BCI Innovation at the Intersection of Restoration, Augmentation, and Intelligent Systems

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Netherlands Organisation for Applied Scientific Research

TNO at Soesterberg:
Defence, Safety & Security – Human Factors

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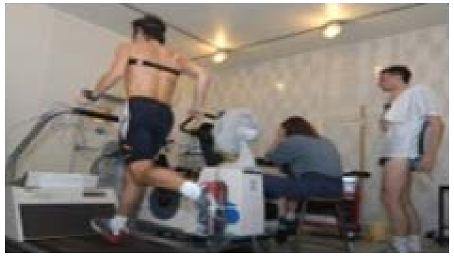
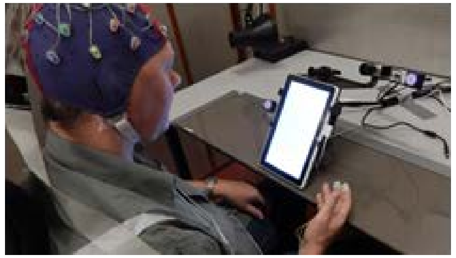
CLIMATE ROOMS



PHYSIOLOGY LAB



DRIVING SIM

A Brief History of TNO BCI Research

BCI in the lab

Out-of-the-lab *mental state monitoring* for augmentation

JHU/APL in Laurel, MD

Nation's largest University Affiliated Research Center (UARC)

Create *defining innovations* that ensure our nation's preeminence in the 21st century

A Brief History of JHU/APL BCI Research

Anthropomorphic Perception & Control

Beyond Anthropomorphic Perception & Control

Human–AI Partnership

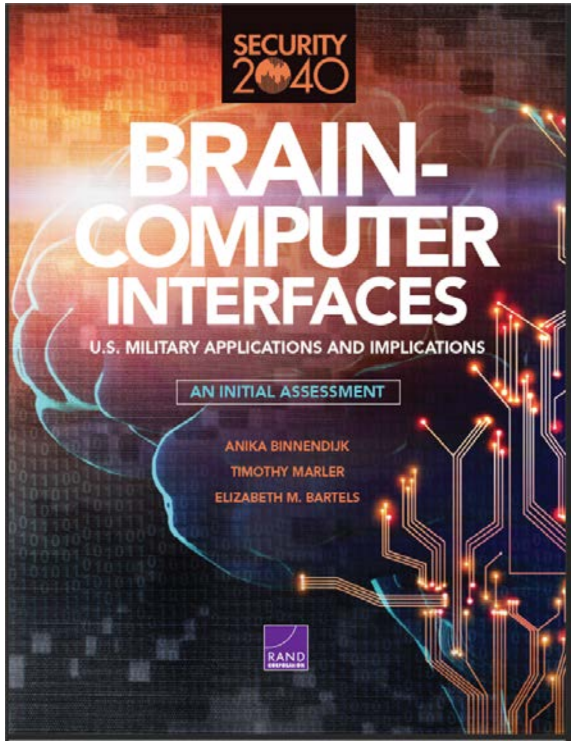
Next Generation Non-Invasive Interfaces

BCI Innovation at the Intersection of Restoration, Augmentation, and Intelligent Systems

Motivation

2030 2040 2050

BCI tool	Near-term capabilities	Long-term capabilities
1) Human-machine decisionmaking	• Immediate transfer of operational risk • Faster decisions to deploy weapons • Shorter preparation cycle with faster feedback from occurrences in battlespace (collapse OODA loop) • Increased speed and accuracy of targeting	• Transfer of risk and threats (increased bandwidth) • Augmented AI systems
2) Human-machine direct system control	• Transfer basic commands to systems • Increase situational awareness and reaction • Collapse OODA loop	• Transfer of complex manipulations (increased bandwidth and degrees of freedom) • Resistance to distraction (use in dynamic environments) • More specific commands and control
3) Human-to-human communication/ management	• Transfer basic commands between individuals • Reduce (radio) weight	• Transfer complex strategies involving commanders/headquarters (increased bandwidth)
4) Monitor performance	• Monitor state • Monitor individual and group cognitive workload, stress, breaking point	• Long-distance standoff assessment • Monitoring of adversary emotional and cognitive states • Archived dynamic cognitive profiles
5) Enhance cognitive performance	• Regulate emotional state (i.e., stress) • Increase focus and alertness	• Modulate emotional state
6) Enhance physical performance	• Improved strength augmentation • Improved sensory capabilities	• Implanted auto pharmaceutical distribution • Pain disruption
7) Training	• Increased learning retention • Deployable training devices • Adaptive individualized training • More immediate and effective assessment	• Implanted knowledge sets



RAND Report – Release 27 August 2020

"Overall, our findings suggest that as the U.S. military increasingly incorporates artificial intelligence (AI) and semiautonomous systems into its operations, BCI could offer an important means to expand and improve human-machine teaming."

Objective

Brain-Computer Interface (BCI) Research and Development (R&D) is regularly segregated by application:

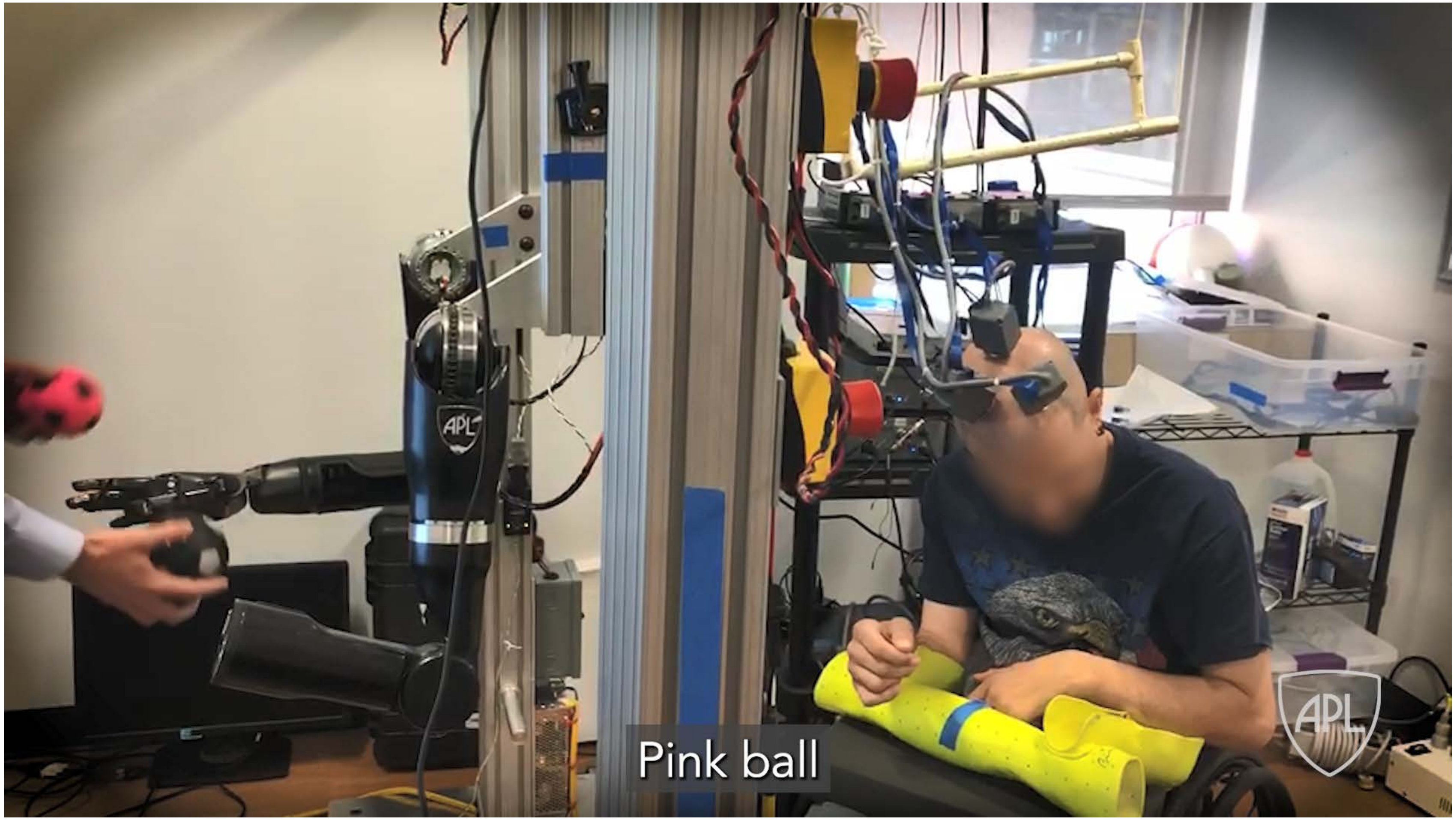
- One set of labs and studies focused on BCI for **restoration** of lost function for clinical population
- Often distinct labs and studies focused on BCI to **augment** the performance of healthy individuals

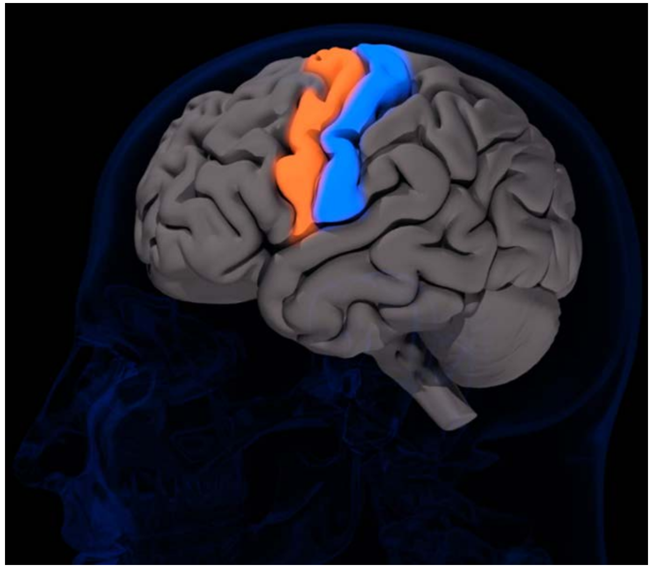
Explore and outline how BCI innovation is now at the intersection of these two targets, and how intelligent systems R&D is critical to both.

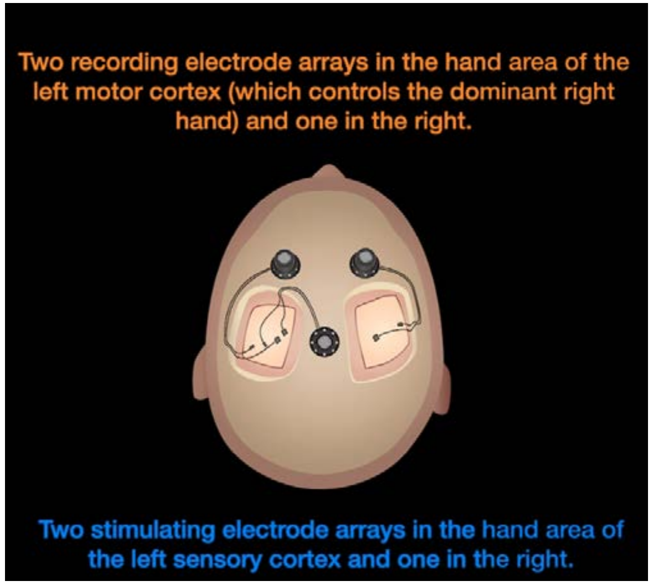
Axes

1. Anthropomorphic and non-anthropomorphic BCI
2. Invasive and non-invasive neurotechnologies
3. Active and passive BCI: From intentional control to monitoring
4. Peripheral measures
5. Neural multiplexing
6. Integration with intelligent systems

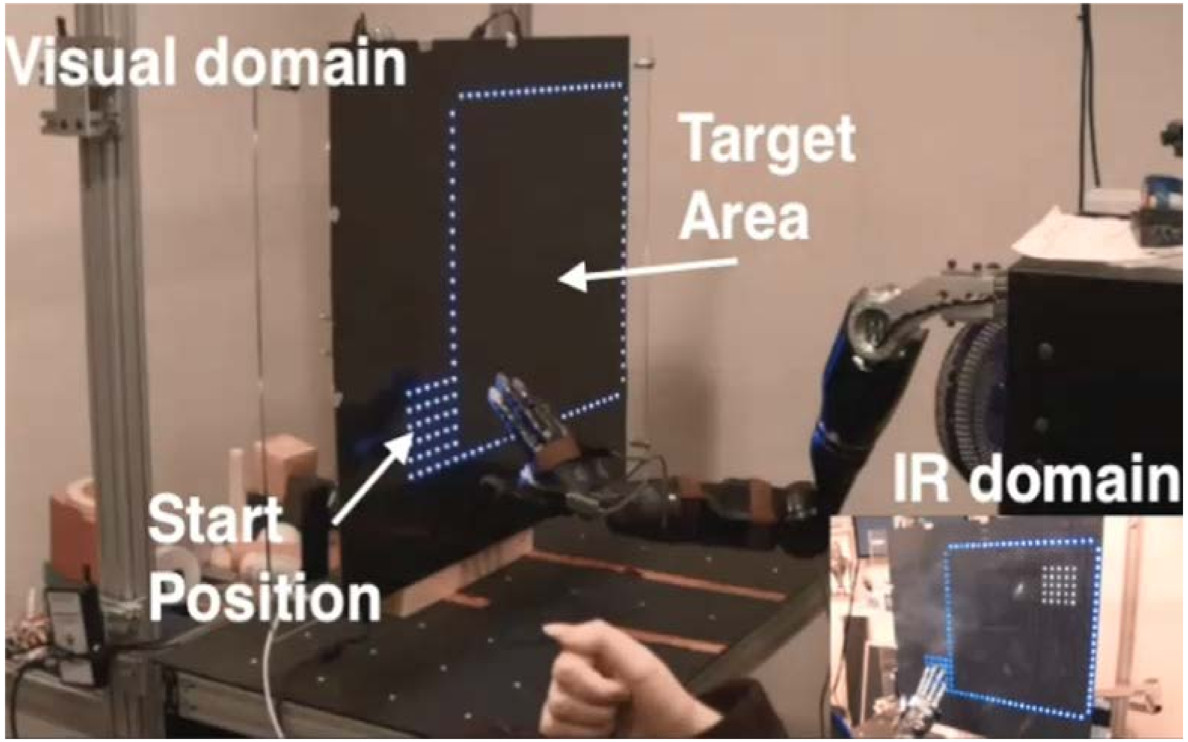
Anthropomorphic Perception & Control



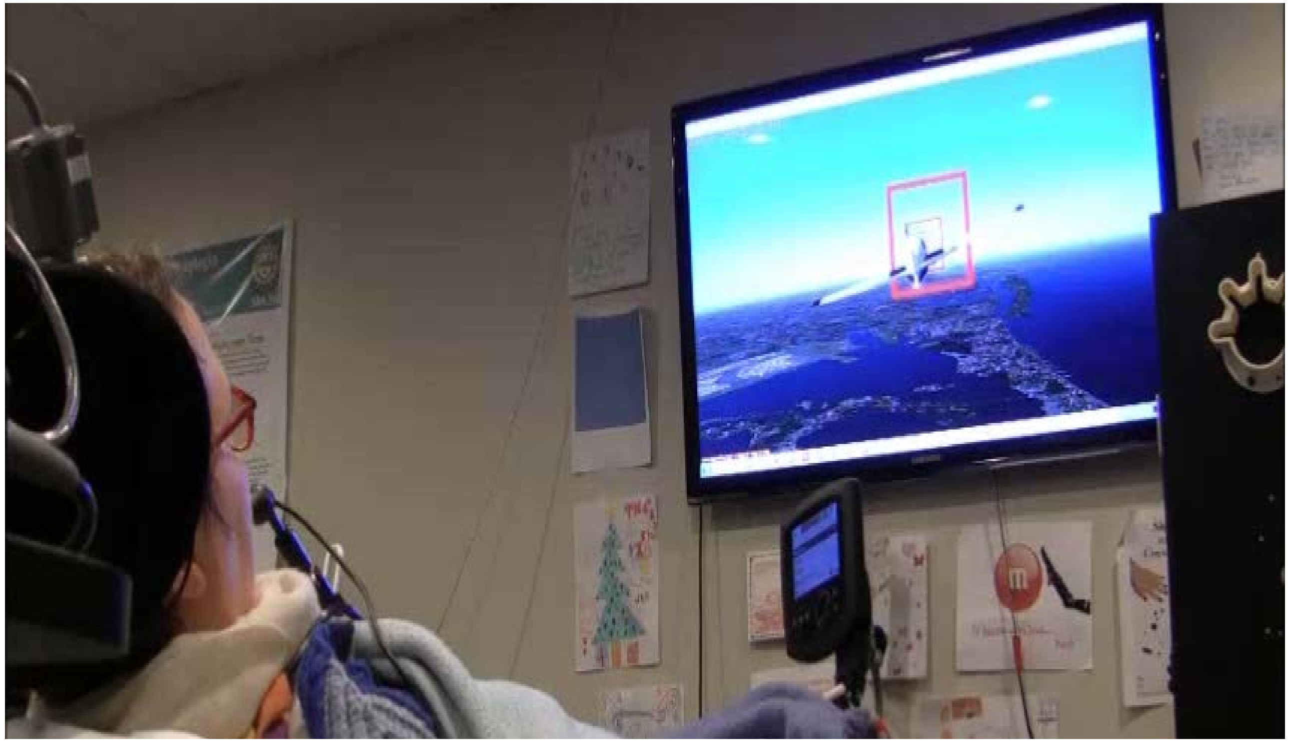




Beyond Anthropomorphic Perception & Control



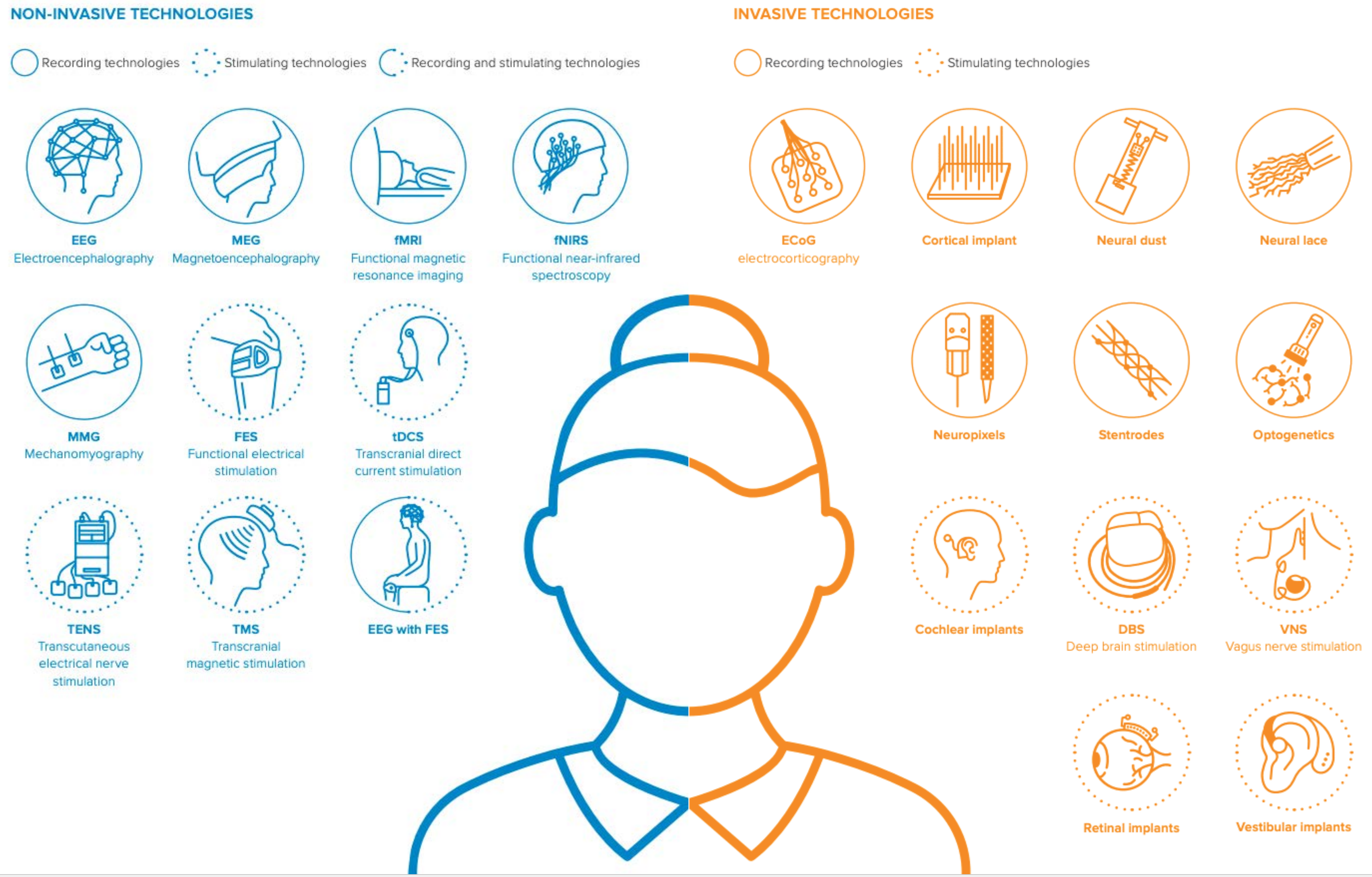
Perception



Control

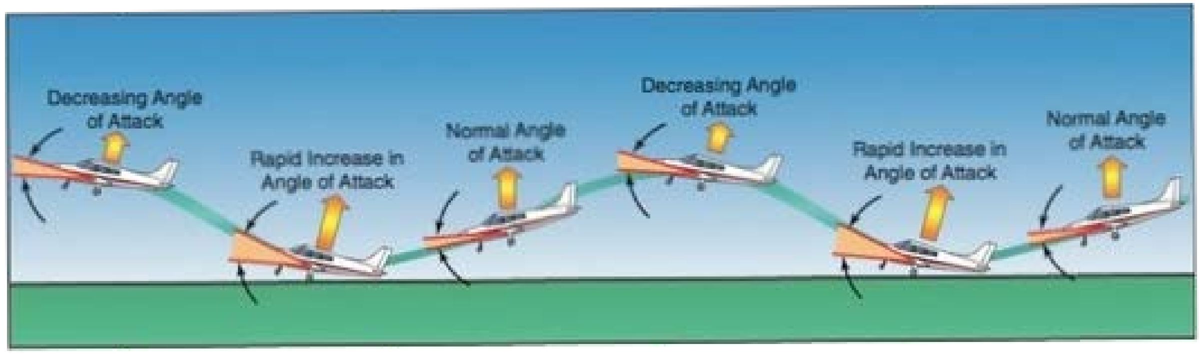
Invasive and non-invasive neurotechnologies

Invasive and non-invasive neurotechnologies

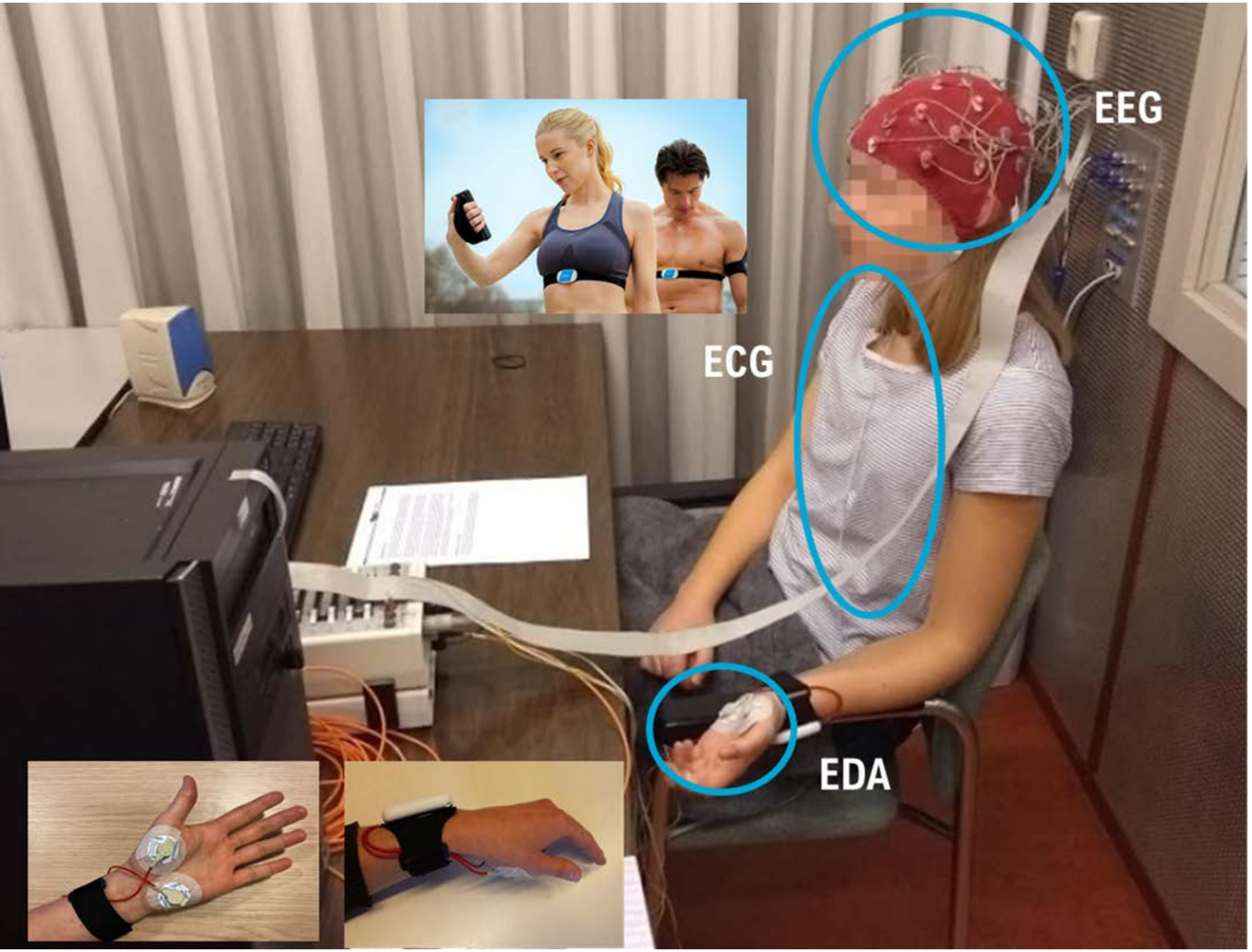


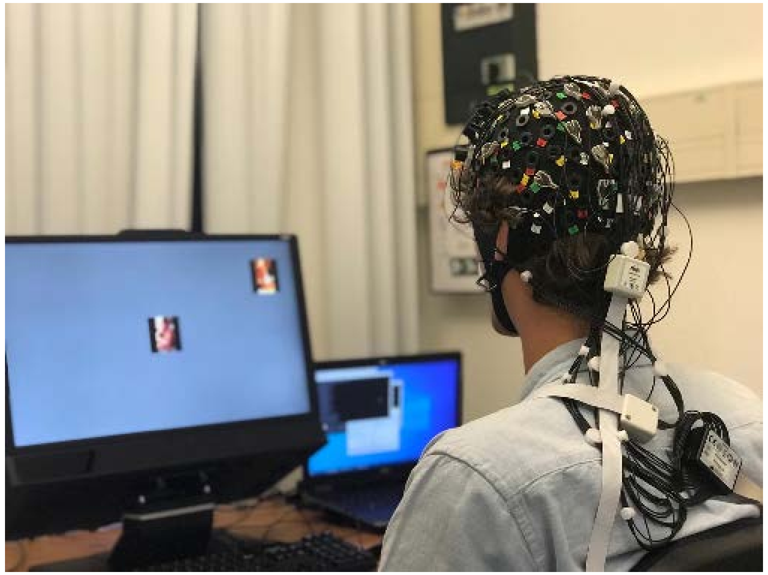
Active and passive BCI: From intentional control to monitoring

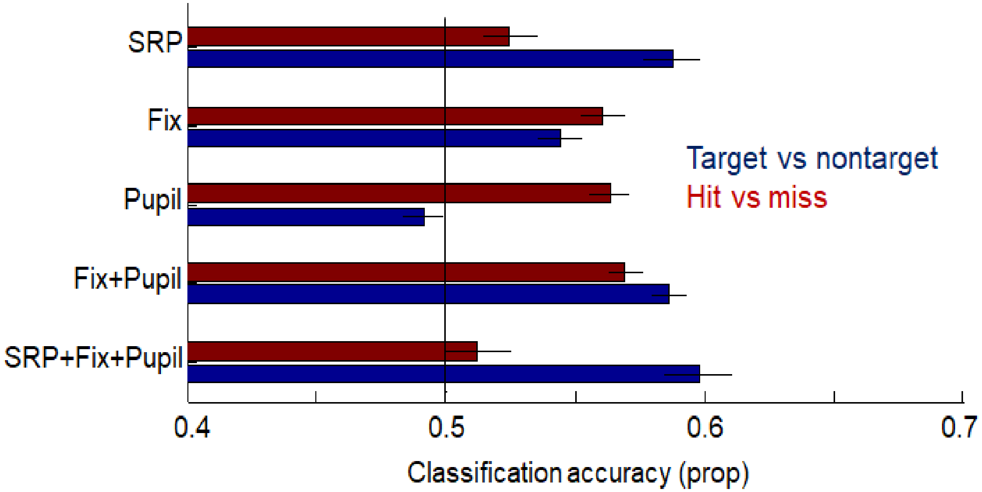
Dehais et al.



Peripheral measures



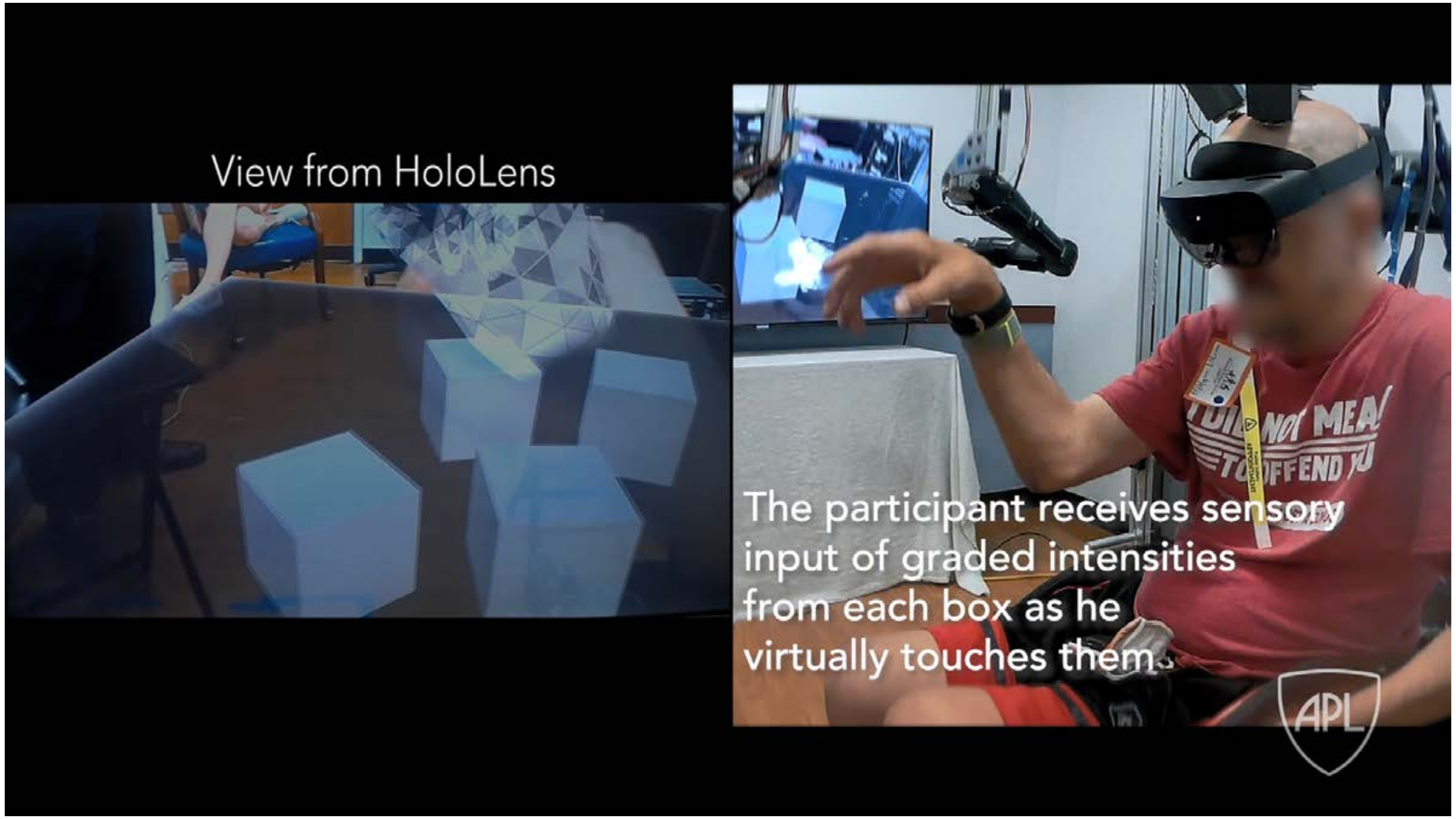




Peripheral measures

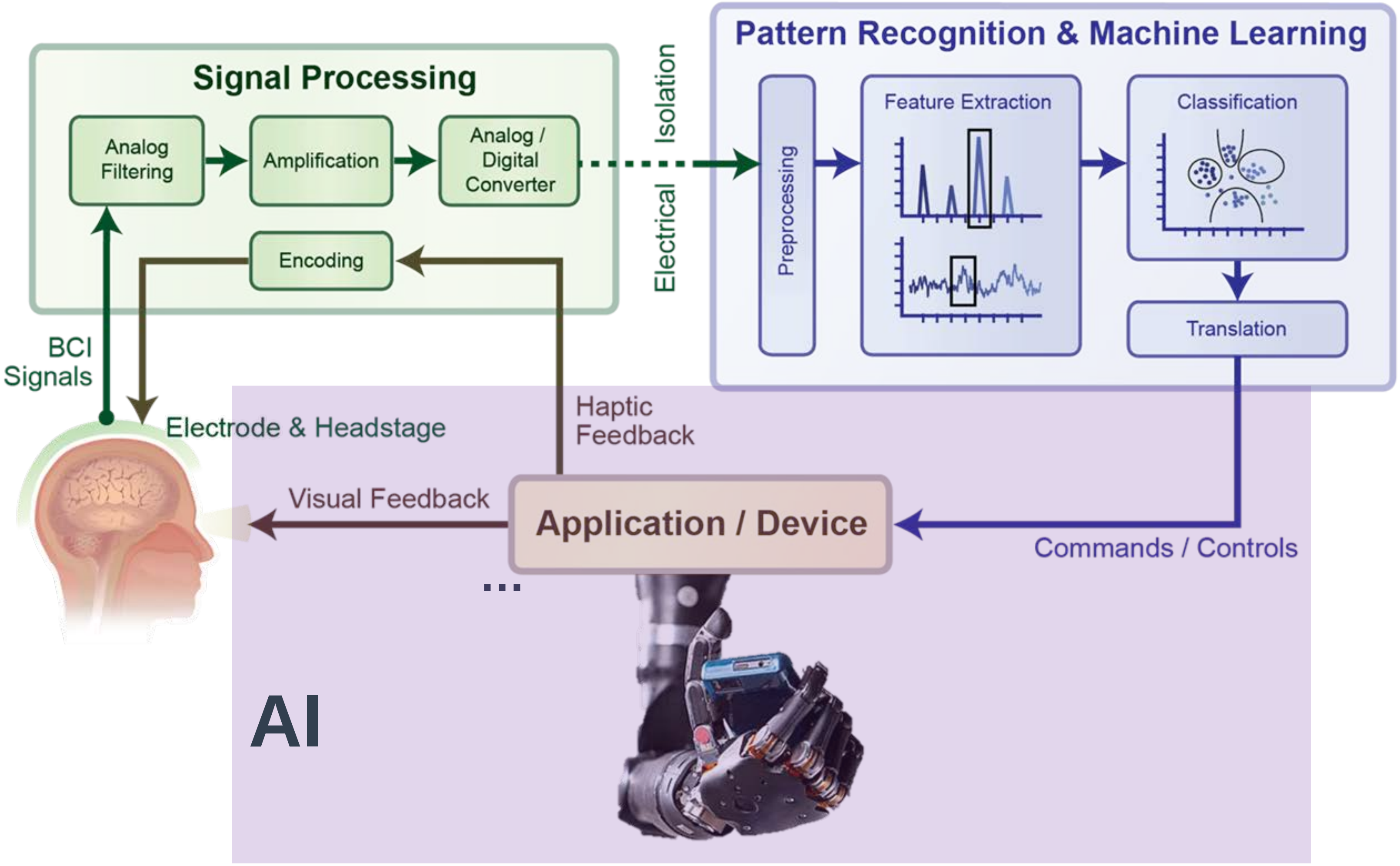
Facebook / CTRL-Labs

Neural multiplexing



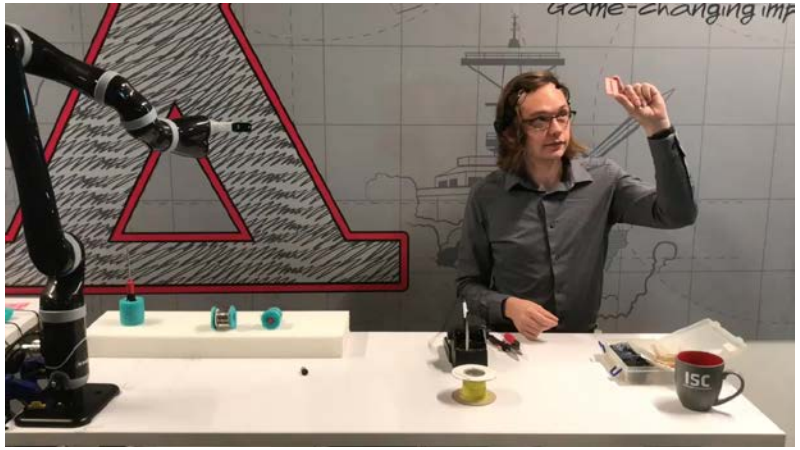
Using the brain's natural mode of operation with the senses and muscles at the same time as a neural interface

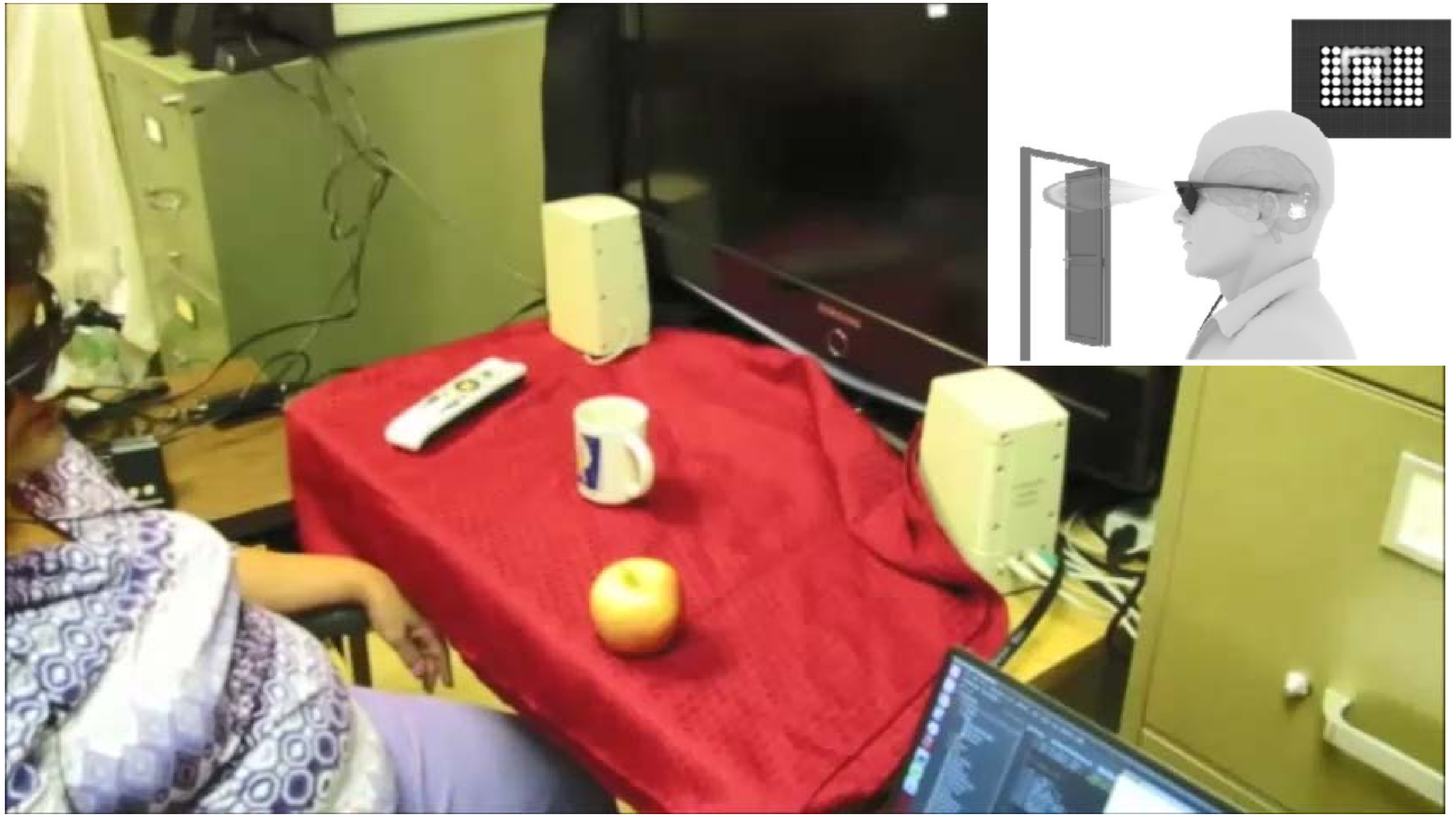
Integration with intelligent systems



Integration with intelligent systems

AI-BCI Shared Control





AI-BCI Shared Perception

Summary and Conclusions: restoration and augmentation

Invasive research will provide critical glimpses of the future of **non-invasive capabilities**

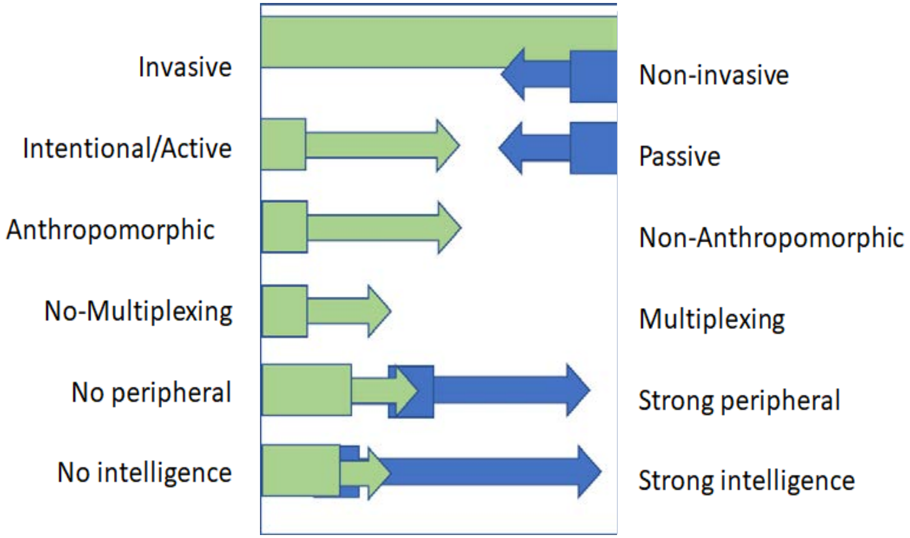
Passive techniques will increase Information Transfer Rate to enable **active BCI** for **augmentation**

Research focused on anthropomorphic and non-anthropomorphic perception, control, and embodiment will improve **restoration** and **augmentation** use cases, from **prosthetics** to **teleoperation**

Neural multiplexing is a prerequisite for BCI in **more moderate impairments** and in **most augmentation use cases**

Peripheral measures will supplement or complement neural measures and provide critical contextual information across **restoration** and **augmentation**

AI-enabled BCI offers new modes of human-machine teaming and helps to overcome limitations in recording and decoding neural signals across **restoration** and **augmentation**



Estimates of historical status (blocks) and recent trends (arrow) for BCI across restoration and augmentation

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