



Finnish Institute of
Occupational Health

How much load can the brain take?

SAFE HMS konferanse

May 5th, 2009, Sandnes, Norway

Research professor Kiti Müller

Brain and Work Research Centre

Brain and Work Research Centre promoting the well-being of the brain and mind

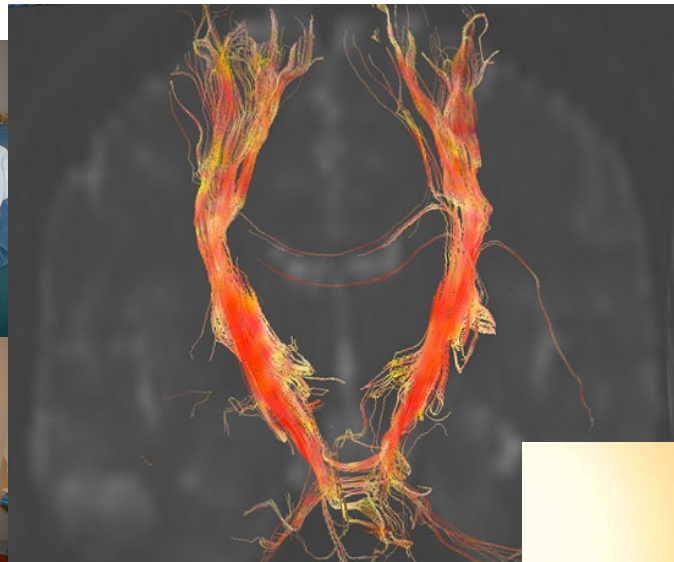
Outpatient clinic



Sleep laboratory
and work shifts



Cognitive
neuroscience and
ergonomics



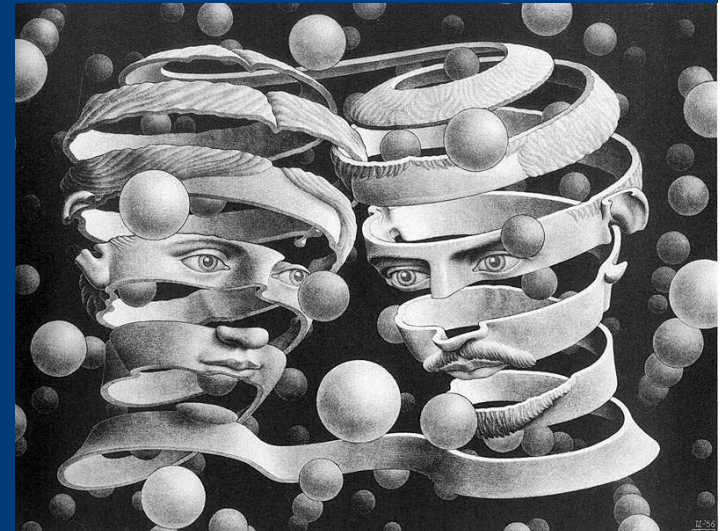
Vision laboratory



Work simulation and
neurophysiology

Outlines of Presentation

- Challenges of work and the brain
- What has neuroscience found out about how the brain functions?
- How to study the working brain and what it can "take"
- Neuroergonomics
 - linking neuroscience with human factors research



Escher

Work challenges and the brain

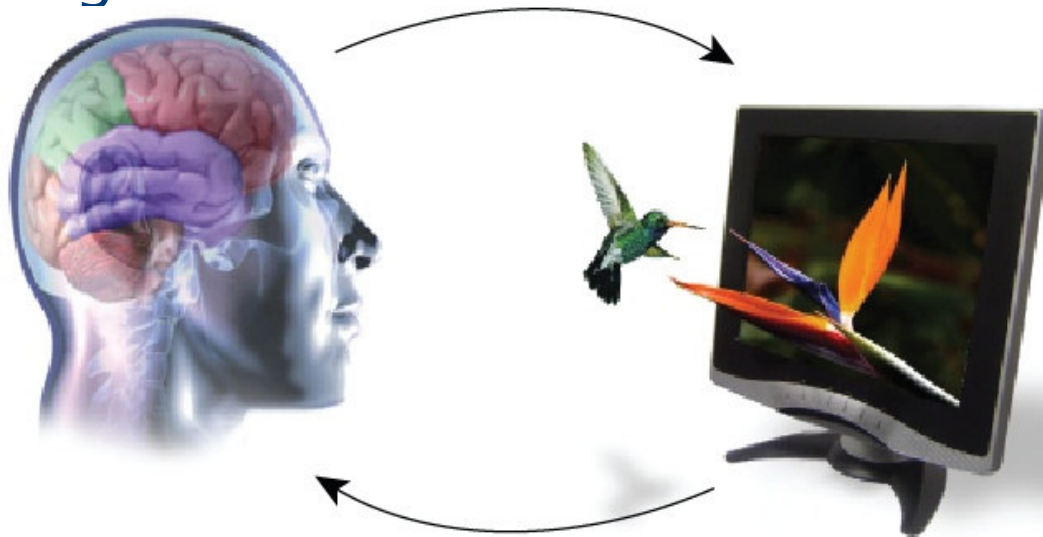
- 24/7 society
 - Shift work and irregular working hours ↑
 - 40% of workers have regular "office hours" (8 am to 4-5 pm)
 - dyssynchrony with human biorythms ↑
- Work pace and intensity ↑
- Information intensive working environments
 - dual- and multitasking, task shifting
- (Rapidly) changing workload
 - automation in monitoring and surveillance work
 - handling of critical incidences
 - traffic control, industrial processes, safety
- Information handling, knowledge management, life-long learning

The human brain & information environment

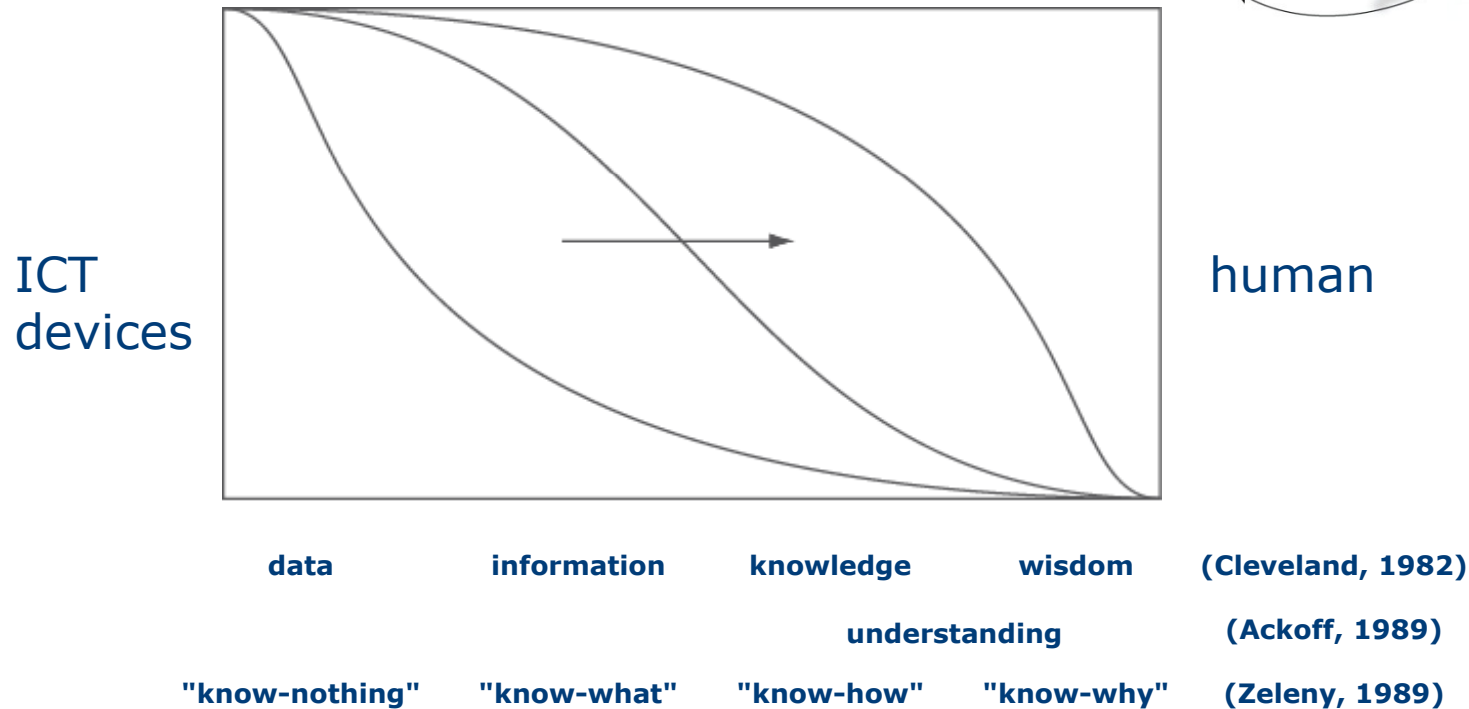
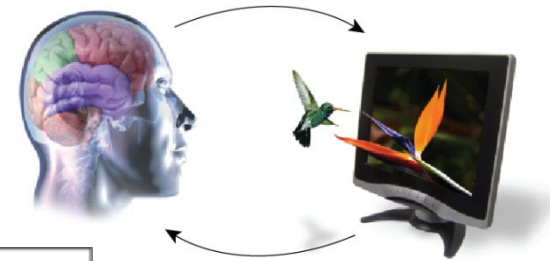


Human and artificial intelligence meet at HCI

- information, main "material" of modern work
- information technology – working tools
- optimizing cognitive performance and decision making
- ensuring human brain and mental well-being



The role of human intelligence in the chain of information



Work and Health 2006, FIOH

- Population based study, > 3100
- aged 24-64 years
- increase in irregular working hours in all professions
- stressful interruptions at work experienced by 30-40% workers
 - all age-groups and all profession classes
- problems with memory and concentration reported by 20 %
 - most significant increase in age-group of 24-35 year-old individuals
- 25-33% suffer from insomnia
- a slight decrease in symptoms of chronic fatigue compared to yr 2003

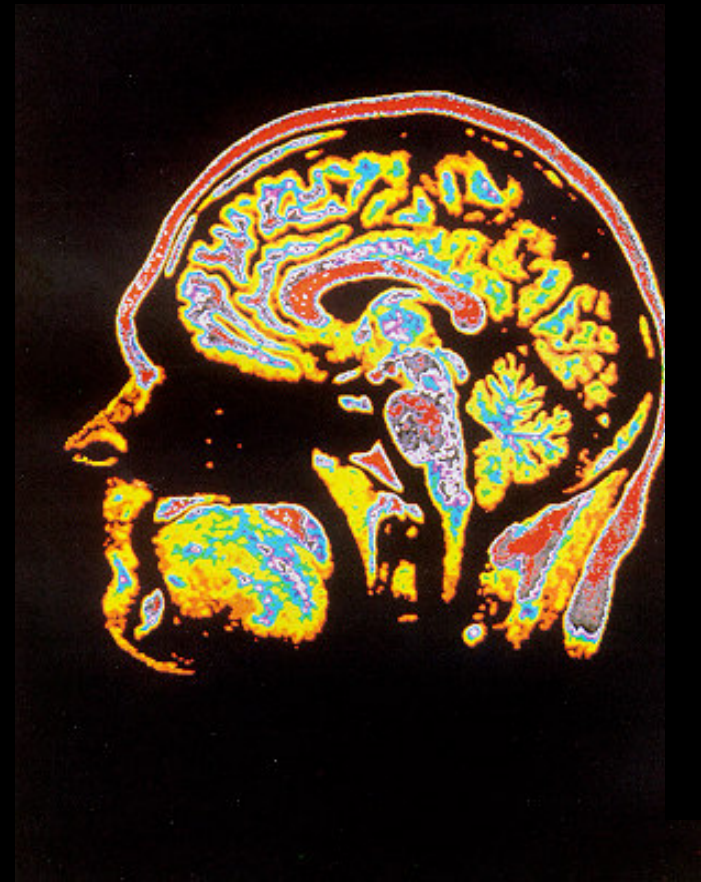
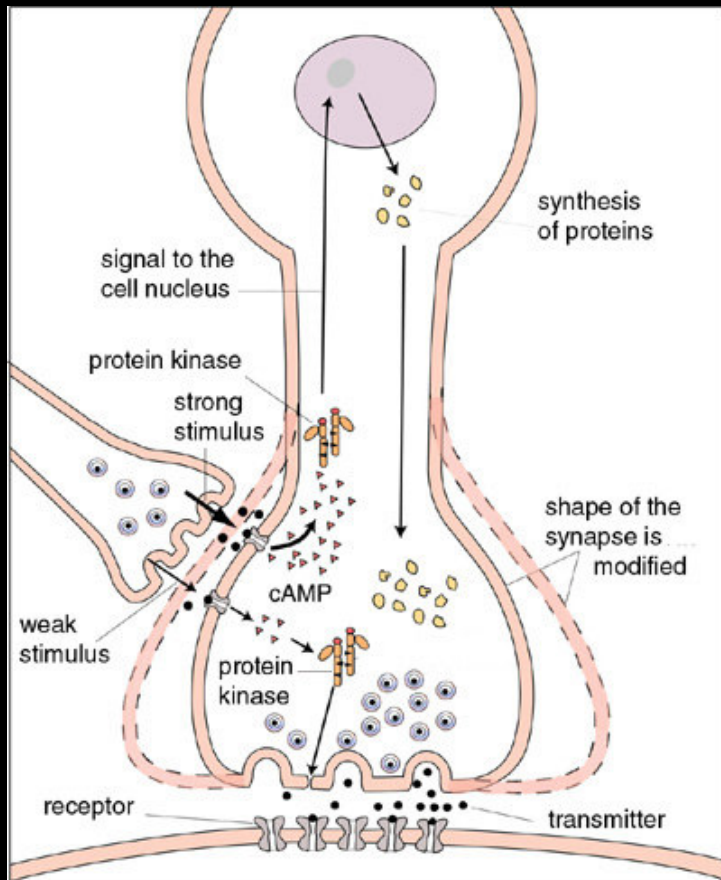
HOW DOES THE BRAIN WORK?

The fuzzy logic
of decision
making



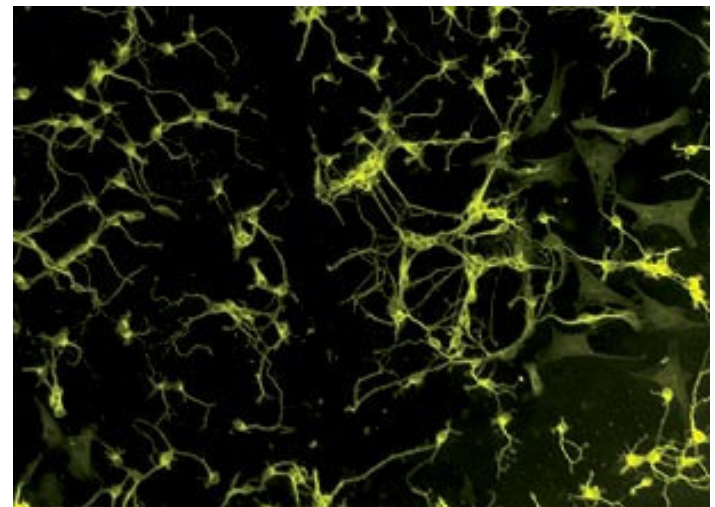
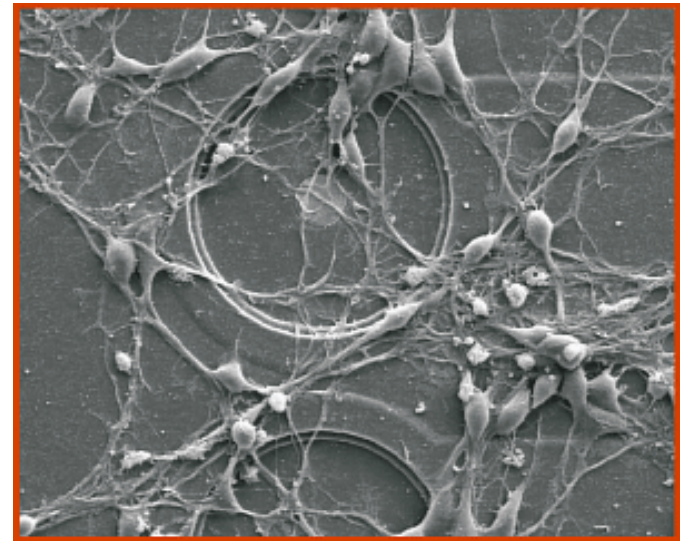
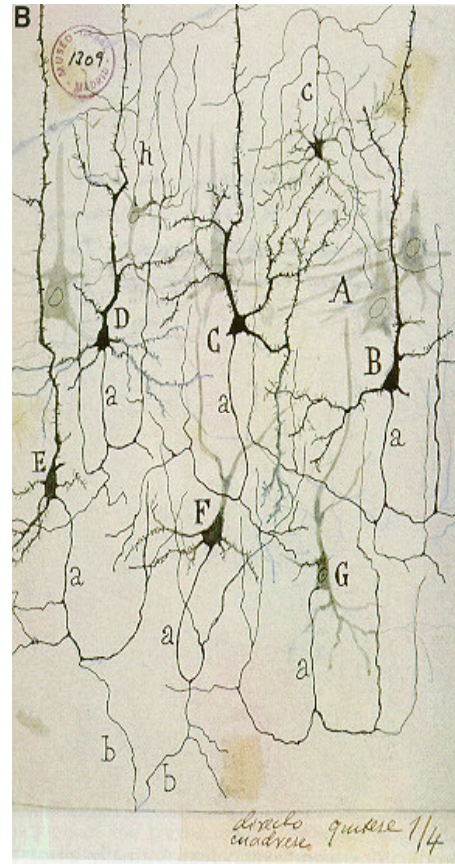
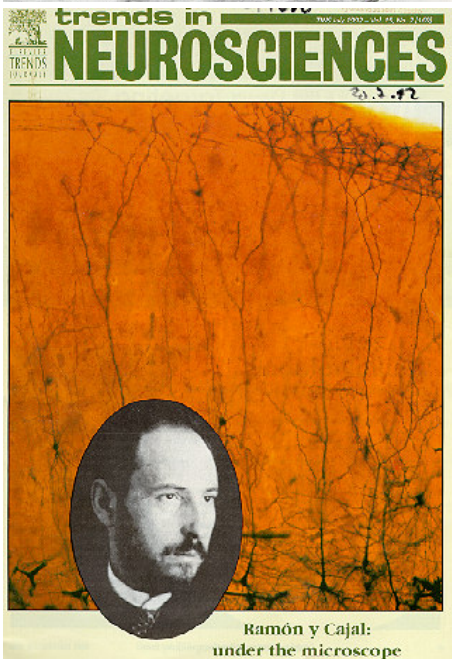
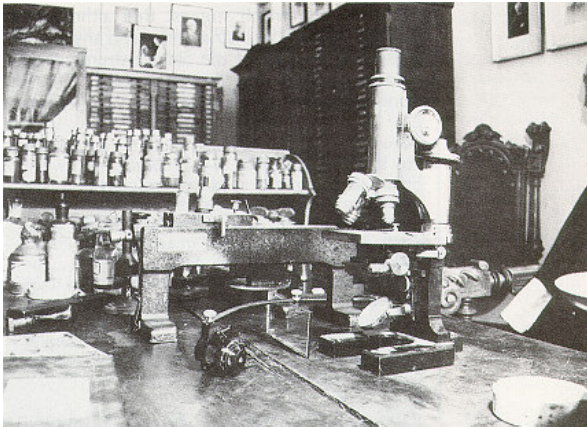
Freud on the cover of Time magazine
in the 1990s

Combining neurobiology, cognitive and behavioural sciences and bioinformatics



Eric R. Kandel, Nobel prize
of medicine 2000

Neural networks of the brain



Ramon y Cajal
Nobel prize in medicine 1906

www.zeiss.de

Mental functions of the brain

LEFT

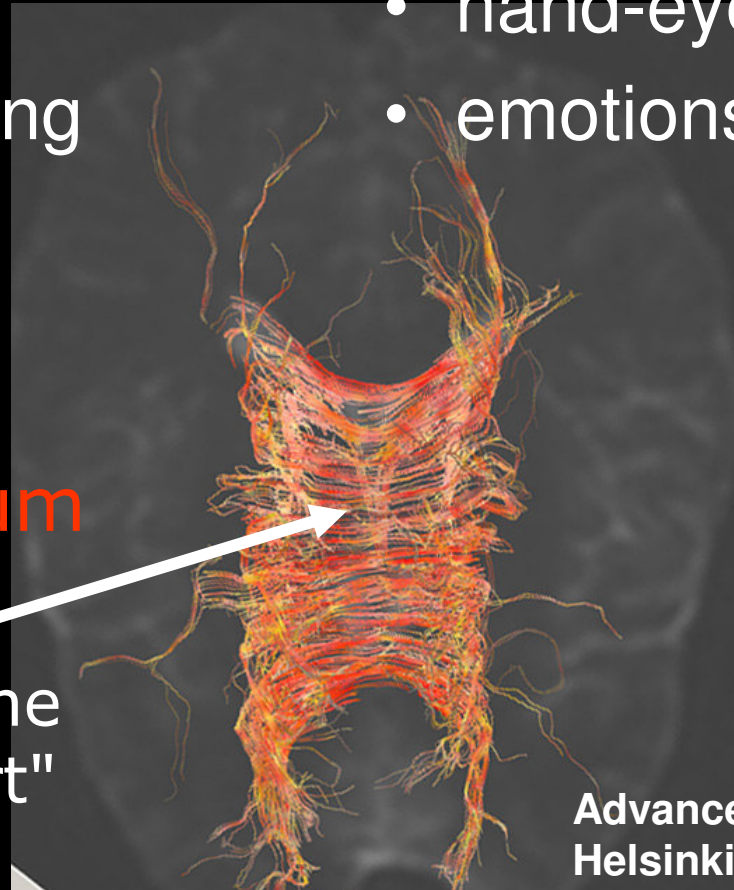
- language
- logic, math
- rational thinking

RIGHT

- visuospatial
- hand-eye co-ordination
- emotions

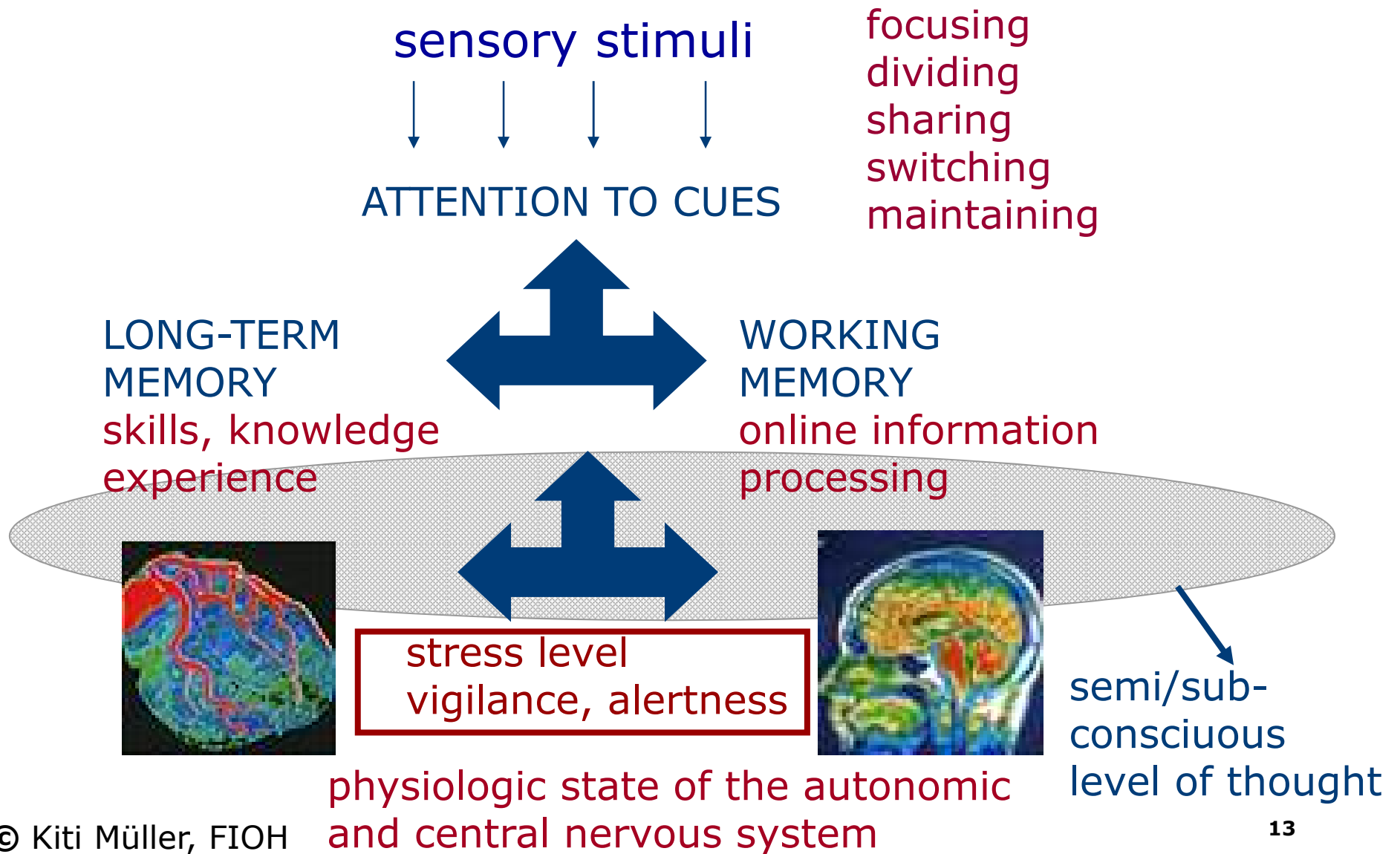
Corpus callosum

Thinking with the
"brain and heart"

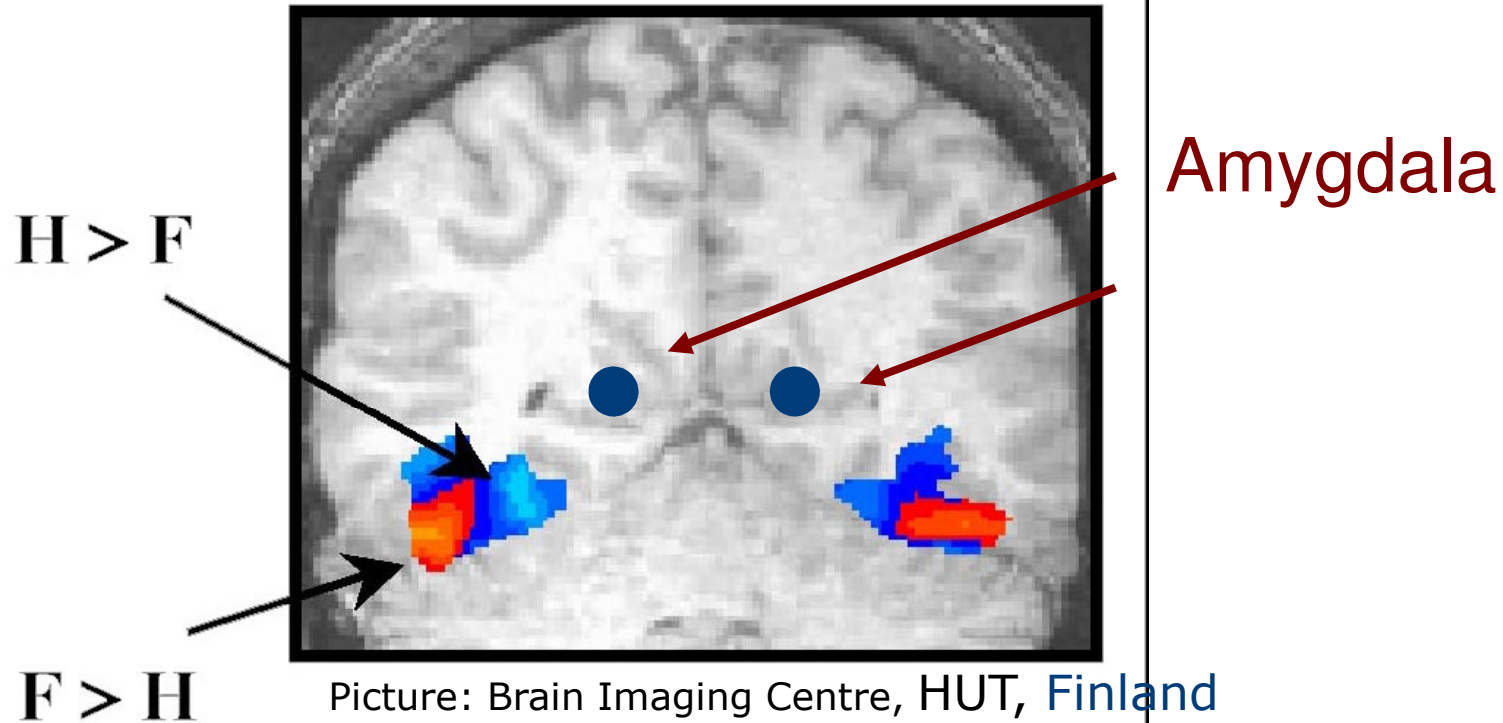


Advanced Magnetic Imaging Centre,
Helsinki University of Technology

Information processing of the human brain ganzheit

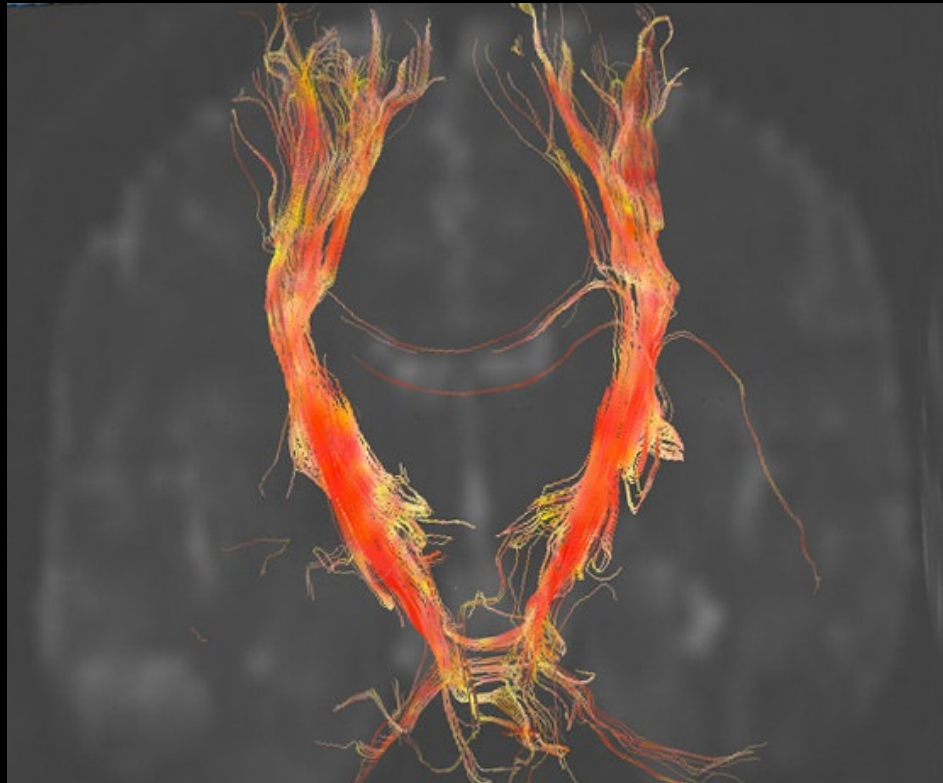


The emotional brain



Complex neural networks between structures of the memory of emotions (amygdala) and the frontal areas of the brain → emotions affect thinking, reasoning, planning, executing tasks - motivation

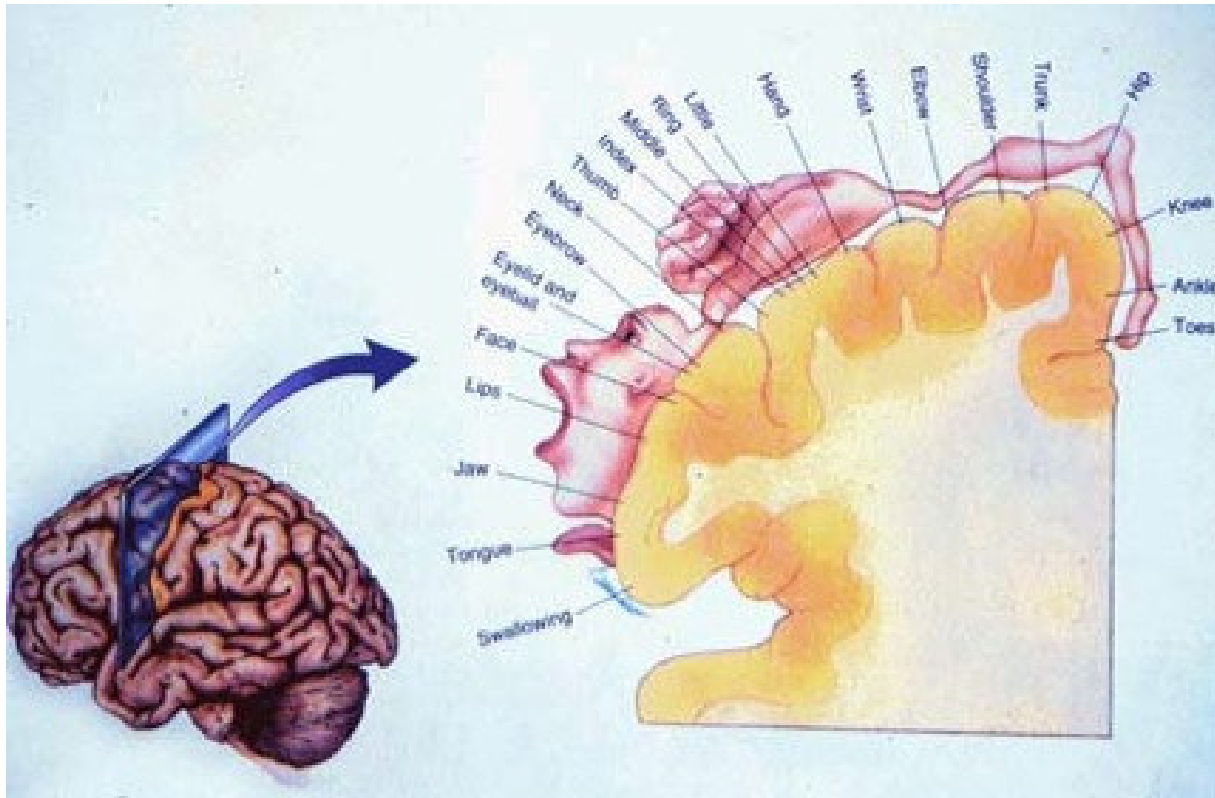
Crossing motor and sensory nerve tracts → directing limb movements



- The right brain lobe "operates" the left side
- The left brain lobe "operates" the right side

Advanced Magnetic Imaging Centre,
Helsinki University of Technology

Motor functions and the brain



Large representation of the hand in the motor cortex of the brain

The hands, an extension of cognition



Escher

Brain control of physical activity

FRONTAL LOBES

planning, executing
situational analysis
attended to cues
eye movements

PARIETAL LOBES

motor, sensation
3D, spatial awareness

MIDDLE BRAIN

emotional state,
cardiovascular
feedback

OCCIPITAL LOBES

visual info

TEMPORAL LOBES

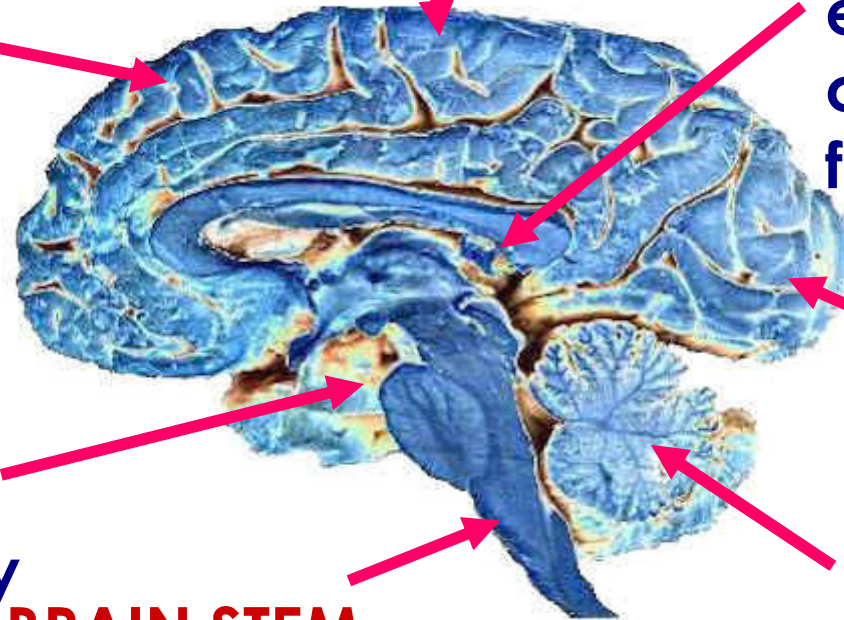
auditory info,
long-term memory
skills, emotions

BRAIN STEM

co-ordinating
movement

CEREBELLUM

balance, co-
ordinating



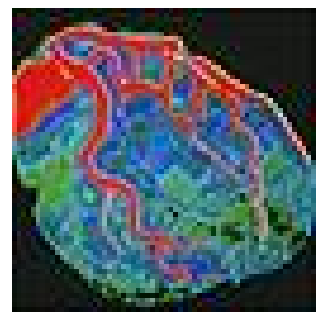
The Brain and Work Research Centre does R&D in the field of neuroergonomics

- **What is neuroergonomics?**
- **Relatively new interdisciplinary area of research and practice (defined 2003)**
- **Focus on the brain performing at work and everyday life**
- **Merges the disciplines of neuroscience and ergonomics (human factors)**
- **Linking brain and autonomous nervous system physiology with human cognition, behaviour and perception in relation work tasks and technologies used to carry out tasks**

Cognitive load

- information load
- multitasking
- cognitively demanding work tasks
- work pace
- working hours

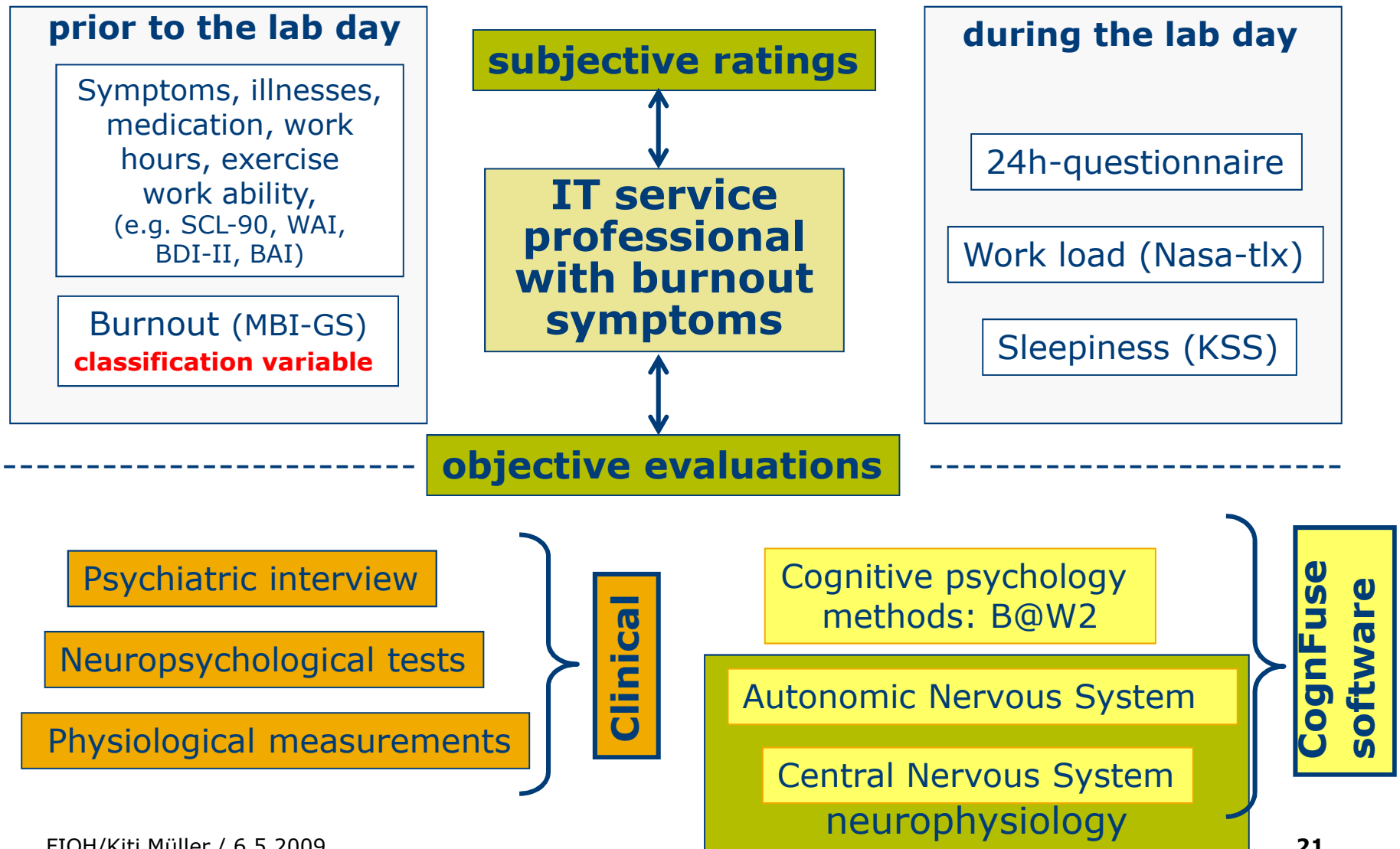
pyhysiology of central and autonomic nervous system



physiologic and cognitive performance capacity

- age
- health
- cognitive abilities
- temperament
- motivation
- vigilance
- medication
- intoxicants

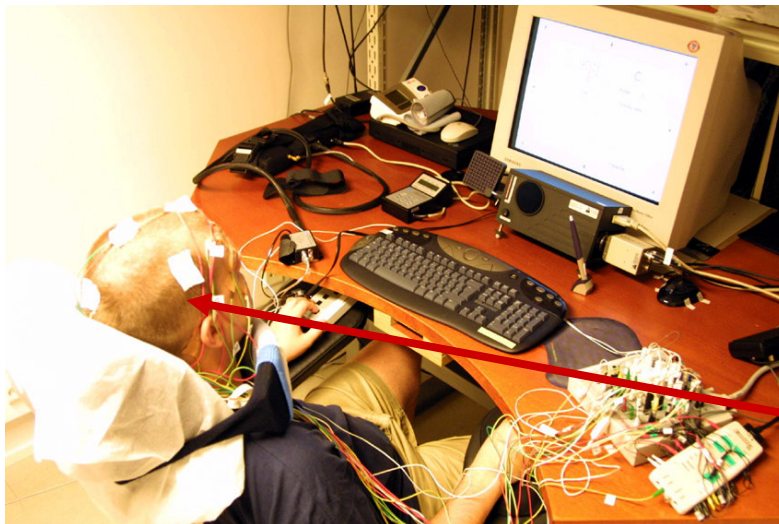
Methodological tool kit of studying and promoting neuroergonomics /BWRC



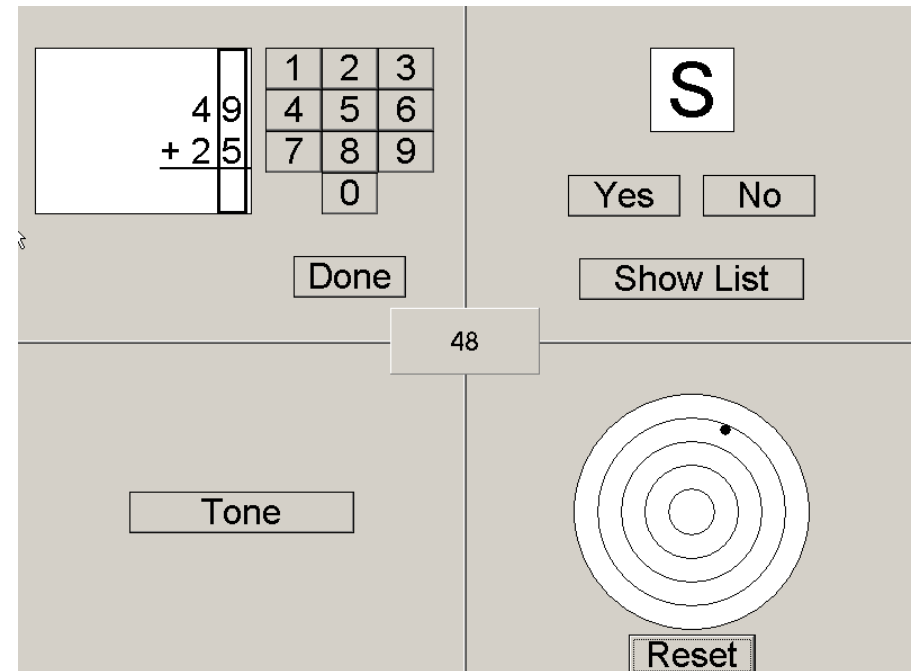
Cognitive demands of work tasks

change work task difficulty/intensity

- number of tasks to perform
 - information load and complexity
 - pace of task
 - time on task, breaks
- different "loading effects"



FIOH/Kiti Müller / 6.5.2009



Brain@Work -test, modified
•from SynWork®

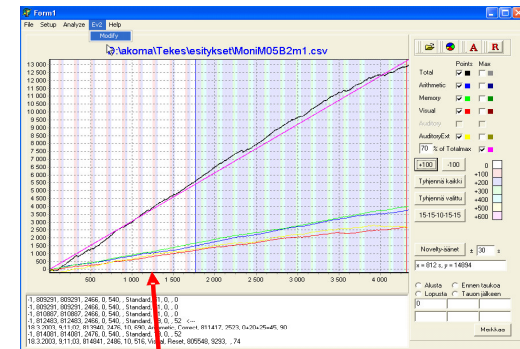
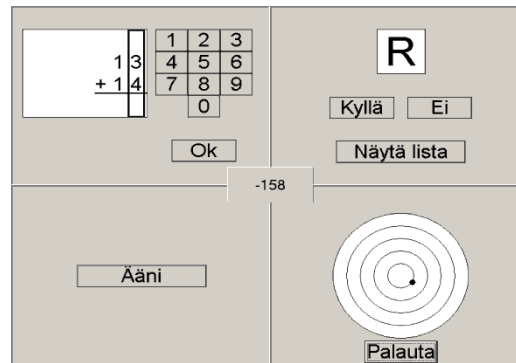
vigilance, sleepiness, alertness
stress -level, motivation of
individual

Time-synchronized linking of cognitive performance with (neuro)physiologic metrics

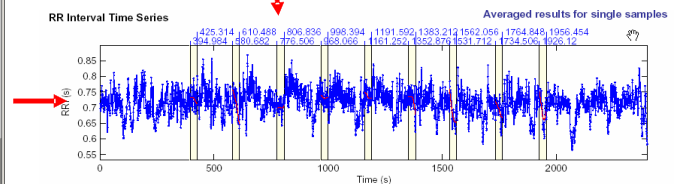
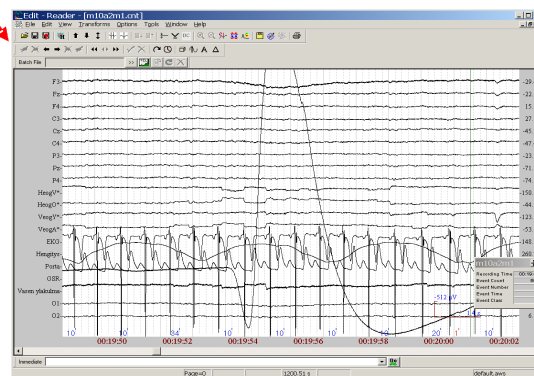
B@W-test

Performance

STIMULU
S



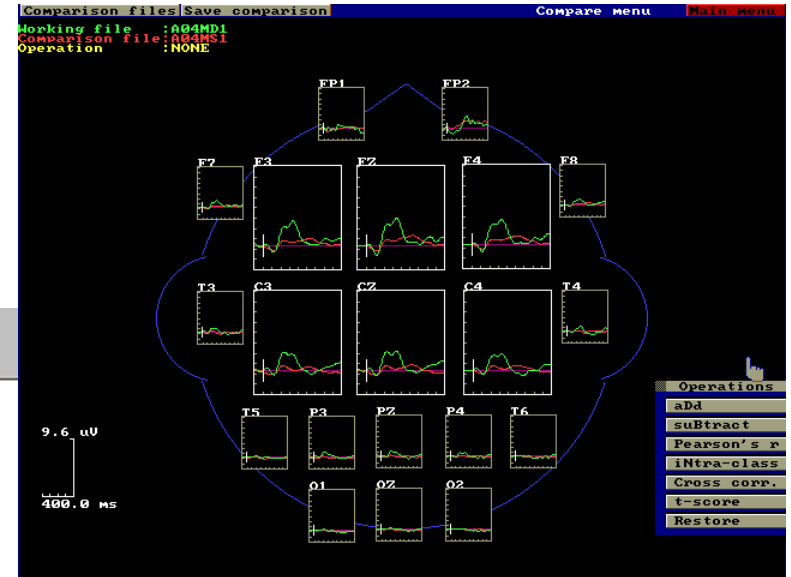
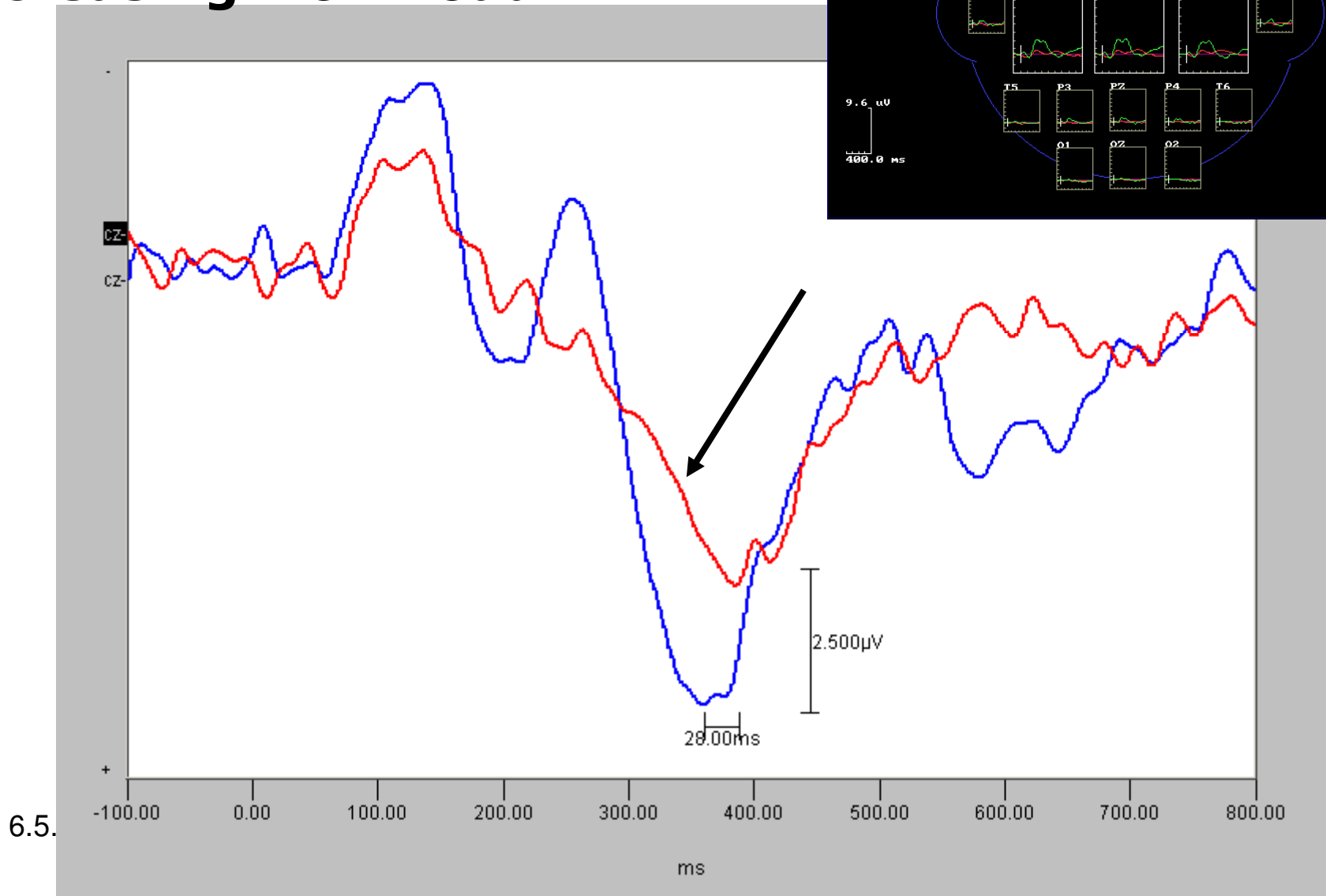
- EEG
- evoked responses to auditory, visual stimuli
- eye-movements
- heart rate
- blood pressure

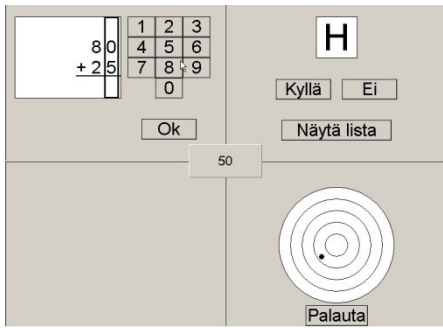


Physiological measurements

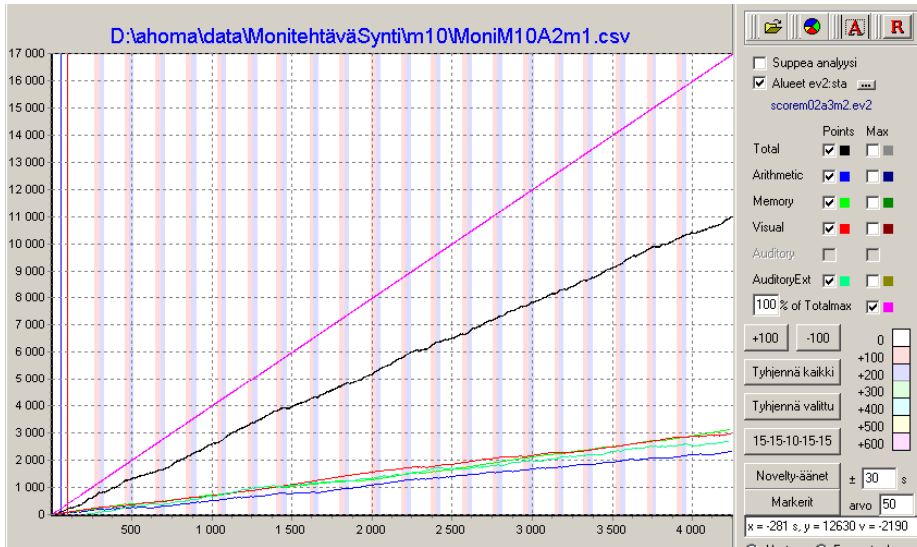
Physiological status

Brain responses to auditorily relevant external stimuli decrease with increasing work load

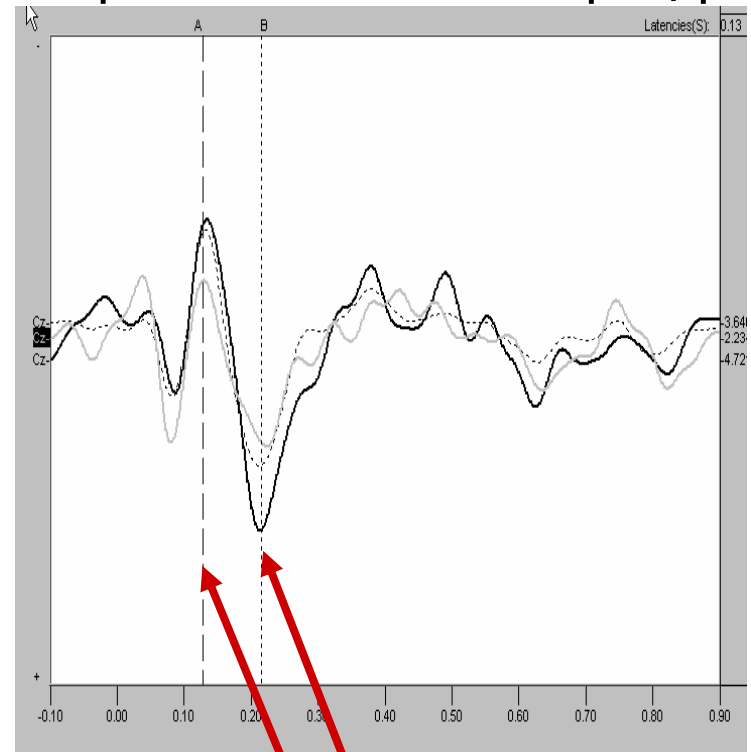




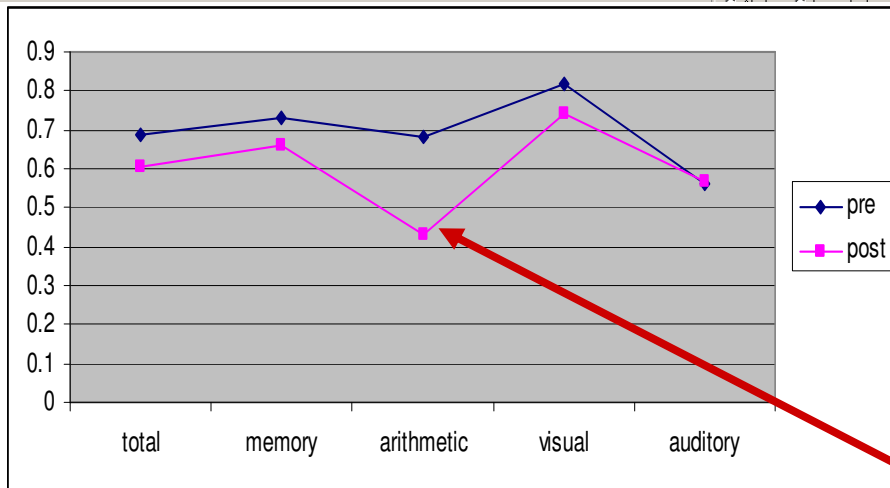
The effect of external events on performance



unexpected noise 30 s pre/post

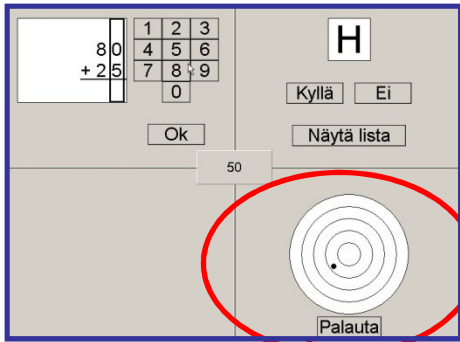


brain evoked response P300



Ulrich Müller
cognitive performance

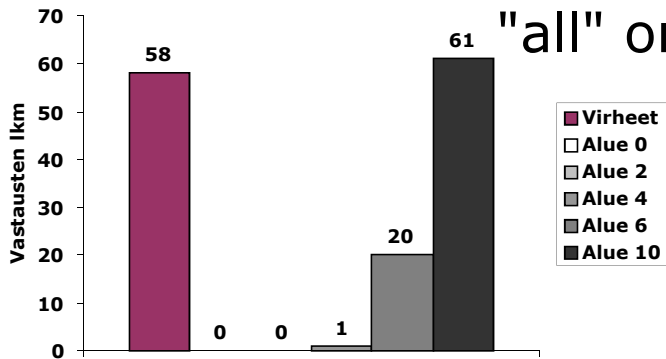
B@W multitasking and individual performance



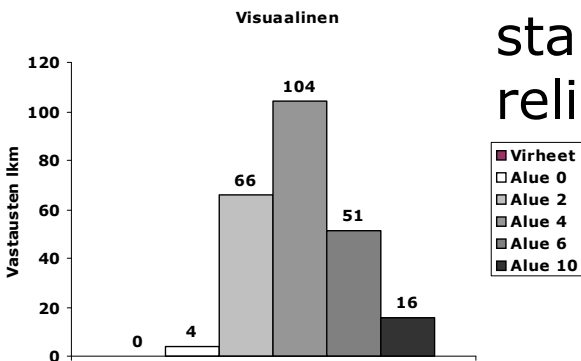
vigilance alertness subtask

70 min multitask performance

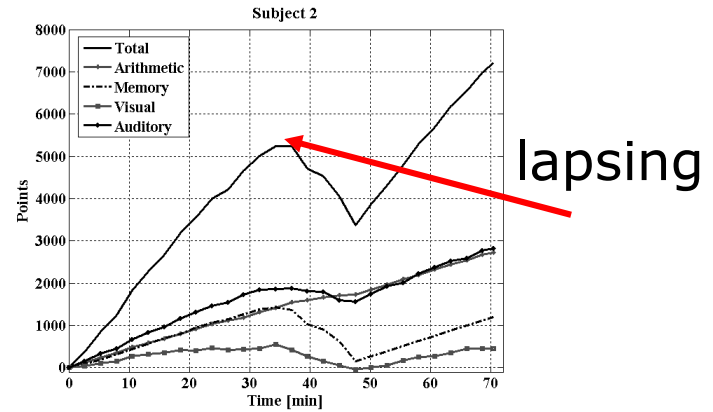
Visuaalinen



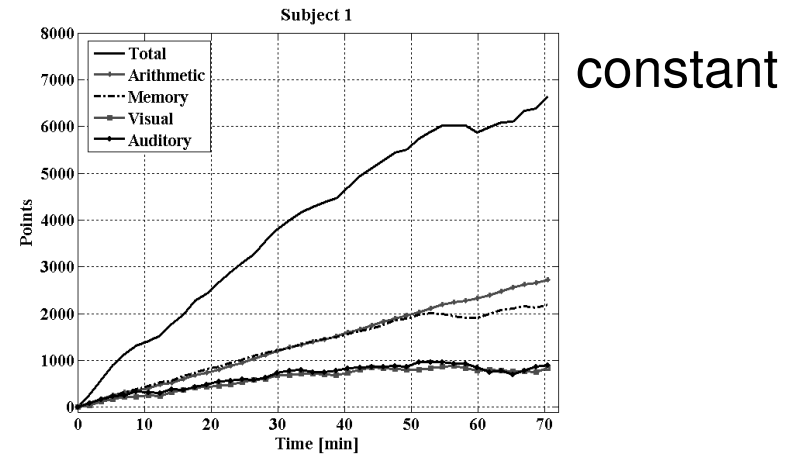
"all" or "nothing"



stable, constant, reliable, no errors

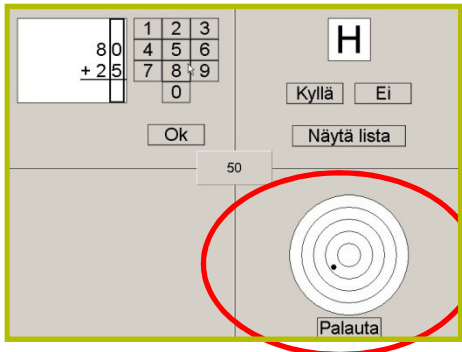


lapsing

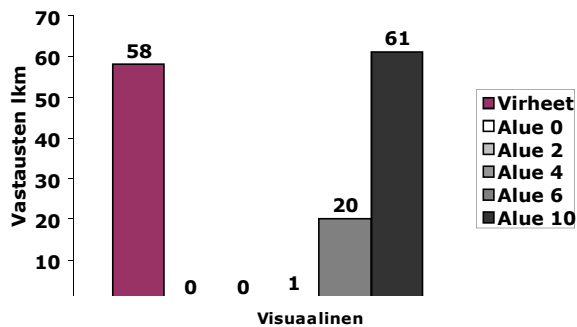


constant

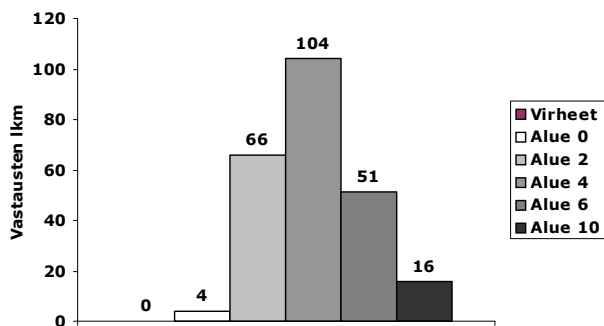
Possible causes underlying performance differences in individuals



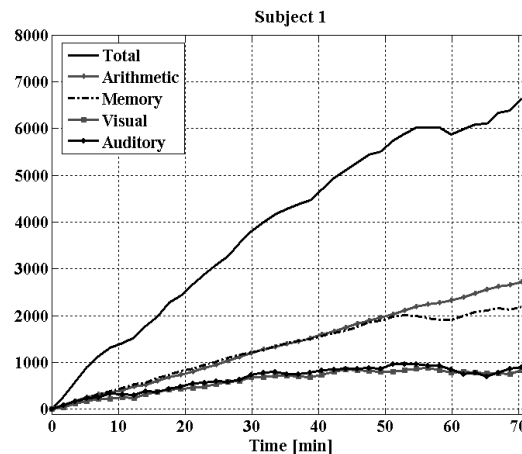
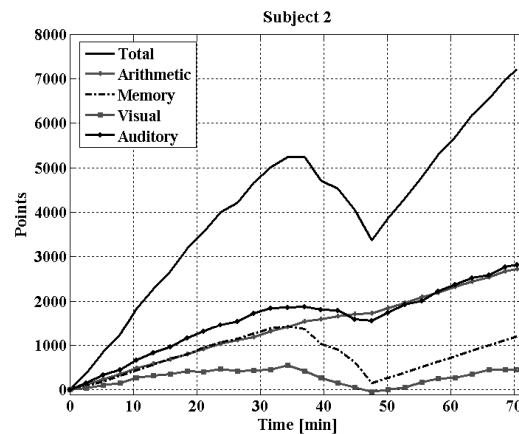
Visuaalinen



Visuaalinen

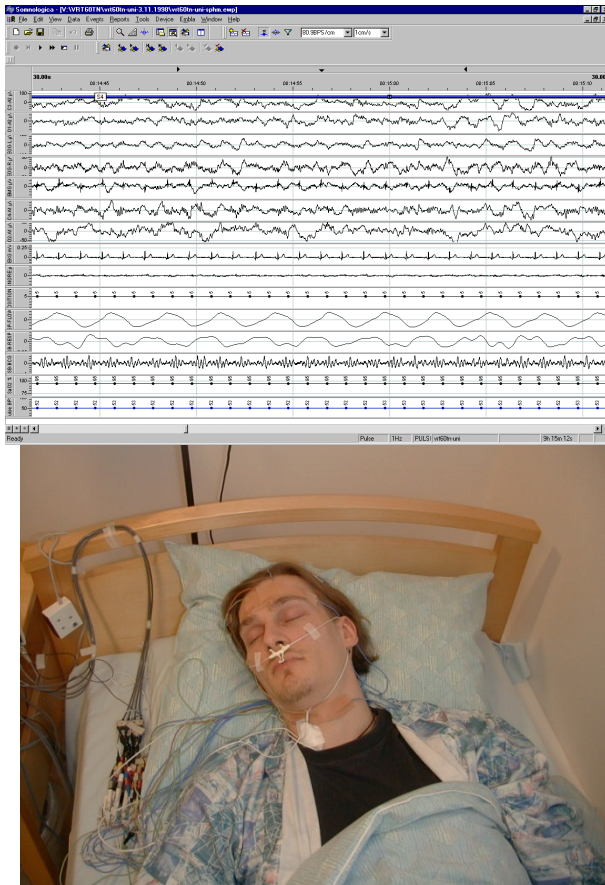


FIOH/Kiti Müller / 6.5.2009



- vigilance, alertness, fatigue, stress, health, age
- cognitive strategy, mental resources, expertise
- quantity and quality of information
- interface usability as a "work tool"

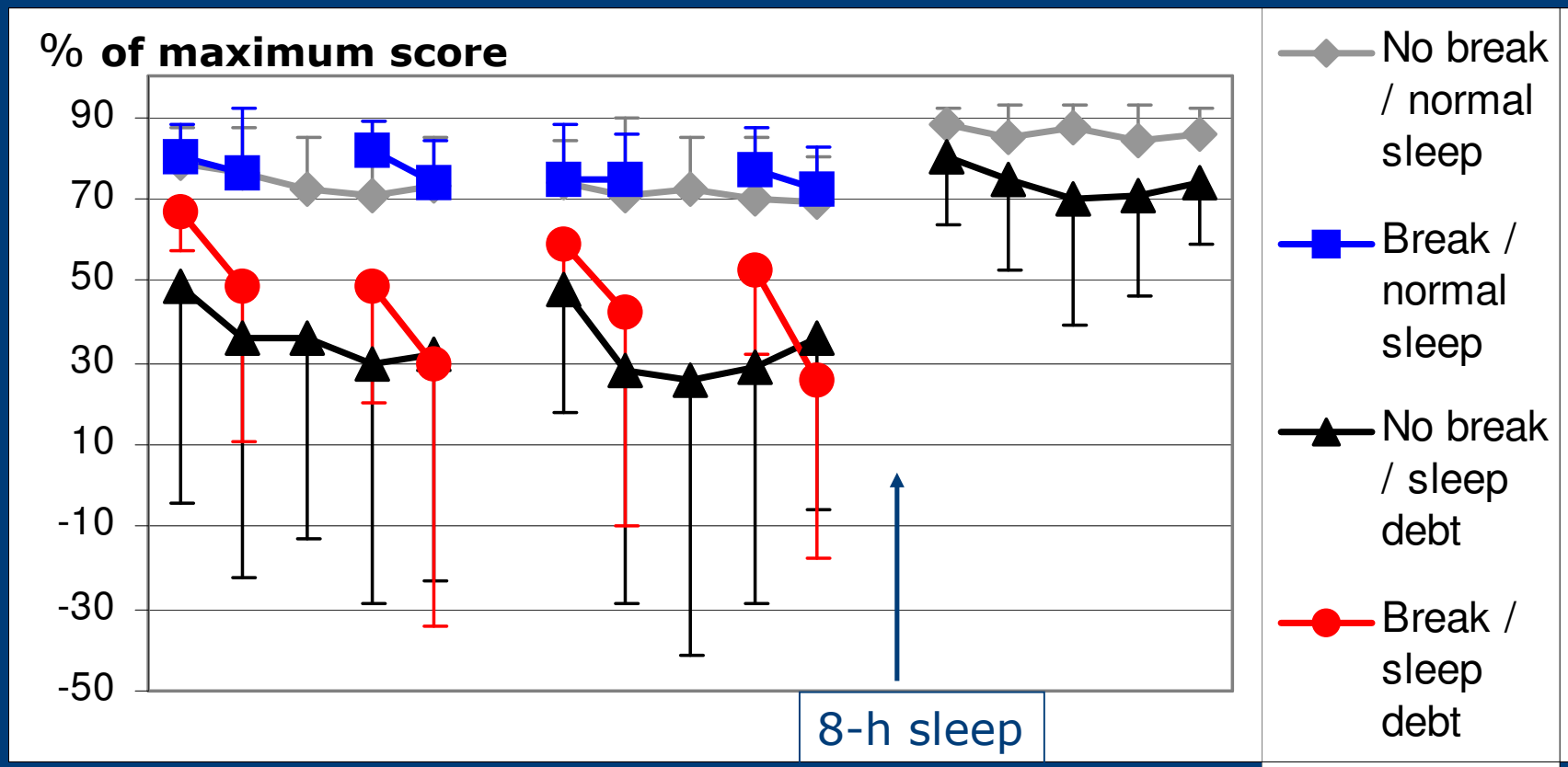
The relevance of sleep for the brain



- restoring energy resources
- reorganizing memory structures
- learning
- problem solving
- the relationships between stress, mental and brain health:
 - sleep disturbances a symptom of brain and mental overload

Multitask performance (Sallinen et al 2007)

- **Sleep debt effect: $F=191.44, p<.001$ (2 h sleep previous night)**
- **Rest pause effect: $F=8.08, p<.05$ (1st 15 min)**
- **Recovery (8 h night) sleep effect: $F=221.20, p<.001$**
- **Sleep debt effect after recovery sleep: $F=60.00, p<.001$**



Time 09:00-10:10 / 11:00-12:10 13:30-14:40 / 15:30-16:40 9:00-10:10

1101/1011/11/11 / 0.0.2007

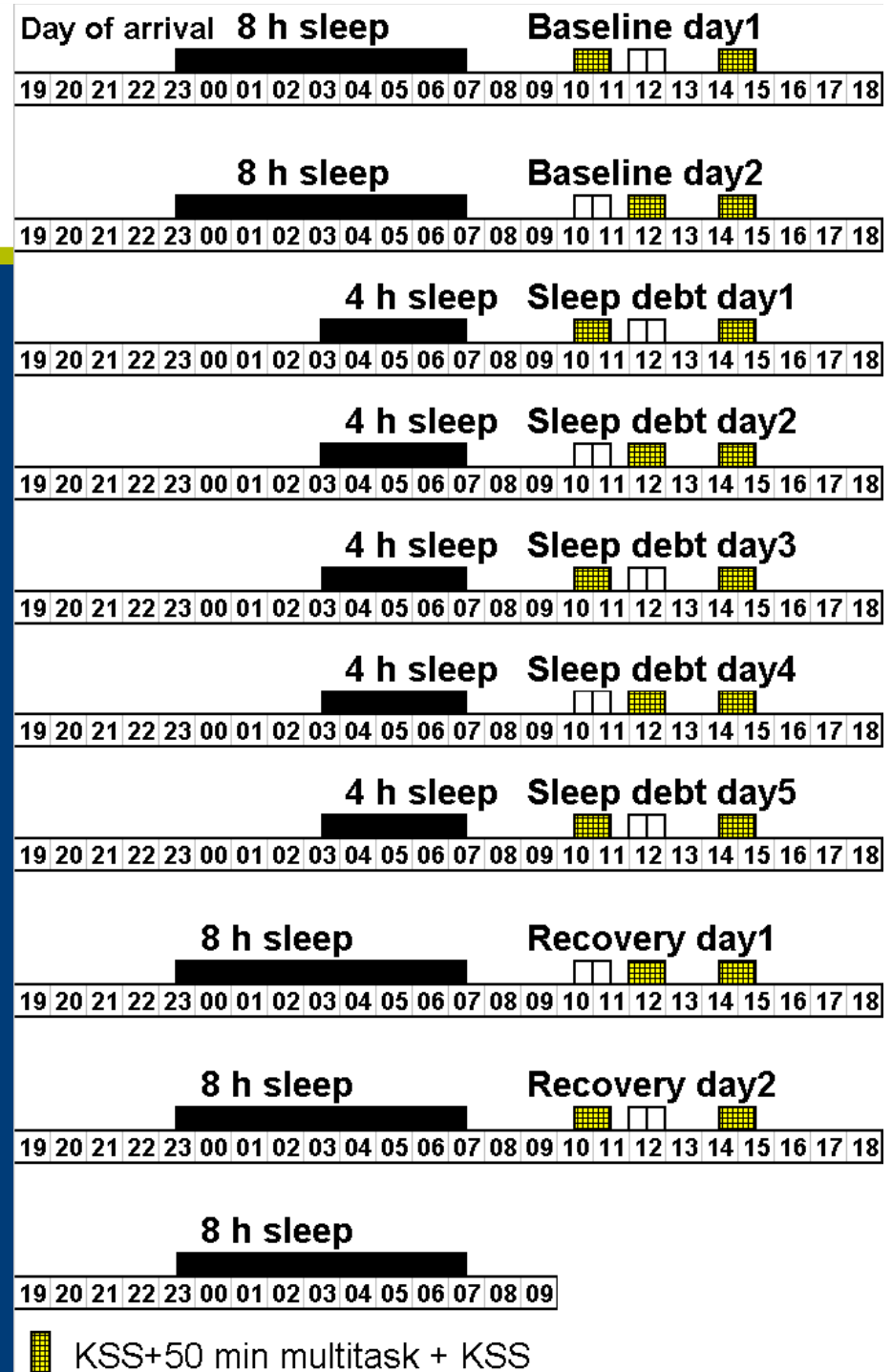
Cumulative sleep debt Study design (Haavisto, Sallinen et al 2008)

- Two 50-minute multiple-task sessions on each day

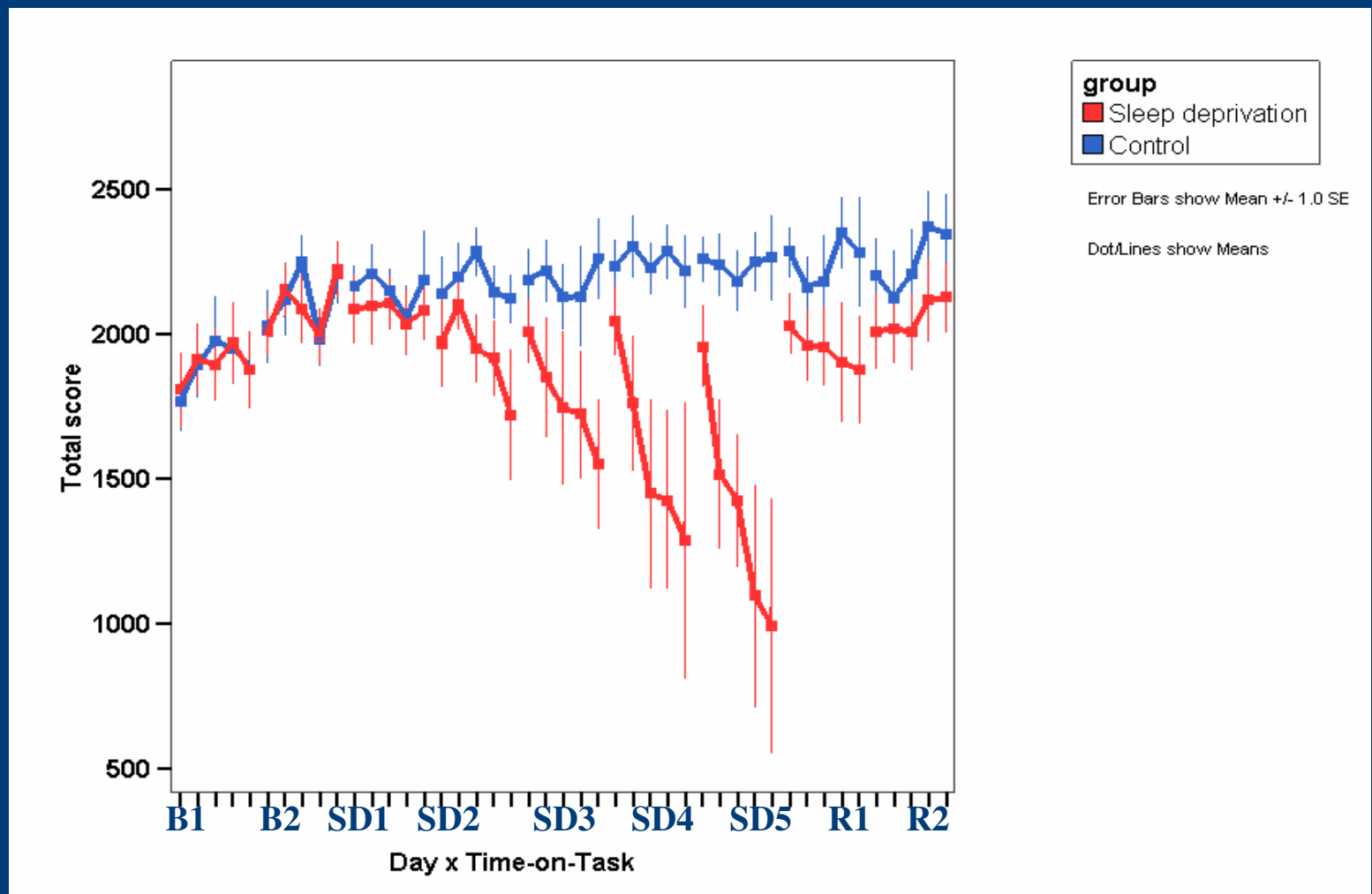


- Self-rated sleepiness with Karolinska sleepiness scale

FIOH/Kiti Müller / 6.5.2009

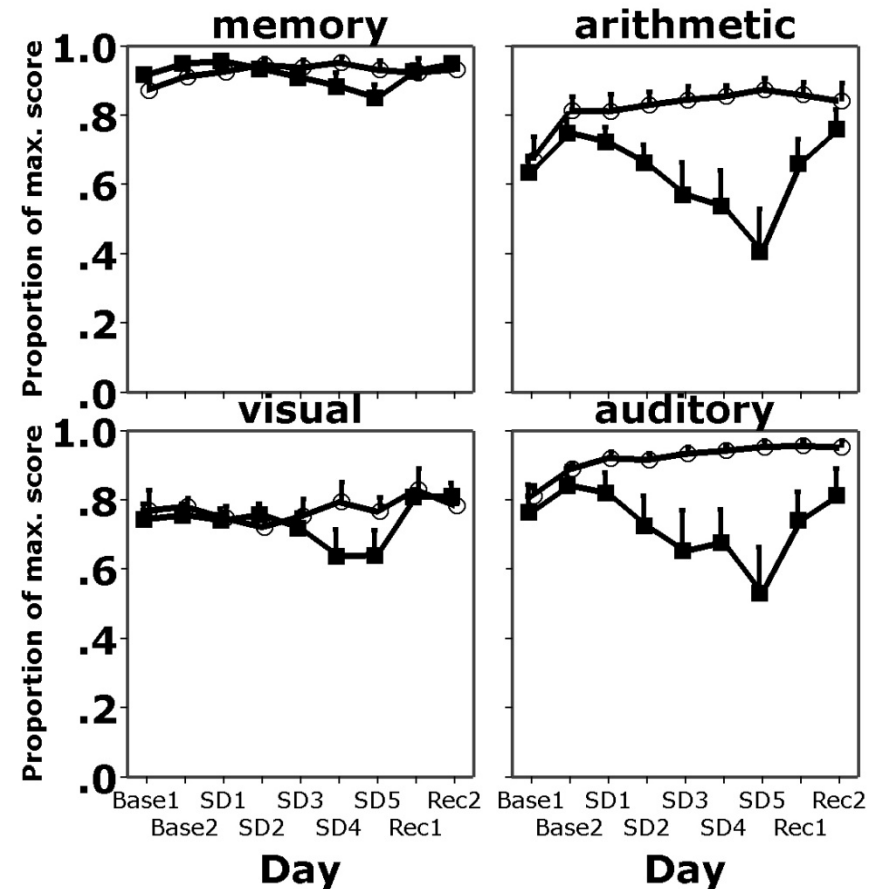


Results: overall multitask-performance with cumulative sleep debt, Haavisto, Sallinen et al FIOH (2008)



Results: Multiple-task performance with cumulative sleep debt, subtasks

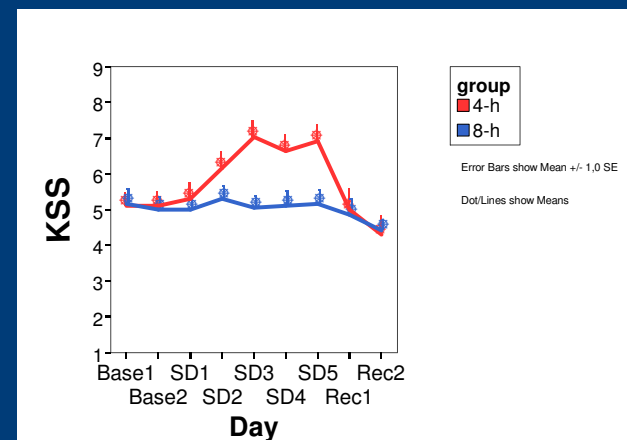
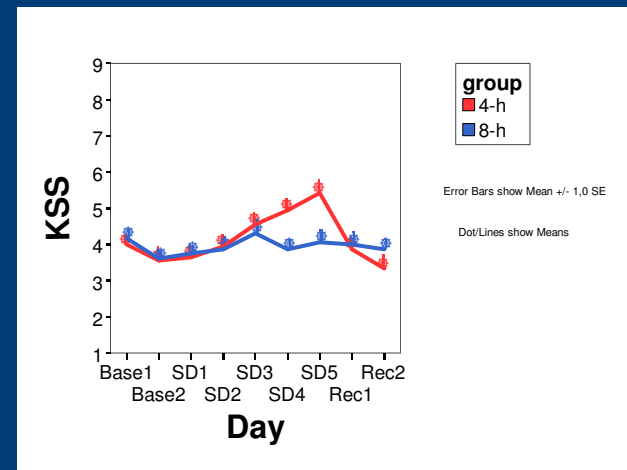
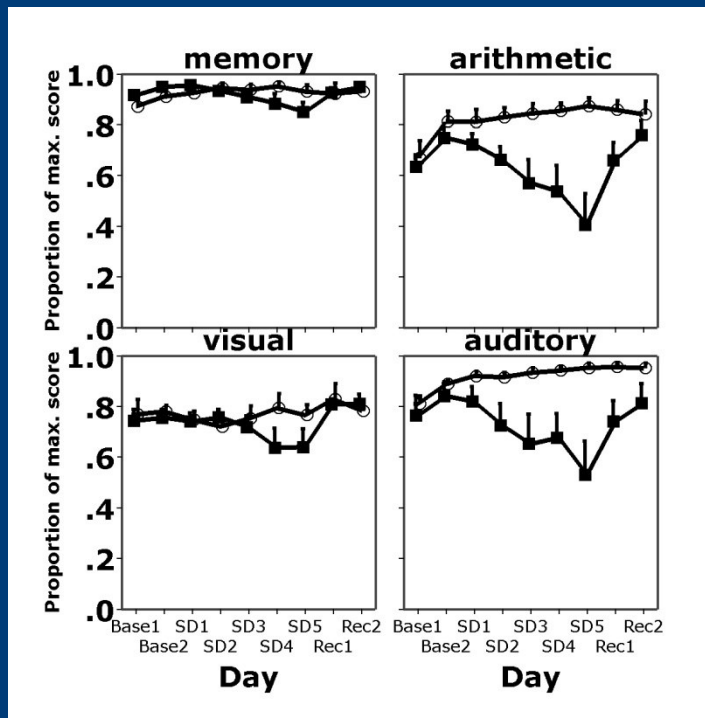
- Under sleep loss
 - Decreased performance
 - memory
 - arithmetic
 - auditory monitoring
 - **NOT** in visual monitoring



Results: After one night recovery sleep (8 h)

Performance did not recovered completely in all subtasks

Subjectived sleepiness recovered completely



Sleep deprivation, stress and performance in multitasking

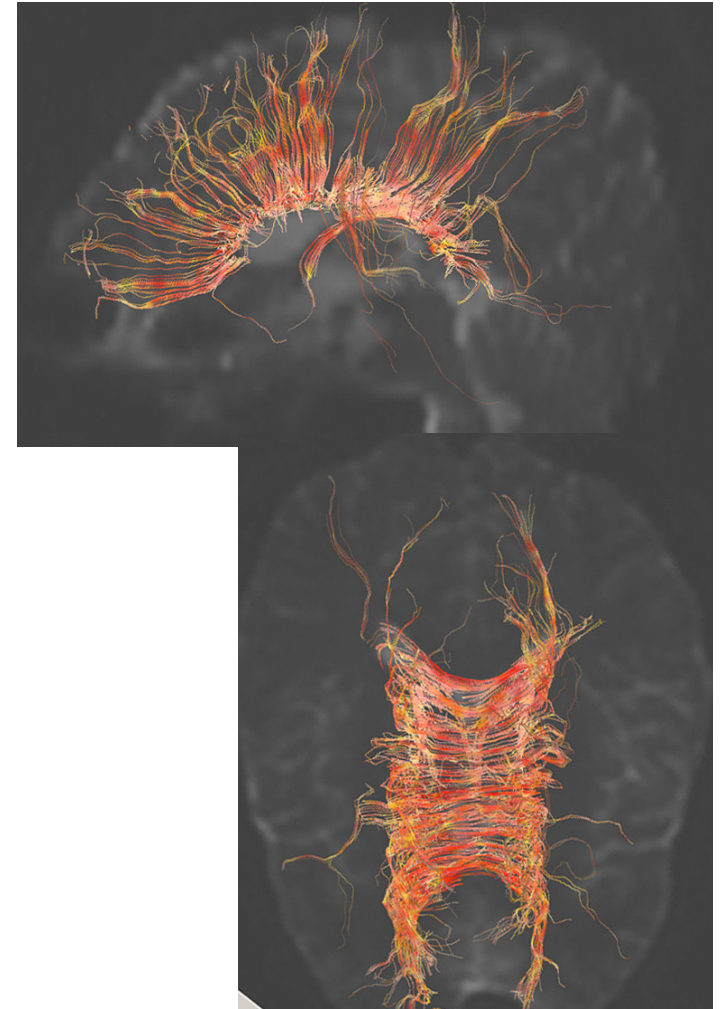
(Sallinen et al 2007, Haavisto et al 2008, van Leeuwen et al 2008)

- Acute sleep deprivation (only 2 hours sleep previous night)
 - individual multitasks performance declines cognitively to levels seen with with blood alcohol levels of 0,5-1 ‰
 - one night of 8 hours sleep does not restore performance
 - subjective estimation of performance quality hampered in acute sleep debt
- Cumulating sleep dept(only 4 hours of sleep per night during a five-day work week)
 - individual performance declines steadily
 - cognitively an individual is "drunk at work" (~ blood alcohol levels 0,5-1 ‰)
 - two nights of 8 hours of sleep do not restore cognitive performance to individual's basic performance level

The Brain, frontal lobes and work

- Attentional resources
- Cognitive control of eye movements
- Dynamic neurocognition
 - Executive functions
 - Problem solving
 - Mental flexibility
- Situational sensitivity
- Social skills
- Effected by
 - emotions, vigilance, physical and mental overload
 - drugs, toxicants
 - age: developmental neurology and psychiatry
- Neuropsychiatric disorders
 - psychosis, severe depression
 - degenerative brain diseases

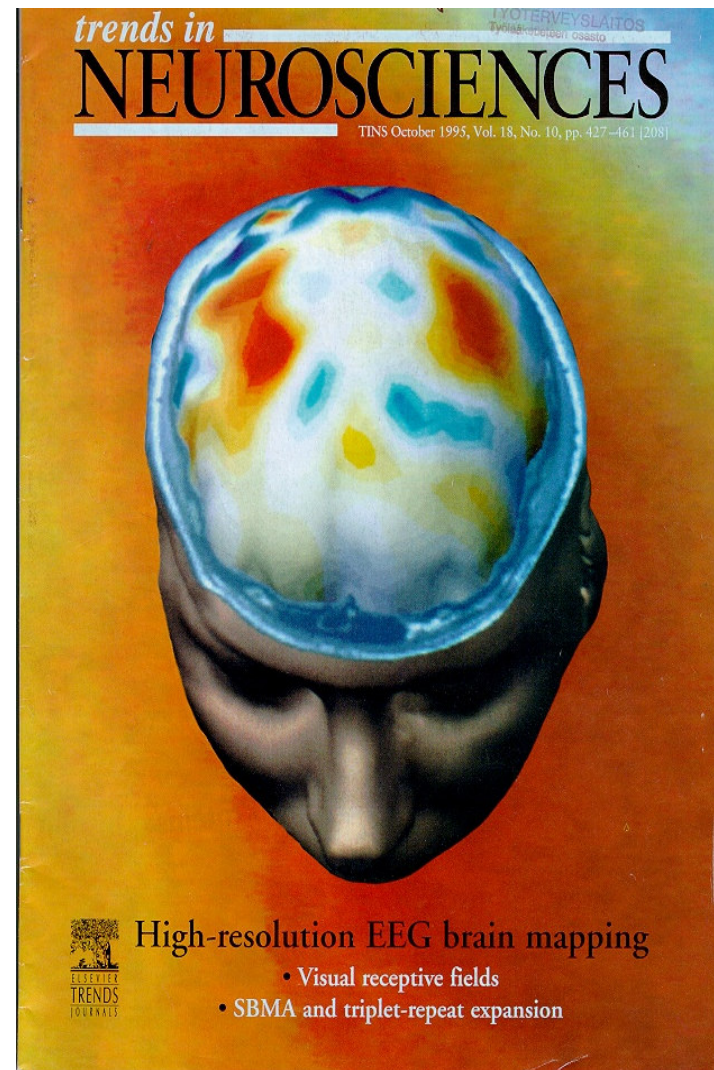
fMRI tractography



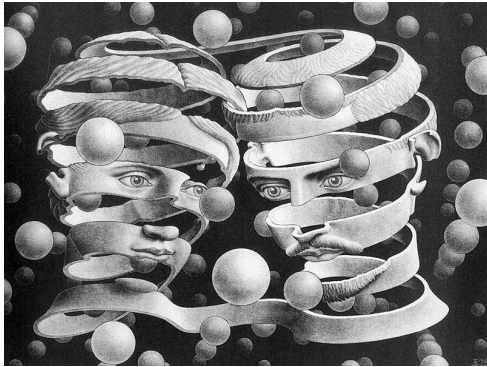
Jaana Hiltunen, Advanced Brain Imaging, HUT and FIOH

How much load can the brain take?

- Mental, physiologic, cognitive overload and fatigue
 - difficulties with concentrating, information handling, ability to think and make decisions
 - mood changes, symptoms of anxiety, depression
 - decreased motivation
 - learning difficulties
 - risks of human error and accidents increase
- Brain and cardiovascular physiology linked together
 - healthy mind and brain in a healthy body
- **OBS underload can also be a stress to the brain**

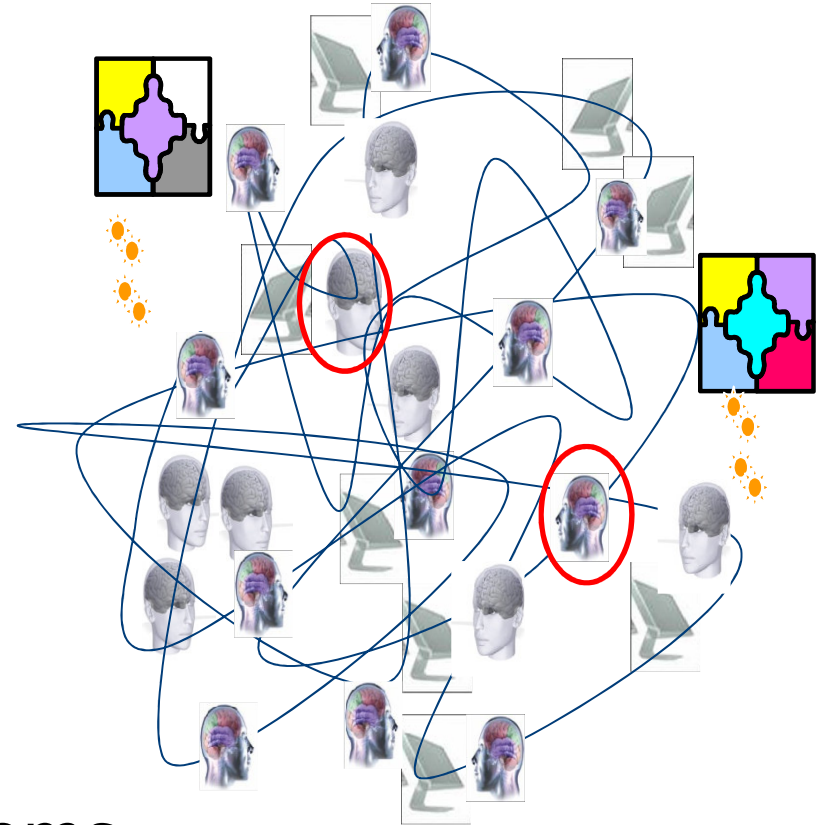


Promoting brain health and cognitive fitness, an essential part of corporate success and risk management



Escher

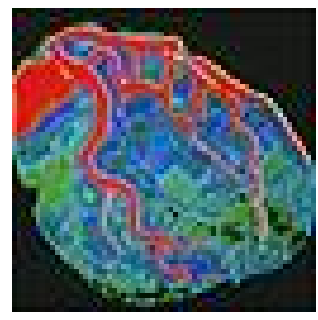
- Early identification of people/groups "in trouble"
- Brain overload raising the risk/causing cognitive dysfunction, mental health problems, physiologic symptoms of stress that hamper working ability (and productivity)



Cognitive load

- information load
- multitasking
- cognitively demanding work tasks
- work pace
- working hours

pyhysiology of central and autonomic nervous system



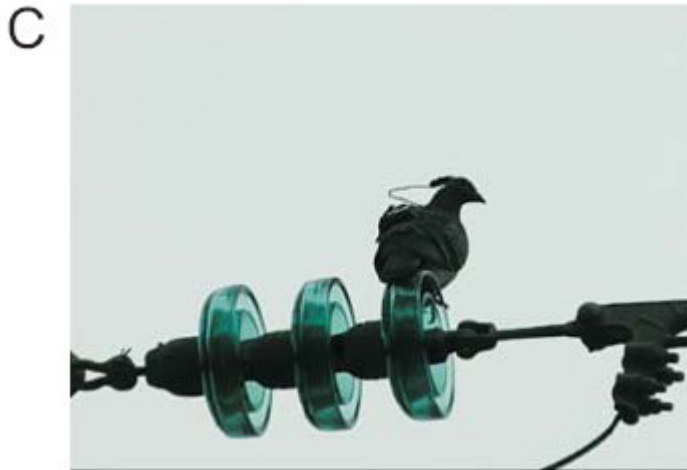
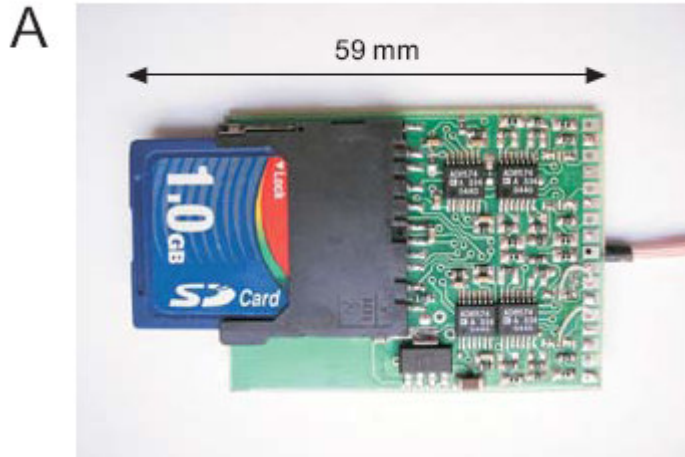
psychological and cognitive performance capacity

- age
- health
- cognitive abilities
- temperament
- motivation
- vigilance
- medication
- intoxicants

Advances in medical and IC technology, -> fusion BioMedIC applications

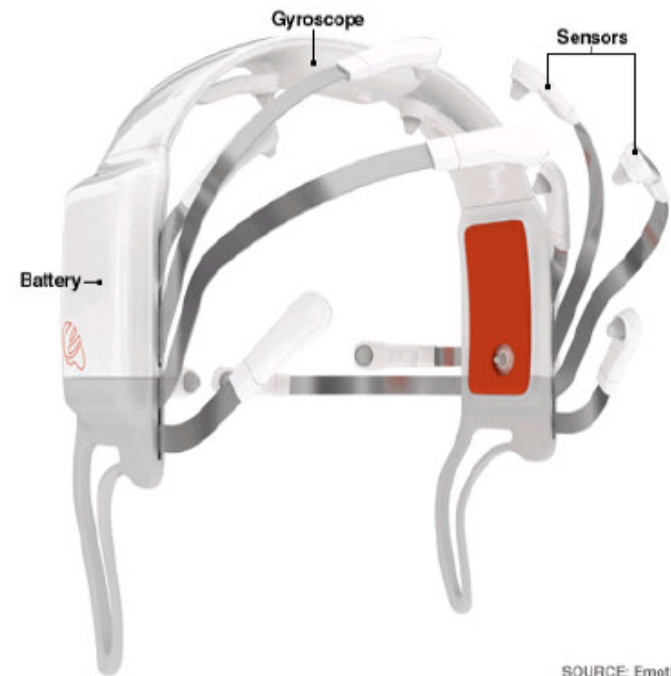
- Emerging neurophysiologic metrics → from lab to field, natural, virtual environments
- Monitoring brain state (over, optimal, underloaded): EEG (brain waves – oscillations, eye movements)
 - EEG electrode(s) hidden in headband, cap, earring, earplug
- Monitoring autonomic nervous system state by cardiovascular outcome measures (EKG, pulse oximeter.....)
 - unobtrusive, inconspicuous devices (only imagine restricts.....)
- Movement detectors: clothes, shoes, gloves, socks.....
- Data gathering devices (micro size, macro data gathering and analysis capacity):
 - neclase, wristband, bracelet, identity card, matchbox.....
- Emerging ICT: handheld, wearable, integrated, everywhere present

From the lab to field studies, the future



J Neurophysiol 95: 1263–1273, 2006.
First published October 19, 2005;
doi:10.1152/jn.00879.2005.

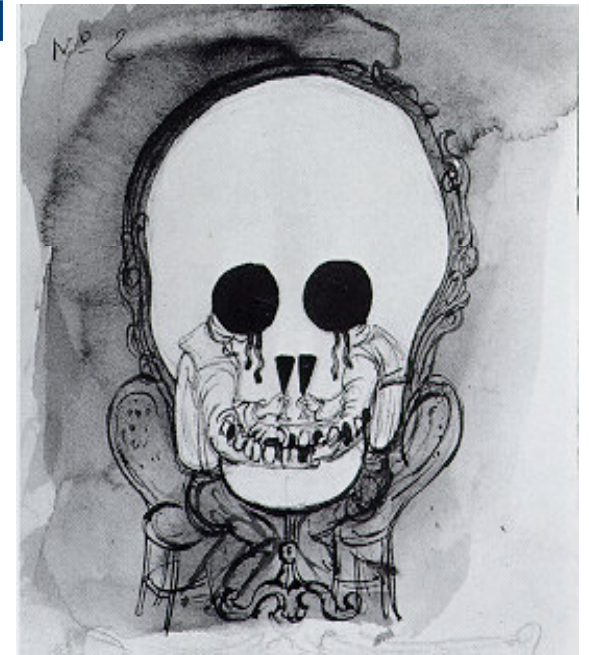
The Future? Neurophysiologic metrics integrated into the safety helmet??




SOURCE: Emotiv

Why measure brain load?

- Goal: advancing neuroergonomics
- Neuroergonomics, (defined in 2003)
 - aiming at humanly optimal cognitive and mental workload
 - promoting good brain performance at work
 - promoting mental, cognitive and physical health (ganzheit) of workers
- Big questions:
 - What and why to monitor?
 - When to pro/re -act?
 - What is acceptable when the goal is prevention, restoration, 0-tolerance to mental and cognitive meltdown
 - Human autonomy and ethics



Salvador Dalí, 1941:
Café scene

A photograph of a forest path with a central evergreen tree, overlaid with a vertical mirror effect. The scene is misty and sunlit, with light rays filtering through the trees. The path is covered in green grass and small white flowers. The text is centered in the lower half of the image.

What we see is
in our mind's eye
Thank you !