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

Brain MRI: Advanced Brain Imaging Centre, HUT
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
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

Sound environment
- background noise
- alarms
- speech
- radio

Physical space
- illumination, smells, vibration, temperature

Information technology
- displays
- technical characteristics
- number, placing

User interfaces
- data structure, navigation
- information load
- information quality
- symbols, colours
- videoclips, etc etc

Other technology?

Quality of information
- used for what

Situational awareness
- novice
- expert
- attention
- perception
- vigilance
- working memory
- problem solving
- decision making

Technology and work tasks
- verbal communication
- face-to-face
- in print
- task analysis
- passive surveillance
- active control of production
- industry, health, services
- handling of critical incidents
- multitasking
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

- data
- information
- knowledge
- wisdom
- understanding
- "know-nothing"
- "know-what"
- "know-how"
- "know-why"

(Cleveland, 1982)
(Ackoff, 1989)
(Zeleny, 1989)

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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

sensory stimuli
\[ \downarrow \downarrow \downarrow \downarrow \downarrow \]
ATTENTION TO CUES

focusing
dividing
sharing
switching
maintaining

LONG-TERM MEMORY
skills, knowledge
experience

WORKING MEMORY
online information processing

stress level
vigilance, alertness

physiologic state of the autonomic
and central nervous system

semi/sub-conscious level of thought

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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
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

TEMPORAL LOBES
auditory info, long-term memory skills, emotions

BRAIN STEM
co-ordinating movement

OCCIPITAL LOBES
visual info

CEREBELLMUM
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

Physiology 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

**prior to the lab day**
- Symptoms, illnesses, medication, work hours, exercise, work ability, (e.g. SCL-90, WAI, BDI-II, BAI)
- Burnout (MBI-GS) classification variable

**subjective ratings**
- IT service professional with burnout symptoms

**objective evaluations**
- Psychiatric interview
- Neuropsychological tests
- Physiological measurements

**during the lab day**
- 24h-questionnaire
- Work load (Nasa-tlx)
- Sleepiness (KSS)

**Clinical**
- Cognitive psychology methods: B@W2
- Autonomic Nervous System
- Central Nervous System neurophysiology

**CognFuse software**
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"

Brain@Work – test, modified
  • from SynWork®

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

FIOH/Kiti Müller / 6.5.2009
Time-synchronized linking of cognitive performance with (neuro)physiologic metrics

**STIMULUS**

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

**Physiological measurements**

**B@W-test**

**Performance**

**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

cognitive performance
B@W multitasking and individual performance

70 min multitask performance

vigilance
alertness
subtask

"all" or "nothing"

stable, constant, reliable, no errors

FIOH/Kiti Müller
Possible causes underlying performance differences in individuals

- 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: $F=60.00$, $p<.001$
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

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<th>Day of arrival</th>
<th>8 h sleep</th>
<th>Baseline day1</th>
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<th>8 h sleep</th>
<th>Recovery day1</th>
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<th>8 h sleep</th>
<th>Recovery day2</th>
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KSS+50 min multitask + KSS
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

- **Acute sleep deprivation (only 2 hours sleep previous night)**
  - individual multitaks performance declines cognitively to levels seen 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

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

- 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)

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Cognitive load

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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

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From the lab to field studies, the future

The Future? Neurophysiologic metrics integrated into the safety helmet??
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 Dali, 1941: Café scene

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