frequency; HF: High frequency; VLF: Very Low Frequency; SCL: Skin Conductance Level; SCR: Skin Conductance Response; ECG: Electrocardiogram; EMG: Electromyogram; BVP: Blood volume pulse.

Complexity of biosignals

- Intrapersonal differences
 - Short term
 - Long term
- Interpersonal differences
 - Physiological
 - Personality traits
 - Communicating
- Humans are holistic systems
- Humans live in a dynamic world

In practice this is, for example, illustrated through ...



January 14, 2009

THE
PSYCHOLOGICAL BULLETIN

VARIABILITY OF REACTION-TIME.

BY ROBERT M. VERKES,

Harvard University.

In an examination of the literature on reaction-time, for the purpose of discovering the relation of average reaction-time to variability, and of both to the quality and intensity of the stimulus and the other conditions which determine the time and constancy of reaction, I have been surprised to find that little attention has been given by most investigators to the variability of their results. The early investigations in this field were made, it would appear, for the sole purpose of determining the absolute time of certain mental processes. And this is not strange in view of the fact that until the astronomers proved the existence of the 'personal equation' mental processes were thought to be too quick for measurement. Psychologists therefore came to problems of the time relations of mental processes with special interest in the duration of the psychic state, and practically no interest in the constancy of reactions. An historical survey shows that investigators were content, early in the development of this line of work, with the presentation of the average reaction-times of their series; no mention was made usually of the range of variability, or of the constancy of the reactions. Somewhat later it became the custom to state the extremes between which a series of reaction-times varied, the range; and it is now common to find the average deviation of results, as well as the average reaction-time, in papers on this subject. In only one paper, that of Jenkins and Carlson on the



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Most recently ...

“Computational complexity and intractability may help scientists better understand how humans process information and make decisions.” *

So, humans invented the computer and its processes, which helps them to understand themselves ...!?

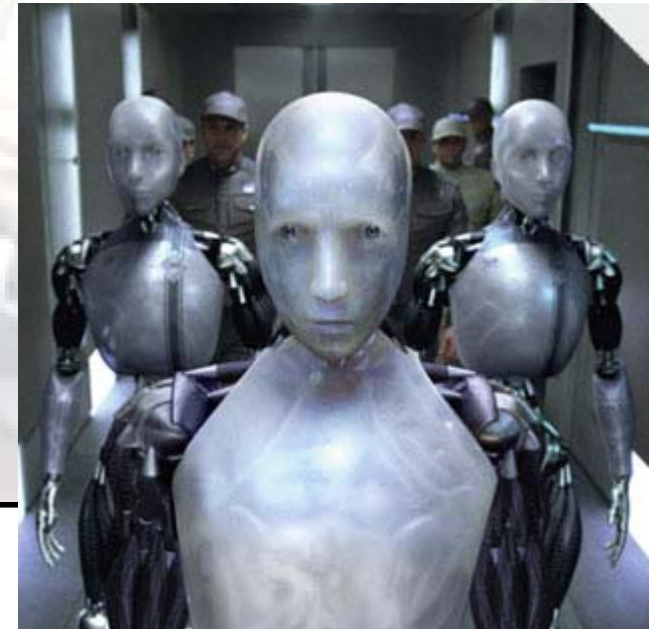
* Lindley, D. (2008). The limits of computability. *Communications of the ACM*, 51(11): 17-19.

Biosignals to detect emotions

- Man-Machine Interfaces (MMI)
 - Adaptive interfaces, adaptive automation
 - Ambient Intelligence (Aml)
 - Gaming
 - Empathic consumer products

can also be applied for:

- Health and cognition
 - e.g., telemedicine
- Man-Man interaction / communication
 - Increasing awareness of yourself and others
- To develop 'true' Artificial Intelligence
 - e.g., robotics, agents



Health and Cognition

*“Positive affect systematically influences performance on many cognitive tasks.”**

* Ashby, Isen, & Turken (1999)

They continue with ...

“(...) influences of positive affect on olfaction, the consolidation of long-term (i.e., episodic) memories, working memory, and creative problem solving. For example, (...) creative problem solving is improved, in part, because increased dopamine release in the anterior cingulate improves cognitive flexibility and facilitates the selection of cognitive perspective.”

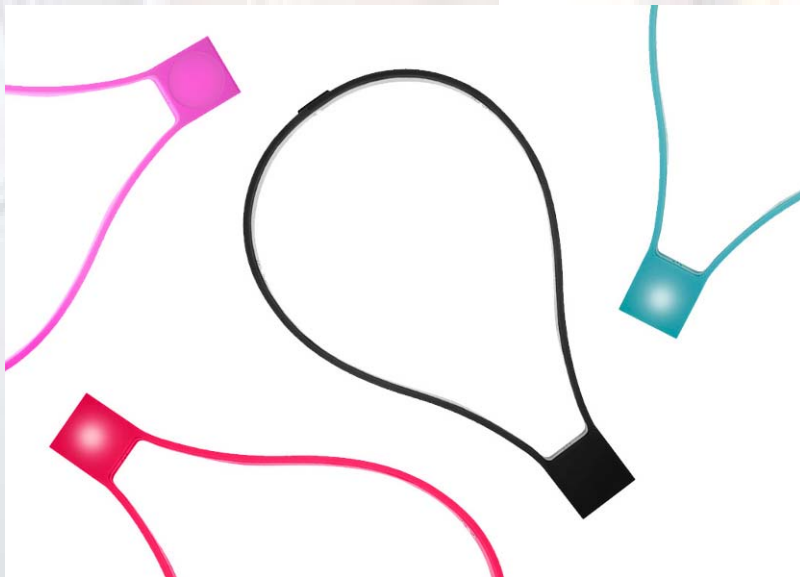
On the other hand ... negative affect causes:

- damage to the cardiovascular system (Matthews & Stoney, 1988; Schuler & O'Brien, 1997)
- lowering cognitive functioning
- lowering social functioning
- lowering subjective well-being

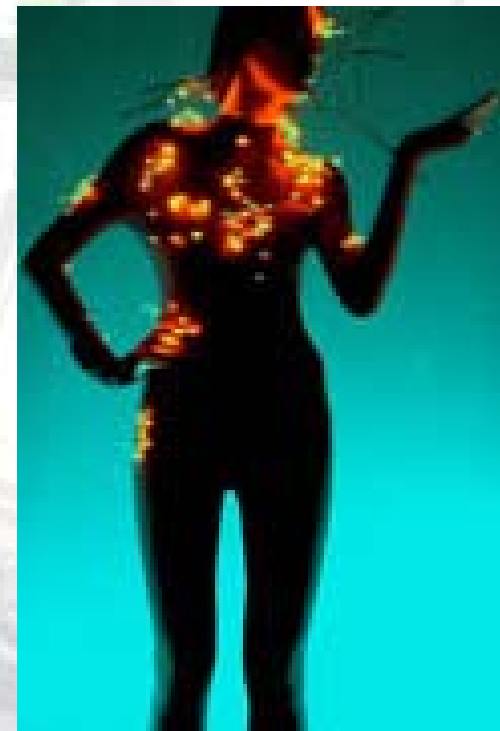
Man-Man Interaction / Communication

- It is said that our language distinct us from other species, that it makes us *superior* ...
- Nonverbal behavior gives away more than 60% of the message
- But how well do we know our communication?
 - The progress with computer vision, speech recognition, and hand writing recognition is limited
 - Moreover, emotions are still often ignored. Although it is well known that, for example, subtle advances at work improve the productivity.

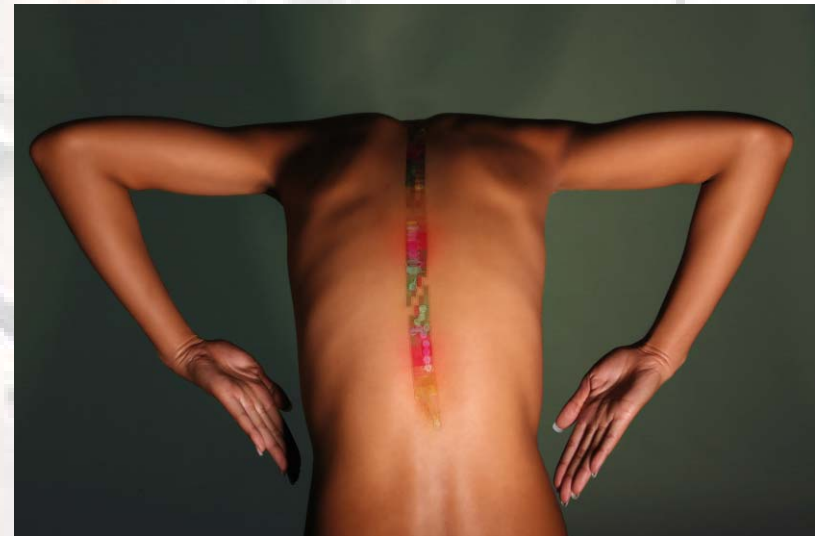
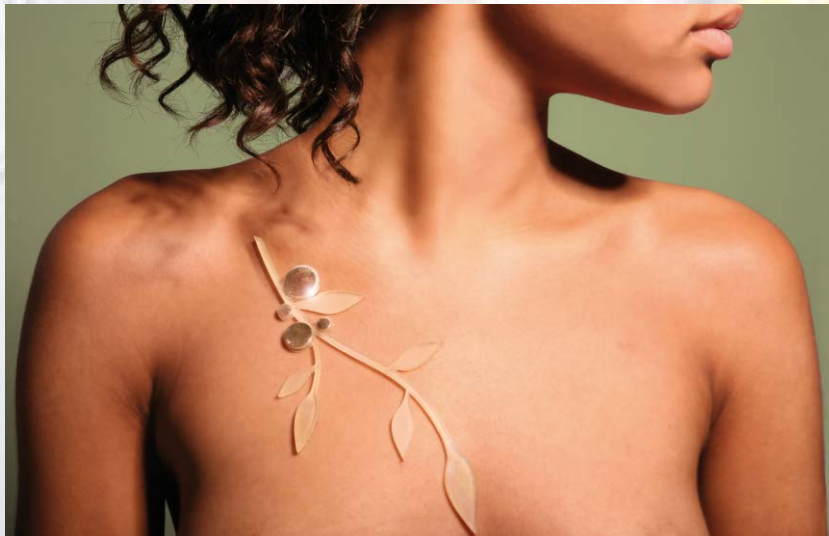
A new era of communication: Emotion sensor (Philips Design)



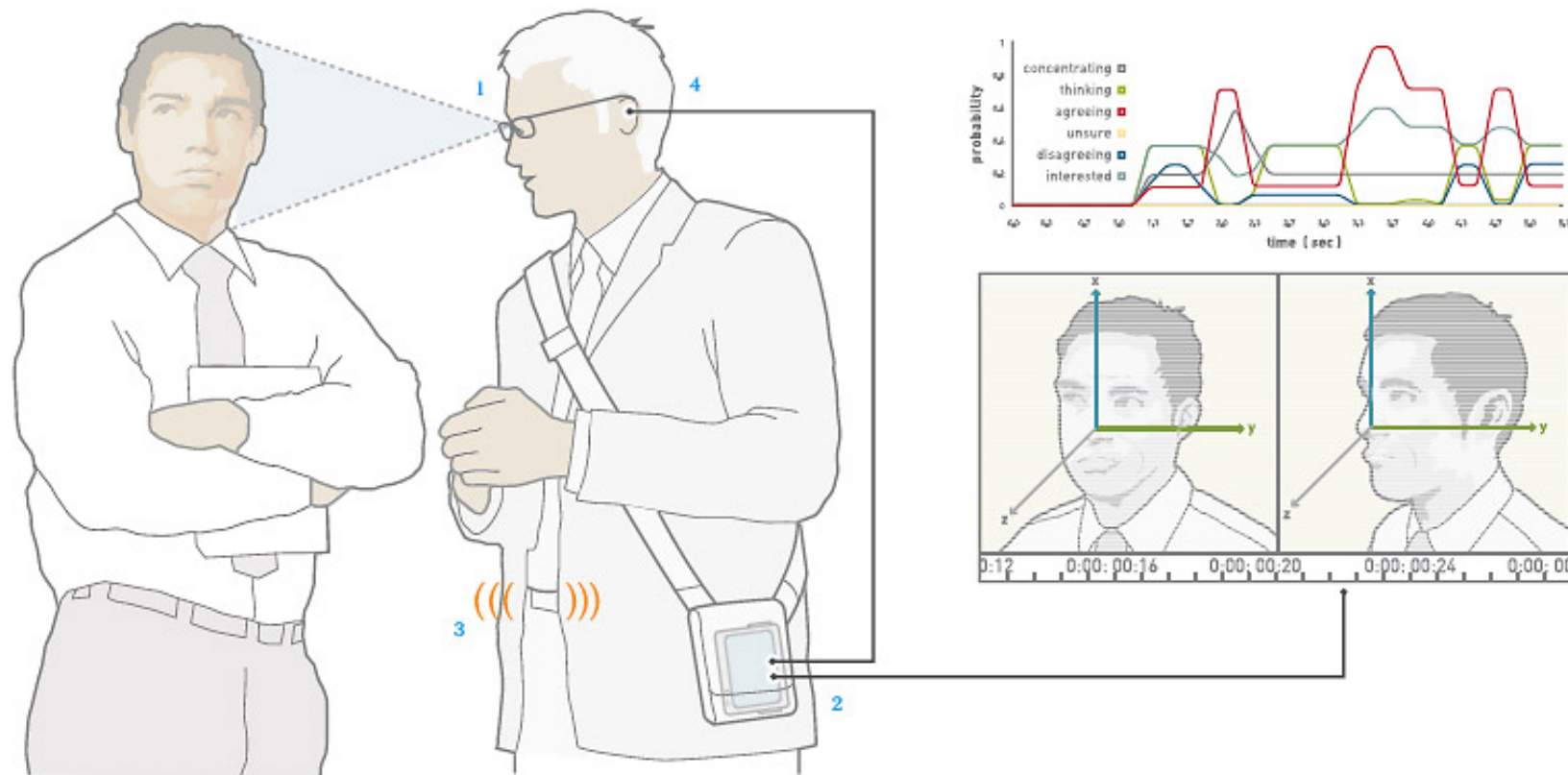
A new era of communication: Empathic clothes (Philips Design)



A new era of communication: Empathic jewelry (Philips Design)



A social cue reader

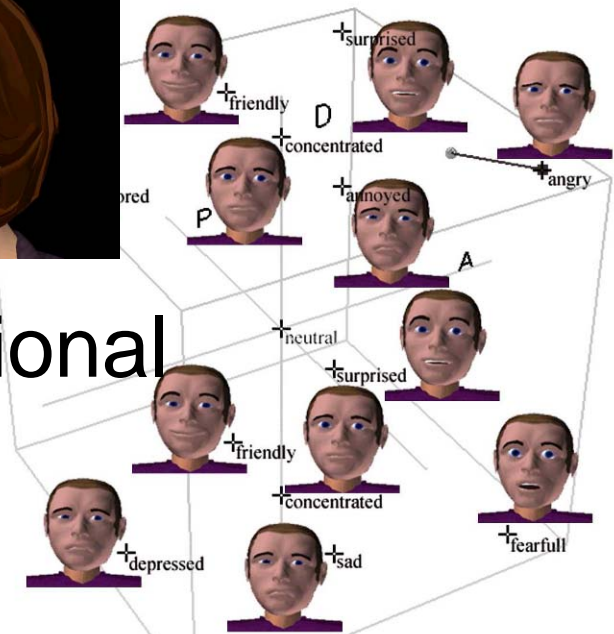


THE SOCIAL-CUE READER ILLUSTRATION BY +ISM

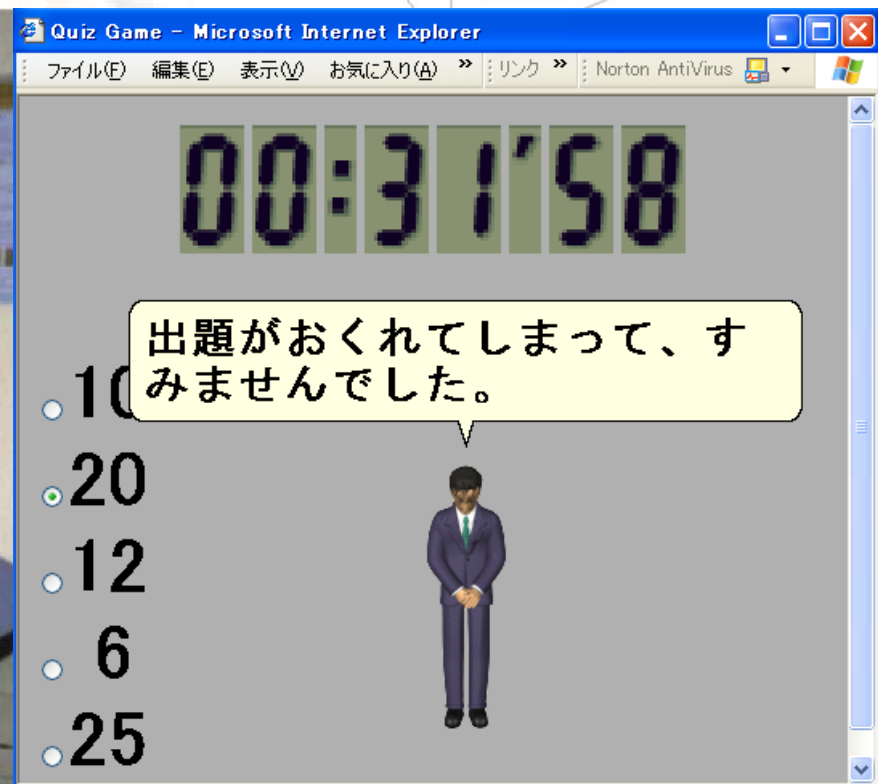
- 1 A small camera monitors the person you're talking to.
- 2 A computer processes the image.
- 3 A vibrator alerts the user to behavioral cues.
- 4 A voice indicates signs of irritation.

Towards true Artificial Intelligence (AI)!?

- Minsky (1985) stated: “*The question is not whether intelligent machines can have any emotions, but whether machines can be intelligent without emotions*” (p. 163)
- Subsequently, both
 - Picard (1997): Affective Computing.
 - Minsky (2006): The Emotion Machine.stress the importance of Minsky’s 1985 claim in their books.



Empathic / embodied / conversational interfaces and agents

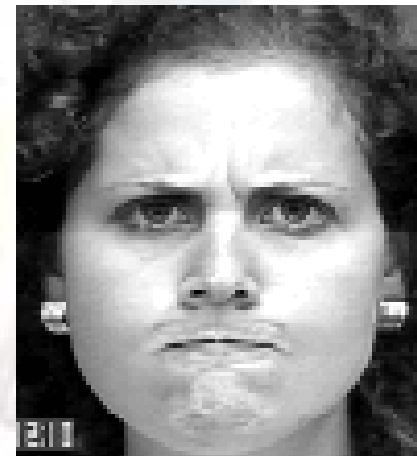


Ultimate MMI uses ... empathy

- *“The action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another of either the past or present without having the feelings, thoughts, and experience fully communicated in an objectively explicit manner.”* (source: <http://www.merriam-webster.com/>)
- How do we do that?
 - context
 - message
 - (background) knowledge
 - biosignals
 - Consciously observed
 - Unconsciously observed
 - other signals ...

Who has empathic abilities?

- humans
 - Visionairs / “sensing people”!?
- mammals
 - monkeys
 - Your own pet:
 - Dog/cat
 - Goldfish?
- Insects?
- Etc.

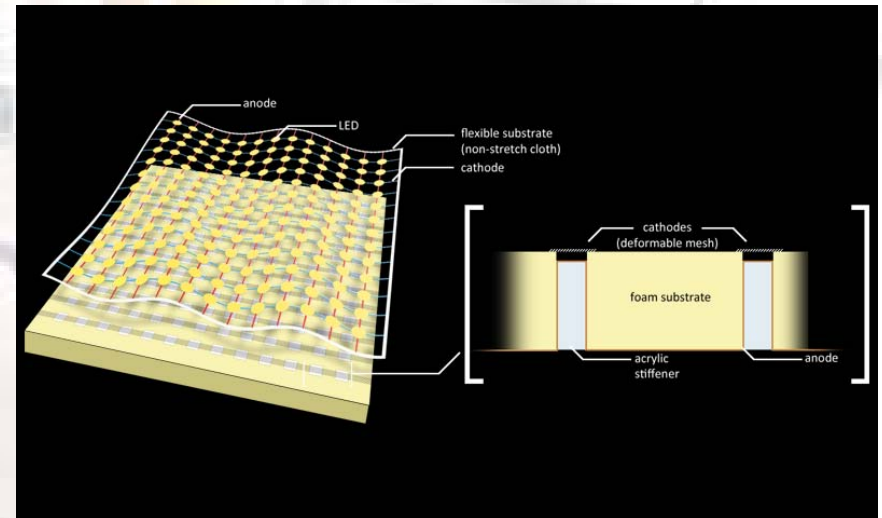


Traditionally



As in the future ...!?

MIT's Relational pillow



Swedish Inst. of CS & Microsoft Research

As in the future ...!?
Affective diary
project



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As in the future ...!?
Next generation Ambilight TV ...



As in the future ...!?

Probes of Philips Design

<http://www.design.philips.com/probes/projects/tattoo/>





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Research on biosignals revealing emotions

The horror of ... lab research



Unobtrusive biosignal recordings



MIT's eye-q



PHILIPS' empathic chair and sensor platform



Martin Ouwerkerk et al. (Philips Research)

TMgames' force feedback gaming vest



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Early sketch of Intel's Connexus



Goals (1)

1. Ecologically valid research

- Research in a home-like environment
- Triggering true emotions using movies; instead of presenting posed emotions. Posed emotions are experienced as:
 - Stronger
 - More prototypical (Feldman Barrett et al., 2007)

2. Enabling processing of noisy data

- ... as is the case in real life

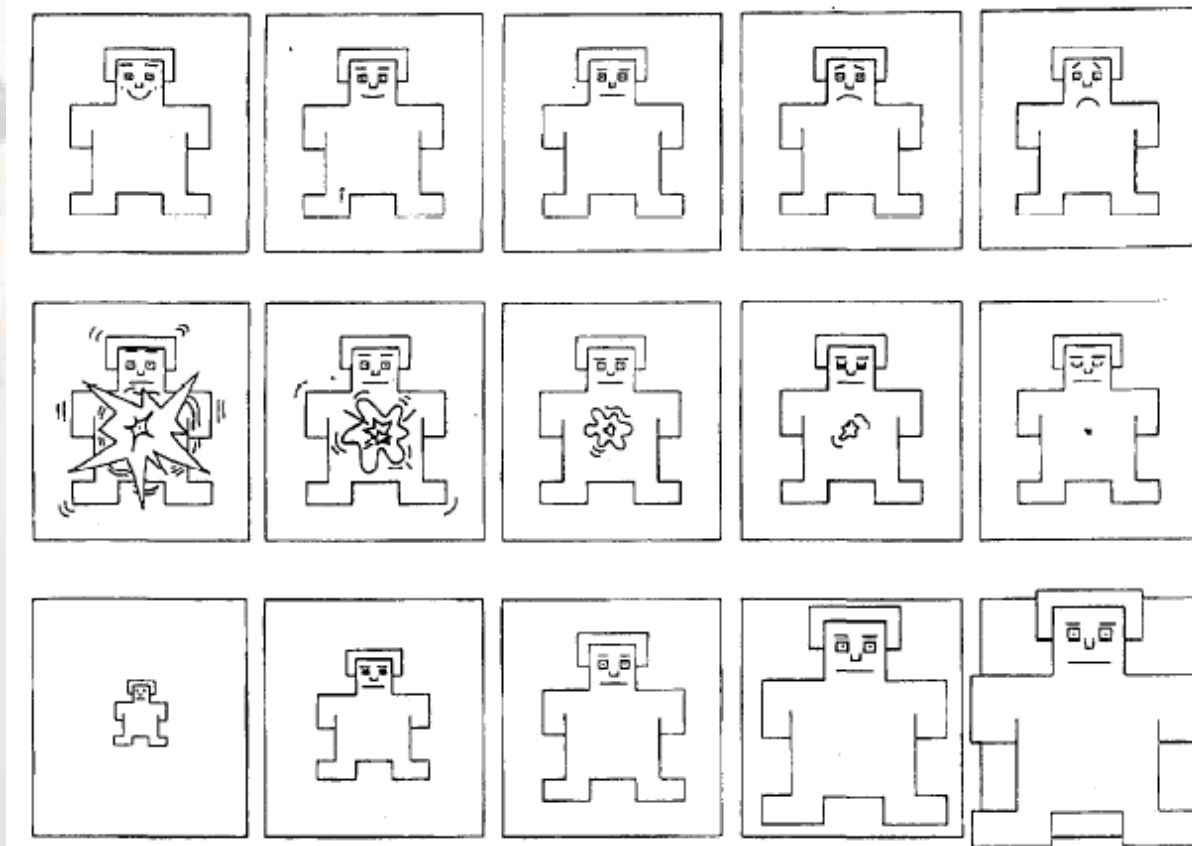
Goals (2)

3. Generic classification scheme
 - Personalization is the very last step
4. The rough emotional state is sufficient
 - Emotions only have to be directed
 - Specific emotional states are hard to identify
 - Identifying mixed emotions

Emotion elicitation: Methodology

1. Home like lab environment
2. 24 participants
3. 8 movie scenes
4. 4 target emotion classes
5. 4 biosignals:
 1. ElectroDermal Activity (EDA)
 2. EMG left frontalis muscle
 3. EMG right corrugator supercilii muscle
 4. EMG left zygomaticus muscle
6. Self Assessment Manikin; i.e., 3 subjective Likert scales:
 1. Arousal
 2. Positive emotions
 3. Negative emotions

Self Assessment Manikin (Lang, 1995)



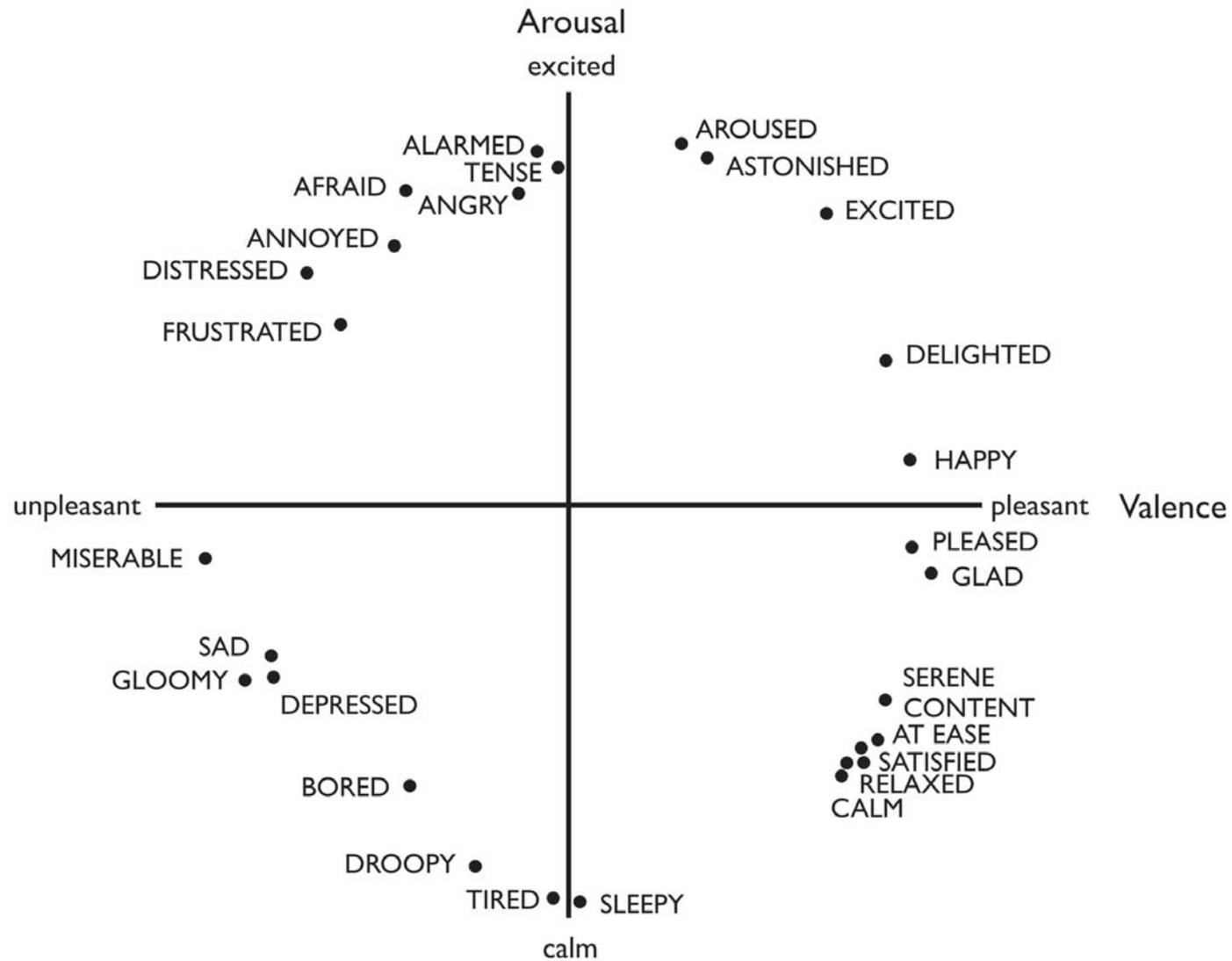


Table 1. The sixteen film scenes with the average ratings with the accompanying standard deviations (between brackets) given by the subjects (n=24) on both experienced negative and positive feelings. Based on the latter two dimensions, four emotion categories are founded: neutral, mixed, positive, and negative. The top eight film scenes were selected for further analysis.

<i>Film scene</i>	<i>Positive</i>	<i>Negative</i>	<i>Emotion category</i>
Color bars	1.60 (1.43)	2.20 (2.04)	neutral
Abstract figures	1.20 (0.70)	2.10 (1.94)	neutral
The bear	5.15 (1.50)	1.65 (0.88)	positive
Tarzan	5.10 (1.17)	1.50 (0.95)	positive
Final destination	3.11 (1.70)	4.32 (1.63)	mixed
Lion King	3.85 (2.21)	3.65 (1.93)	mixed
Cry freedom	1.95 (1.54)	6.25 (1.07)	negative
Pink flamingos	1.75 (1.20)	5.60 (1.54)	negative
Silence of the lambs	2.30 (1.38)	3.85 (1.73)	neutral
When Harry met Sally	4.60 (1.47)	1.80 (1.15)	positive
The champ	2.65 (1.46)	4.35 (1.05)	mixed
Jackass the movie	1.85 (1.57)	5.95 (1.47)	negative
Sea of love	2.15 (1.31)	3.90 (1.74)	neutral
Sweet home Alabama	4.35 (1.66)	1.70 (1.26)	positive
The shining	2.65 (1.39)	3.55 (1.47)	neutral
Nature documentary	4.50 (2.04)	1.45 (1.28)	positive

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Classification of biosignals

Classification of biosignals ...

- No consistent results
- No general standards
- Low performance

so, it is far from trivial ...

Preprocessing

- Normalization
 - A broad range has been introduced; e.g., see Boucsein (1992) and Iglewicz (1993)
 - We choose two linear normalizations
- Baseline matrix
 - adopted from Picard et al. (2001)
- Feature selection
 - No criterion function
 - Exhaustive search not feasible
 - ANOVA-based heuristic search

Classification techniques used

- K-Nearest Neighbors (k-NN)
- Support Vector Machine (SVM)
- Neural Network (NN)
- Validation
 - Leave-One-Out Cross Validation (LOOCV)

Results

- k-NN: 61.31 %
- SVM: 60.71 %
- NN: 56.19 %

with

- 4 emotion categories (incl. mixed emotions)
- 24 participants
- No personalization

State-of-the-art

- Picard et al. (2001)
 - 1 participant
 - 4 biosignals
 - 8 emotions
 - 81 %
- Kim & André (2008 @ Biosignals; IEEE PAMI, 2008)
 - 3 participants
 - 4 biosignals
 - 4 emotions
 - 70 % / 95 %
- A state-of-the-art report will be presented next Saturday, Parallel session 10 @ Biosignals 2009

Discussion

- Observation in more advanced labs
 - Philips HomeLab, Smart House Japan, and Welfare Techno House
- Observations in real life
 - MIT's BoxLab or wearable computing devices
- Personalization
 - Large interpersonal variety!
- Exploring differences between men and women
- Exploring differences between basic and social emotions
- Using (more) multiple biosignals in parallel
- Closed loop Man-Machine Interaction using biosignals



Thank you for your attention!

Questions?

More info?

- **Next Saturday @ BioSignals2009, Parallel session 10:**
Prerequisites for Affective Signal Processing (ASP)
- Broek, E.L. van den & Westerink, J.H.D.M. (in press).
Considerations for emotion-aware consumer products.
Applied Ergonomics (Elsevier)
- Westerink, J.H.D.M. et al. (2008). *Probing Experience: From academic research to commercial propositions*. (Springer)
- Ouwerkerk, M. et al. (in preparation). *Probing Experience II: The impact of context on behavioural and physiological experience measurements*. (Springer)