

Happy Brain, Happy Life?!
Potenziale der Neurotechnologie, KI
und Psychologie

Dr. Mathias Vukelić / Verein Risiko & Sicherheit, 05.07.2023

Happy Life?

zunehmende Mensch-Technik-Integration und Auswirkungen auf Mensch und Arbeit



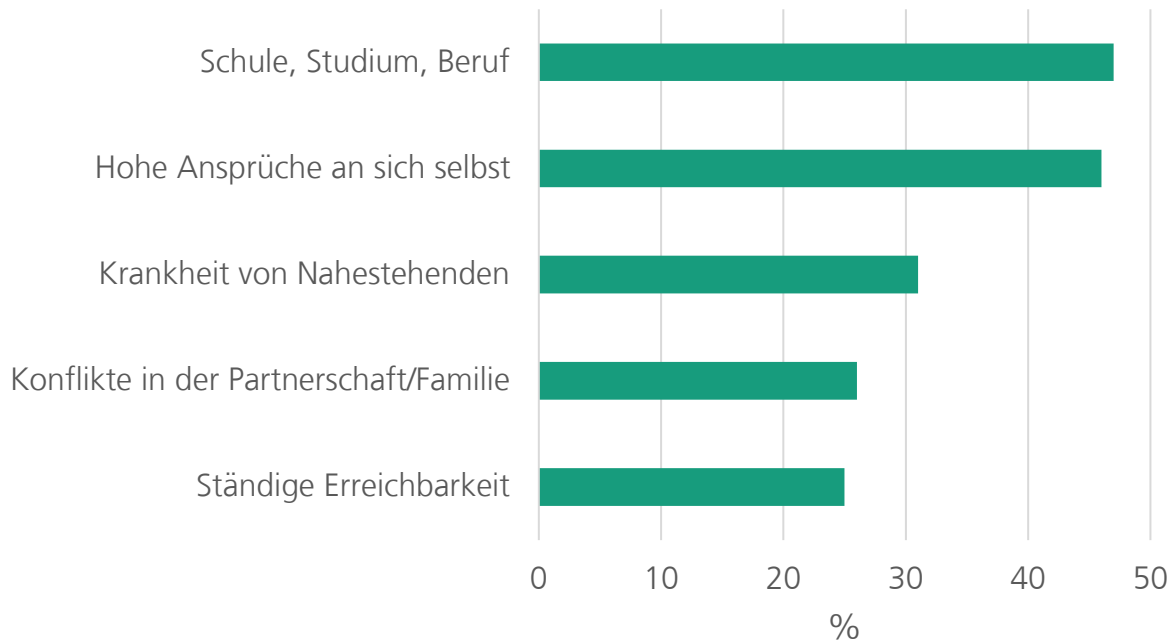
»Metaverse ist mehr als ein Hype.
Sicher ist: Es wird kommen, wie und im
welchem Ausmaß auch immer«
Dietmar Laß, Fraunhofer-Verbund IUK



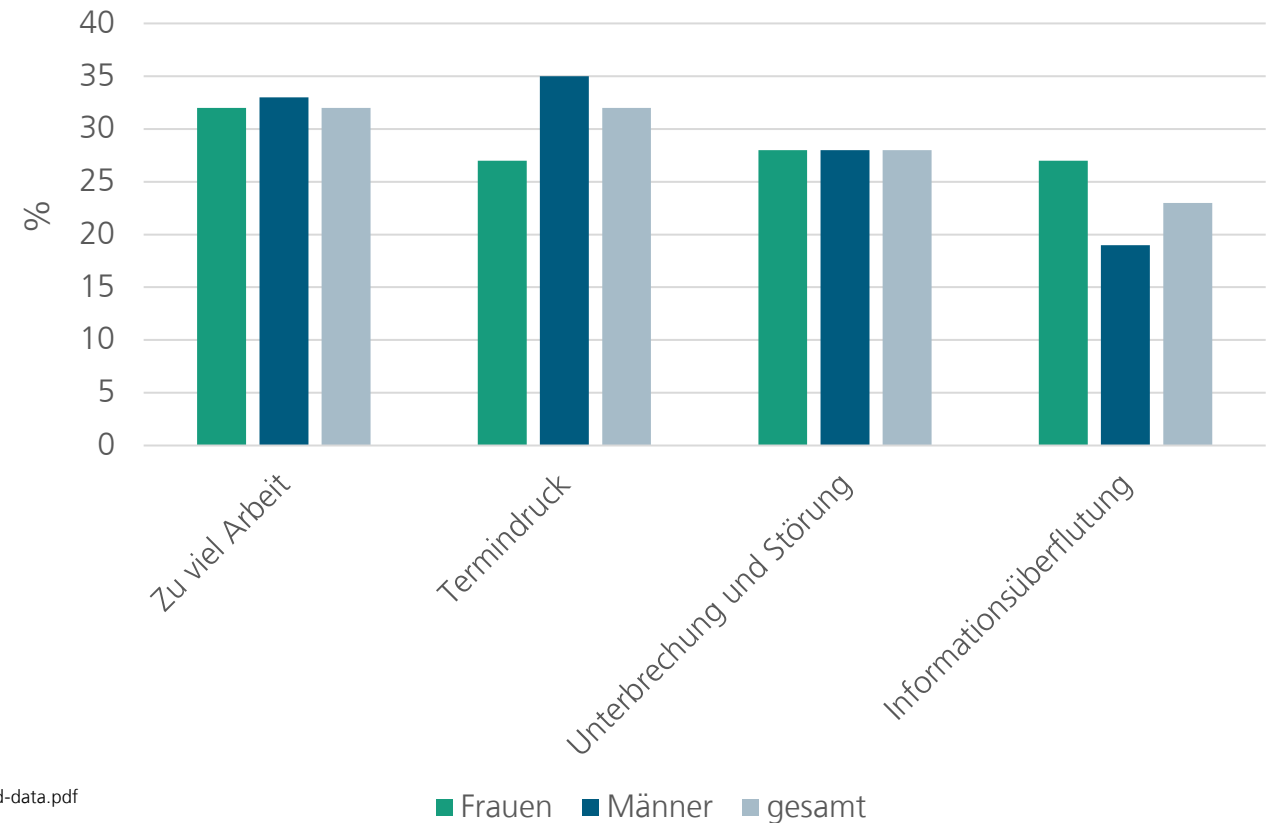
Happy Life?

Was stresst uns?

Top 5: Das stresst Deutschland am meisten



Top 5: Das stresst am meisten im Beruf



TK Stressstudie 2021, <https://www.tk.de/resource/blob/2118106/cbdb7ed26363a35145d753516510f92d/stressstudie-2021-pdf-zum-download-data.pdf>

Happy Life?

Stress und dessen Relevanz

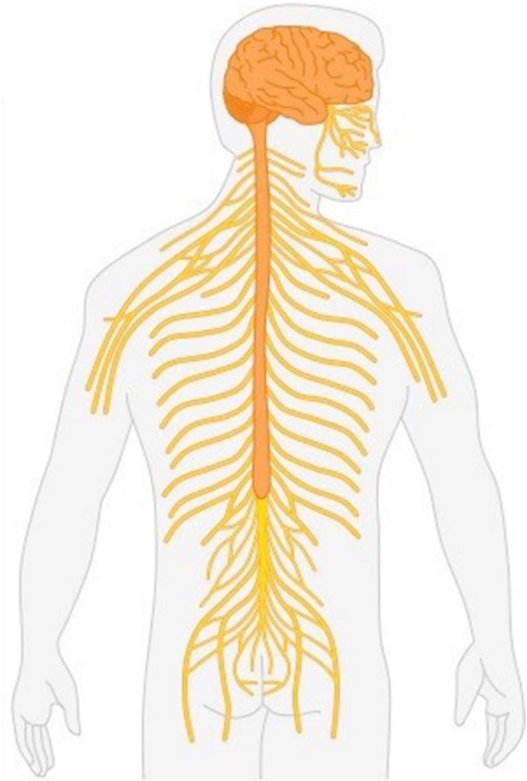
- Macht »Stress« per se krank?
 - »Stress« kann unter bestimmten Voraussetzungen ausgesprochen gesund sein
 - »Stress« ist keine Erfindung unserer Zeit!
- Aus evolutionärer Sicht ist der Mensch geradezu für Herausforderungen »gemacht«
 - Unser Körper ist darauf ausgelegt auf »Gefahren« (Aufgaben) zu reagieren
 - Was sind die Voraussetzungen dafür, dass es zwischen Mensch und Aufgaben passt?



©tony241969, <https://pixabay.com/de/illustrations/smilodon-s%C3%A4belzahnkatze-ausgestorben-7540040/>

Happy Life?

neuronale Stresssysteme

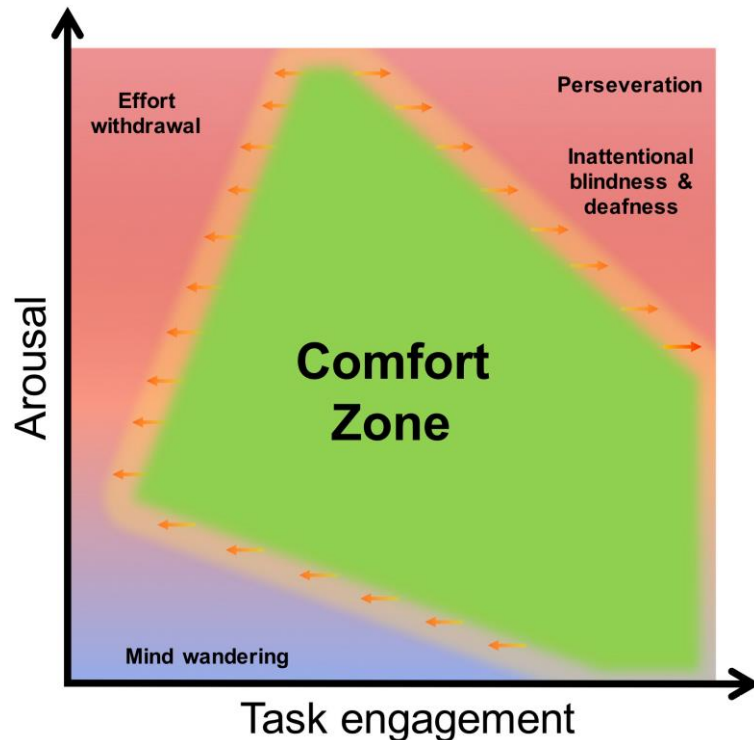


1. **Das »klassische« Stresssystem**
 - auch Task-System genannt
2. **Das »Unruhe-Stresssystem«**
 - auch Monitoring-System genannt

Kandel et al. (2000) Principles of Neural Science

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zwei neuronale Stresssysteme (I)

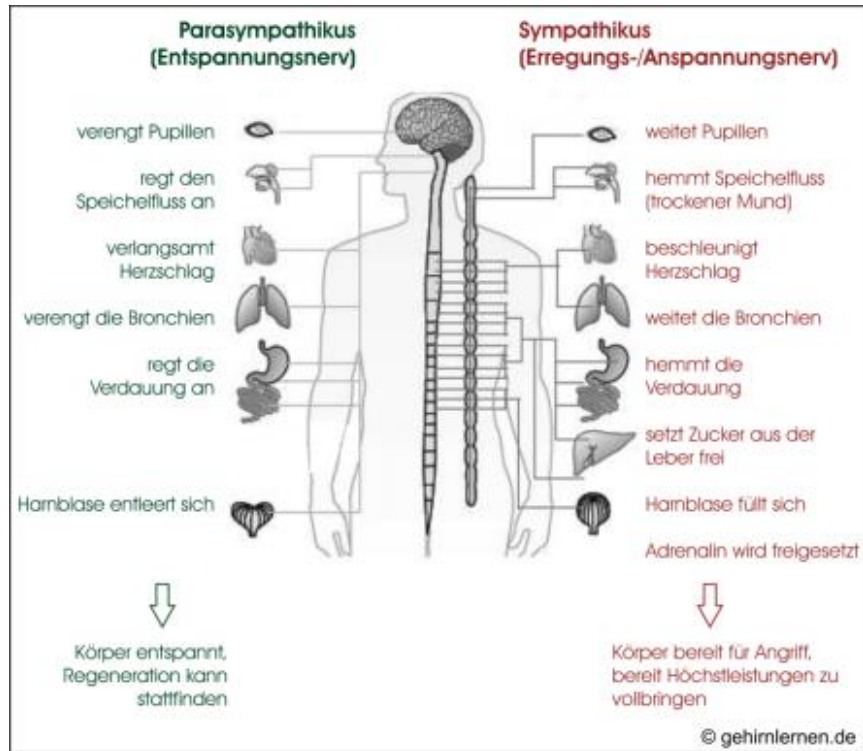


- Das »klassische« Stresssystem – »Task-System«
 - Mentaler Stress: Arousal, Engagement und Performanz
 - Die Bedeutung der individuellen Bewertung von Stress!
 - Menschen antworten auf eine gegebene Anforderungssituation mit *unterschiedlichen biologischen* Stressreaktionen
 - Äußere Anforderungen sind daher nicht gleichzusetzen mit der Belastung, die ein Mensch biologisch und psychisch erlebt!

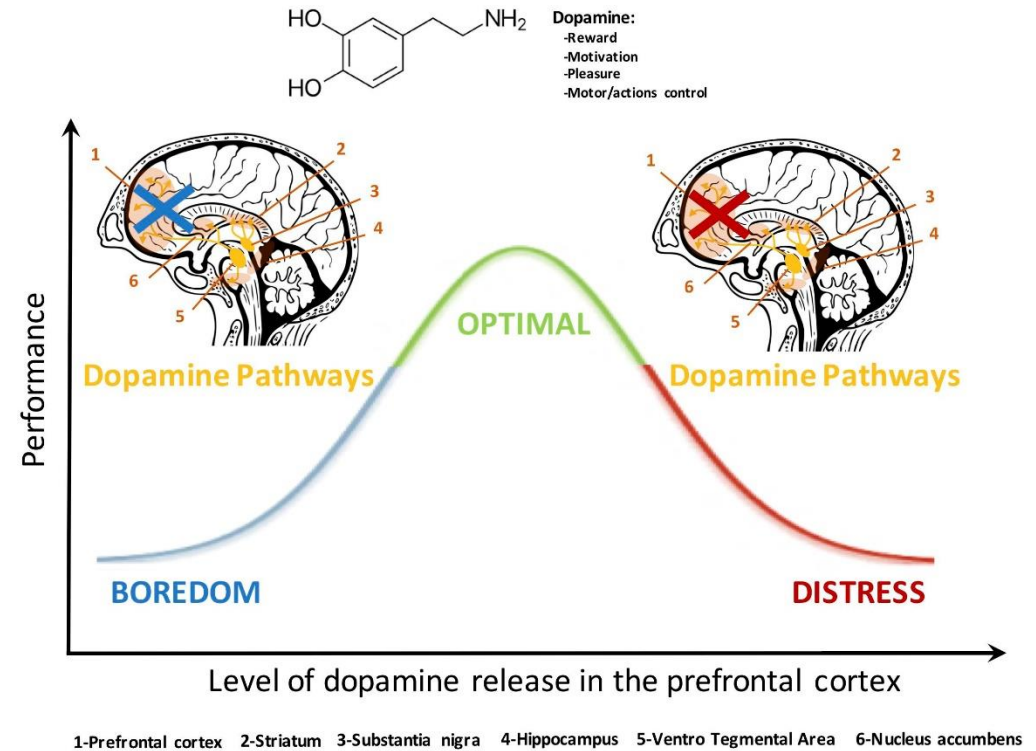
F. Dehais et al.: An neuroergonomics approach to mental workload, engagement and human performance. Front. Neurosci. 14:268. (2020).

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zwei neuronale Stresssysteme (I)



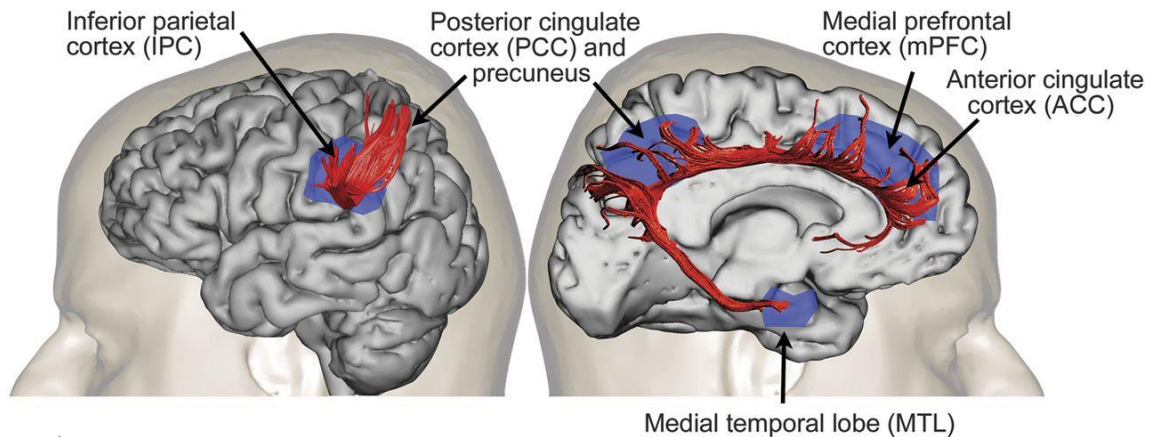
<https://www.gehirnlernen.de/gehirn/das-nervensystem/>



F. Dehais et al.: An neuroergonomics approach to mental workload, engagement and human performance. Front. Neurosci. 14:268. (2020).

Happy Life?

zwei neuronale Stresssysteme (II)



Stefano Sandrone, and Marco Catani
Neurology 2013;81:e172-e175

- Das »Unruhe-Stresssystem« – »Monitoring-System«
 - »Default mode network« im Gehirn
 - Breit gestreute aber flache Aufmerksamkeit
 - Sehr stark gefordert in der »Ökonomie der Aufmerksamkeit«
 - (digitales) Multitasking
 - ...

Happy Life?

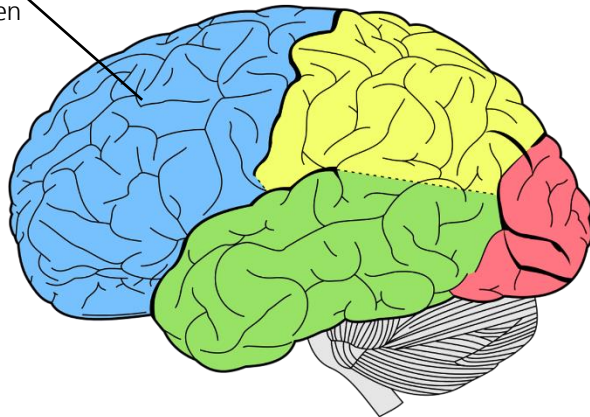
Stress und seine langfristigen Folgen

Zentrales Nervensystem

- Chronischer Stress kann den präfrontalen Cortex verändern: Abbau der Dendriten

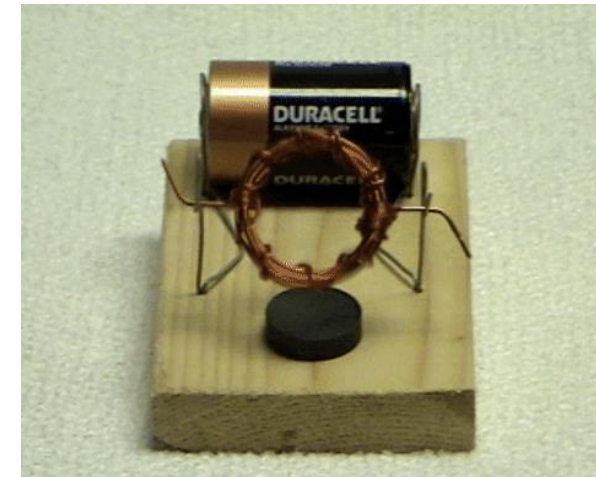
Frontallappen

Bewegungsabläufe
Höhere kognitive Funktionen
Sprachproduktion
Soziale Aspekte



Peripheres Nervensystem

- Chronischer Stress führt zu Überaktivierung des Sympathikus und Dysbalance von Aktivierung und Erholung



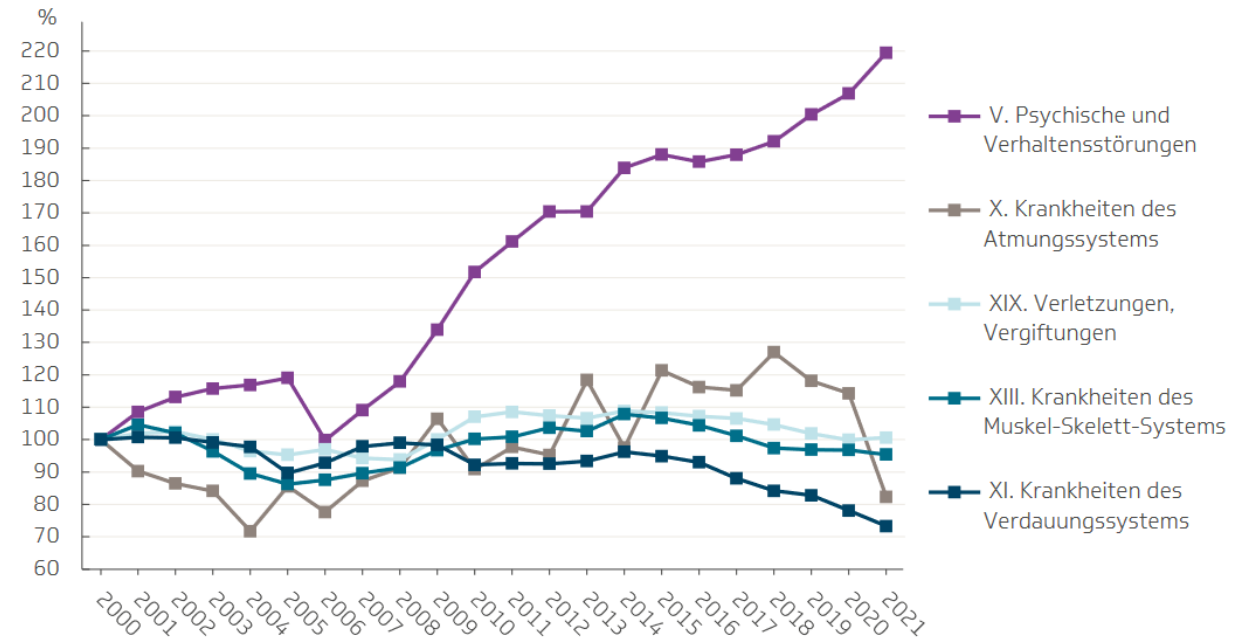
<https://giphy.com/gifs/hO92ovxHHPOw0/fullscreen>

- **Folgen:** Blutdruckprobleme, Magen-Darm-Probleme, schlechteres Immunsystem, Herz-Kreislauf-Erkrankungen....

Happy Life?

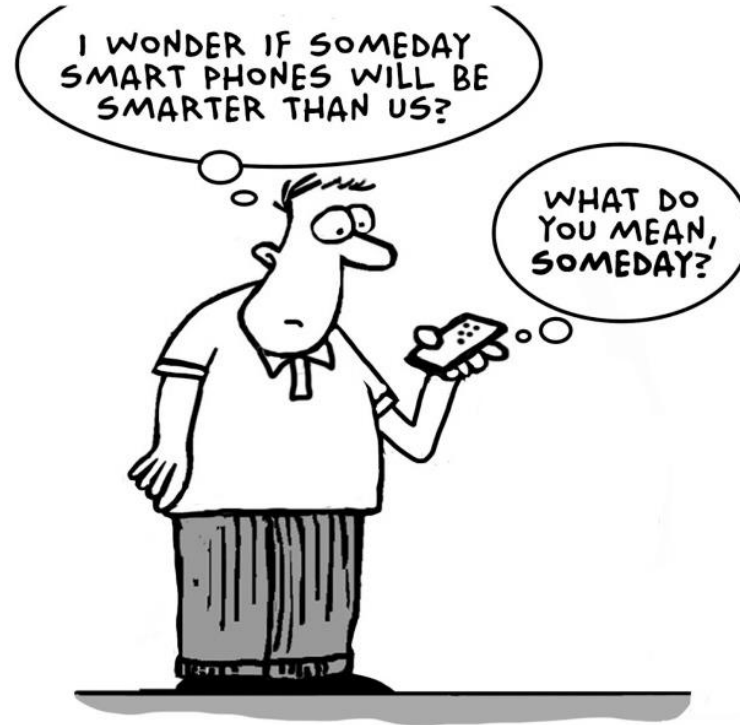
Was passiert, wenn der Stress zu groß wird?

- Gesundheitliche Beschwerden
 - HKS, Wirbelsäule, Schlafstörungen, Tinnitus, Magen-Darm
- Emotionale Erschöpfung
 - Reizbarkeit, Resignation, Zynismus, Verlust von Empathie, Verbitterung
- Reduzierte Leistungsfähigkeit
 - Konzentrationsprobleme, Reizüberempfindlichkeit, Ermüdung
- Arbeitsplatzprobleme
 - Unzufriedenheit, Geringere Verbundenheit mit dem Arbeitgeber, Geringere Bindung an den Arbeitsplatz



TK Stressstudie 2021, <https://www.tk.de/resource/blob/2118106/cbdb7ed26363a35145d753516510f92d/stressstudie-2021-pdf-zum-download-data.pdf>

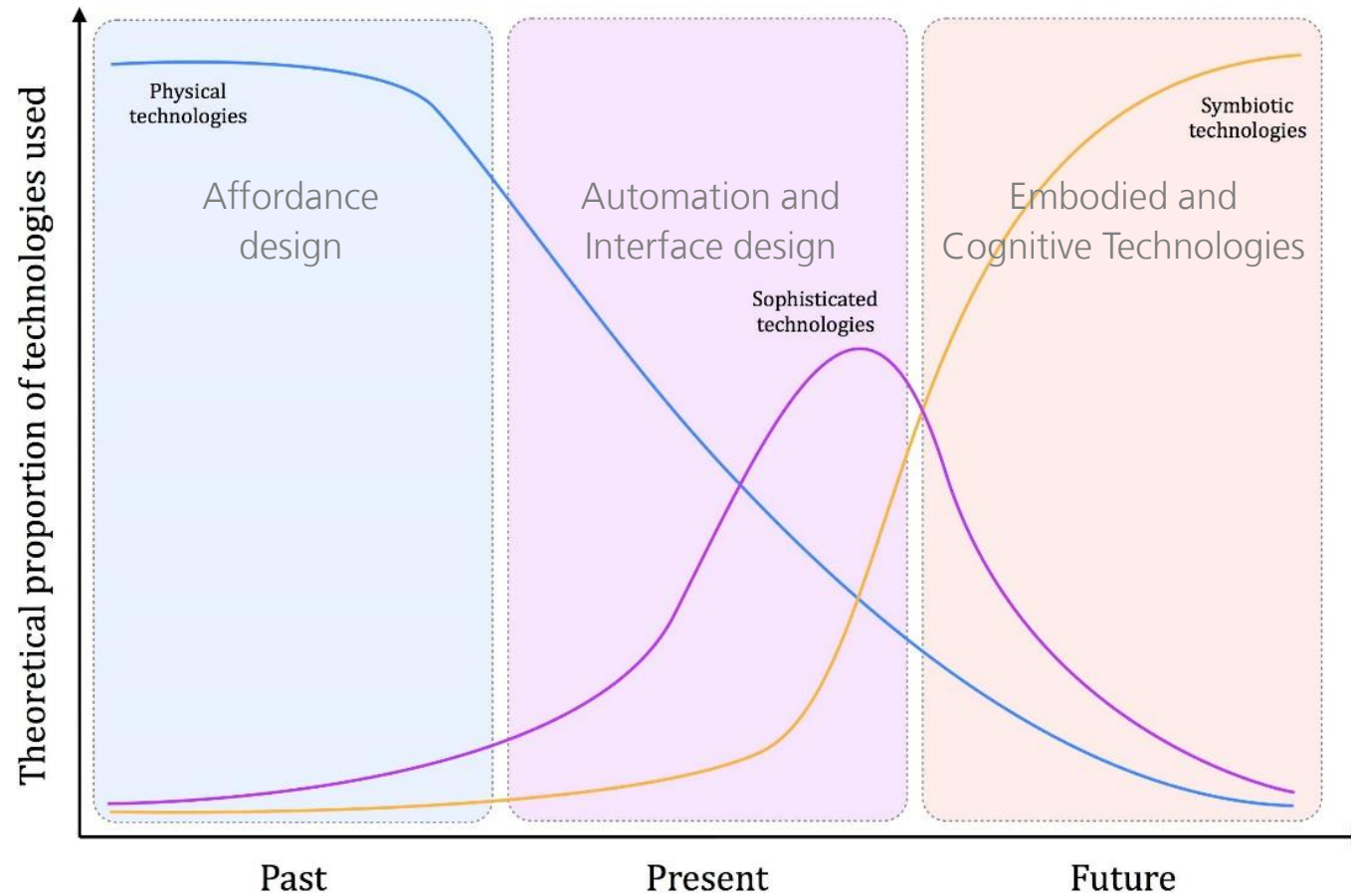
Human-Technology Interaction



Source: pinterest.com

Human-Technology-Interaction

interfaces to the world



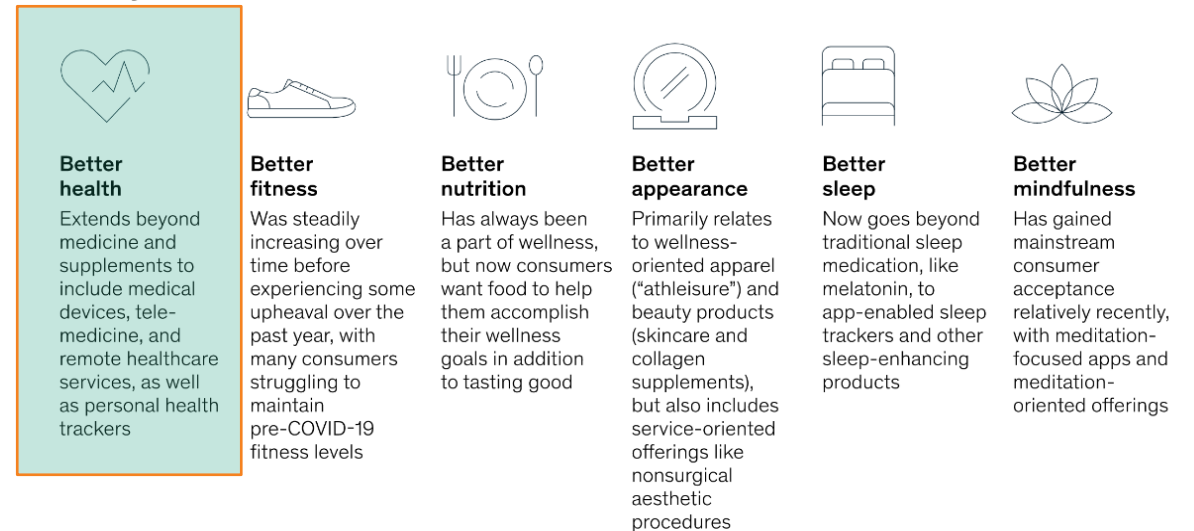
F. Osiurak, 2018, How our cognition shapes and is shaped by technology: A common framework for understanding human tool-use interactions in the past, present and future. *Frontiers in Psychology*. Vol 9 Article 293

Human-Technology-Interaction

consumer wearables

- *Health and Wellness Industry* important part of the economy
- Most money invested in better health
- Future trend: **Personalised, digital applications for certain questions**

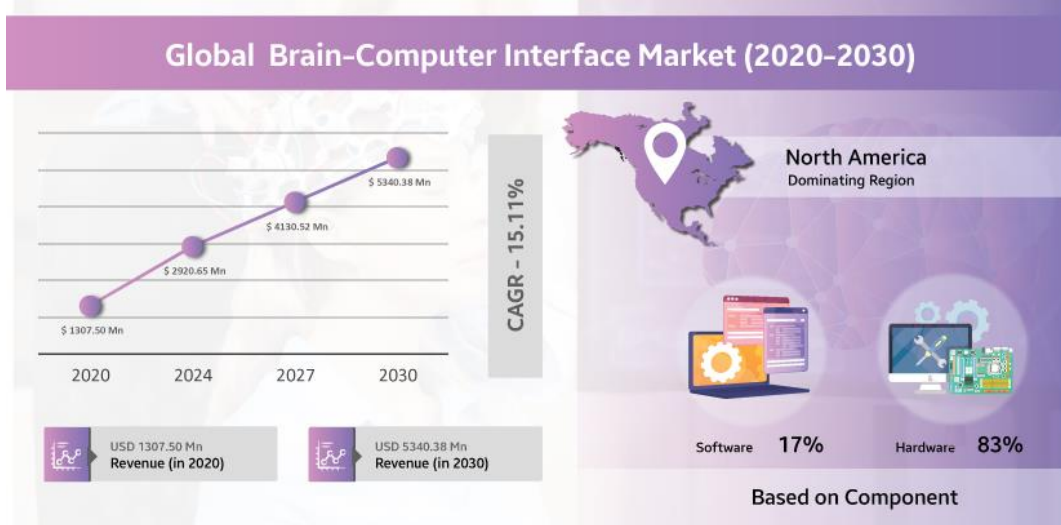
Today's consumer views wellness across six dimensions.



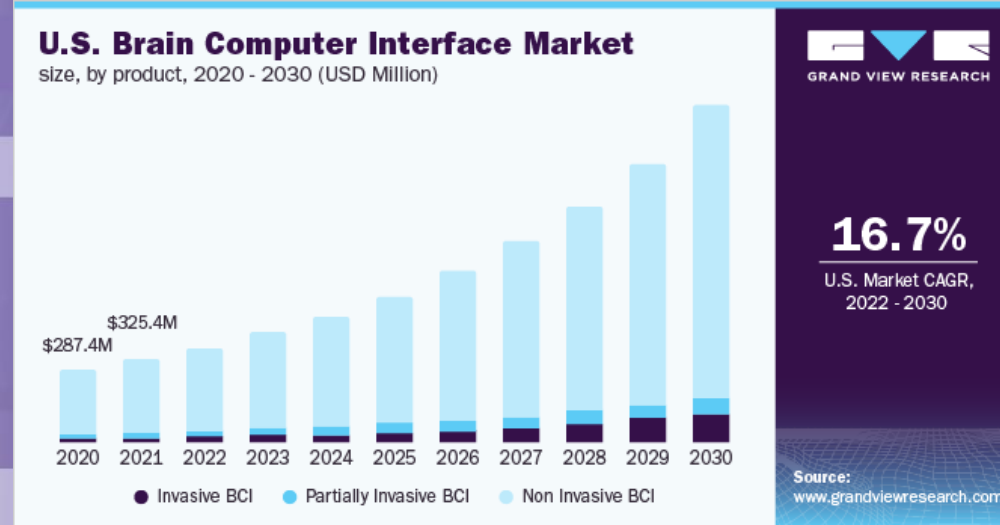
<https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/feeling-good-the-future-of-the-1-5-trillion-wellness-market>

Human-Technology-Interaction

future technological innovation?



<https://www.strategicmarketresearch.com/market-report/brain-computer-interface-market>



<https://www.grandviewresearch.com/industry-analysis/brain-computer-interfaces-market>



Ubiquitous Neurotechnologies

will become convenient personal computing devices

2000 - 2010



2010 - today

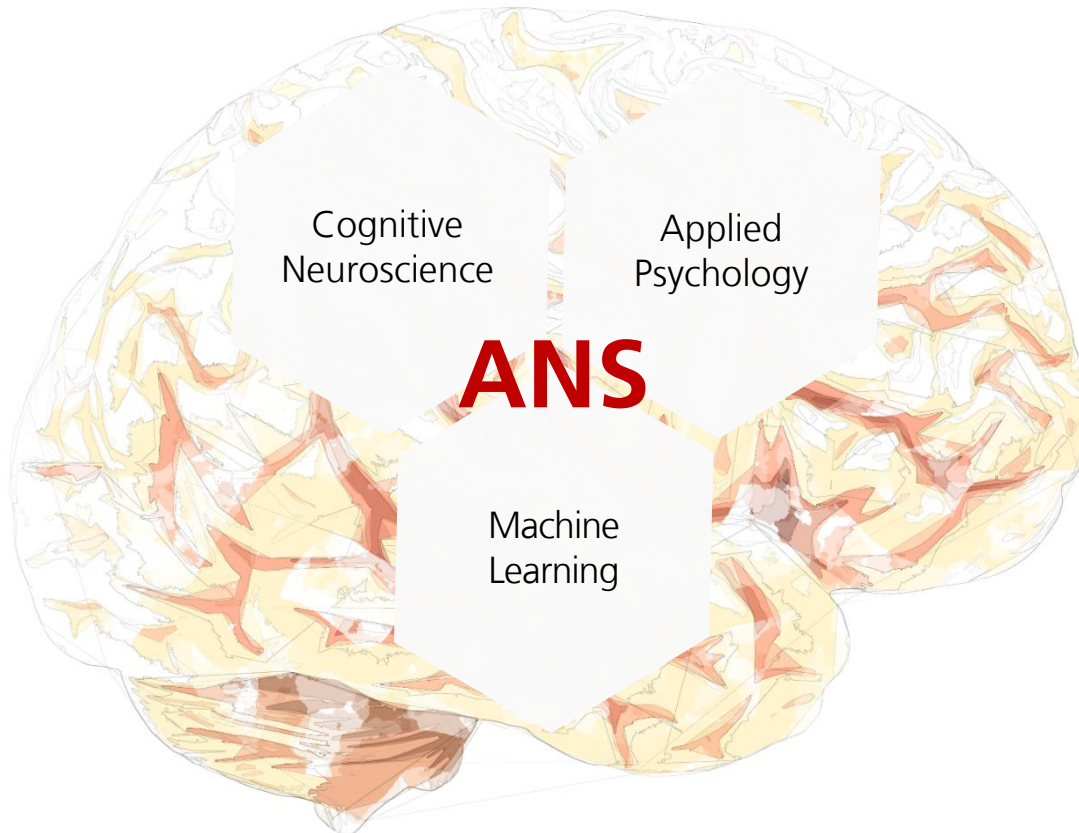


Today - near future



Applied Neurocognitive Systems (ANS)

we unlock the human potential!



Our vision is to create a better future of work and everyday life; where people are at the forefront while technology is assistive in the background!

Applied Neurocognitive Systems (ANS)

we unlock the human potential!



Neurophysiological Recordings

Electroencephalography (EEG)

Functional Near-infrared Spectroscopy (fNIRS)



Physiological Recordings

Electrodermal Activity

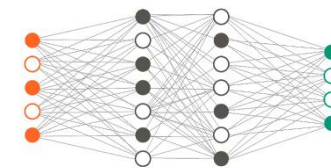
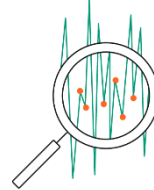
Heart-rate Variability

Respiration

Eye-tracking

Facial Decoding

Signal Processing



Machine Learning

Mental User States

Identifying Psychological Constructs

- Attention and Concentration
- Mental Load (Cognitive Workload)
- Error Perception
- Affect and Emotion

(Envisioned) Applications

- Evaluation, Improvement and User Acceptance of Human-Machine Systems
- Emotion- and Cognitive-Adaptive Human-Machine Interfaces

Applied Neurocognitive Systems (ANS)

we unlock the human potential!



Human-Robot Collaboration

Decoding Mental States

KI Fortschrittszentrum
LERNENDE SYSTEME UND KOGNITIVE ROBOTIK



Baden-Württemberg
MINISTERIUM FÜR WIRTSCHAFT, ARBEIT UND TOURISMUS



VECTOR
STIFTUNG

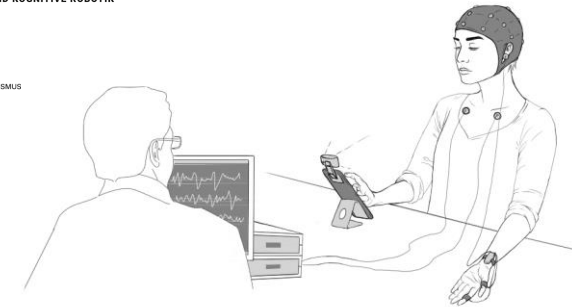


KIT
Karlsruher Institut für Technologie
NEURA
ROBOTICS

KI Fortschrittszentrum
LERNENDE SYSTEME UND KOGNITIVE ROBOTIK



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Assistive Communication Systems

Neuroadaptive Learning

Bundesministerium
für Bildung
und Forschung



seracom

Bundesministerium
für Bildung
und Forschung

Bundesminister
für Wirtschaft
und Energie



Neuroadaptive Learning

monitoring learning progress



Towards User-Aware VR Learning Environments: Combining Brain-Computer Interfaces with Virtual Reality for Mental State Decoding

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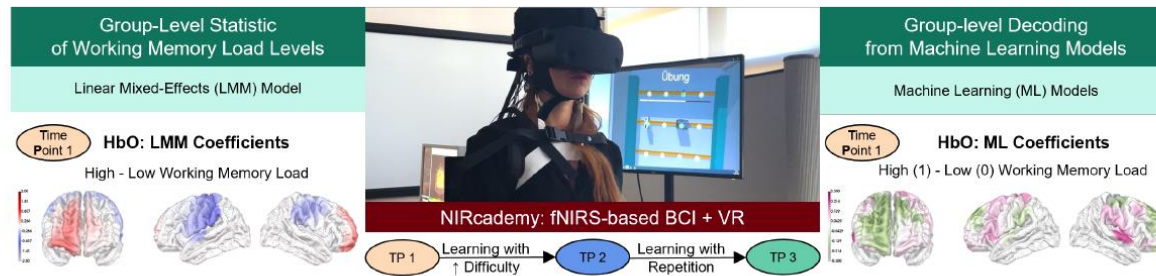


Figure 1: Investigating brain patterns of mental states across multiple virtual reality (VR) learning sessions. Two approaches are introduced, (1) left side: a group-level statistic with a linear mixed-effects (LMM) model and (2) right side: a decoding approach using machine learning (ML). In both approaches, model coefficients were visualized on the cortical surface of a 3D brain image to identify informative patterns distinguishing between low and high working memory load.

[Link: NIRcademy - BCI für Lernumgebungen der Zukunft](#)

Motivation

- monitor user's mental states (mental load)
- tailor learning to individual skills and needs

Methods

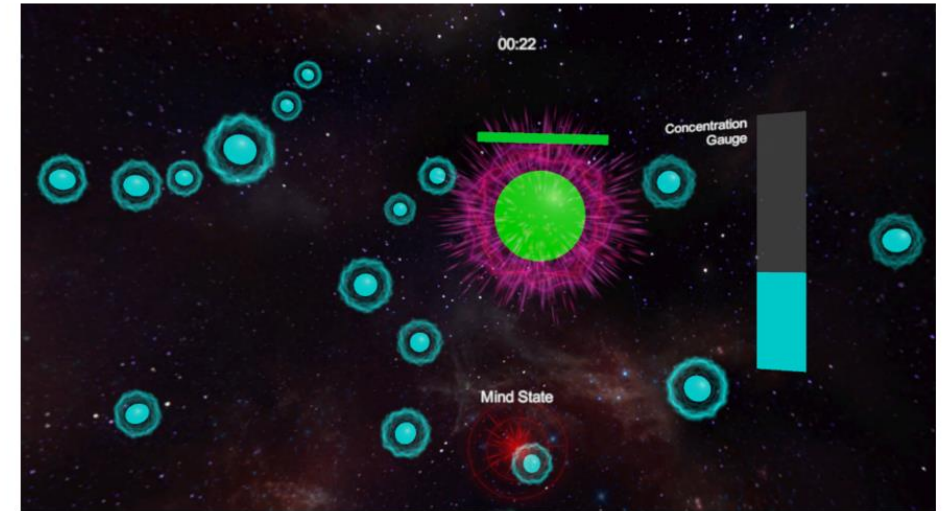
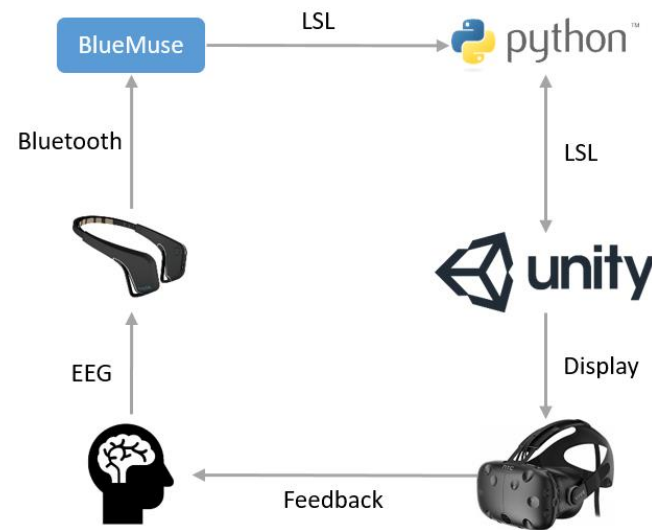
- functional near-infrared spectroscopy (fNIRS) to measure brain activity
- investigate mental load to identify learning progress

Lingelbach, K., Diers, D., Bui, M. and Vukelić M (2023). Investigating Feature Set Decisions for Mental State Decoding in Virtual Reality based Learning Environments. In: AHFE 2023 Conference Proceedings, San Francisco, USA, *accepted*

Lingelbach, K., Diers, D. and Vukelić M (2023). Towards User-Aware VR Learning Environments: Combining Brain-Computer Interfaces with Virtual Reality for Mental State Decoding. In 2023 CHI Conference on Human Factors in Computing Systems Proceedings (CHI 2023). Article No. 292, pages 1-8

Neuroadaptive Learning

brain-computer interface and virtual reality based neurofeedback

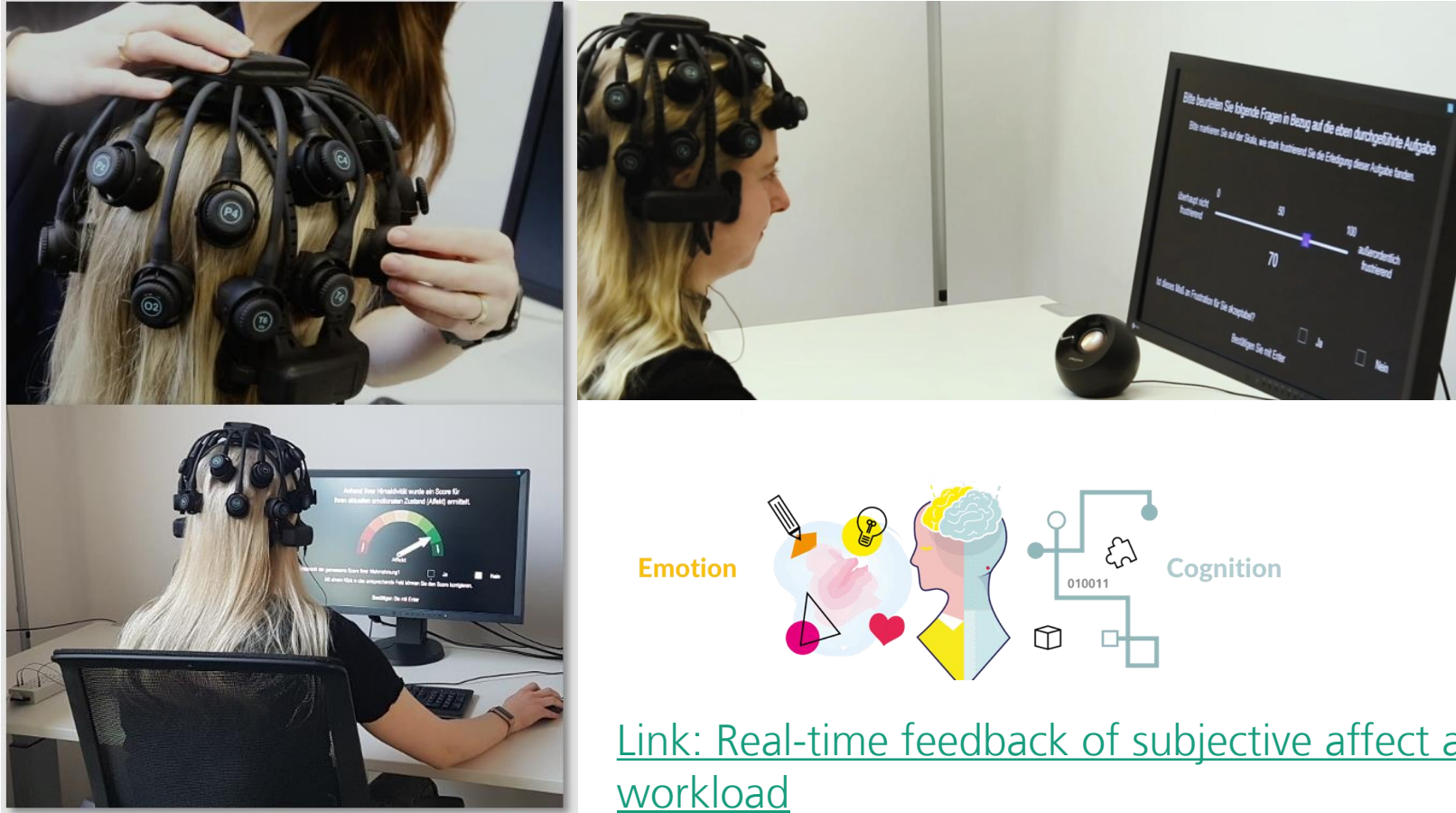


[Link: MindTrain - Förderung mentaler Fitness](#)

Kosuru RK, Lingelbach K, Bui M and Vukelić M (2019). MindTrain: How to Train Your Mind with Interactive Technologies. Proceedings of Mensch und Computer 2019, 643-647

Decoding Mental States

how does emotional distraction influence mental load



Lingelbach, K., Gado, S., Rieger, J. W and Vukelić M (2021). What I feel and what I say: Decoding neurophysiological correlates of cognitive and affective states. In: The 3rd International Neuroergonomics Conference, Munich, Germany, September 11-16, 2021

Lingelbach, K., Gado, S., Rieger, J. W and Vukelić M (2021). Investigating the Emotion-Cognition Interaction: Effects of Affective Distractors on Working Memory Load. In: The 3rd International Neuroergonomics Conference, Munich, Germany, September 11-16, 2021

Gado S, Lingelbach K, Bui M., Rieger JW. and Vukelić M (2021). Real-time feedback of subjective affect and working memory load based on neurophysiological activity. International Conference on Human-Computer Interaction, 80-87

[Link: Real-time feedback of subjective affect and workload](#)

Human-Robot Collaboration

motivation

What do we need?

- good feedback function (criticism and reward) that captures the task to be learned

What are the real-world characteristics and problems?

- challenge of sparse extrinsic rewards – *sparse environments*
- sparsity is a natural way to define a reward - *agent only receives a positive reward if the task is completed, or a goal is achieved!*
- provide poor learning signals for the agent, especially if the task horizon is long - *very time-intensive training!*

What could be a possible solution?

- learning from human feedback through an implicit Brain-Computer Interface (BCI)

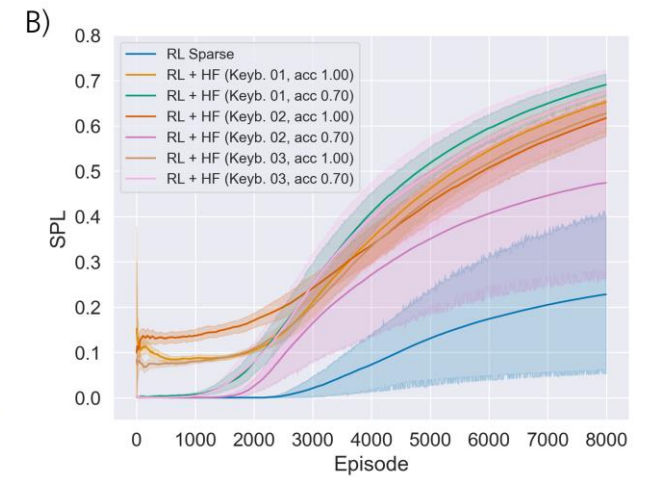
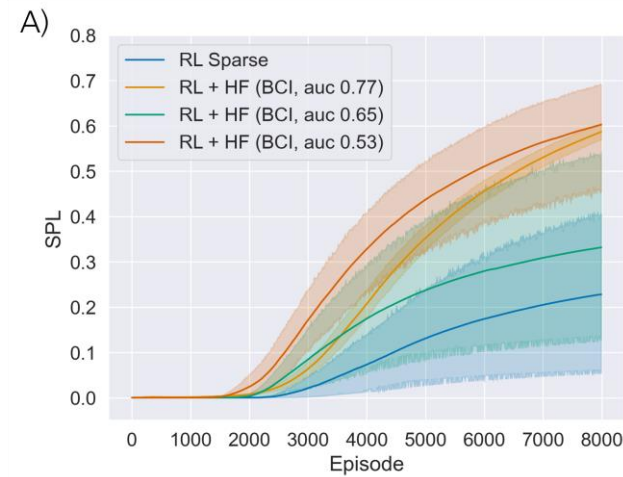
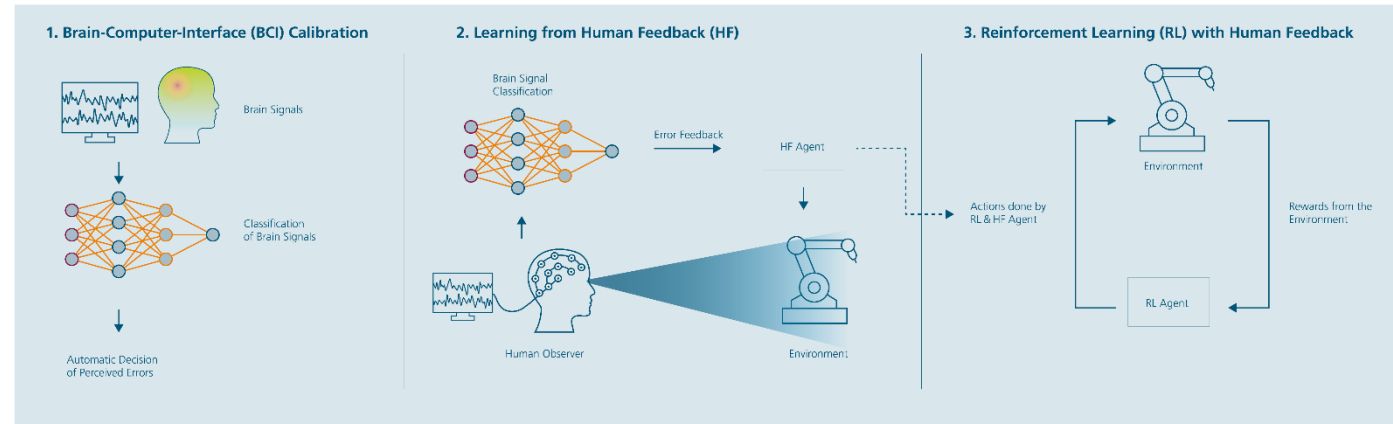
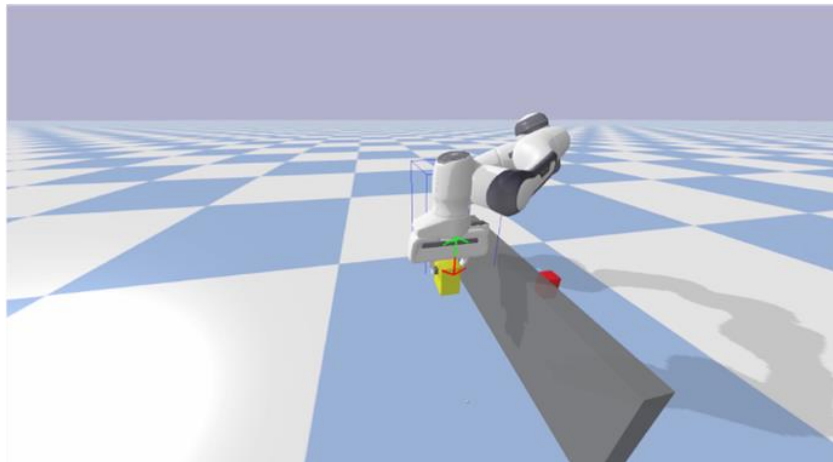
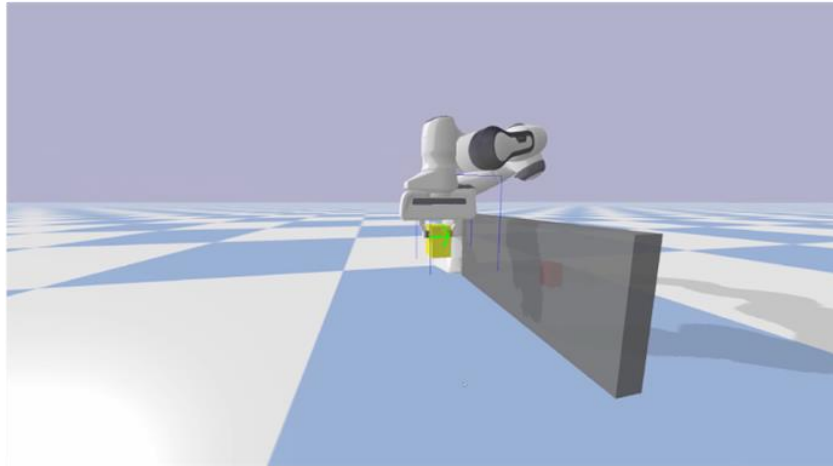
What are the perspective(s)?

- estimation of personalized trust zones for interaction
- improvement of gesture and voice interaction in cobots



Human-Robot Collaboration

human-guided deep reinforcement learning

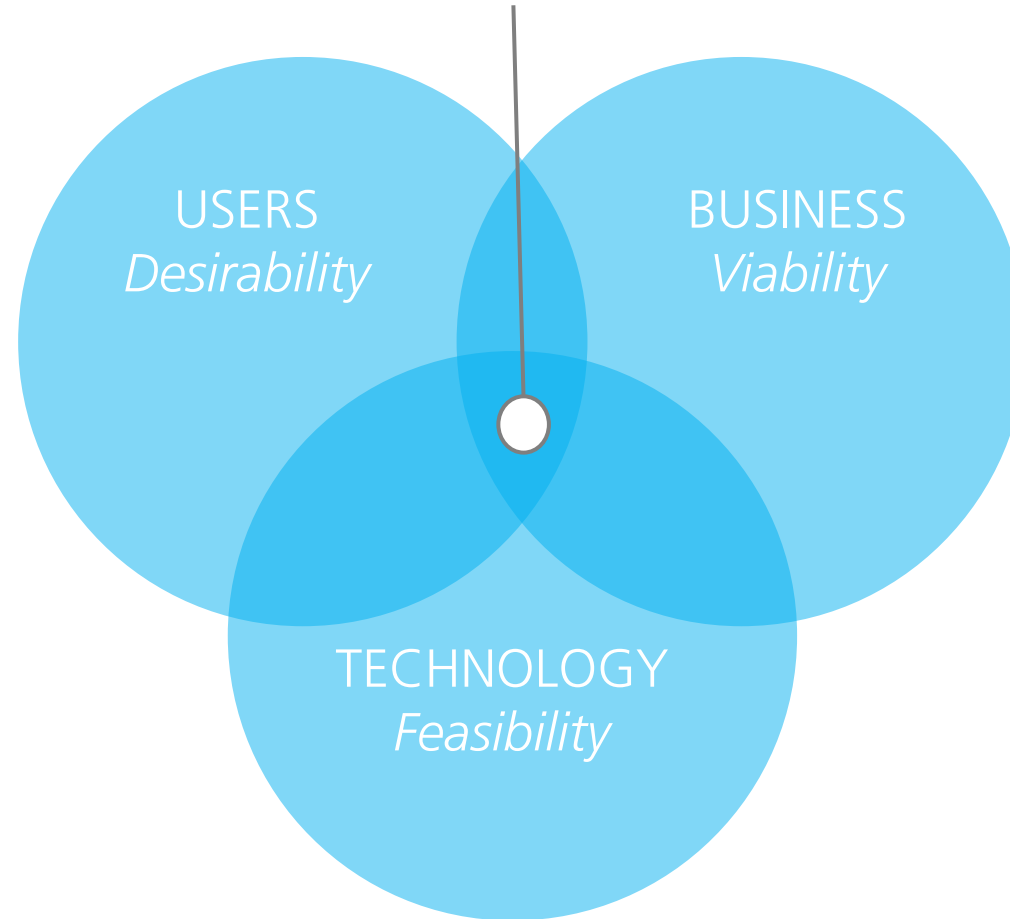


Vukelić, M. et al. 2022, Neuroadaptive Technology Conference, Best Talk Award

Happy Brain!

Innovative technology – but how?

*Innovation**
**Invention that is successful on the market*

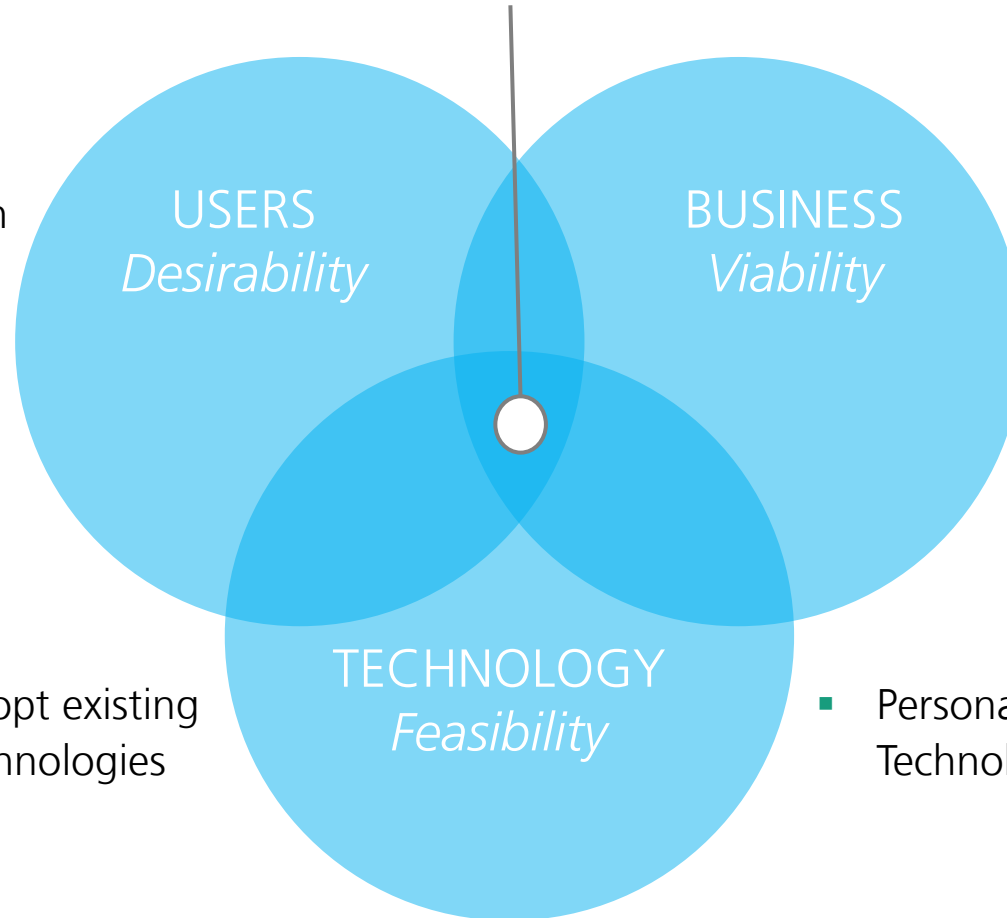


Happy Brain!

Innovative technology – but how?

*Applied Neurocognitive Systems**
**Sustainable Human-centred Technologies*

- Involve users throughout design and development
- Include user needs and requirements
- Effective and affordable development



- Analyse economic context
- Team up with companies
- Exploitation plans are anchored in development objectives

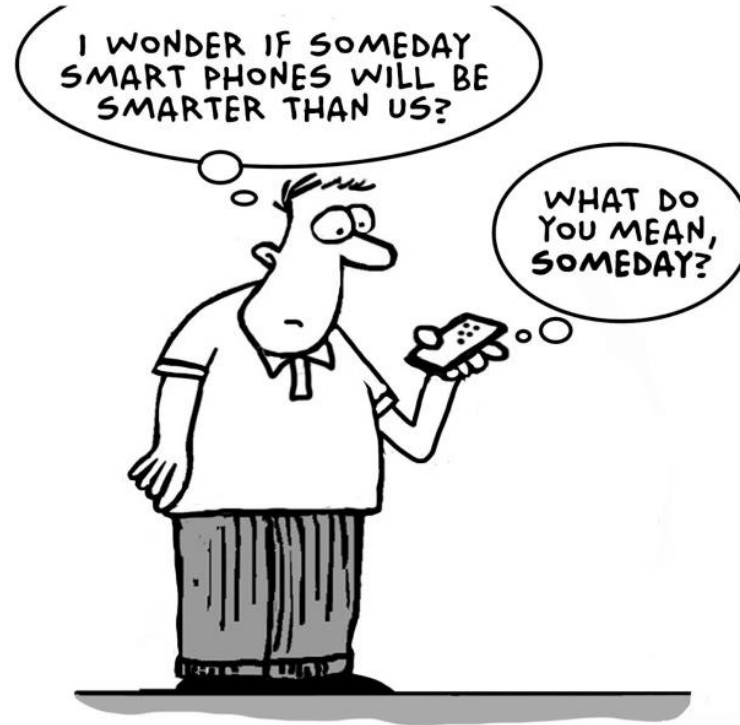
- Adopt existing technologies

- Personalized Neuroadaptive Technological Innovations

Happy Brain, Happy Life!

foster human abilities and needs

- **Sustainable Human-centred Technologies**
Shape intelligent technology to foster human abilities, needs and preferences
- **Symbiotic Interaction**
Empathic or augmented technologies are gaining importance for future human-technology-interaction
- **Personalized (neuro-)technology**
for secure and safe, acceptable and pleasant interaction with intelligent machines



Source: pinterest.com

Applied Neurocognitive Systems (ANS)

News und Marketing



Studie Feinfühligkeit Technik

Blogreihe Feinfühligkeit Technik



Feinfühligkeit Technik – Blogreihe des Teams »Applied Neurocognitive Systems«

Im Zeitalter von Digitalisierung und Künstlicher Intelligenz nimmt die Gestaltung der Schnittstelle zwischen Mensch und Maschine eine Schlüsselrolle ein. Neuroadaptive Technologien versprechen große Potenziale sowohl für die Wissenschaft als auch für die Praxis.



BRAINPALACE @ ARS Electronica
Brain-Computer-Interface steuert Kunst

*Dyadisches Neurofeedback:
Per Hirnwellen auf dieselbe
Wellenlänge kommen!*



Autopoesis @ ZKM Karlsruhe »Renaissance« 3.0
EEG und audio-visuelle Kunst

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