HFM-RSY-334
Symposium on Applying Neuroscience to Performance: From Rehabilitation to Human Cognitive Augmentation
Day 1

Human Factors and Medicine (HFM) Panel
Science & Technology Organization, Collaboration Support Office

! HFM Etiquette for Virtual Meetings

Preparing for the Virtual Discussion

- **Allow 15-20 minutes** to set yourself up and log in to the meeting – particularly if you are new to WebEx.
- When **initially connecting**, please ensure that you clearly identify your name and nation/NATO organization in your WebEx name (for example: "Ulf Ehlert, STO").
- It is good practice to **use headphones** with a built in microphone to avoid audio feedback.
- We appreciate that not all of you will be able to join via a personal computer / tablet / smart phone App, but please try to do so if you can, rather than just dialing in on the phone.
  - This means we will all be looking at the same slides at the same time.
  - It also means you can use the "virtual hand" to make the Chair aware that you want to make a point. This will make chairing a large group easier.

TEST

- **Mute and Unmute**
- **Activate and Deactivate Videos**
- **Use the Chat Function**
- **Use the "Raise Your Hand" Function**

During the Virtual Discussion

- It is good practice to **mute your microphone** when you are not speaking to make the audio clearer for everyone.
- Also, please **deactivate your video**. Only the Chair and the person speaking will should use their video. This is to avoid any bandwidth issues with such a large group.
- If you want to ask a question or make a statement during the discussion, please ask by **"raising your virtual hand"**. The Chair will invite you to take the floor.
- Alternatively, unmute and just say your name, then your question / point. In general it is a good idea to say your name when you start to speak.
- When you are invited to speak, please activate your video and microphone; and then deactivate them after completion of your discussion item.

AGENDA

1	Introduction
2	Keynote on Cognitive Warfare
3	Keynote on Neuroethics
4	Keynote on Brain Plasticity
5	Session 1 – Paper 1, Paper 2 Paper 3
6	Coffee and Stretching Break
7	Paper 4, Paper 5
8	Session 2 – Paper 8, Paper 9, Paper 10
9	End of Day 1

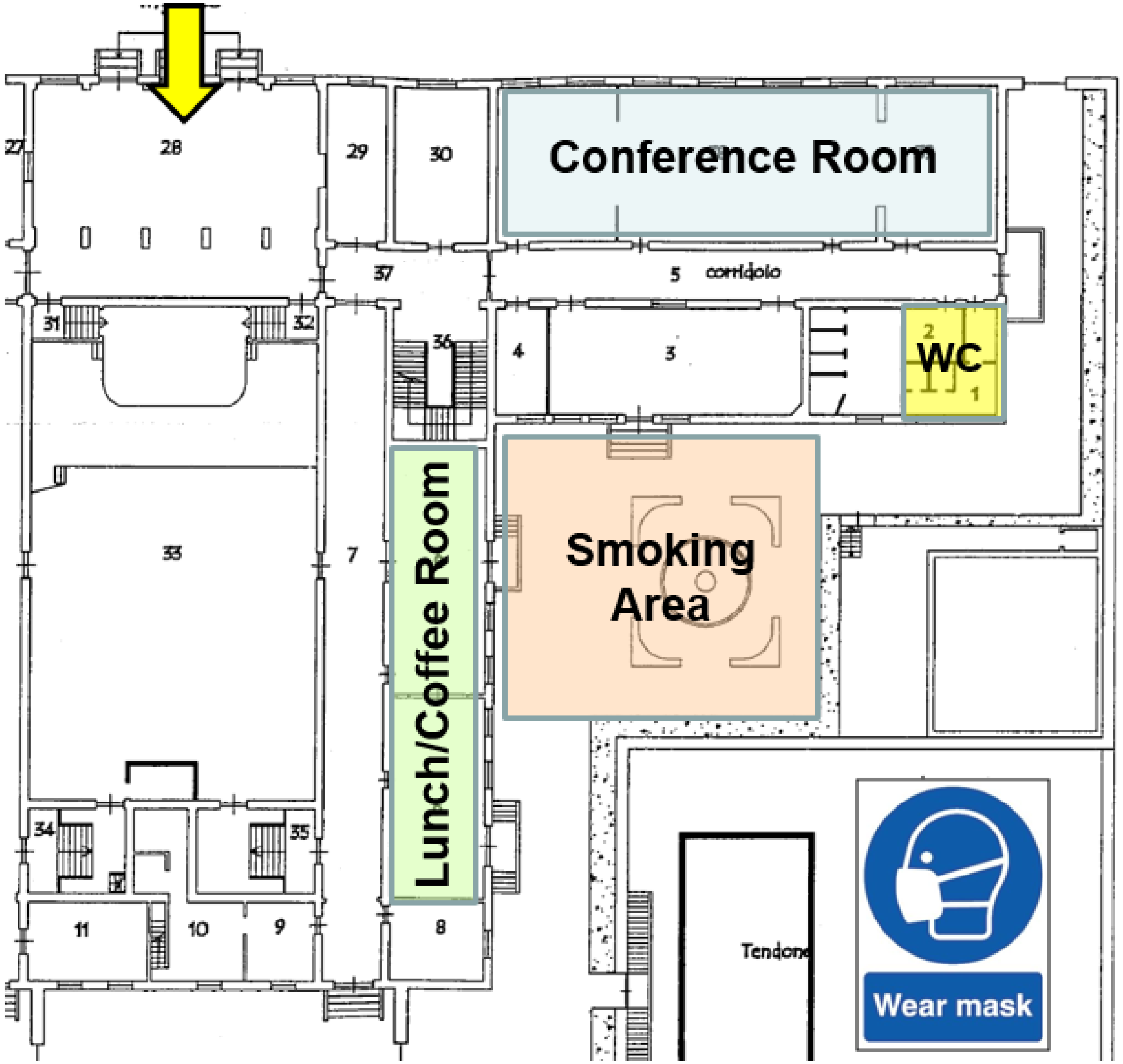
1 INTRODUCTION

WELCOME

to

HFM-334 Symposium on

Applying Neuroscience to Performance: from Rehabilitation to Human Cognitive Augmentation



Wear you badge all the time

No free walking

Light Lunch at 12:00

Coffee Breaks 15:30 or 16:00

Keep your mobile muted

Smoking area outside

BUS

	DATE	TIME	ACTIVITY
RSY	Mon 11 Oct	11:00	Departure from Pick-up Point (American Palace Hotel)
		11:20	Arrival at Logistics Support Command
		18:15	Departure from Logistics Support Command
		18:30	Arrival at Pick-up Point (American Palace Hotel)
	Tue 12 Oct	11:20	Departure from Pick-up Point (American Palace Hotel)
		11:40	Arrival at Logistics Support Command
		18:15	Departure from Logistics Support Command
		18:30	Arrival at Pick-up Point (American Palace Hotel)
		19:30	Departure from Pick-up Point (American Palace Hotel)
		20:15	Arrival at Social Event
		22:30	Departure from Social Event
		23:00	Arrival at Pick-up Point (American Palace Hotel)

On occasion of the
Human Factor & Medicine Panel Symposium
on
Applying Neuroscience to Performance:
from Rehabilitation to Human Cognitive Augmentation

You are cordially invited to the
Host Nation Reception

On Tuesday, 12th October, at 20:30
at the Campidoglio (Rome City Hall)

This invitation acts as entrance tickets, please bring with you to the event

Dress code: Cocktail (after five)
Busses leave from the American Palace Hotel, Rome at 19:30
Green Pass required

Networking

Objectives of the HFM-334 Symposium

This Symposium has the objective to summarize the several research activities carried on the subject in order to assess the benefits and advantages on using neuroscience and neuro-technologies

4 Sessions have been organized:

- Enhancing Operational Performance
- Enabling Technology and Methods
- Applied Neuroscience in Health and Wellbeing
- Optimizing Personnel Selection and Training

Programme

		Monday 11th October 2021	
	13:00	Introduction	
	13:15	Welcome	
K3	13:30	**Keynote on Cognitive Warfare**	Dr. Francois Du Cluzel De Remaurin
K2	14:00	**Keynote on Neuroethics**	Prof. James Giordano *(remote)*
K1	14:30	**Keynote on Brain Plasticity**	Prof. Michael Merzenich
		Session: Enhancing Operational Performance (I)	
1	15:00	Neuroenhancement in Military Personnel: Conceptual and Methodological Promises and Challenges	Dr. Kathryn Feltman
2	15:20	Using Interpersonal Similarity in Complex Networks from Physiological Data to Assess Attentional Focus	Dr. Michael T. Tolston *(remote)*
3	15:40	Effects of prefrontal brain stimulation by tDCS on stress regulation in healthy military personnel	Dr. Fenne Smits
	16:00	*Coffee & Stretching Break*	

Programme

	Monday 11th October 2021		
	Session: Enhancing Operational Performance (I)		
4	16:20	Effects of transcranial electrical stimulation (tES) in defence and security related tasks: Meta-analysis of findings from healthy populations	Dr Gorana Pobric
5	16:40	Accelerating Image Analyst Training With Transdermal Vagal Nerve Stimulation (TVNS)	Dr. R. Andy Mc Kinley
	Session: Enabling Technology and Methods		
8	17:00	BCI Innovation at the Intersection of Restoration, Augmentation, and Intelligent Systems	Dr. Anne-Marie Brouwer
9	17:20	Vagus Nerve Stimulation-Induced Cognitive Enhancement In Rats Is Associated With Enhanced Expression Of Brain-Derived Neurotrophic Factor In The Hippocampus	Dr. Candice Hatcher-Solis *(remote)*
10	17:40	Using SocialXR to measure social cognitive performance to address isolation associated with deployment and post-traumatic life events	Dr. Christopher Stapleton *(remote)*
	18:00	*End of Day 1*	

Programme

		Tuesday 12th October 2021	
	13:00	Introduction	
		Session: Applied Neuroscience in Health and Wellbeing	
6	13:10	Perceived Stress and Brain Network Efficiency	Dr. Chiara Massullo
7	13:30	Cerebrum- Virtual Cognitive Rehabilitation: a modern therapeutic tool oriented to the recovery of military operative disorders that interfere with cognitive performance	Dr. Valerio de Lorenzo Capt. Rosalba Vergini *(remote)*
		Session: Optimizing Personnel Selection and Training	
11	13:50	From Genes To Personalised Cognitive Training: Mapping The Genetic Architectures Of Cognitive Functioning	Dr. Liliana G Ciobanu *(remote)*
12	14:10	Brains in Sync: Team coordination and interpersonal prefrontal neural synchrony during cooperative e-gaming	Dr. Adrian Curtin
13	14:30	Wearable Brain and Body Sensing for Multimodal Assessment of Cognitive Workload and Training	Mr. Mark Jesse
14	14:50	A Flexible Gaming Environment for Reliably Measuring Cognitive Control	Dr. Andrew Heathcote
15	15:10	Performance Based Training: Monitoring the Flow of Cognitive Load based on Psychophysiological Measurements in a Fighter Cockpit Simulator	Mr. M.P.G. (Maykel) van Miltenburg
	15:30	*Coffee & Stretching Break*	

Programme

	Tuesday 12th October 2021		
	Session: Enhancing Operational Performance (II)		
16	15:50	Assessing cognitive-motor interference in military settings: validity and reliability of two dual-tasking tests	Dr. Samuele Maria Marcora
17	16:10	Development of an AI pipeline for real time assessment of fighter pilots' mental state based on hybrid stream processing	Dr. Magnus Bång
19	16:30	Interoceptive technologies. New technological solutions for stress management and human neuroenhancement	Dr. Daniele Di Lernia *(remote)*
20	16:50	Military pilot´s emotional stress analysing	Mr. Ferdinand Tesar
	17:10	Discussion	
	17:30	Symposium Closing remarks	
	17:50	*End of RSY*	

Thanks to

B. Gen. Roberto NARDONE

(Logistic Support Commander)

Dr. Luisa RICCARDI

(Head of IT MoD RT&I Department and Italian STB Member

B. Gen. Florigio LISTA

(HFM ITA Principal Member)

LTC Erik LAENEN

(HFM Executive)

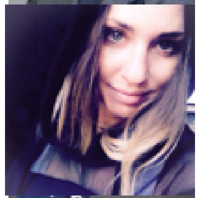
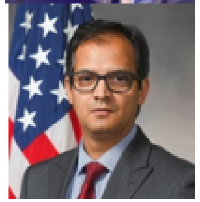
Mr. Paolo PROIETTI

(HFM Panel Mentor)

and their Staff

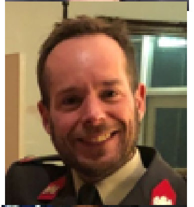
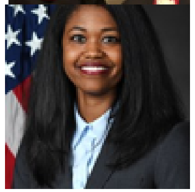
Thanks to



PROGRAMME COMMITTEE

- Maj Giorgio FANELLI (General Chair)
- Dr. Anne-Marie BROUWER
- Dr. David CRONE
- Dr. Anton DE WEIJER
- Dr. Elbert GEUZE
- Dr. Candice HATCHER
- Dr. Federica PALLAVICINI
- Dr. Matthew RICHINS
- Dr. Gaurav SHARMA

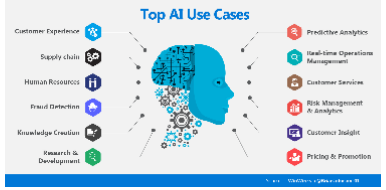




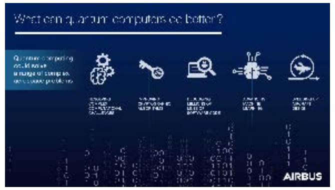

Cognitive Warfare
A battle for the brain

PBM HFM HFM-RSY-334

Applying Neuroscience to Performance: From Rehabilitation to Human Cognitive Augmentation

Background





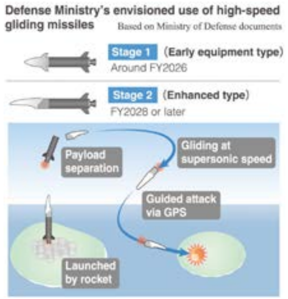
AI

Quantum

Autonomy

EDTs

Data



Hypersonic

BioTech& Human Enhancement

Space

Emerging Sciences and Technologies introduce **new threats** and **opportunities** in the Cognitive Dimension

Innovation Hub Study on CW 2020

Plan

- Defining the Cognitive Warfare
- The weaponization of Neurosciences
- A new domain of Operations?

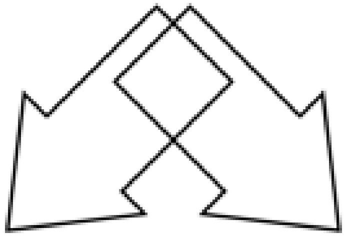
From Information to Cognitive Warfare

*“Hyper-connectivity created the opportunity to transform Information Warfare from a set of episodic activities, […] into **a single continuous effort to disrupt and deny the cognitive conditions in which whole societies are situated.**”*

Dr. Zac Rogers, in The Cove, 2018

PSYOPS vs. Cognitive Warfare

Exploitation of the error of rationality



Motivated influence

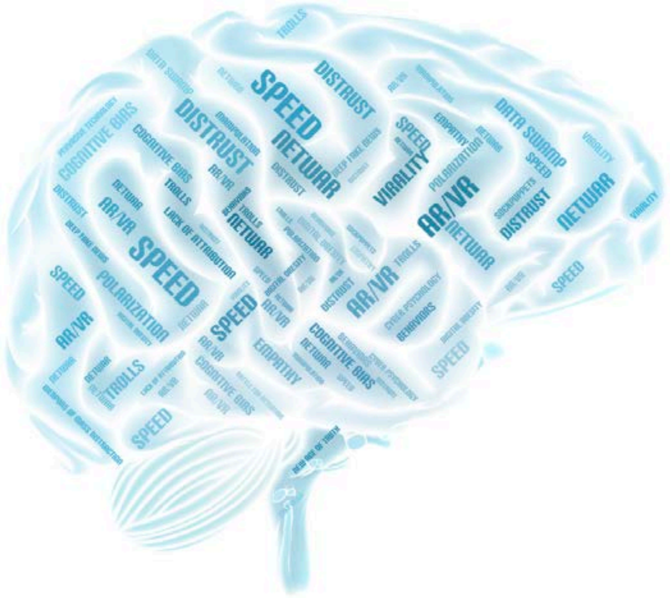
Cognitive disability

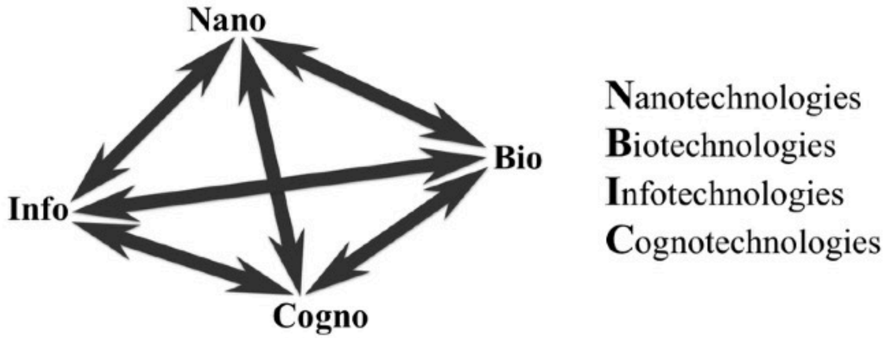
PSYOPS Domain	Cognitive Warfare Domain
Action on beliefs Distorted perceptions Cultural illusion Anxieties and fears Personality weaknesses or strengths Repression...	Action on cognitions Sensory and perceptive overflow Attentional saturation Tunneling of attention Errors of judgment Cognitive biases...

The centrality of the brain

“The brain is the HQ of the Human body and precisely attacking the HQ is one of the most effective strategies for determining victory or defeat on the battlefield”

Pr. Hai Jin, Li-Jun Hou, and Zheng-Guo Wang
Chinese Journal of Traumatology, May 2018





NBIC technologies tetrahedron
Roco and Bainbridge (2012) report

Chinese MBS classification of brain functions

Understanding the brain	Understand the risk factors of brain injury caused by military activities
Protecting the brain	Targeted prevention of the brain damage caused by military activities
Monitoring the brain	Monitoring brain function through new technologies and equipment
Injuring the brain	Promoting the research and development of sound, light, explosion, magnetic and other new types of weapons
Interfering with the brain	Causing brain dysfunction and a loss of control with “smokeless” methods
Repairing the brain	Achieving brain function reconstruction with advanced novel medical technology
Enhancing the brain	Improving the level of the brain function of personnel who carry out special tasks
Simulating the brain	Brain-inspired robot intelligence and predicting human decisions
Arming the brain	Studying the arming of the brain, with brain and machine interfaces as the focus

Government Programs

BRAIN Initiative
2014
$110 million/year

China Brain Project
2016
$157 million (est.)

Human Brain Project
2016
$88 million/year

Japanese
Brain/MINDS
2014
40 billion Yen

Australian Brain Initiative
2016
$100 million/year

Korean Brain
Initiative
2016

The global neuro-bio economy

US$27.6 billion in 2018

US$38.9 billion in 2027

Private actors

2045 Initiative

A new Domain of Operations ?

"…the Human Domain is the one defining us as individuals and structuring our societies. It has its own specific complexity compared to other domains, because of the large number of sciences it's based upon (…) and these are those our adversaries are focusing on to identify our centres of gravity, our vulnerabilities."

Herve Le Guyader- August Cole
NATO 6th Domain of Operations

Conclusion

- NATO is late in responding to the CW challenges
- Building a common understanding of CW is key
- A very sensitive topic
- Ethical and legal aspects
- A multi-disciplinary approach is required

GEORGETOWN UNIVERSITY

INSTITUTE FOR BIODEFENSE RESEARCH

Neural Approaches to Performance Optimization…
…and the Need for
Performance Optimization of Neuroethical Apporaches

James Giordano PhD

Diane DiEuliis PhD

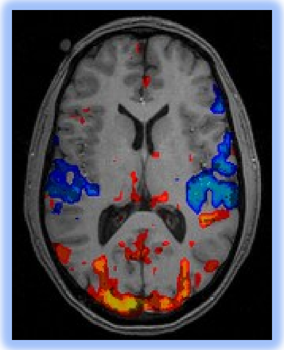
John R. Shook PhD

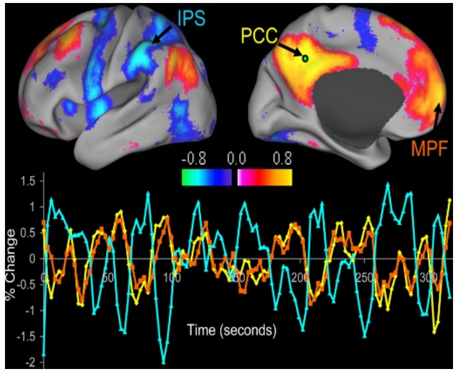
Neuroscience and Technologies (NeuroS/T)

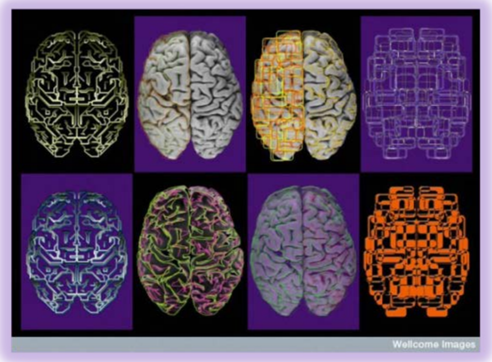
- <u>Assessment</u>
  - Biomarkers
  - Genetics/genomics
  - Imaging
  - Brain modeling/mapping

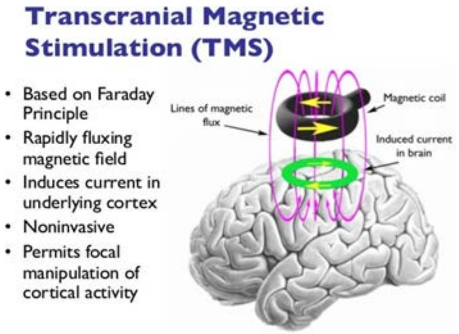
- <u>Interventional</u>
  - Technopharmaceutics
  - P-Stim
  - Neurofeedback
  - Transcranial Modulation
  - Deep Brain Stimulation
  - BCI
  - Neuroprosthetics

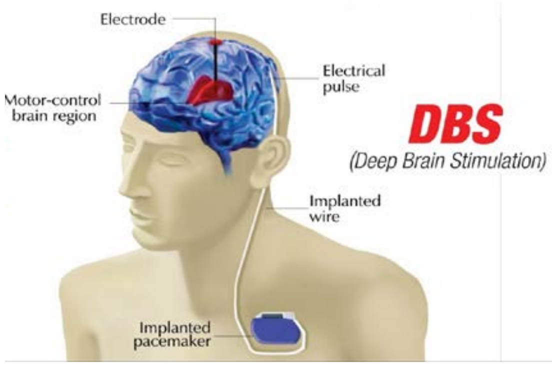
- <u>Derivative</u>
  - Big Data
  - AI technologies

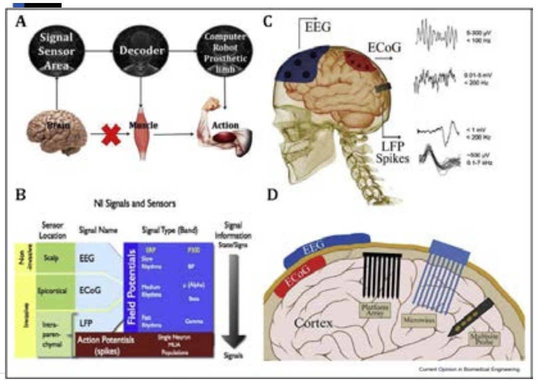












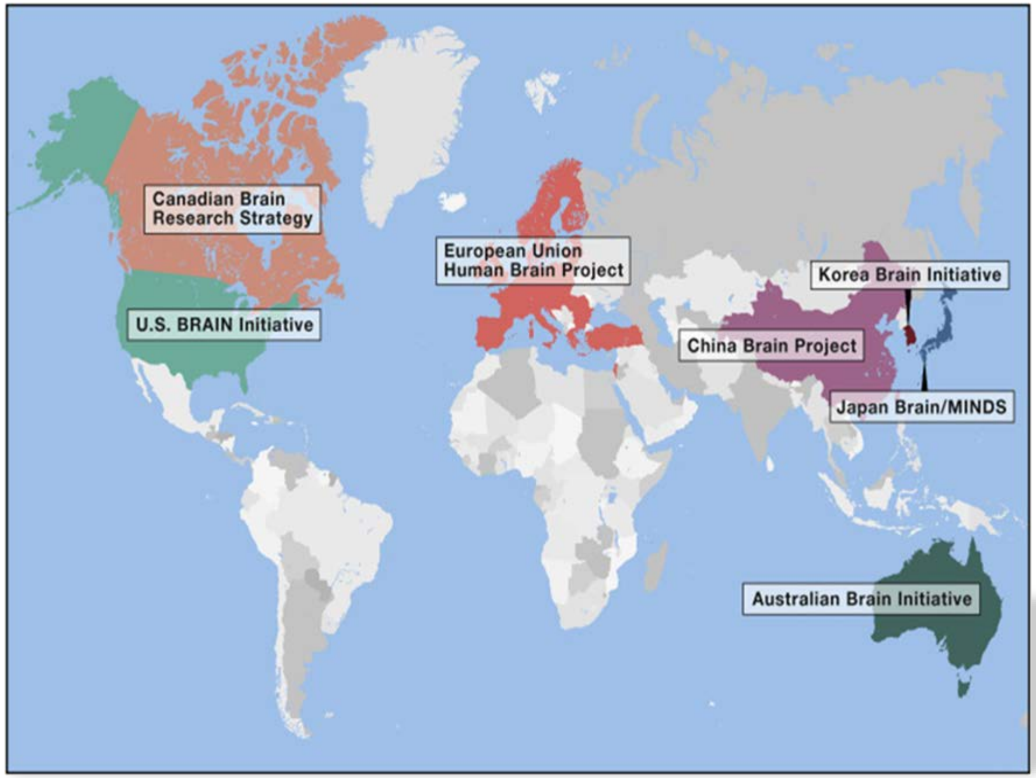
<u>A-3:</u> Actual Ability to

Assess...Access...Affect

To What Effect(s) and Ends?

Neuroscience and Technology on the 21st Century Global Stage

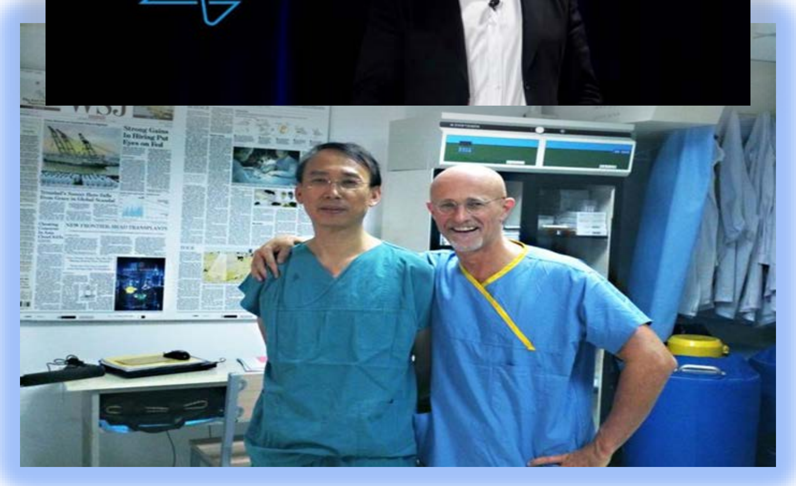
- Increasingly Multi-national
- Increasing Asian Effort(s)
- Advancing Developed Nations
- Capabilizing Developing Nations
- Establishing Bio-psycchosocio-economic
  - Leveraging
  - Hegemonies
- Creating Contingencies in Non-Developed Nations



Considerations of *Bio-Power* & *Bio-Politics*

Contingencies

- Culture
- Circumstance/Context
- Control/Leverage
- Commercialization
- Capitalization/Hegemony



Preparedness

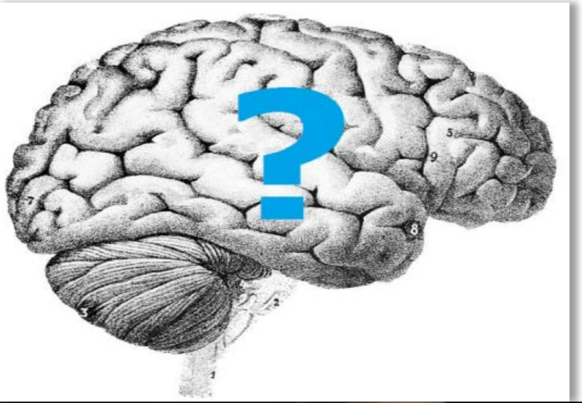
Preparation ≠ Prevention (of Relative Promise of Positive Outcomes)

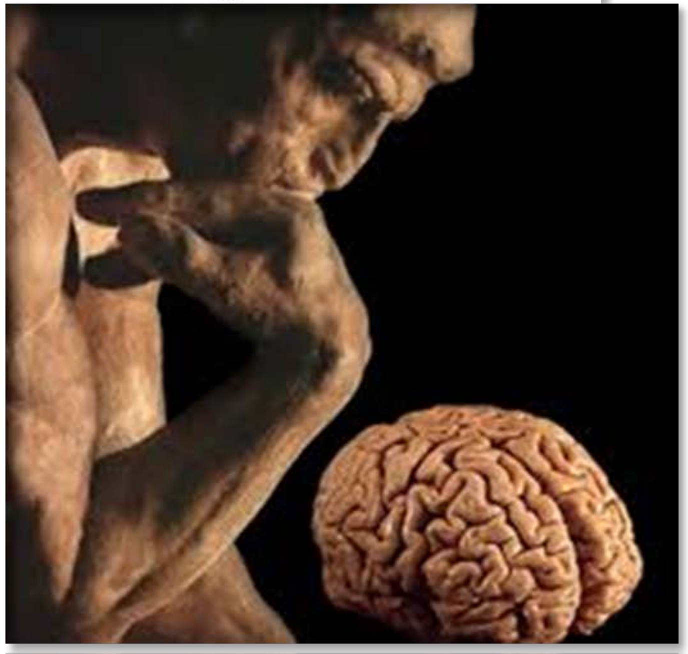
Readiness Stance/Posture: Focused, Flexible, and Fast Moving/Adapting

Recognition and Responsiveness to *Both* Idiosyncratic and Systemic

Benefit(s)
Burden(s)
Risk(s)
Threat(s)
Harm(s)

Neuroethico-legal Issues & Risks





<u>Technology-focal</u>

- **Intersecting unknowns**
- **Capabilities, limitations**
- **Validity, viability of use**
- **Runaway and Wexelblatt effects**

<u>Social</u>

- **Inviolability of “mind”/“cognitive liberty”**
  - ***“Reading minds”***
- **Autonomy: “*Mind control*”**
- **Awareness, understanding, consent**
- **Treatment/protection/enhancement**
- **Justice: Provision/access**
- **Informed Consent**
- **Dual-use**

Neuroethics on World Stage

- **Cosmopolitan Cognizant**
- **Community Capable**
- **Accommodating pluralist**
  - **Needs**
  - **Values**
  - **Norms**
  - **Mores**
- **Affected by/Affecting:**
  - **Economics**
  - **Politics**
  - **Power Balances**

Ethics in Biology, Engineering & Medicine - An International Journal, 4(3): 211–229 (2013)

Advancing Neuroscience on the 21st-Century World Stage: The Need for and a Proposed Structure of an Internationally Relevant Neuroethics

Elisabetta Lanzilao[1], John R. Shook[2], Roland Benedikter[3], & James Giordano[1,4,5,*]

Shook and Giordano *Philosophy, Ethics, and Humanities in Medicine* 2014, **9**:1
http://www.peh-med.com/content/9/1/1

PEHM PHILOSOPHY, ETHICS, AND HUMANITIES IN MEDICINE

EDITORIAL **Open Access**

A principled and cosmopolitan neuroethics: considerations for international relevance

John R Shook[1] and James Giordano[2,3*]

ON-RAMP

O*perational* N*euroethical* R*isk* A*ssessment and* M*itigation* P*aradigm* ***(from Giordano, 2015; 2018 ©)***

<u>6-R Approach</u>

- ***Responsibility***
- ***Realistic Assessment*: of the neurotechnology**
- ***Research*: evaluating use/effects-in-practice**
- ***Responsiveness:* to burdens and deleterious effects**
- ***Revisions:* in technology and marketing**
- ***Regulation*: insure rigor in development and claims**

Poses key questions

Framed within defined parameters

Particularity of “Collective Efforts”

Requires:

1. **Defining Context(s)**
2. **Setting Ethical Goal(s)/Ideal(s)**

    e.g.- Rescherian Framework:

    Prescriptive

    Conclusive

    Projective

3. Habermas’ Discursive Approach

…establish ethical sets and goals by examining presuppositions of discourse

Possible Method(s):

Thagard Equilibrium

(Identifying a domain of practices, identifying candidate norms for the practices, identifying the appropriate goals of the practices, evaluating the extent to which different practices accomplish these goals, and adopting as domain norms the practices that best accomplish these goals)

***Maximin* Attempt (Maximizing possible gain while minimizing loss; conferring benefit to the least-advantaged)**

Consensus Parameters

Quo Vadis?

- **Neurobioeconomic Savvy**
- **Biosecurity-by-Design**
- **Globally Relevant & Responsive Neuroethics**

Additional Information

- **DeFranco JP, Rhemann M, Giordano J. The emerging neurobioeconomy: Implications for national security. *Health Security* 18(4): 66-80 (2020).**
- **Shook JR, Giordano J. Toward a new neuroethics in a multipolar and multicultural world. *Global-E* 13(56): (2020)**
- **De Franco JP, Giordano J. Mapping the past, present, and future of brain research to navigate the directions, dangers, and discourses of dual-use. *EC Neurol* 12(1): 1-6 (2020).**
- **DeFranco JP, DiEuliis D, Giordano J. Redefining neuroweapons: Emerging capabilities in neuroscience and neurotechnology. *PRISM* 8(3): 48-63 (2019).**
- **Giordano J. Looking ahead: The importance of views, values, and voices in neuroethics – now. *Camb Q Health Care Ethics* 27(4): 728-731 (2018).**
- **DiEuliis D, Lutes CD, Giordano J. Biodata risks and synthetic biology: A critical juncture. *J Bioterrorism Biodef* 9(1): 2-14 (2018).**
- **Giordano J. Toward an operational neuroethical risk analysis and mitigation paradigm for emerging neuroscience and technology (neuroS/T). *Exp Neurol* 287(4): 492-495 (2017)**
- **Giordano J. A preparatory neuroethical approach to assessing developments in neurotechnology. *AMA J Ethics* 17(1): 56-61 (2015).**

Contact

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4 KEYNOTE ON BRAIN PLASTICITY

NATO, Roma | October 11, 2021

Assessing Then Improving Organic Brain Health And Functional Ability

A Neuroscience Perspective

Dr. Michael M. Merzenich

Professor Emeritus, Neuroscience, University of California, San Francisco
CSO, Posit Science Corporation
CSO, Stronger Brains

BRAIN PLASTICITY: The basis of the brain's creation of a model of your world, and of the control of your operations within it.

Your brain made YOU (your **SELF**)…

…and whatever your age, you are still a work in progress.

WHAT is changing, exactly, as the brain remodels itself — throughout life — to make the most of its unique experiences?

1. **Its revises its detailed WIRING (synaptic connections) and its elementary processing machinery in ways that enable the skills and abilities that define YOU.**
2. **It also changes MANY OTHER physical and chemical aspects of its processing machinery.**
3. **It advances the machinery that <u>controls</u> change itself.**

Changes are <u>PHYSICAL.</u>

The product of all that change?

The creation and the continuous elaboration of a unique *PERSON*.

Measures of ATTENTION control and processing SPEED (with sustained accuracy) index the brain's performance capabilities and organic health.

1. They are easy to measure.
2. Processing speed (and accuracy) has been convincingly argued to be THE 'general' factor indexing individual ability/intelligence.
3. Performance at EVERY cognitive operation (memory; categorization; logical thinking; problem solving; creativity; et al.) is highly correlated with indices of neurological speed.
4. **ATTENTIVE and FAST brains are NECESSARILY physically and chemically advanced** (= **HEALTHY**).

IT'S ***EASY*** TO IMPROVE ATTENTIVENESS AND SPEED IN THE BRAIN.

The Brain is like the body. WHEN YOU WAKE UP AND SPEED UP THE BRAIN, EVERYTHING GETS STRONGER

With appropriate training EVERY physical and functional index of brain health and brain power advances. In the environmentally challenged (unhealthy; low-performing) brain, EVERY index of brain health and brain power can be NORMALIZED. WHAT'S RESTORED? (a partial list)

WHAT'S IMPROVED? (a partial list)

1. The brain's PHYSICAL machinery (dendrite & axon elaboration; myelination; et al

2. Its CHEMISTRY (synaptic processes; modulators; growth factors; et al)

3. Its DEFENSES (immune response; 'blood-brain barrier'; et al)

4. Its NUTRITIONAL SUPPORT (on-demand blood flow; neuronal metabolism; et al)

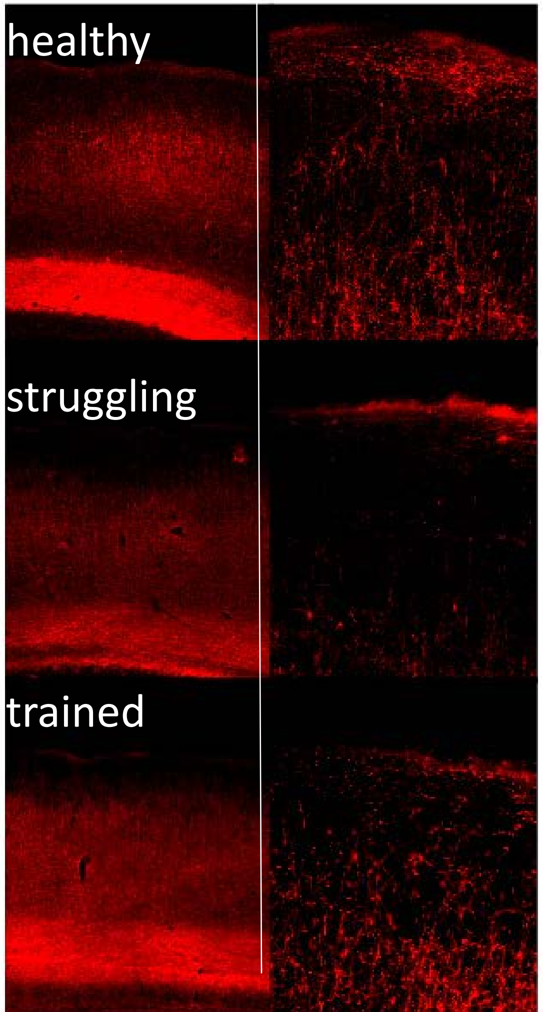
5. Its INFORMATION PROCESSING MACHINERY (association; predictive flow; et al.

6. Its RECORDING MACHINERY (work and serial memory; memory retrieval; et al)

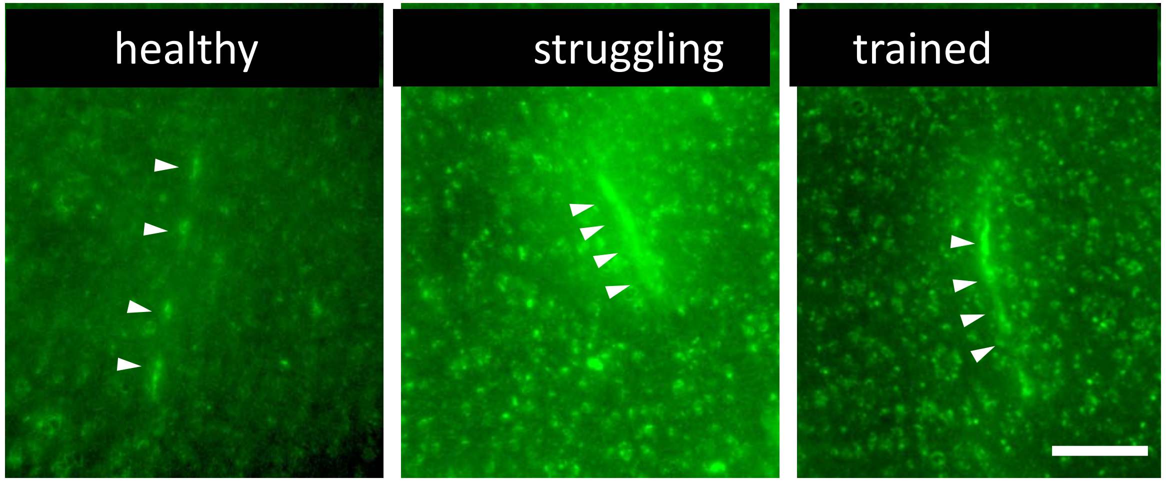
7. Its EXECUTIVE CONTROL MACHINERY (agency; voluntary initiation and control of movement and thought; emotion control; et al)

We have repeatedly shown that <u>specific forms</u> of brain exercise 1) grow brain-power, and 2) restore neurological integrity, in normal and struggling adult brains.

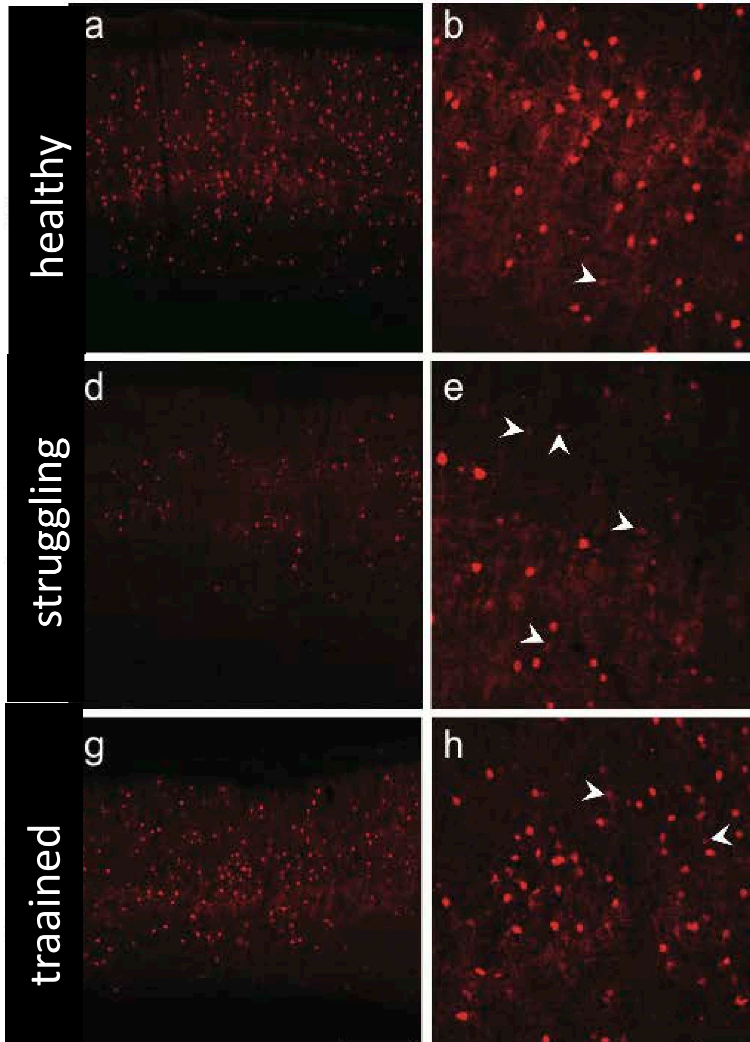
A myelin basic protein



B neurovascular unit integrity ("blood-brain barrier")



C parvalbumin inhibitory neurons



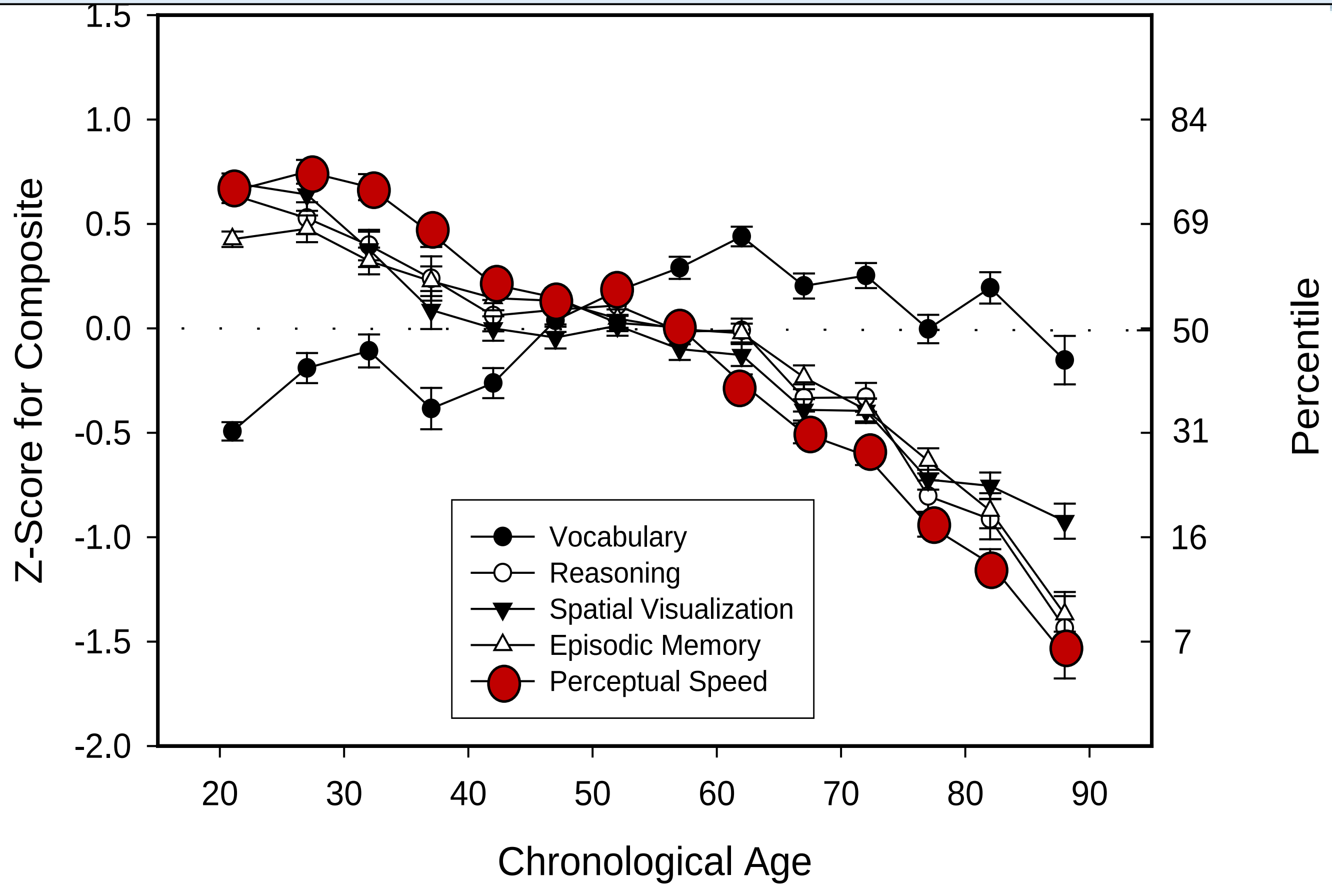
≥40 specific indices of brain health were restored by training.

The Bottom Line

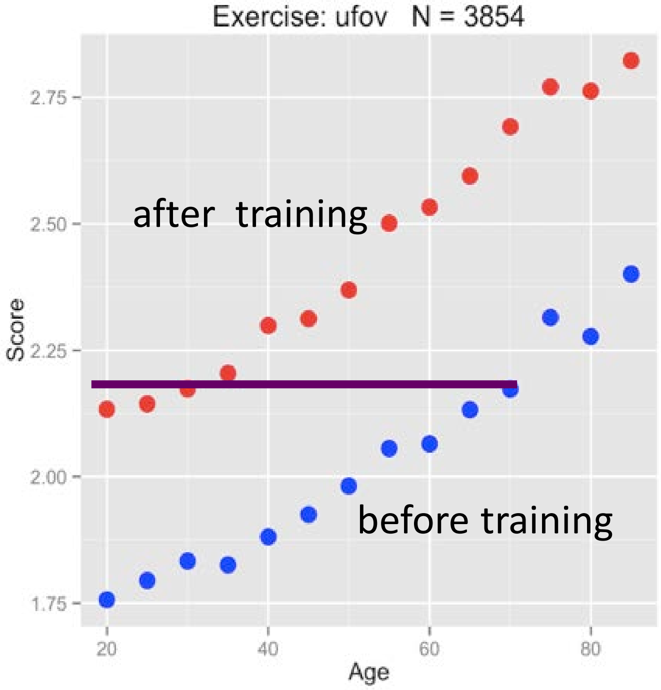
The organic ***HEALTH*** and the functional capacities of the brain (like the body) can almost always be substantially improved by appropriately exercising it…

(…and as a bonus, improving brain health will have a major impact on general health, and on healthy longevity.)

An example (among many): Improving **brain speed**, for individuals with different levels of ability/impairment.



AGE-–or differences in initial ability—does not matter. Almost EVERYONE improves.



<u>All</u> of these declining abilities can be improved by training.

Performance gains in speed <u>must</u> arise from a coordinated series of brain-strengthening physical changes .

Adapted from studies conducted by University of Virginia professor Timothy Salthouse.

We achieve this strengthening of brain health and brain power using brain-exercise programs delivered via the Internet on computers, pads and smartphones. Training programs are:

BrainHQ

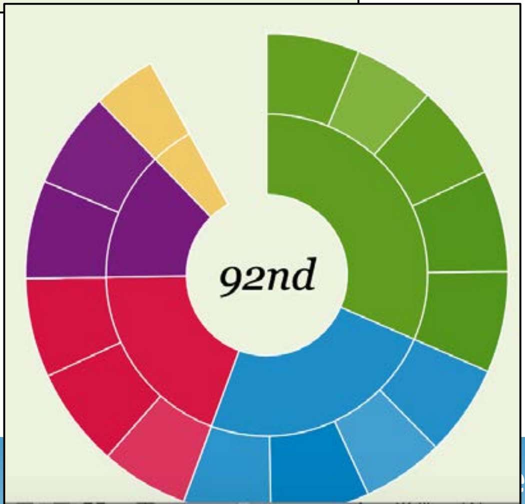
1. Adaptive, for individualizing training
2. Optimized, for rapid gains
3. Targeted, to recover/strengthen key abilities
4. Extensive, to achieve ‘rejuvenation’ at all brain system levels, in all affected domains
5. Continuously validating outcomes (in every exercise cycle
6. PROVEN to work,via >250 ‘gold standard’ trials
7. Clinically monitored (optionally) via the Internet
8. Scalable

It's easy to calibrate a trainee engaged in training and to deliver ongoing compliance and progress information to a training monitor or supervisor.

Percentile rank for a person of my age

PERCENTILE OVERVIEW — Your ranking

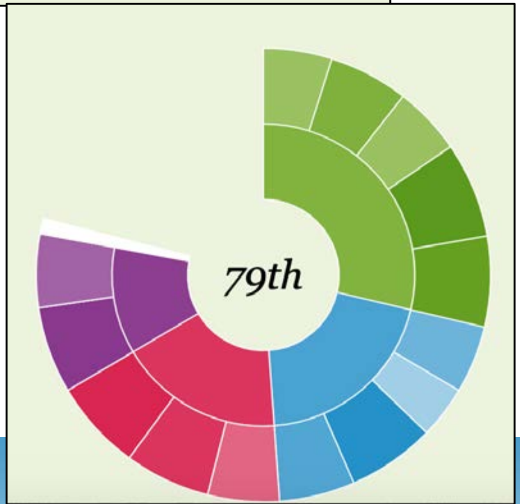
OVERALL	**92** +12	
ATTENTION	93 +8	
BRAIN SPEED	89 +14	
MEMORY	95 +9	
PEOPLE SKILLS	0	
INTELLIGENCE	95 +26	
NAVIGATION	61	



If I was 20 years old…

Your ranking

OVERALL	**79** +19	
ATTENTION	78 +15	
BRAIN SPEED	77 +21	
MEMORY	85 +14	
PEOPLE SKILLS	0	
INTELLIGENCE	84 +35	
NAVIGATION	15	



It is important to understand that it is just as easy to drive the brain in a NEGATIVE (unhealthy; less functionally capable) direction.

1. ANYTHING that increases the 'noisiness' of brain processes drives every index of brain-change progressions in reverse.
2. **There are several hundred known sources of >>> brain chatter/noise.** [For example: CONCUSSION and other TBIs; persistent STRESS; MOOD DISORDERS; ACE history; PHYSICAL/SEXUAL/MENTAL ABUSE; SLEEP DISORDERS; PTSD; ENVIRONMENTAL NOISE; AlCOHOL ABUSE; TINNITUS; SSRI DRUGS; et alia.] **They DEGRADE brain function and health.**
3. There is also a rich variety of ways to engage neurological operations in ways that DISTORT them.

The brain has a kind of gene-regulation "Master Switch".

ADVANCE

RETREAT

You want that "switch" thrown **UP** for your key personnel.

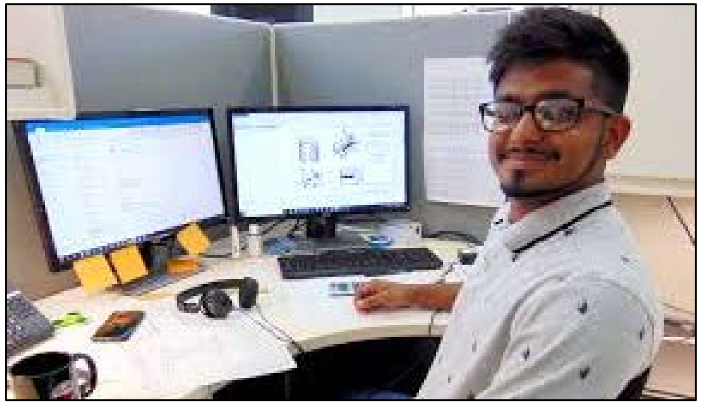
How can you apply this science to improve your personnel?

1. **Deploy neurological** (not just psychological) **testing strategies to assist in recruiting personnel with a high chance of succeeding.**
2. **IDENTIFY—then ADDRESS issues of organic brain health that manifest or foretell current or sub-optimal work performance**
3. **Review how your training practices might be further optimized to minimize negative and to maximize positive neurological and operational impacts.**
4. **Routinely monitor** (through computerized assessment) **the neurological and mental health, and the brain performance status, of all personnel**.
5. **Re-evaluate the neurological status of personnel who have been historically exposed to direct** (concussion; TBI; blast injury) **or indirect** (high stress; persistent anxiety) **brain health-degrading experiences.** Then **ADDRESS** those emergent neurological weaknesses.
6. **Re-evaluate the neurological status of all older (>35 yo) personnel. They'll likely substantially benefit from a 'brain health training update'.**

Examples:

High accident rate jobs

Drivers; equipment operators



Engineers, program designers

Military recruits
Special ops forces

Tom Brady

Law enforcement personnel

Finally, you should routinely apply computerized assessments that indicate neurological weaknesses or distortions that indicate extant problems, or a significant risk of a future progression to **depression, anxiety disorder, suicide, oppositional behaviors, substance abuse, personality disorders, et alia**.

They plague every modern group of people—even high-performance people in the military.

With appropriate forms of brain training, the neurological health and resilience of your team members can be strengthened in ways that can reduce the neurological distortions and impairments associated with these 'illnesses', and attenuate and often reverse the progression of symptoms anticipated to lead to their onsets

How can you apply this science to improve (normalize) the health and welfare—and to increase (normalize) the lifespans—of <u>retired</u> personnel?

1. **Provide them with computerized "How To Be A Civilian Again" training courses.** We'd help you develop them.

2. **Provide them with a (computerized) "Brain Checkout"—subsequently repeated annually.** We'd assist you in implementing strategies for shipping these assessment outcomes to medical specialists/therapists in your venue.

2. **Provide them with an individualized brain health (computerized) training programs—on an "as-needed" basis.** We'd assist you in implementing strategies to monitor and assure compliance, and provide you (and local medical specialists) with a continuous and complete documentation of brain health training outcomes that would inform other useful health-support options.

How can you apply this science to improve performance—of active duty personnel who need to operate with peak performance?

1. **Measure performance – and then change it.** At every stage of a person's career in the military, their cognitive performance can be measure – from new recruit to experienced commander. And at each stage, performance is not fixed – it can be changed and improved. And where there is room for enhancement, cognitive training can be used to take good brains and make them great brains.

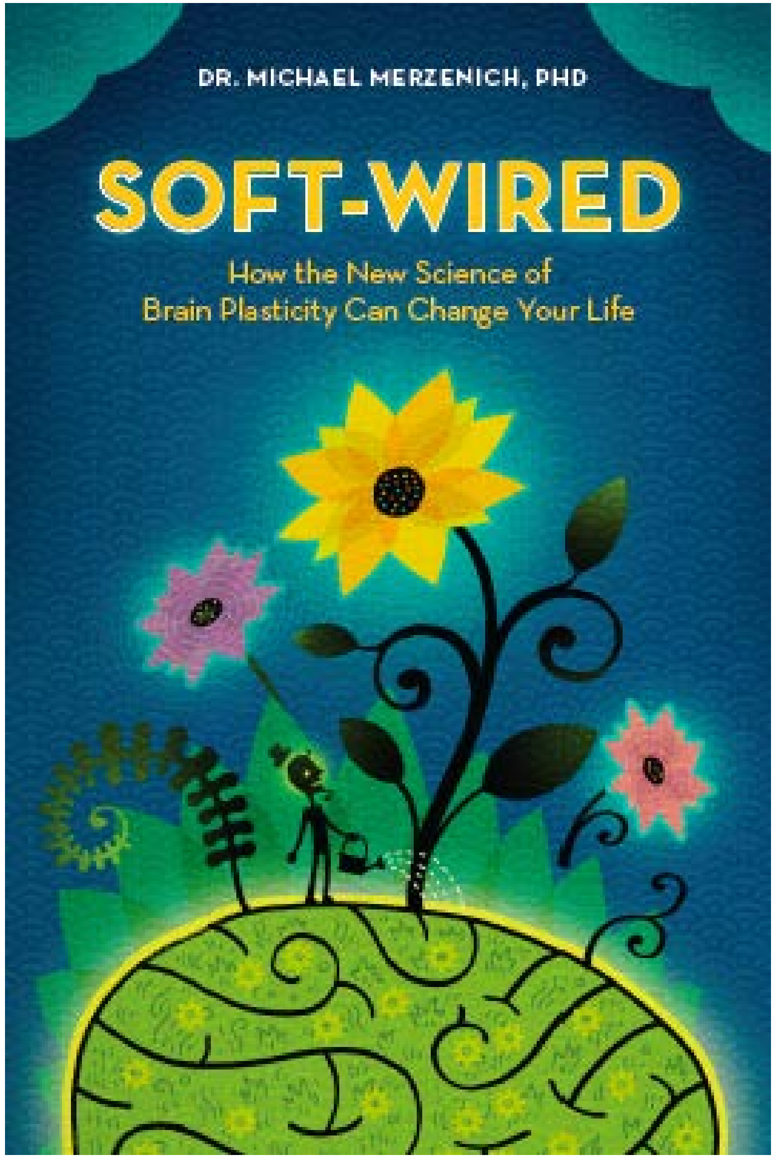
2. **Predict success – and train for it.** Use cognitive performance data to evaluate who goes on over time to successful military careers (and who doesn't). Then provide cognitive training to ensure that people on the wrong track get on the right track – and that people on the right track stay on it to succeed.

Thank you to our collaborators!

Federico Gori
CEO, Microgate
Bolzano, Trentino-Alto Adige

Col. sa. (me.) s.SM Fabio CIPPITELLI
Italian Army General Staff
Head of Military Psychology and Psychiatry Office

And for even more unasked-for advice, read my book!



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5 SESSION 1 – ENHANCING OPERATIONAL PERFORMANCE

Paper 1 - Neuroenhancement in Military Personnel: Conceptual and Methodological Promises and Challenges: Prof. Jan B.F. Van Erp / Tad Brunye / Dr. Kathyrn Feltman

Paper 2 - Using Interpersonal Similarity in Complex Networks from Physiological Data to Assess Attentional Focus: Dr Michael T. Tolston

Paper 3 - Effects of prefrontal brain stimulation by tDCS on stress regulation in healthy military personnel: Dr. Fenne Smits

Paper 4- Effects of transcranial electrical stimulation (tES) in defence and security related tasks: Meta-analysis of findings from healthy populations : Dr Gorana Pobric

Paper 5- Accelerating Image Analyst Training With Transdermal Vagal Nerve Stimulation (TVNS) : Dr. R. Andy Mc Kinley

Neuroenhancement in Military Personnel: Conceptual and Methodological Promises and Challenges

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Disclaimer

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Enhancing Military Personnel

Prolonged operations

- Severe environments
- Scarce resources
- Physical and mental strain

Degradation of perceptual, cognitive, and emotional resources

New training and technological interventions to:

- Sustain
- Optimize
- Enhance

New Training and Techniques

Neuromodulation Techniques

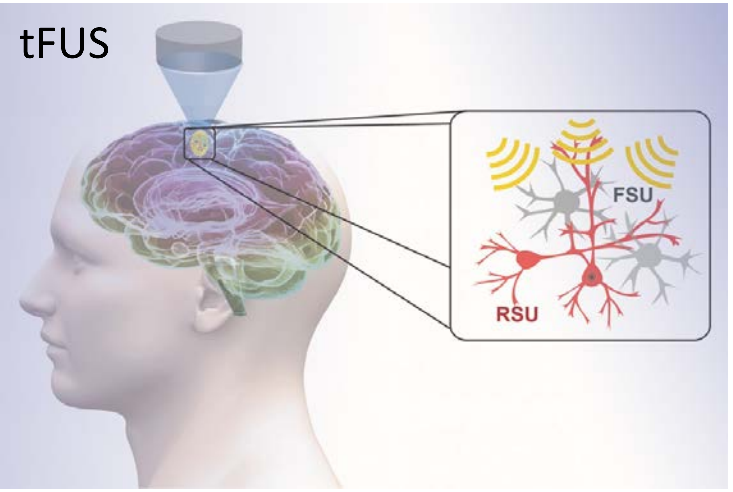
- Defined: Introduction of exogenous energy into the central or peripheral nervous system to alter nervous system activity, neurotransmitter and hormonal activity, and affect behavior

Five techniques considered:

1. Transcranial magnetic stimulation (tMS)
2. Transcranial focused ultrasound stimulation (tFUS)
3. Transcranial electrical stimulation (tES)
4. Transcutaneous peripheral nerve stimulation (tPNS)
5. Cranial electrotherapy stimulation (CES)


tES
HILL


TMS


tFUS
FSU
RSU


CES
CES
Clip electrode
Leads
Stimulator


tPNS

Neuromodulation Techniques

Technique	Demonstrated Areas for Utility	Applications to Military	Limitations
TMS	• Perceptual discrimination • Motor learning • Visual search / Object identification • Attention • Memory • Language	• Accelerating knowledge acquisition • Facilitating memory retention • Accelerating motor skill training	• Costly equipment • Trained technicians • Not readily portable • Long-term effects not demonstrated • Potential for serious side effects
tES	• Vigilance • Working memory • Executive functions	• Sustaining attention • Improving decision making	• Inconsistent findings • Unknown long-term effects • Consumer-grade devices not well researched • Lack of clinical certifications • Limited mechanistic understanding

Neuromodulation Techniques

Technique	Demonstrated Areas for Utility	Applications to Military	Limitations
tFUS	• Minimal research in humans to date	• To be determined	• No formal guidelines for use • Lack of research in human application • Potentially high short-term risks
tPNS	• Reward learning • Mediating stress-induced cognitive declines • Clinical disorders	• Mitigating performance decrements under stress • Threat detection • Marksmanship training	• Limited research
CES	• Altering subjective feelings of anxiety • Pain management	• Modulation of physiological, affective, and cognitive responses to stress	• Conflicts of interest in current studies • Methodological concerns

New Training and Techniques Cont.

Neurofeedback Techniques

- Defined: Form of biofeedback involving monitoring of neural signal and the presentation of that signal to participants to assist in self-regulation of neural signal and behavior

Three techniques considered:

1. Electroencephalography (EEG)
2. Functional magnetic resonance imaging (fMRI)
3. Functional near-infrared spectroscopy (fNIRS)

EEG

fNIRS

fMRI

Neurofeedback Techniques

Technique	Demonstrated Areas for Utility	Applications to Military	Limitations
EEG	• Clinical rehabilitation • Therapy • Human performance	• Attention and working memory training • Accelerated learning • Performance maintenance during stress	• Methodological concerns • Unknown durability and generalizability of effects
fMRI	• Clinical rehabilitation • Therapy • Human performance	• Increase working memory capacity	• Methodological concerns • Unknown durability and generalizability of effects • Costly / requires specialized technicians
fNIRS	• Clinical rehabilitation • Therapy • Human performance	• Attention training	• Few studies to date • Methodological concerns • Unknown durability and generalizability of effects

Methodological Challenges

Side effects and adverse events

Risk of bias

Reproducibility

Parameter heterogeneity

Conflicts of interest

Additional Challenges

Ethical considerations

Net zero-sum gains

Undefined biological limits of human performance

Future Directions in Neuroenhancement

Improved mechanistic and predictive modeling / software tools

Addition by subtraction and subtraction by addition

Developing closed-loop neuroenhancement and human-machine teaming

Combined interventions and additive effects

Survey on Experience / Familiarity with Techniques

Link to Survey

https://bit.ly/3BnZG4M

SCAN ME

Survey Point of Contact

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Questions?

U.S. AIR FORCE

USSF

AFRL

Using Interpersonal Similarity in Complex Networks from Physiological Data to Assess Attentional Focus: A Cautionary Tale

Michael T. Tolston, Ivo V. Stuldreher, Gregory J. Funke, Anne-Marie Brouwer

711 HPW / RHWCT

Distribution A: Approved for public release 88ABW Cleared 2021-09-28; AFRL-2021-3284

Teaming and Shared Attention

- Military teams are moving into increasingly dynamic environments and organizational structures that rely on distributed teaming
- Team SA is essential for proper and efficient handling of team tasks
- However, Team SA is difficult to measure and manage in distributed teaming settings
- It is critical to be able to evaluate joint attention and similarity of task investment so that targeted and timely interventions aimed to improve team functioning can be intelligently designed

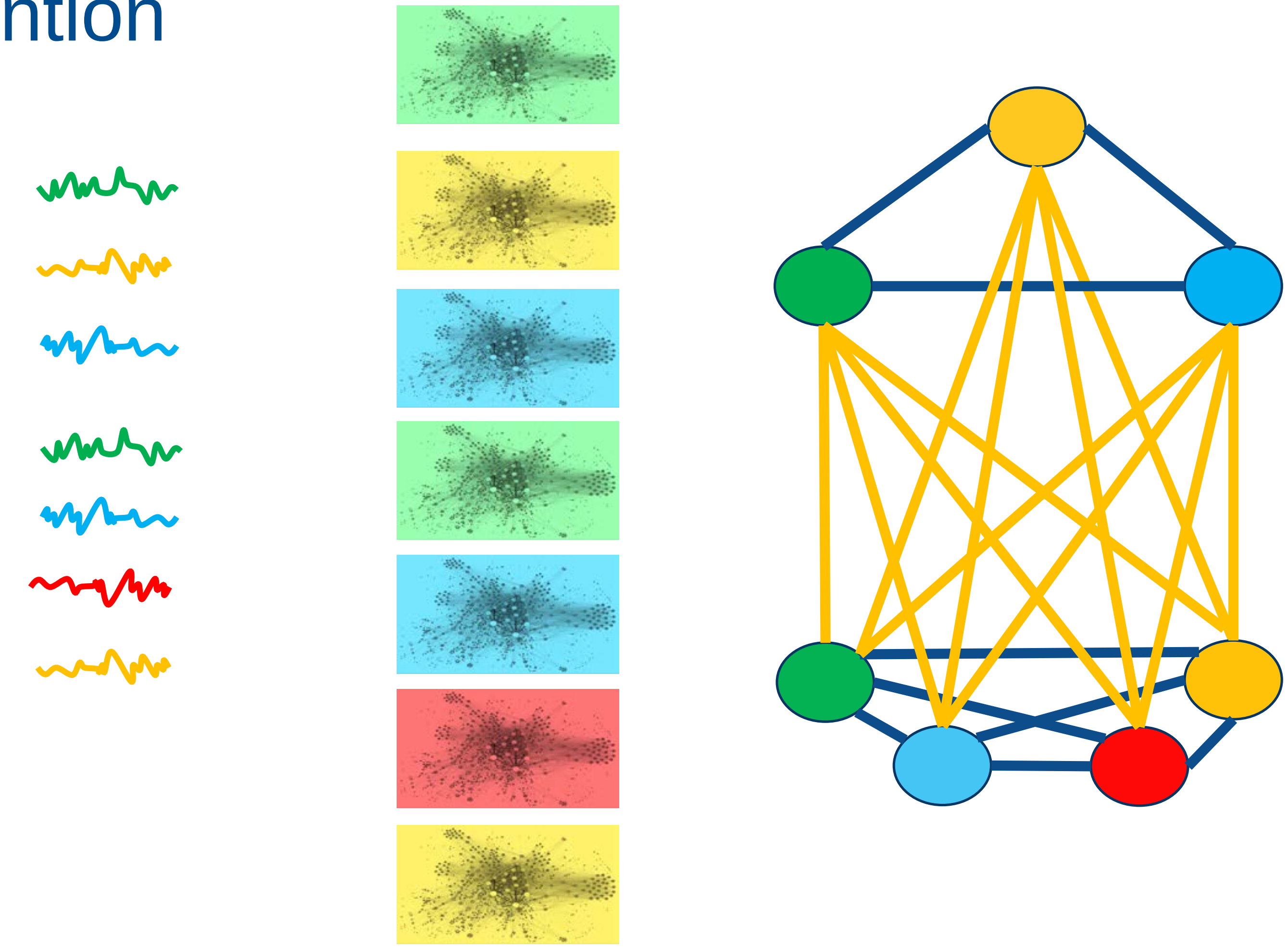
Image source: https://en.wikipedia.org/wiki/Air_Battle_Manager#/media/File:961st_AACS_Cope_North_2019.jpg
https://en.wikipedia.org/wiki/Military-digital_complex#/media/File:Monitoring_a_simulated_test_at_Central_Control_Facility_at_Eglin_Air_Force_Base_(080416-F-5297K-101).jpg

Measuring Shared Attention

- Measuring shared attentional constraints in environments with multiple sources of disturbance is quite difficult (Stanton, Salmon, Walker, Salas, & Hancock, 2017).
  - Using techniques that can objectively evaluate similarity in complex and potentially multivariate data sources can help with this problem
- Hyperscanning: Simultaneously measuring multiple individuals for similarity or synchrony in physiological and behavioral data
  - Often relies on correlation
  - Correlation assumes stationarity and linearity, often violated in real world teaming situations

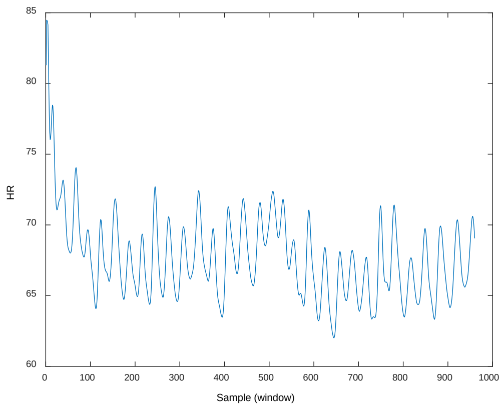
Measuring Shared Attention

- Multiplex recurrence network analysis can evlaute the dynamical similarity of complex multivariate data
- Average mutual information, conceptually similar to a nonlinear correlation, of degree distribution measures the topological similarity of networks

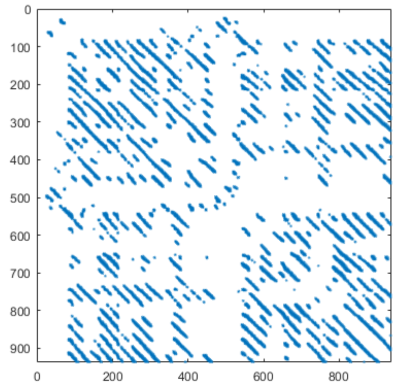


https://en.wikipedia.org/wiki/Network_theory#/media/File:Social_Network_Analysis_Visualization.png

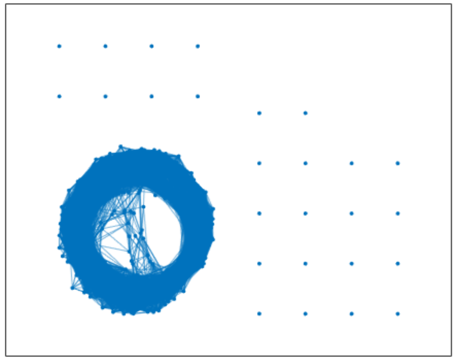
Multiplex Recurrence Network Analysis

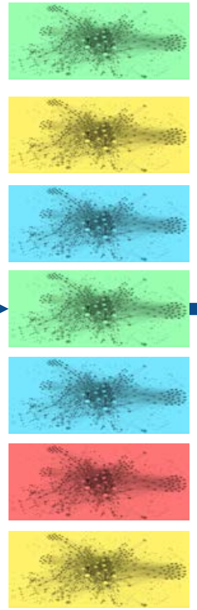


Conduct RQA

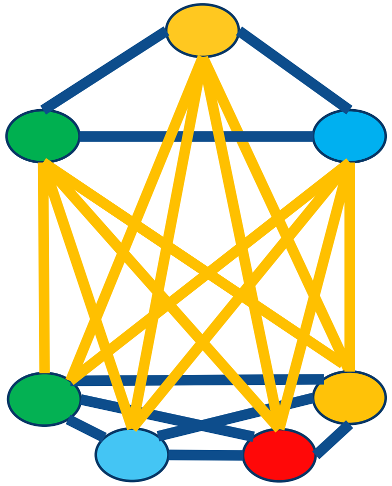


Create Network





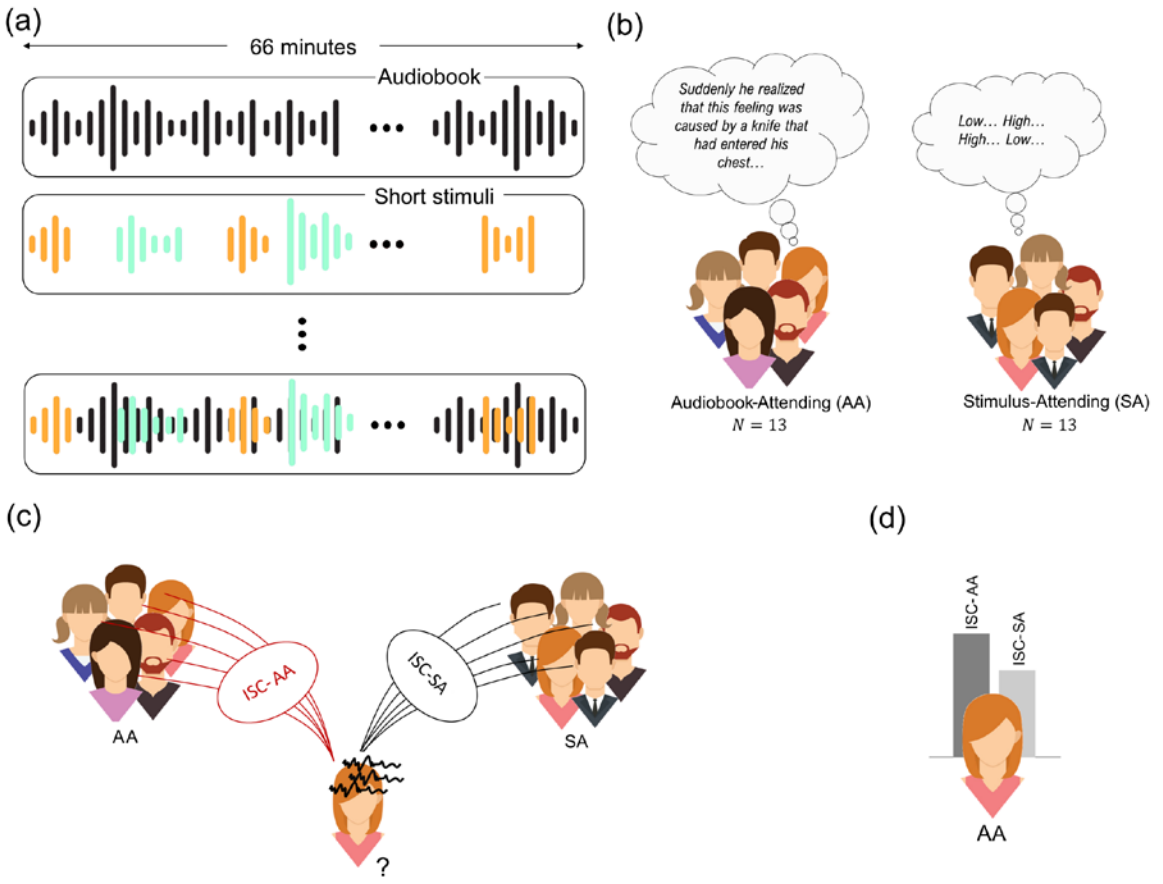
Similarity Determined using Average Mutual Information



Average values of similarity to create a Network of Networks

Present Work

- We used the multiplex recurrence network approach to re-evaluate existing data (Stuldreher, Thammasan, van Erp, & Brouwer, 2020)
- Individuals listened to an audiobook while also occasionally being presented with affectively salient or cognitively demanding stimuli
  - Instructed to attend audio book or stimuli
  - Researchers found that intra-group synchrony was a predictor of attentional instruction



Present Work

- Purpose: Evaluate the similarity in physiological responses between individuals as a function of whether individuals were instructed to attend to the stimuli or to attend to the audiobook.
  - Try to improve classification outcomes obtained from previous study by moving to a multivariate approach
  - First step: univariate between subjects analysis for dynamical similarity (more general than synchrony)
    - What we are presenting in this work
  - Second step: multivariate analysis
- Expectations:
  - Expect within-group similarity to be higher than between group similarity
  - E.g., Participants in the audiobook attending group will be more similar to other participants in the audiobook attending group than to participants in the stimulus attending group and vice versa (main effect of similarity type)

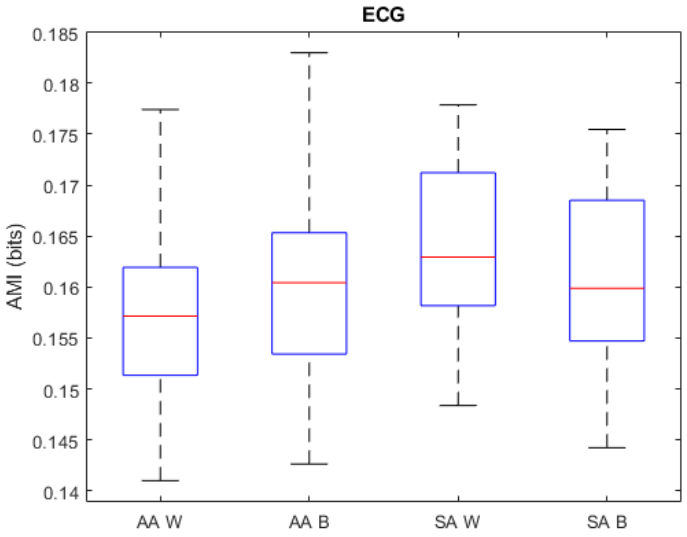
Method

- Data were collected while participants listened to a 66 minute long audiobook.
  - During the presentation of the audiobook, distracting sounds were played at certain times throughout the audiobook (fixed to the same time for all participants).
  - Participants were either instructed to attend the audiobook (audiobook attending group) or the distracting sounds (stimulus attending group).
- Physiological data (EEG, EDA, and ECG) were collected from participants using an ActiveTwo MK II system (BioSemi, Amsterdam, Netherlands) sampling at 1024 Hz.
- For ECG and EDA, data were downsampled and split into 120 s epochs with 87.5% overlap.
- For EEG, theta power was estimated from .5 s of data with a 75% overlap.
  - These summary data were then split into 120 s epochs with 87.5% overlap.

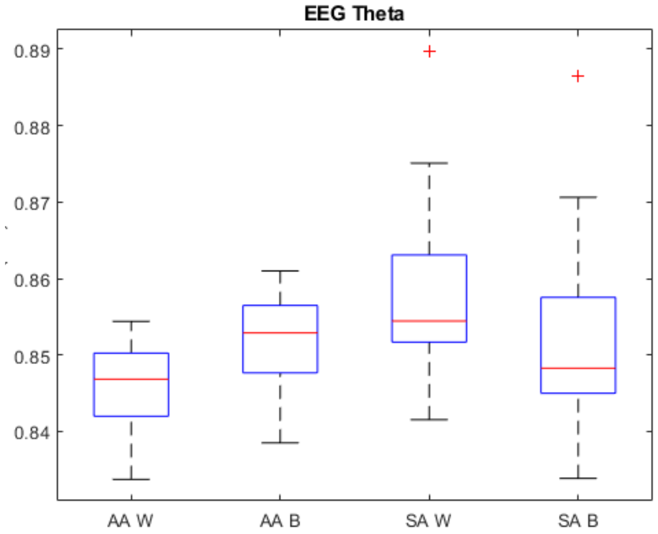
Method

- In each 120s window, recurrence quantification analysis was conducted to create a complex network representation of the system dynamics.
  - Recurrence networks were used to assess similarity between time series using average mutual information (Eroglu et al., 2018).
- **Average values of similarity between an individual's time series and the time-series of all other individuals in the same condition (intra-group similarity) and the time-series of all individuals in the other condition (inter-group similarity) were calculated.**
  - These values of intra- and inter-group similarity were entered into a mixed ANOVA, with similarity type (intra, inter) as the within-subject's variable and stimulus attending condition as the between-subject variable.
- To verify findings, surrogate data analyses were conducted

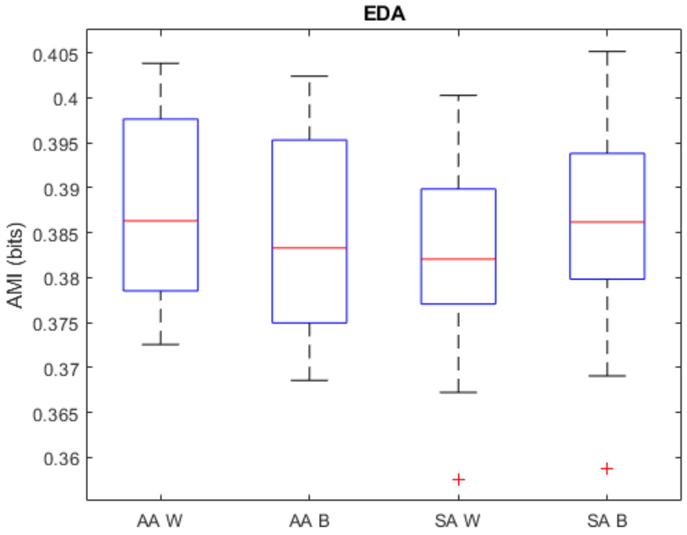
Findings: Interactions!



$F(1,24) = 164.50, p < .001$

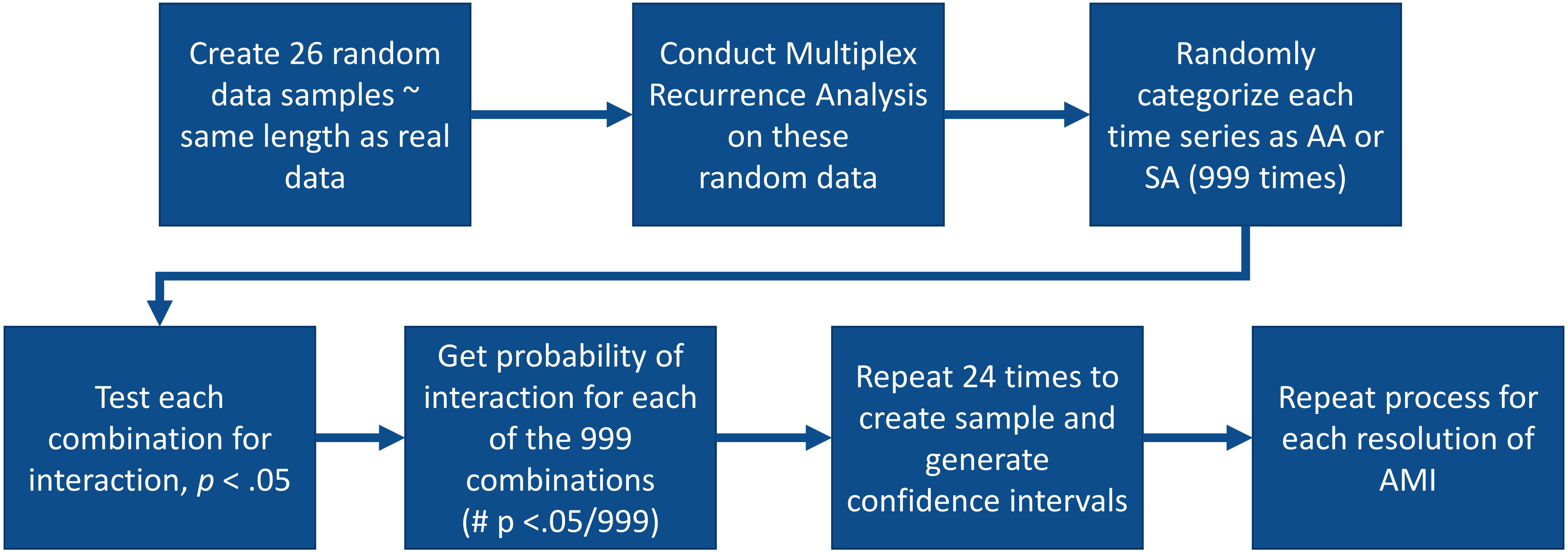


$F(1,24) = 1078.78, p < .001.$

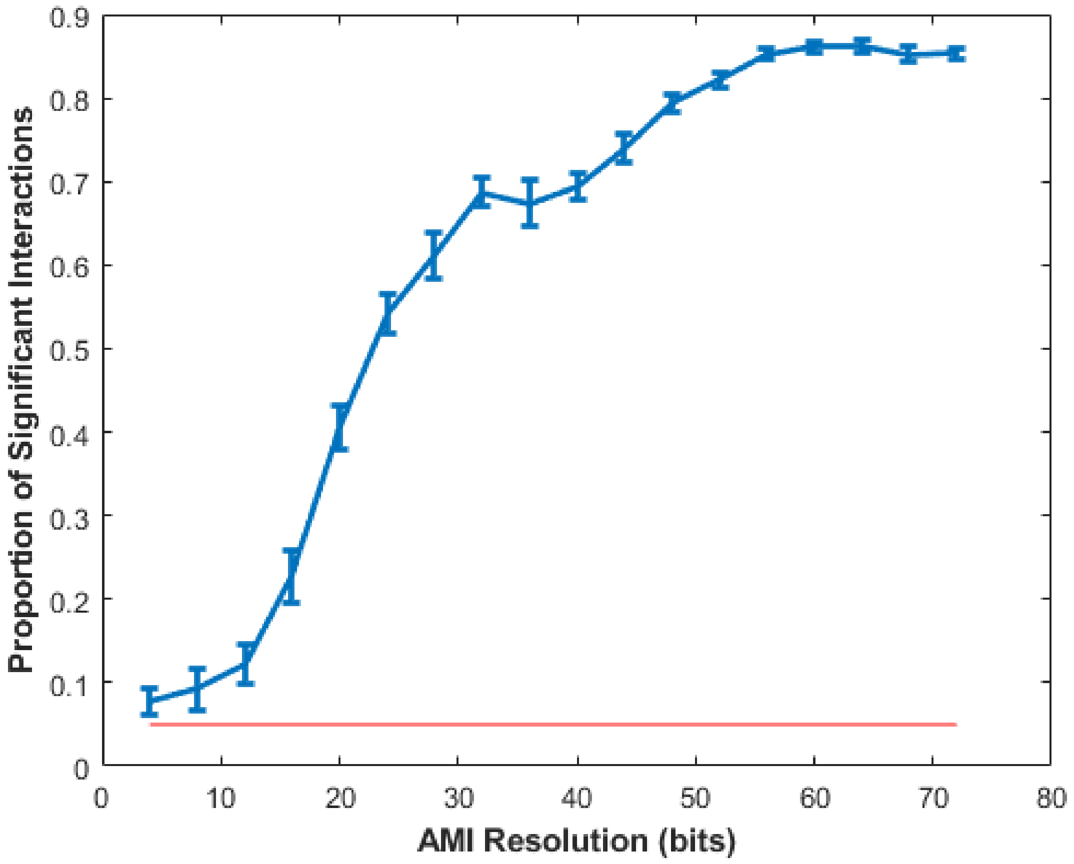


$F(1,24) = 268.624, p < .001$

Surrogate Analysis: Test the Probability of an Interaction



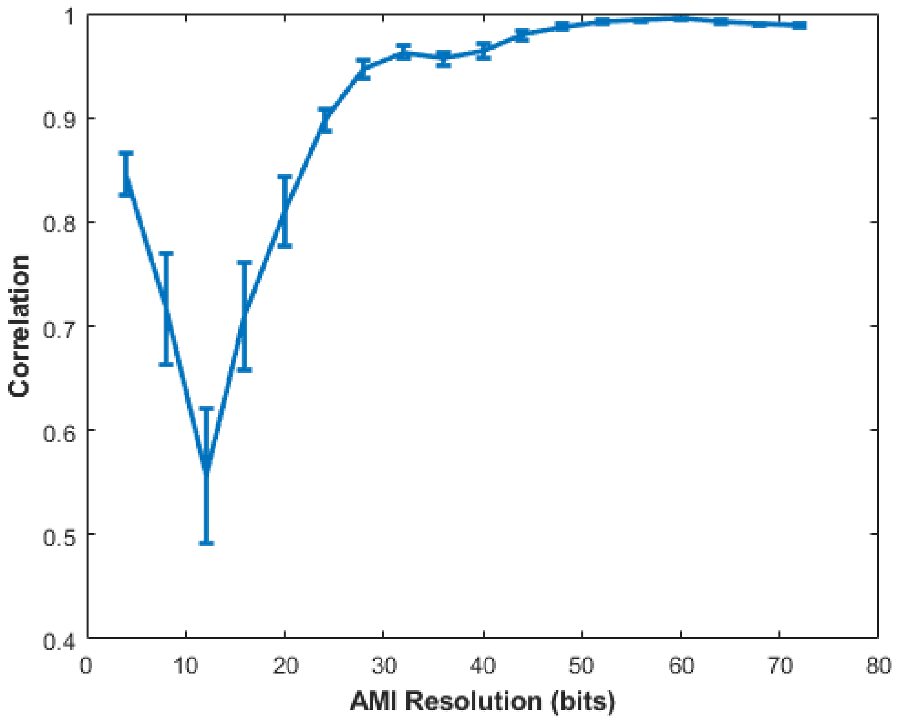
Surrogate Analyses



The average value of the proportion of significant interactions as a function of bin size

Surrogate Analyses

- To evaluate what may be driving the disparity of information content, we evaluated the relationship between the **entropy of each random time series and the average AMI between that time series and all others**:



The average Pearson correlation between the entropy (randomness) of each time series and the average AMI between that time series and all others for each of the 24 sets of randomly generated data

Conclusions

- Analyses showed strong differences in the repeated measure of inter-group similarity as a function of stimulus attending condition.
- However, the strength of these interactions, with extreme *F* statistics, was concerning and the disparity in patterning is confusing: EEG and ECG were consistent, though EDA was the opposite.
- When we conducted surrogate analyses using **randomized data** similar patterning resulted: One group was shown to consistently have more canonical dynamics, on average, than the other group.
- It was found that patterning in the data were dependent upon the resolution of the AMI algorithm (i.e., the number of bins used in discretizing the data), with high resolutions generating patterning in random data that were similar to that found in actual participant data.

Conclusions

- Due to the method of averaging pairwise similarity between all individuals, a very small subset of the data can have a disproportionate effect on group averages.
- In the case of random data, due to the limitations of sample size, some randomly generated number sequences resulted in networks with higher entropy of degree distribution, causing increased similarity with other random networks.
- The pairwise averaging of similarity with these files appears to disproportionally inflate their influence and cause higher average similarity in the condition to which they are assigned.
  - Many more additional outstanding questions remain, including those regarding the limitations of this method of pairwise comparison for intra- and inter-group similarity generally, and how the resolution of partitioning algorithms affect outcomes from network similarity metrics from networks that are generated with different types of structure.
- Hyperscanning and evaluating similarity of peoples' signals is an informative tool for group processes
  - However, these analyses are not straightforward and results should be critically viewed and always checked against surrogate analyses.

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Joint Support Command
Ministry of Defence

UMC Utrecht

Utrecht University

Electrical brain stimulation to improve stress regulation

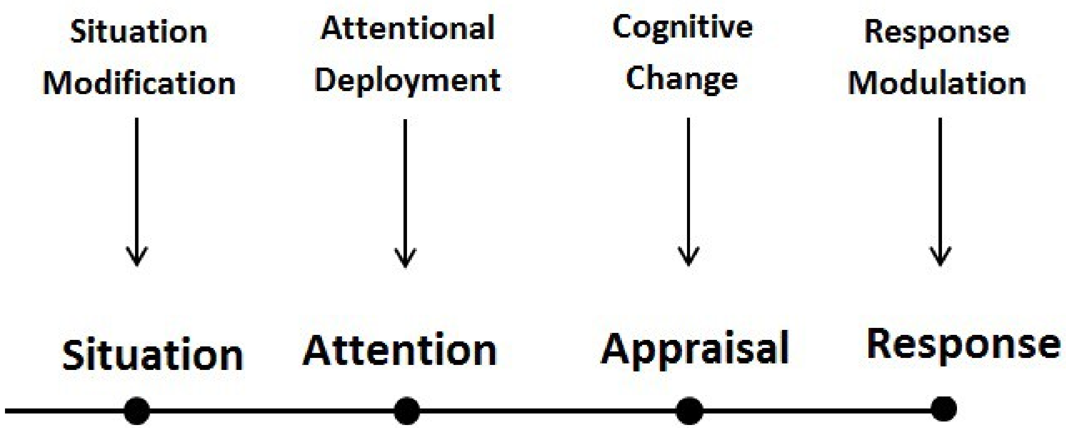
Fenne Smits

Ministry of Defence, The Netherlands
Utrecht University, The Netherlands

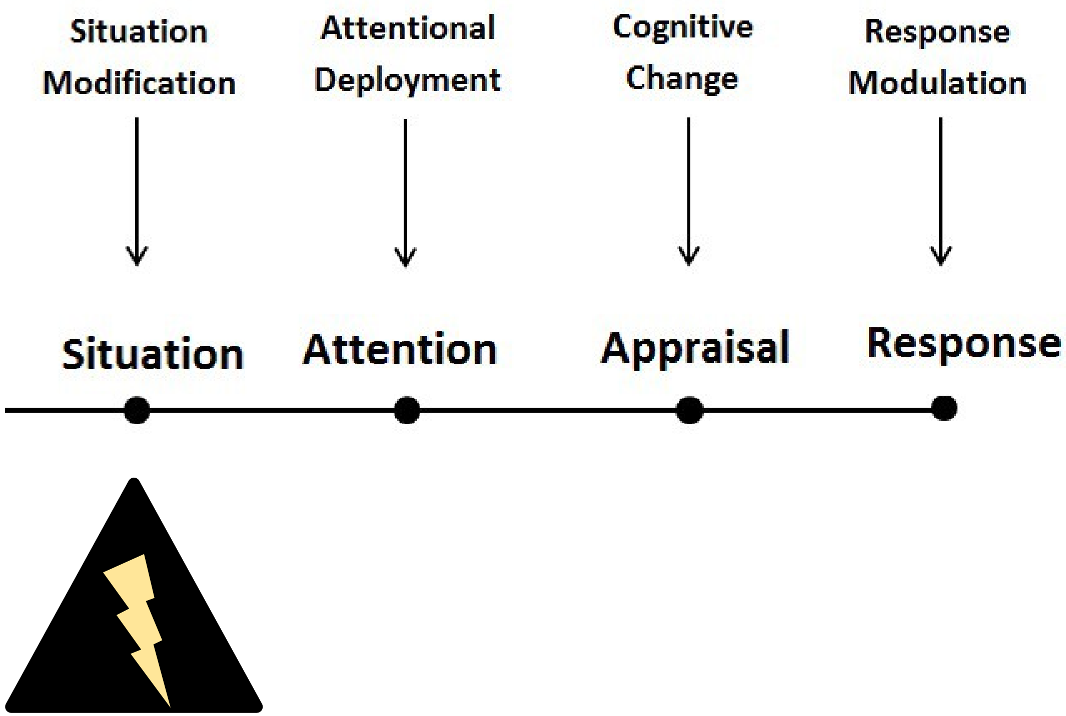
Brain Research
and Innovation Centre

www.braic.nl

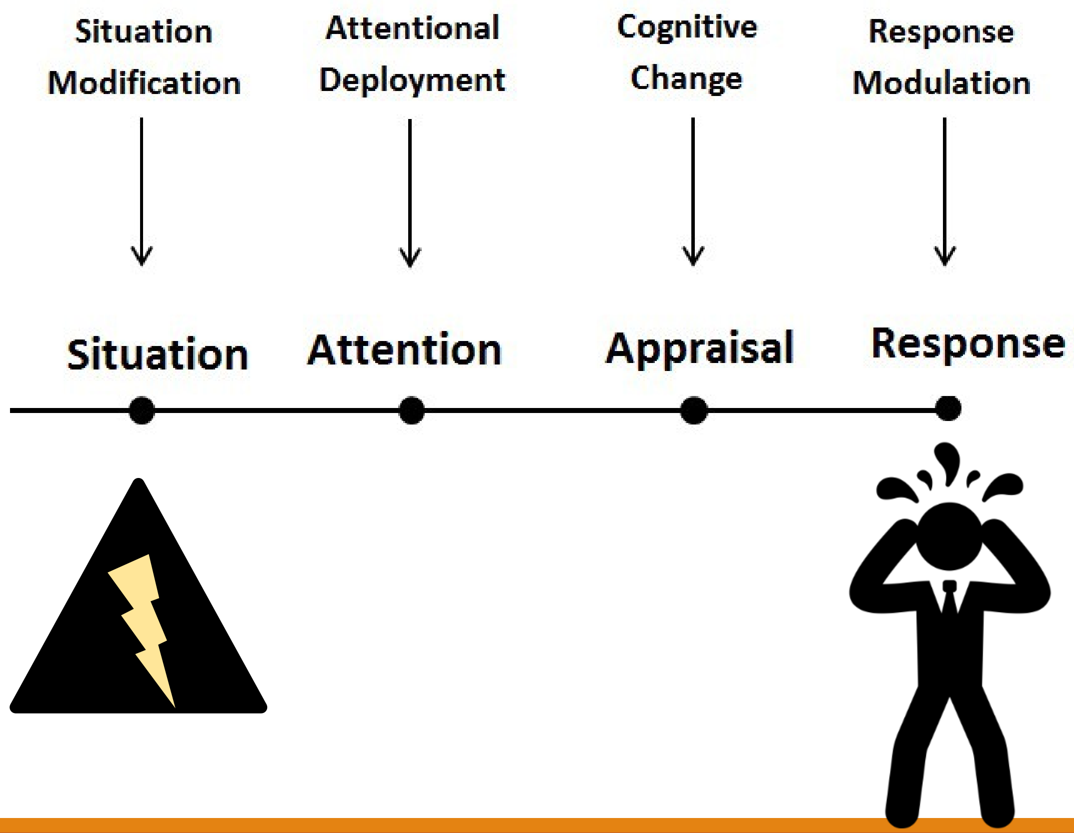
Stress regulation & the brain



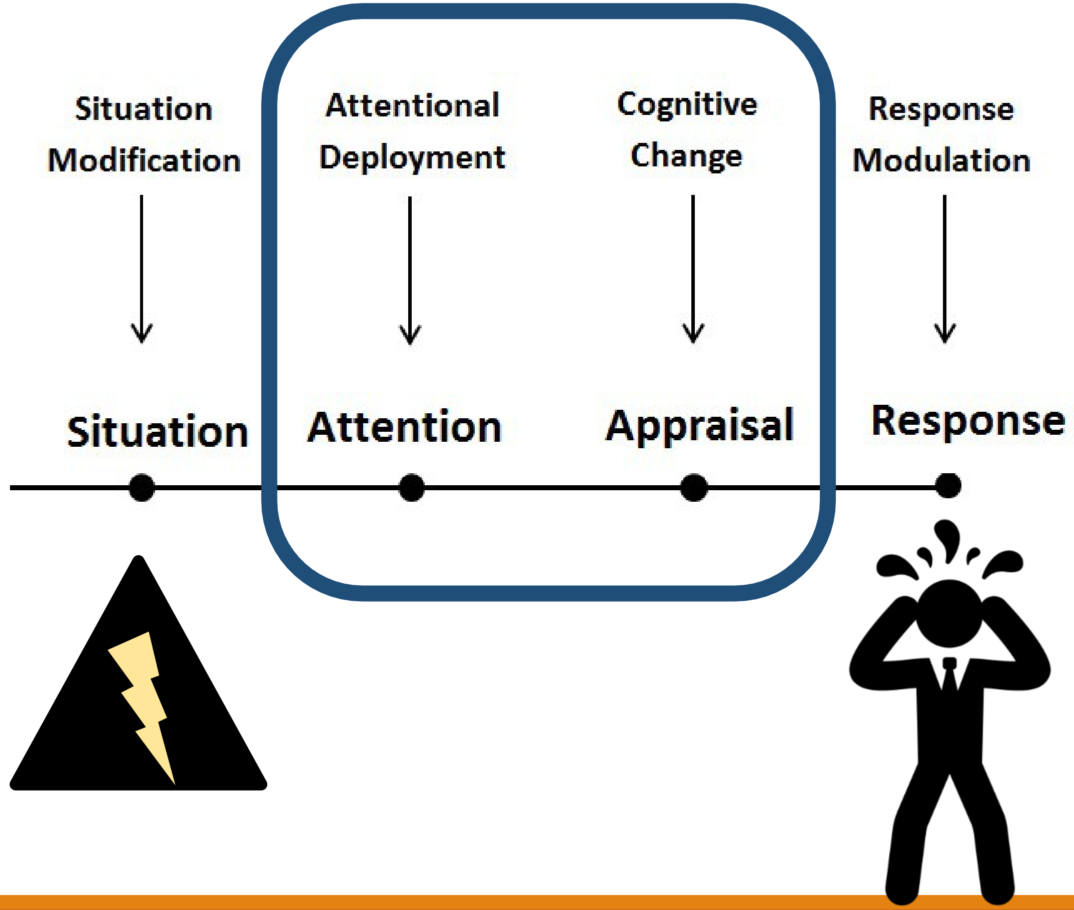
Stress regulation & the brain



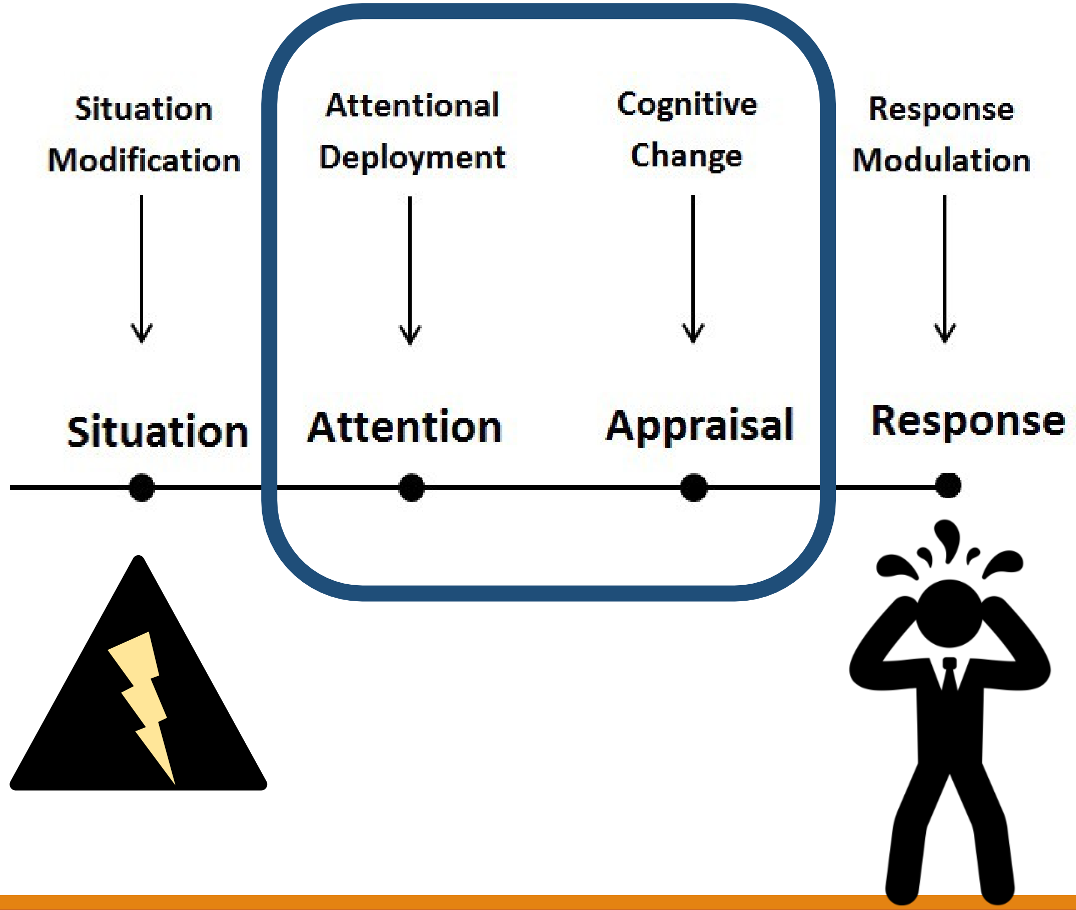
Stress regulation & the brain

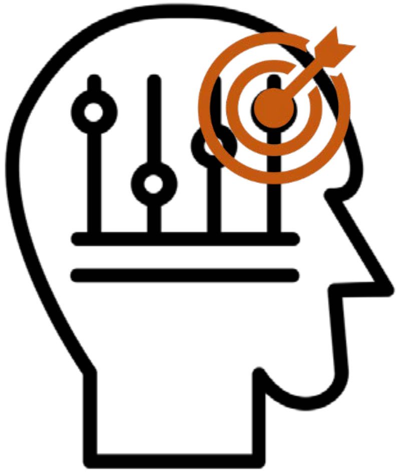


Stress regulation & the brain



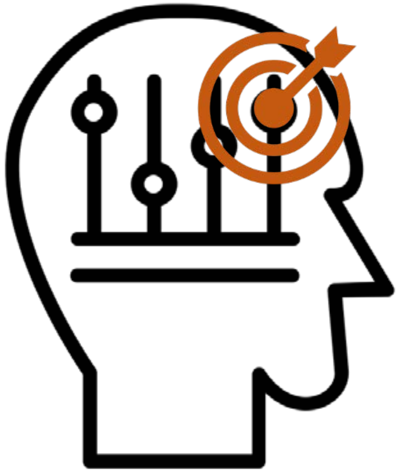
Stress regulation & the brain



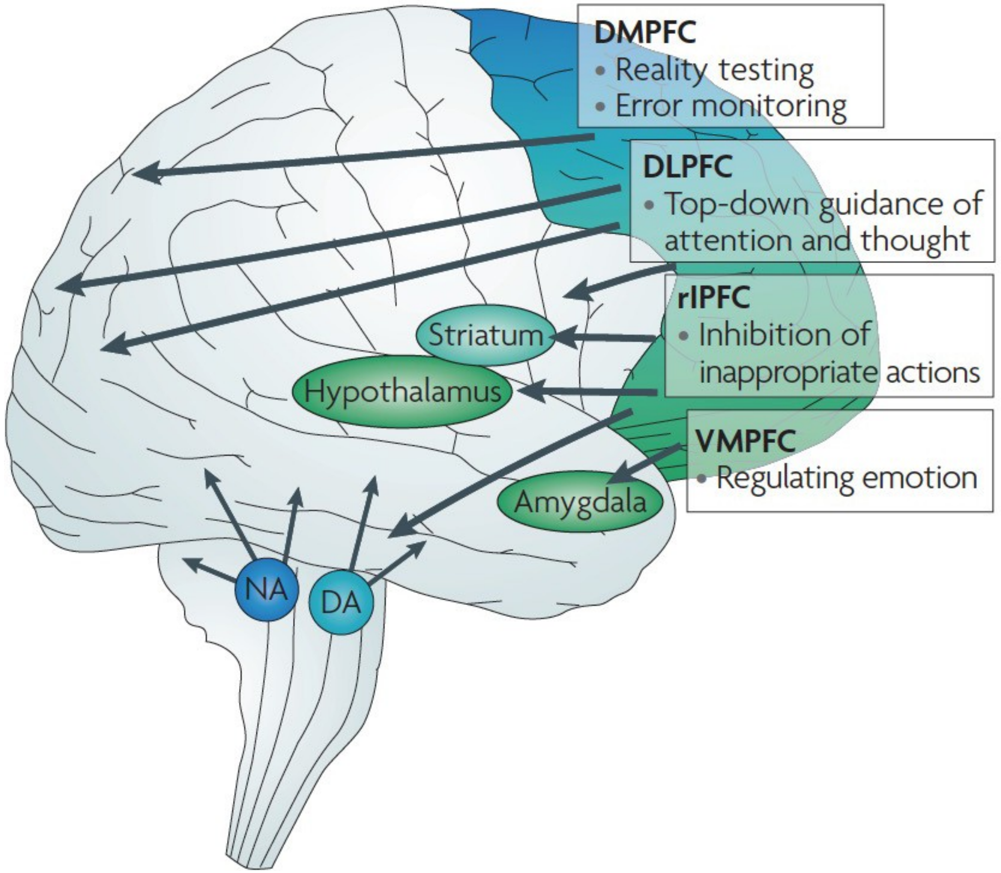


Transcranial stimulation

tDCS

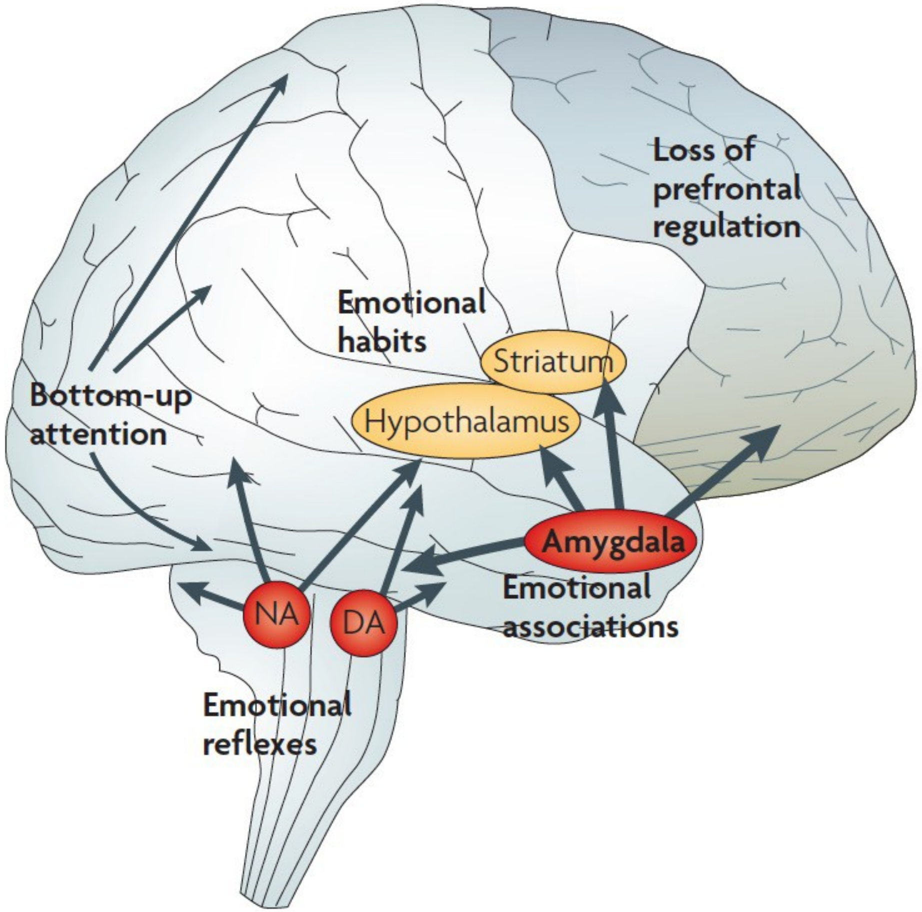


Prefrontal cortex

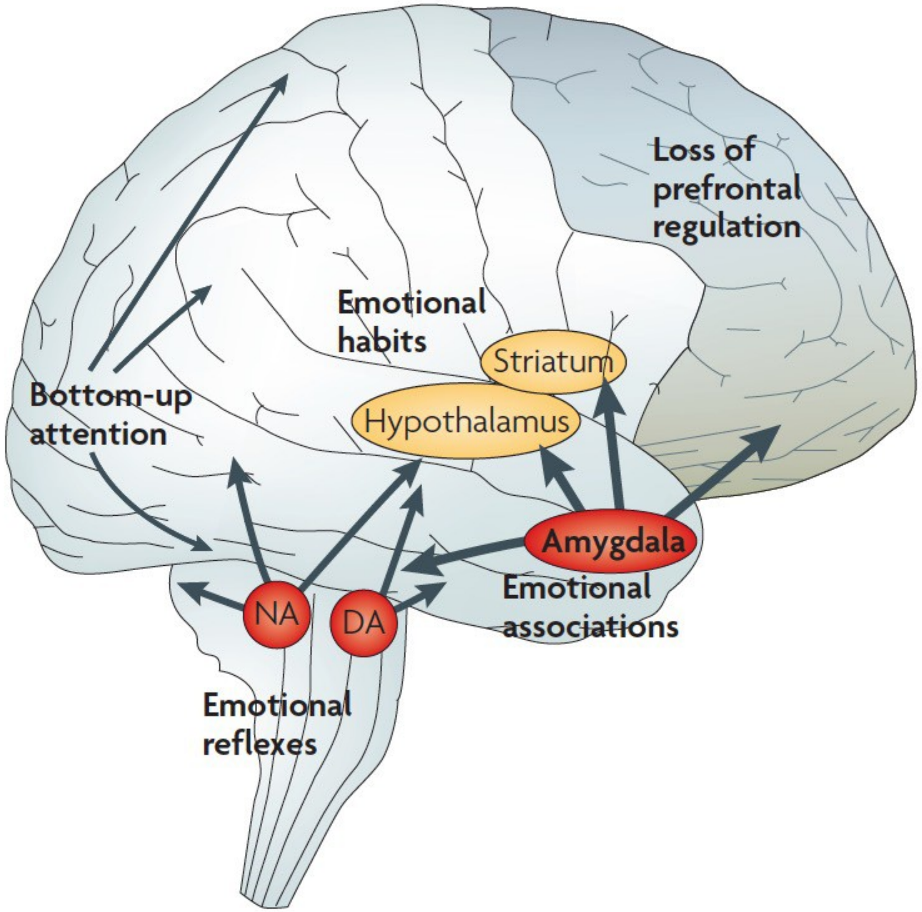


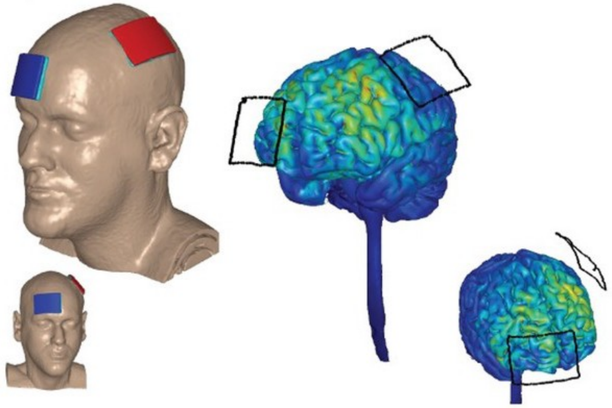
Arnsten, 2009, 2015

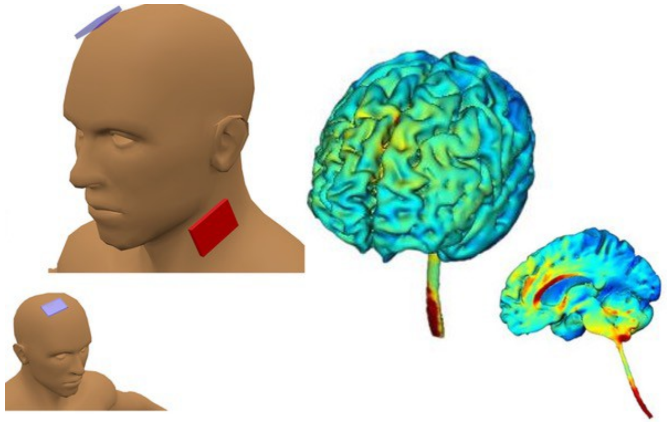
Prefrontal cortex



Prefrontal cortex







tDCS: mechanisms

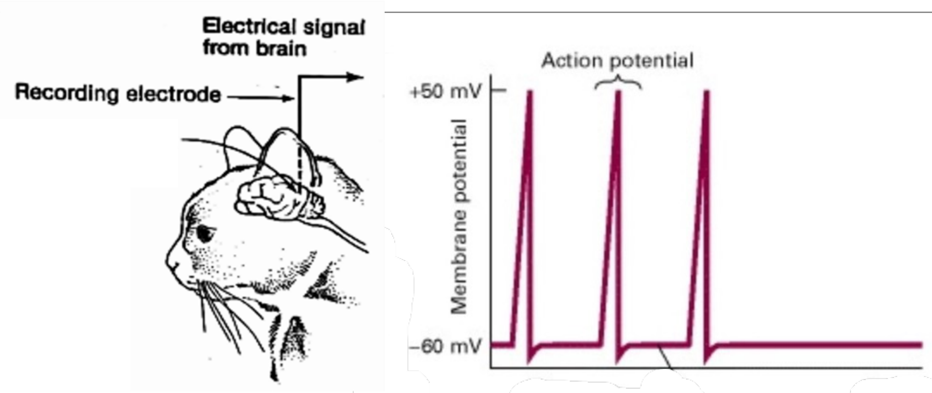
Brain Research and Innovation Centre

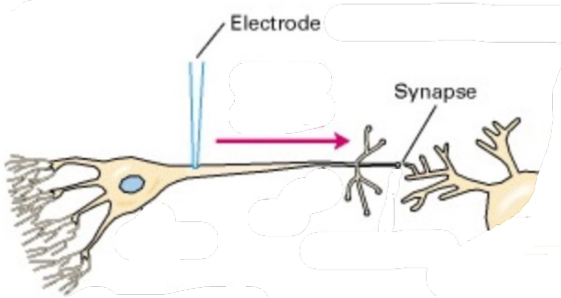
+ facilitates

− inhibits

tDCS: mechanisms

Brain Research
and Innovation Centre





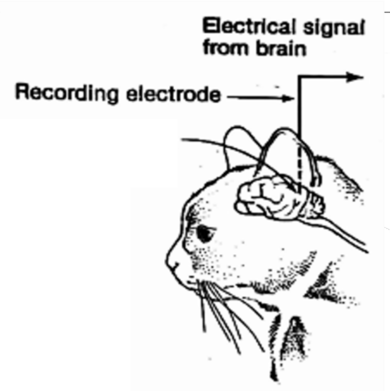
\+ facilitates

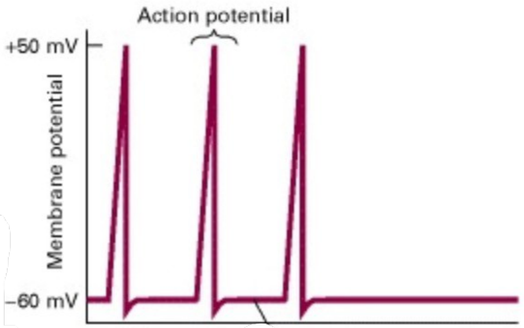
− inhibits

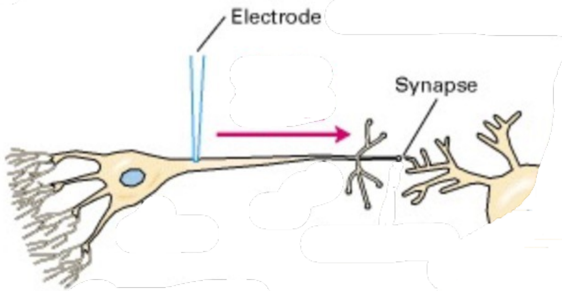
tDCS: mechanisms

+ facilitates

− inhibits







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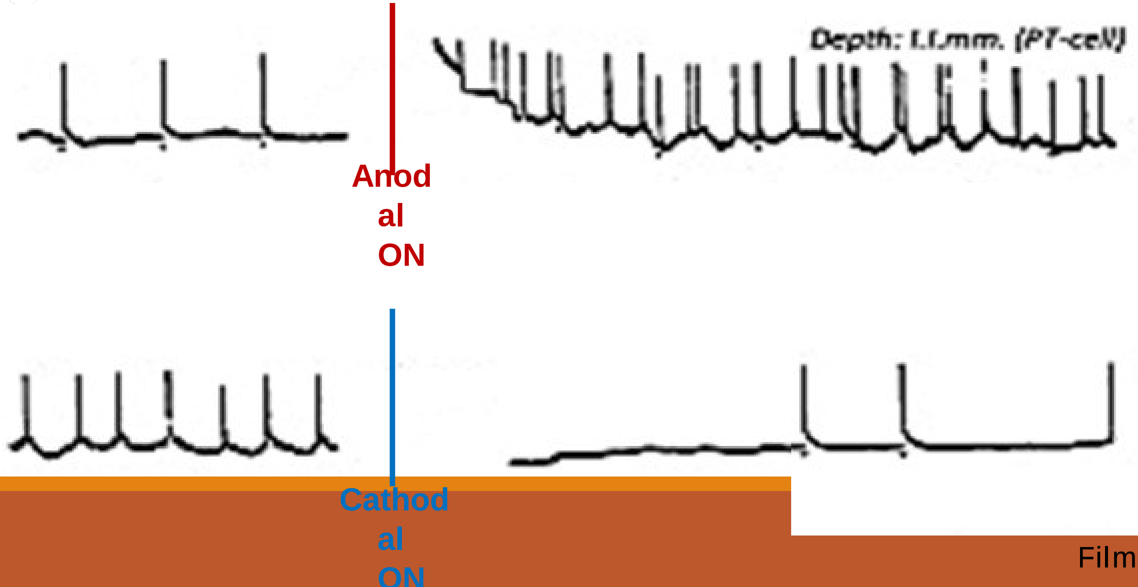

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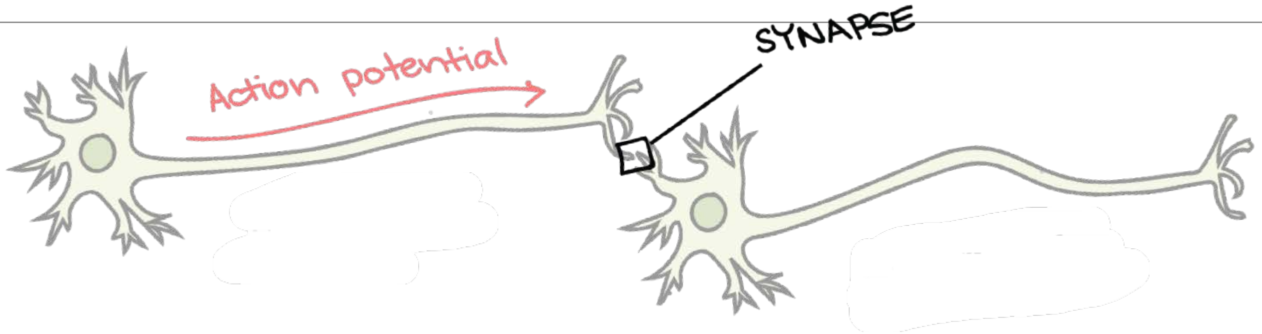
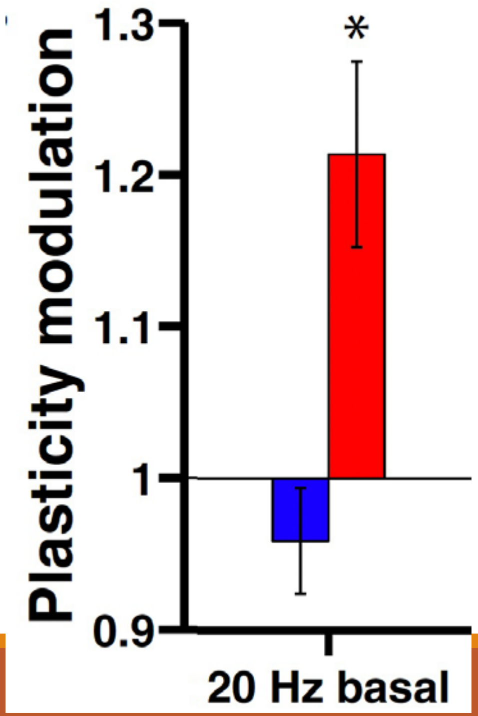
Filmer et al. 2014

tDCS: mechanisms

facilitates

inhibits



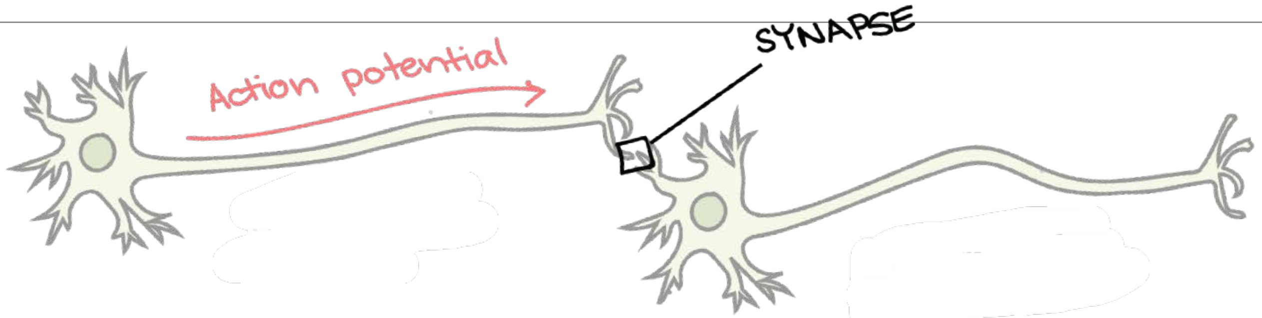


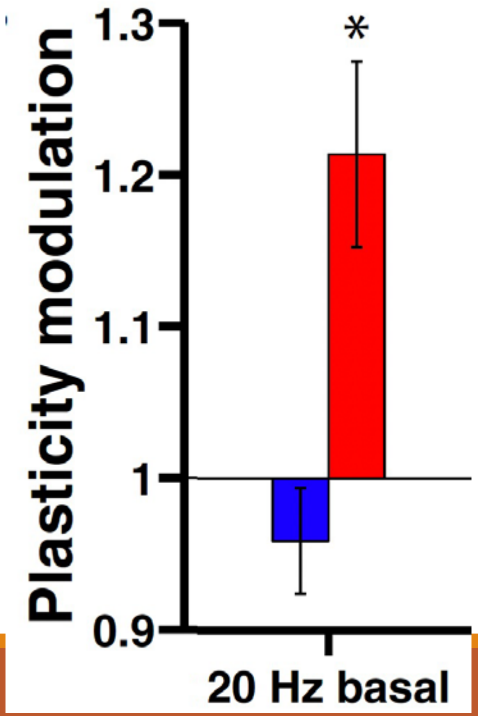
Kronberg et al. 2017

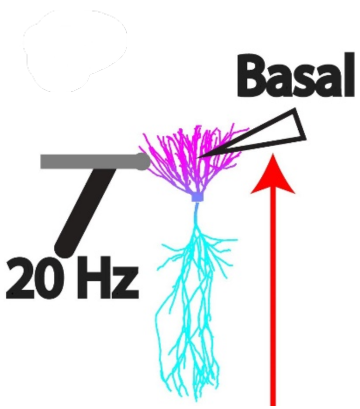
tDCS: mechanisms

+ facilitates

− inhibits

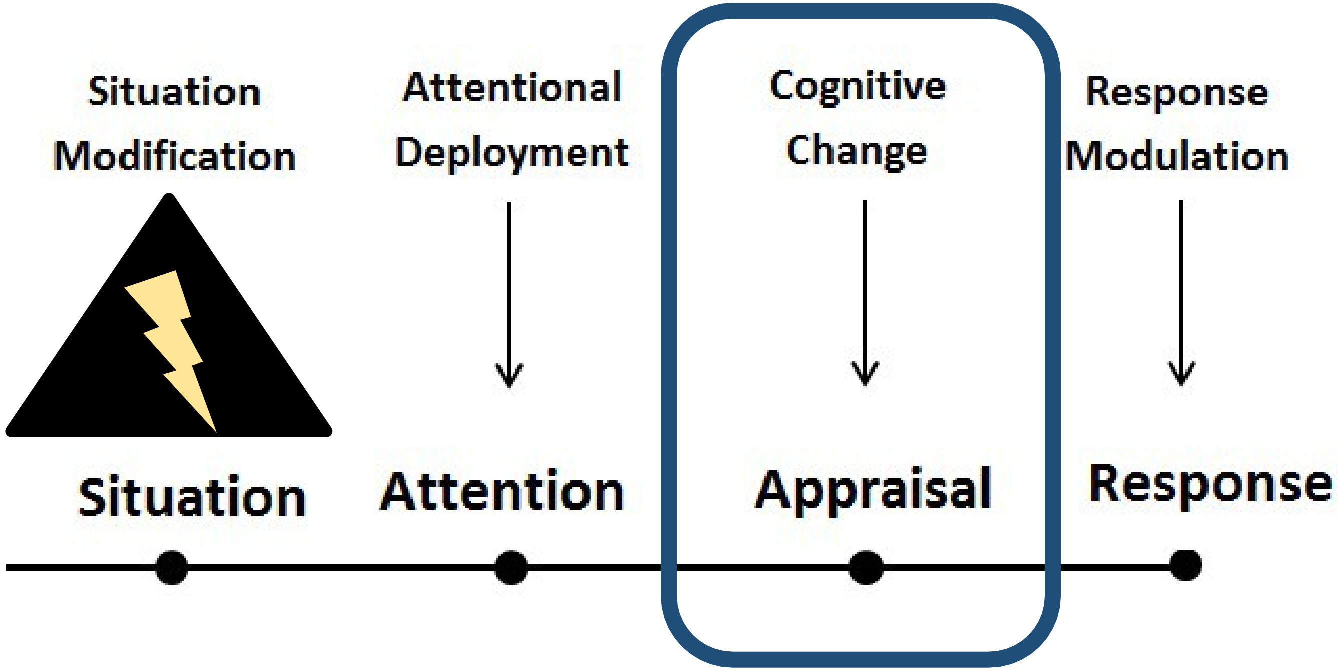




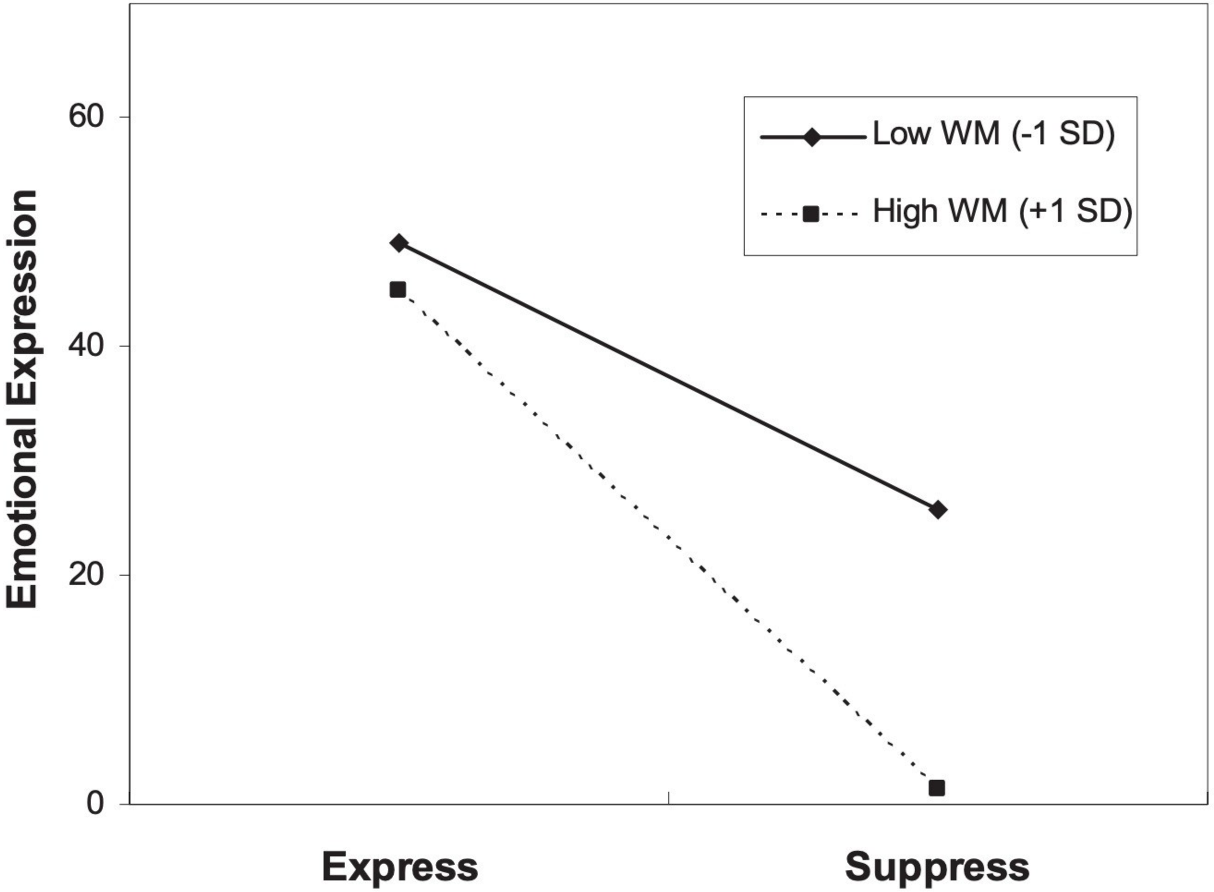


Kronberg et al. 2017

Stress regulation

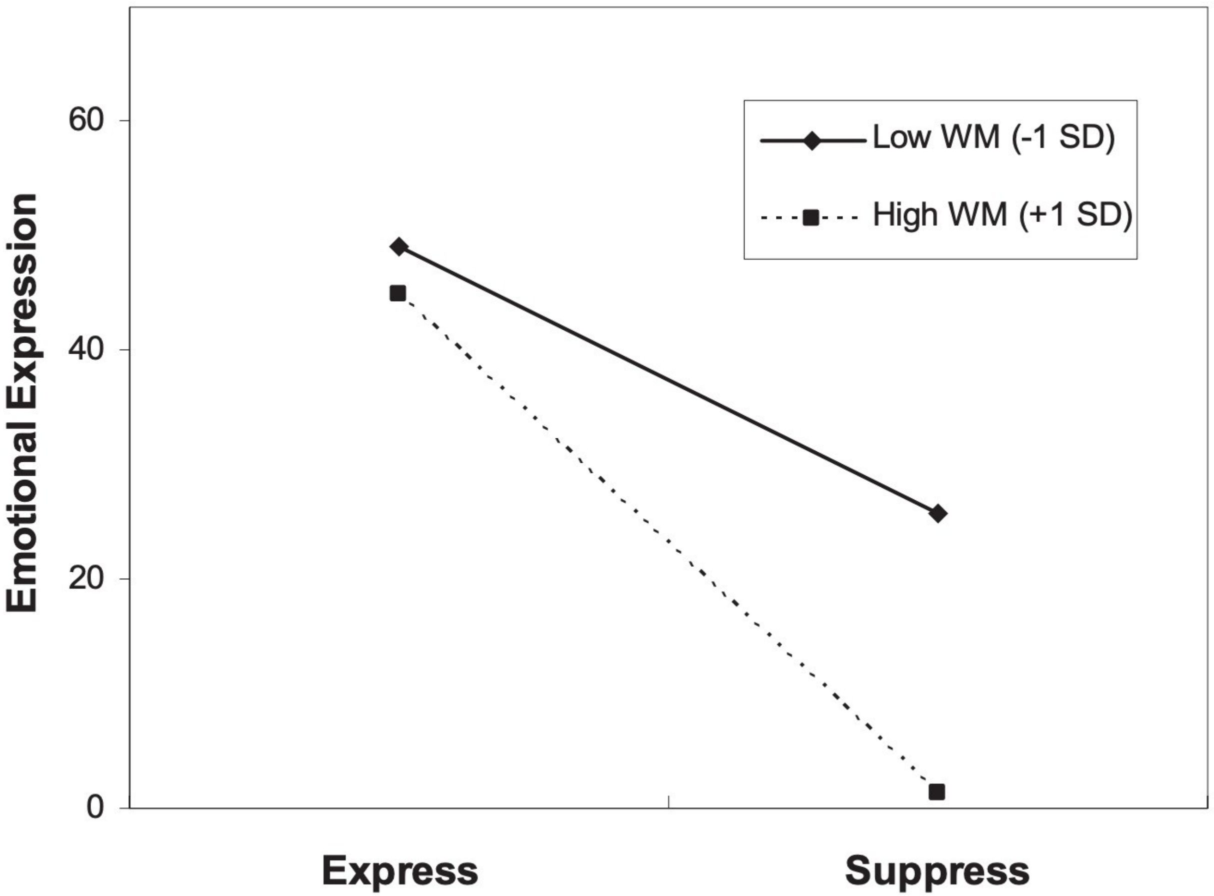


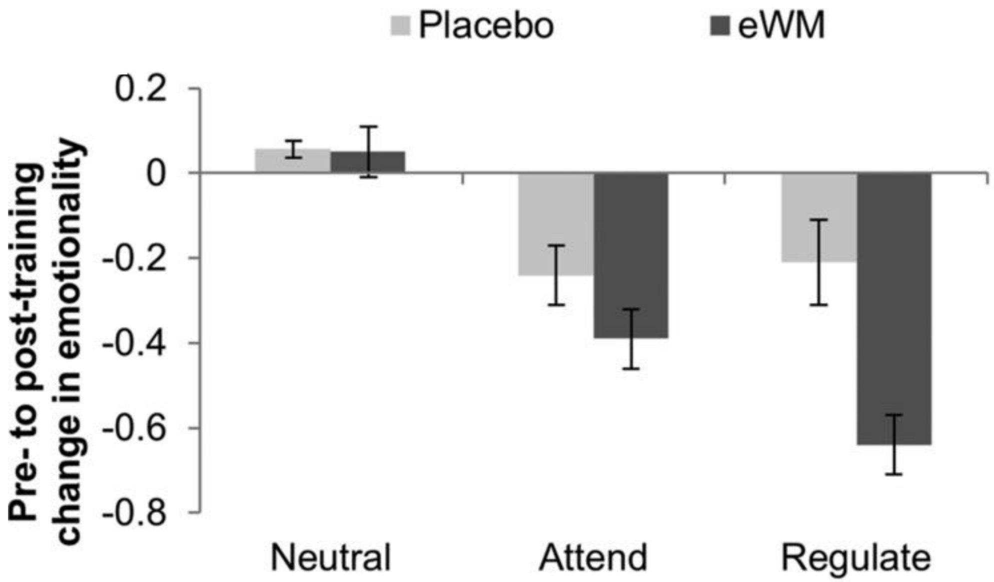
Working memory & stress regulation



Schmeichel et al. 2008

Working memory & stress regulation

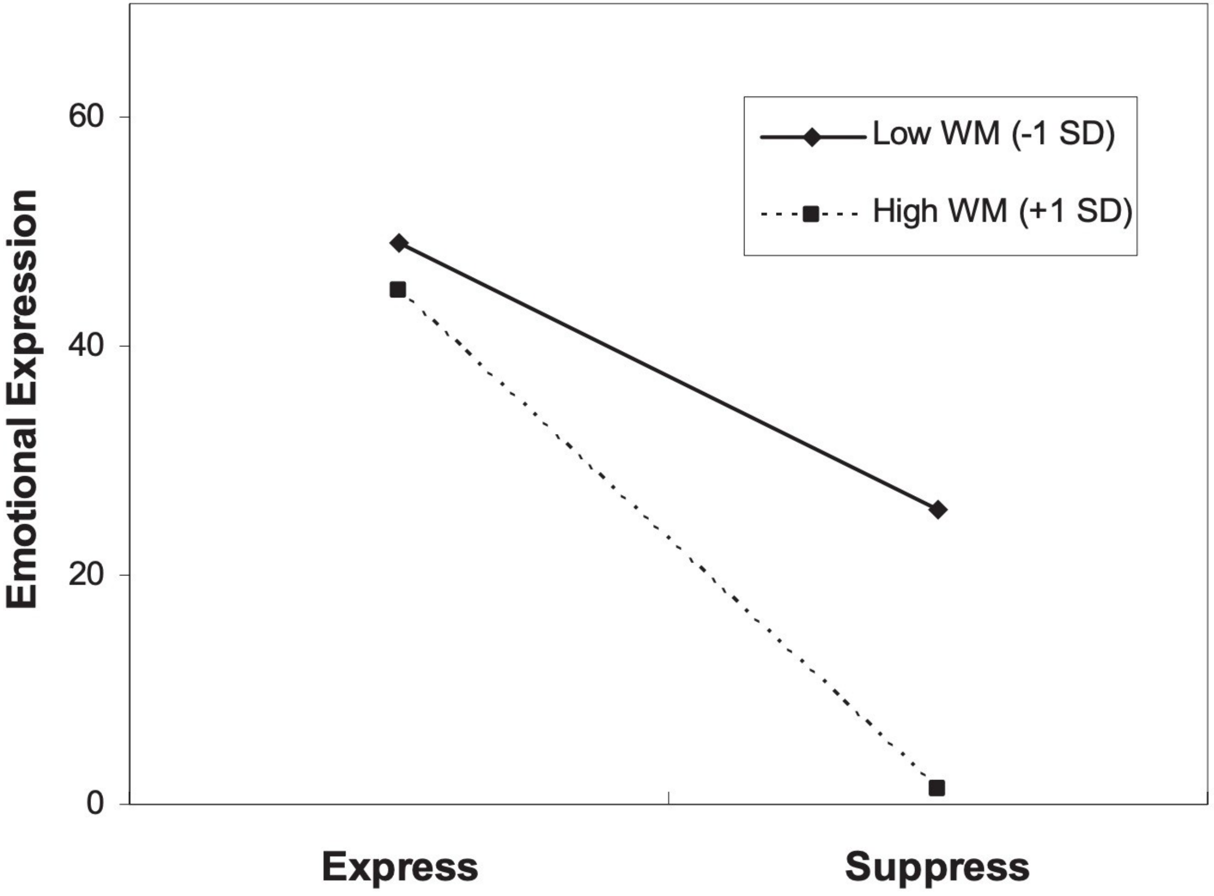


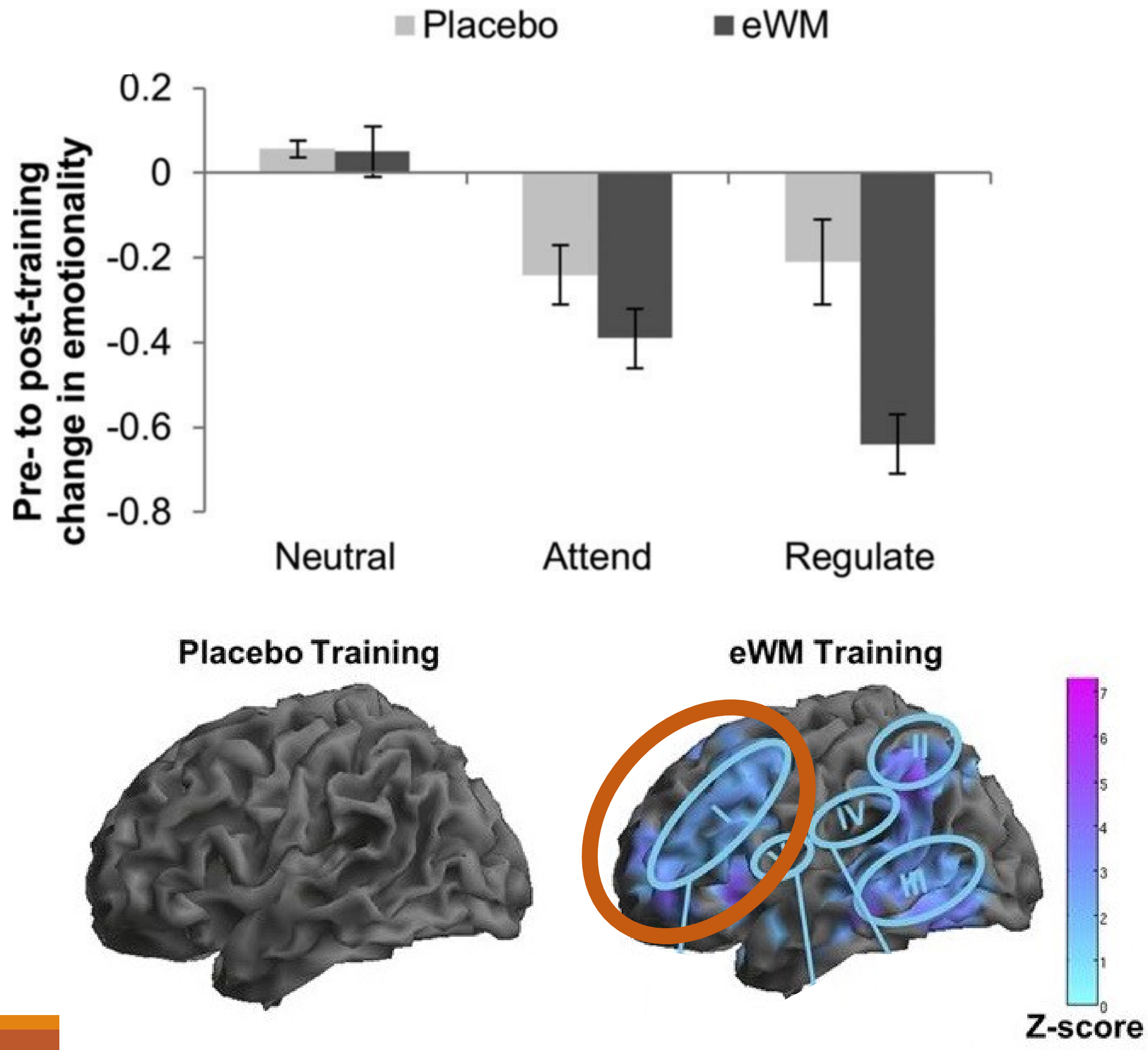


Schmeichel et al. 2008

Schweizer et al. 2013

Working memory & stress regulation

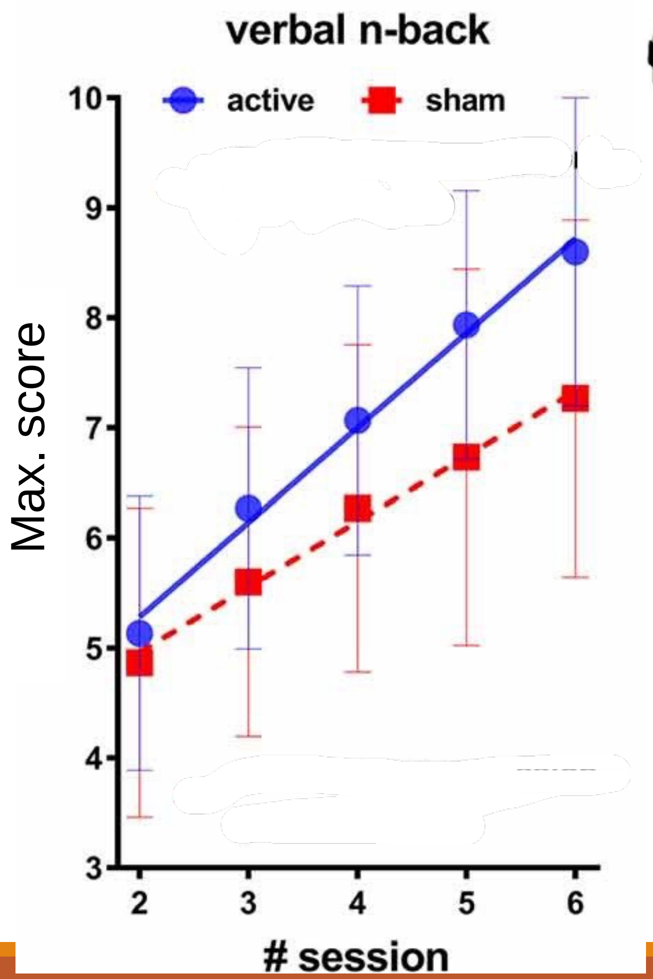




Schmeichel et al. 2008

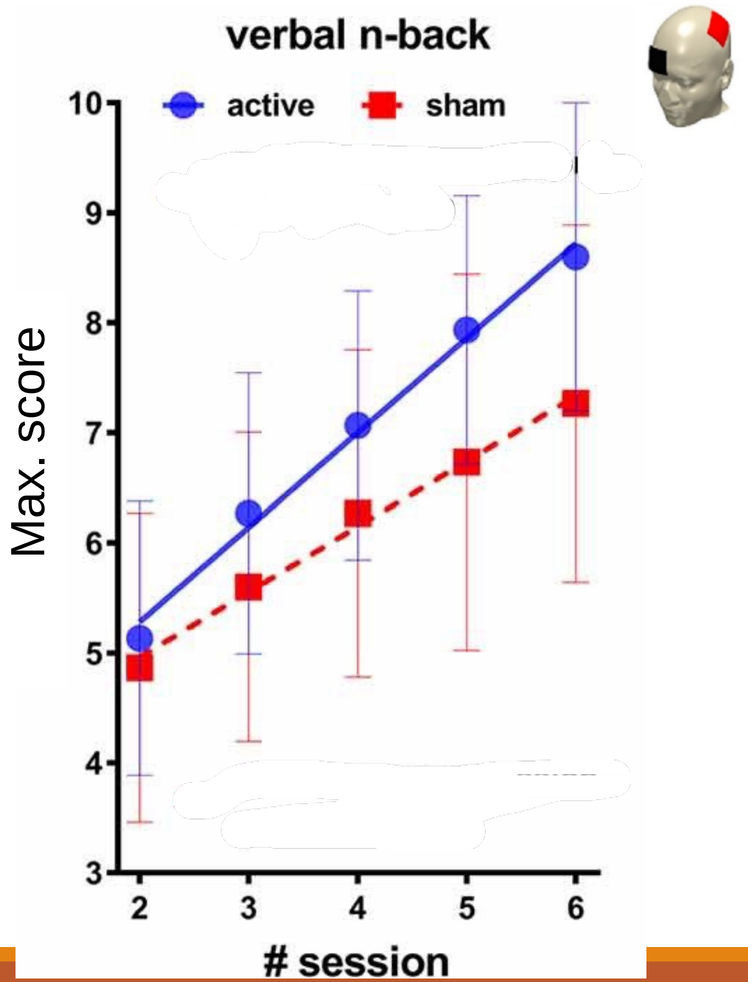
Schweizer et al. 2013

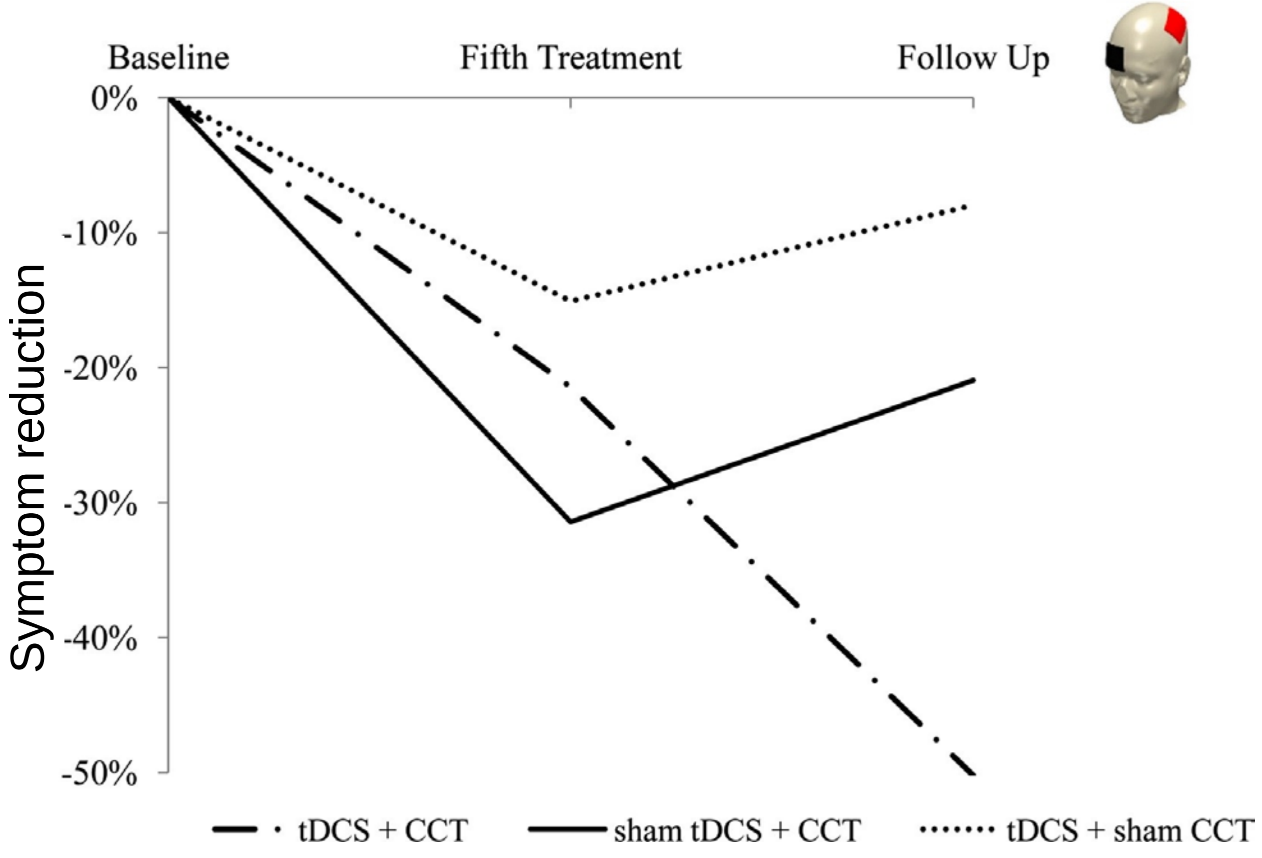
tDCS + cognitive training



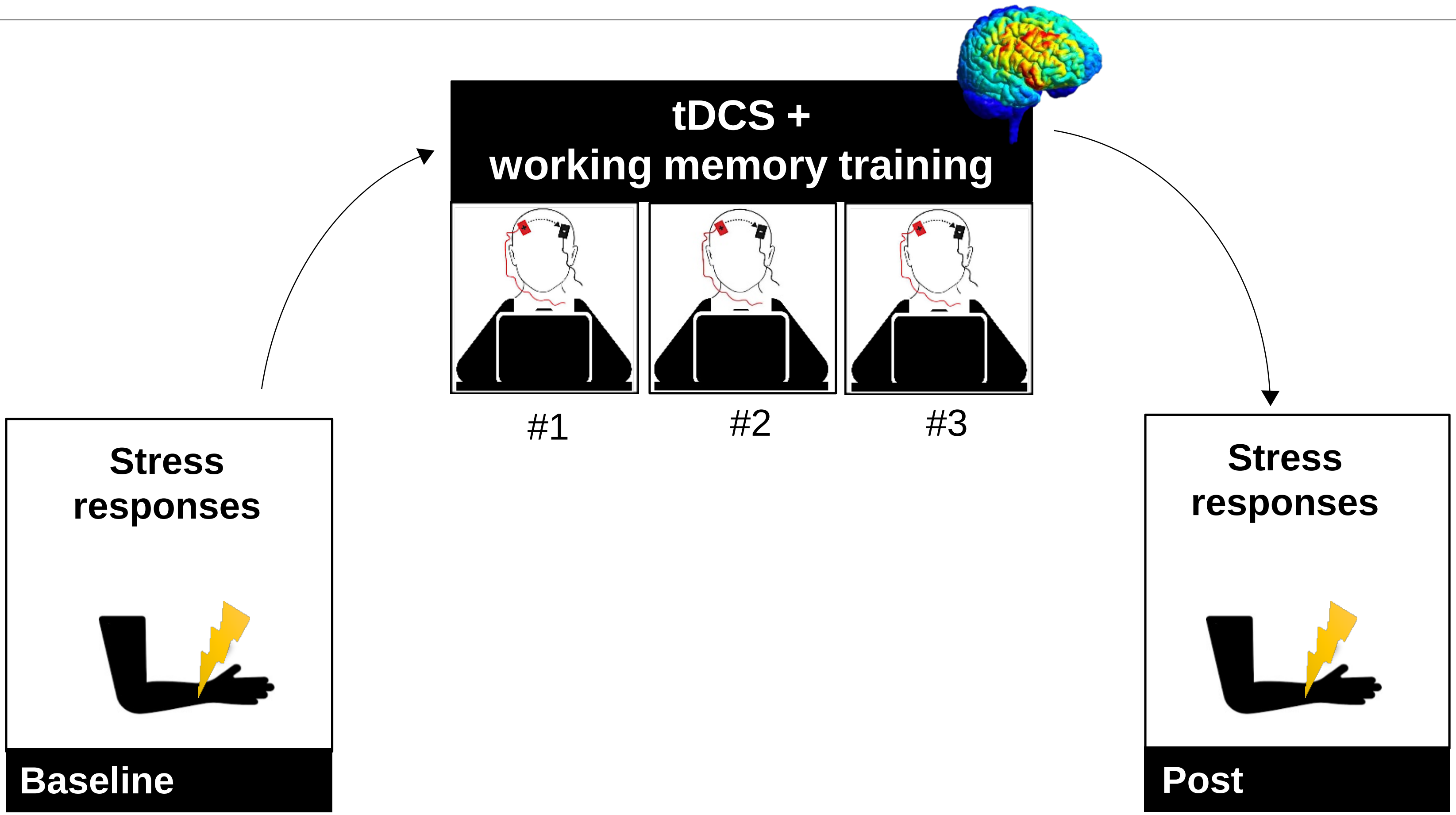
Ke et al. 2019; Segrave et al. 2014

tDCS + cognitive training



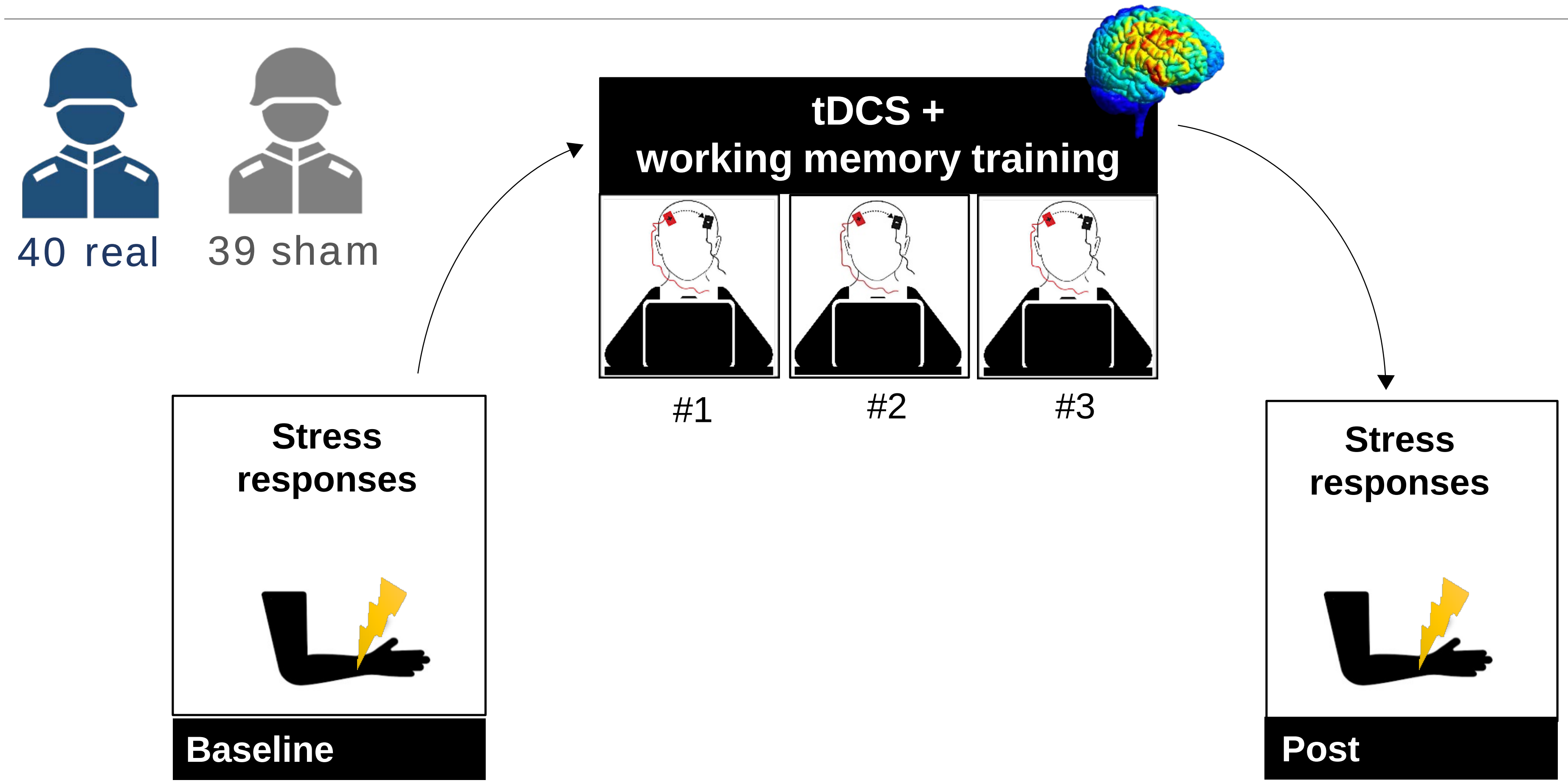


Study design

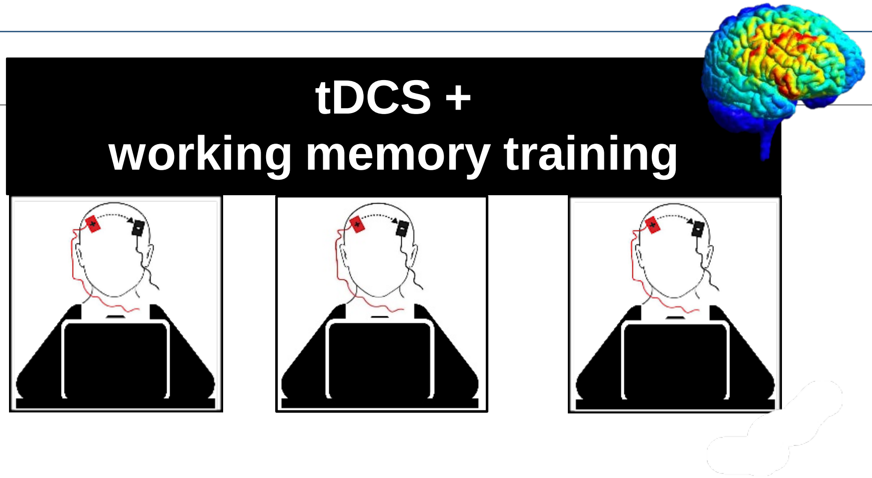


Study design

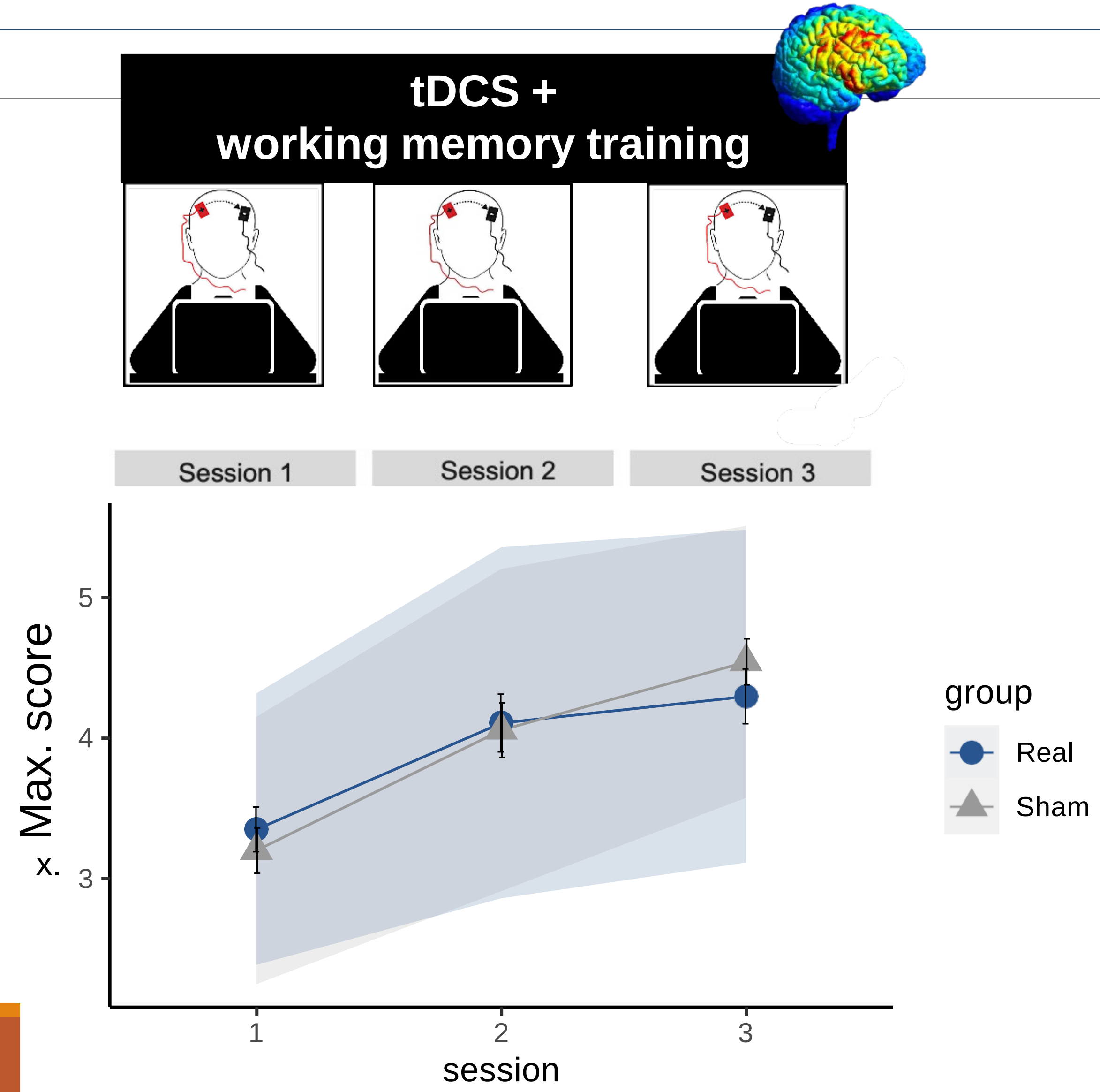
Brain Research
and Innovation Centre



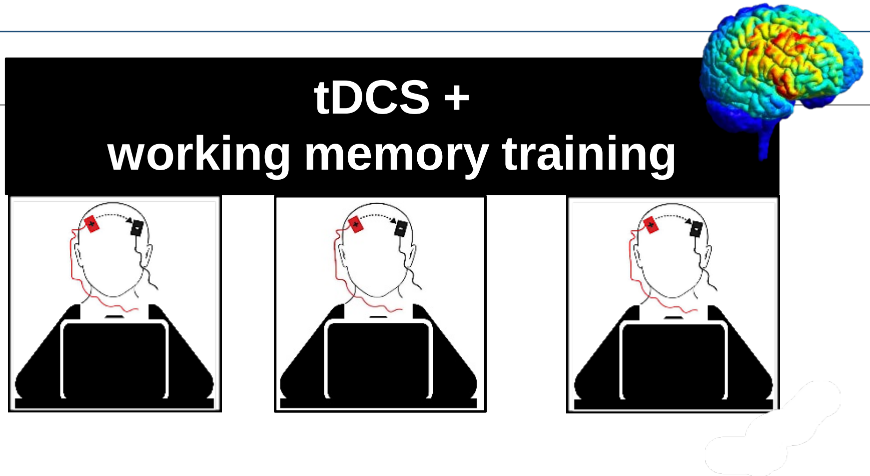
Study results

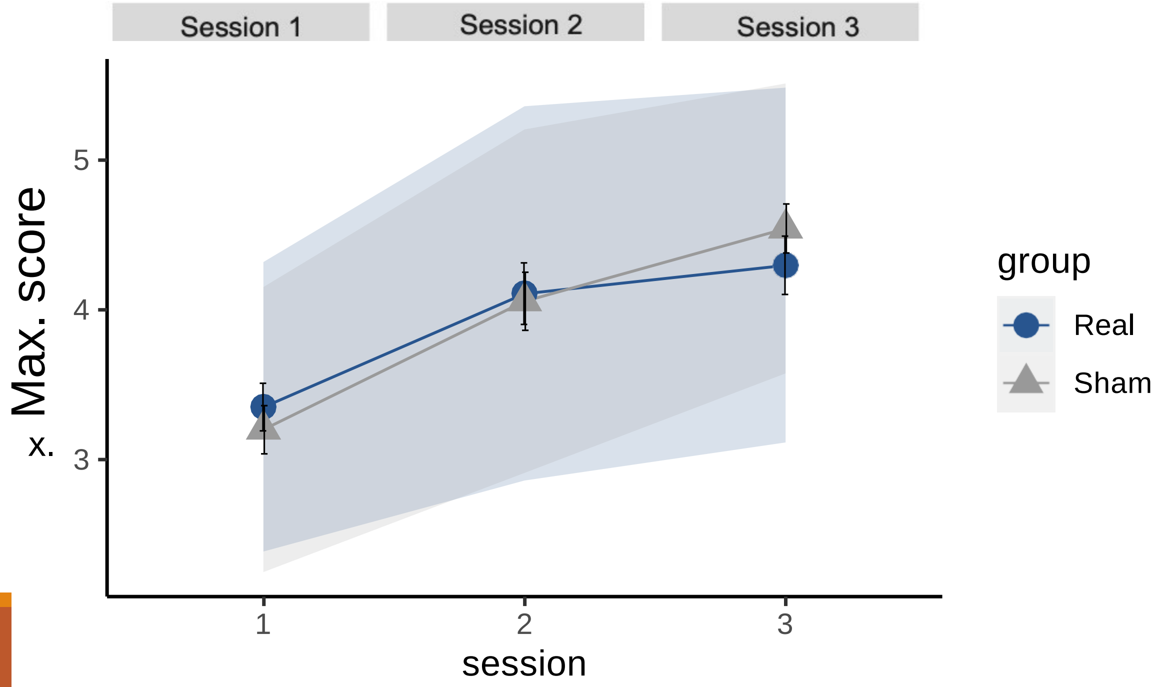


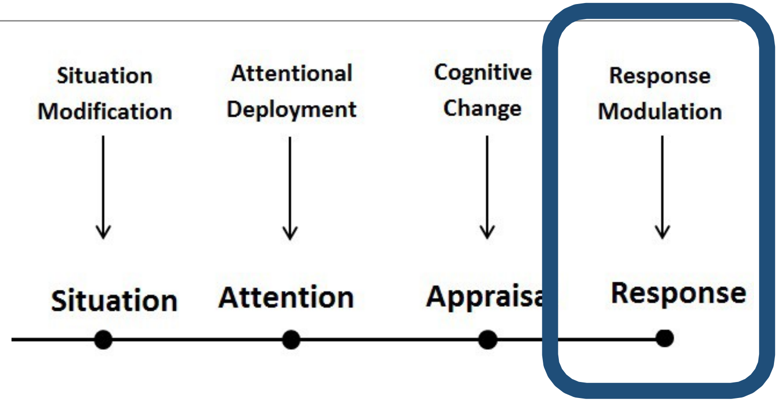
Study results

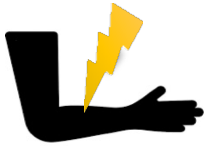


Study results









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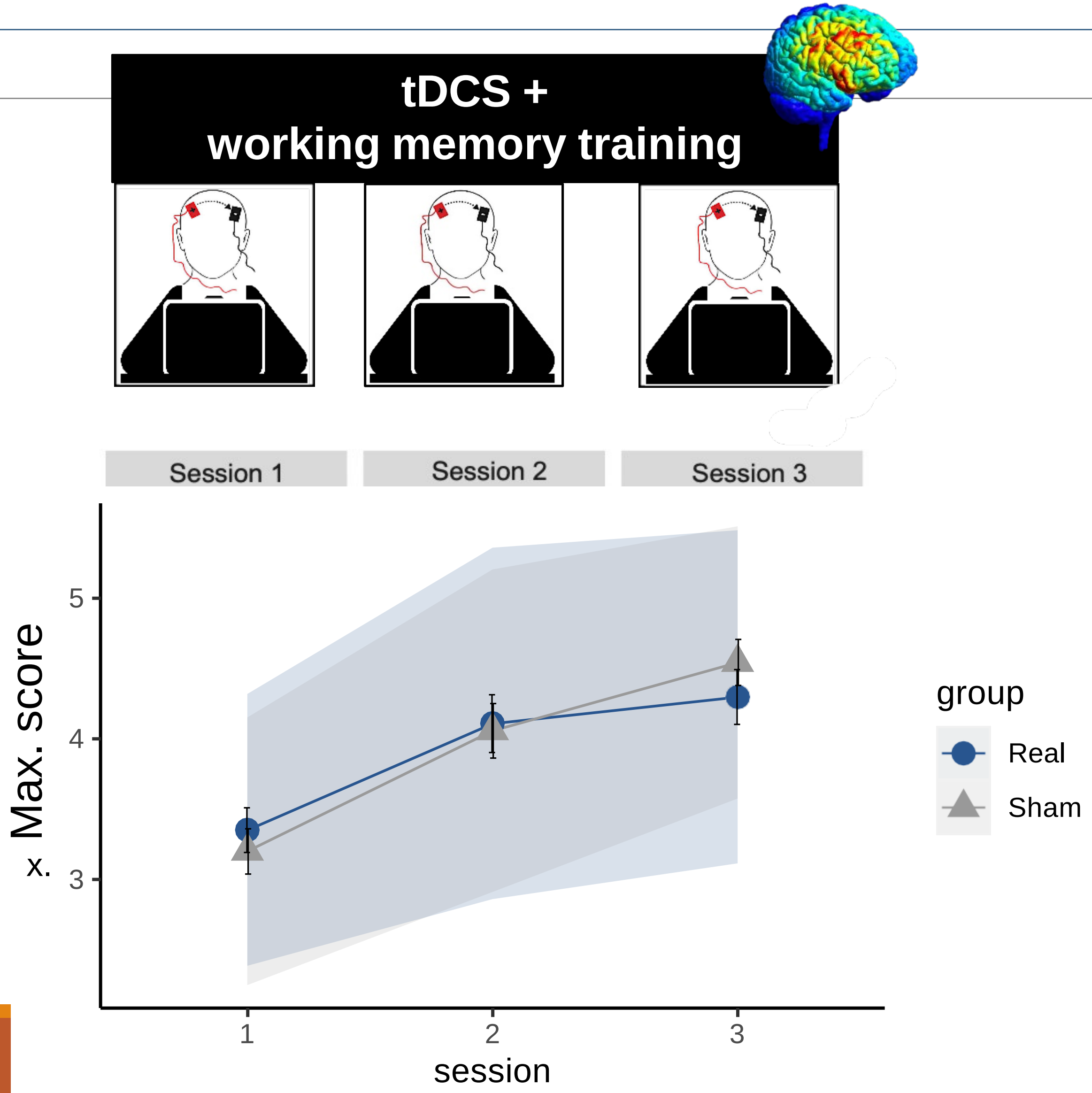

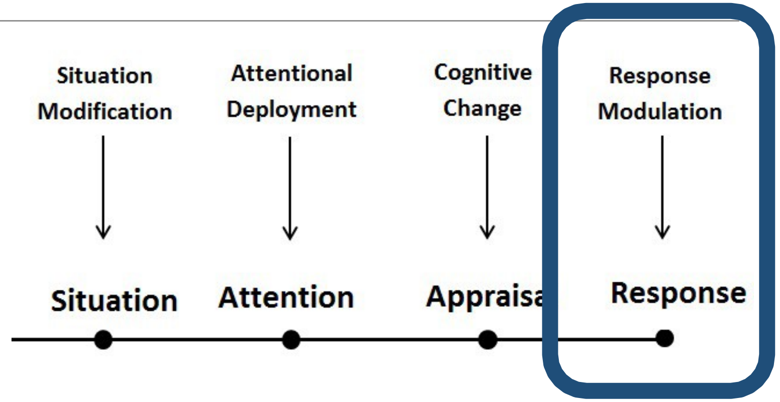

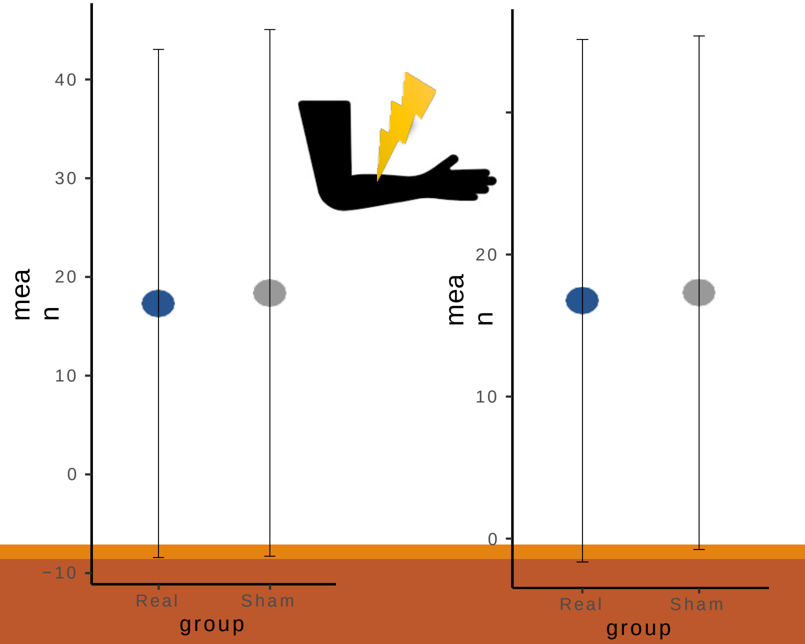

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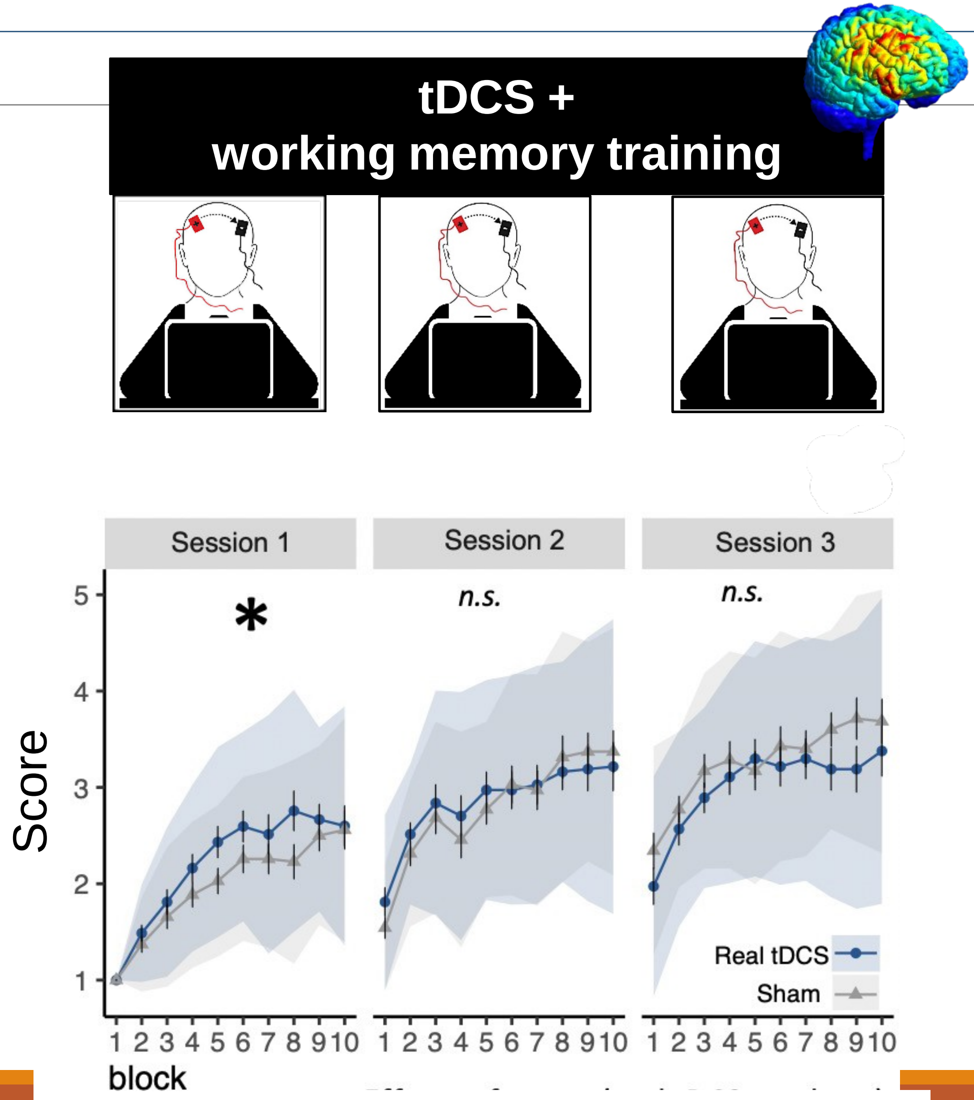

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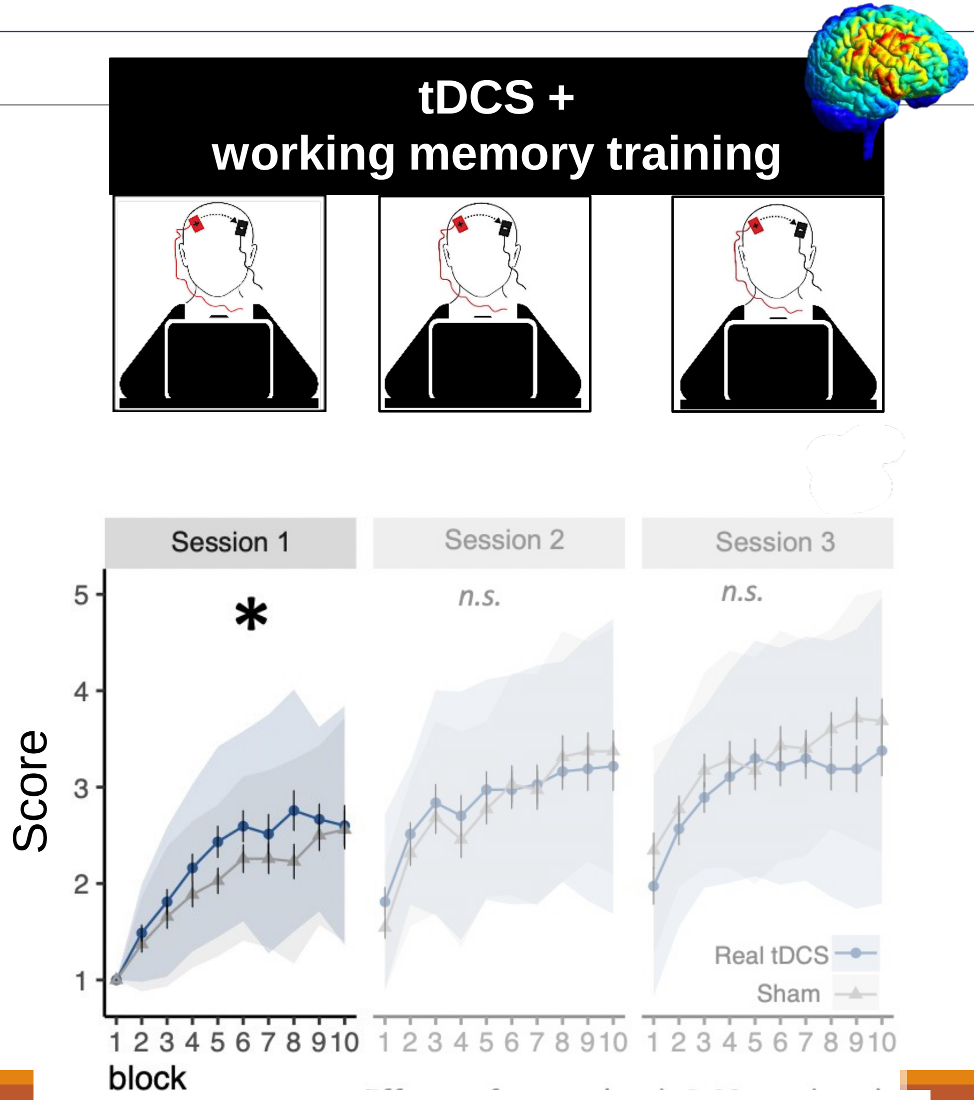

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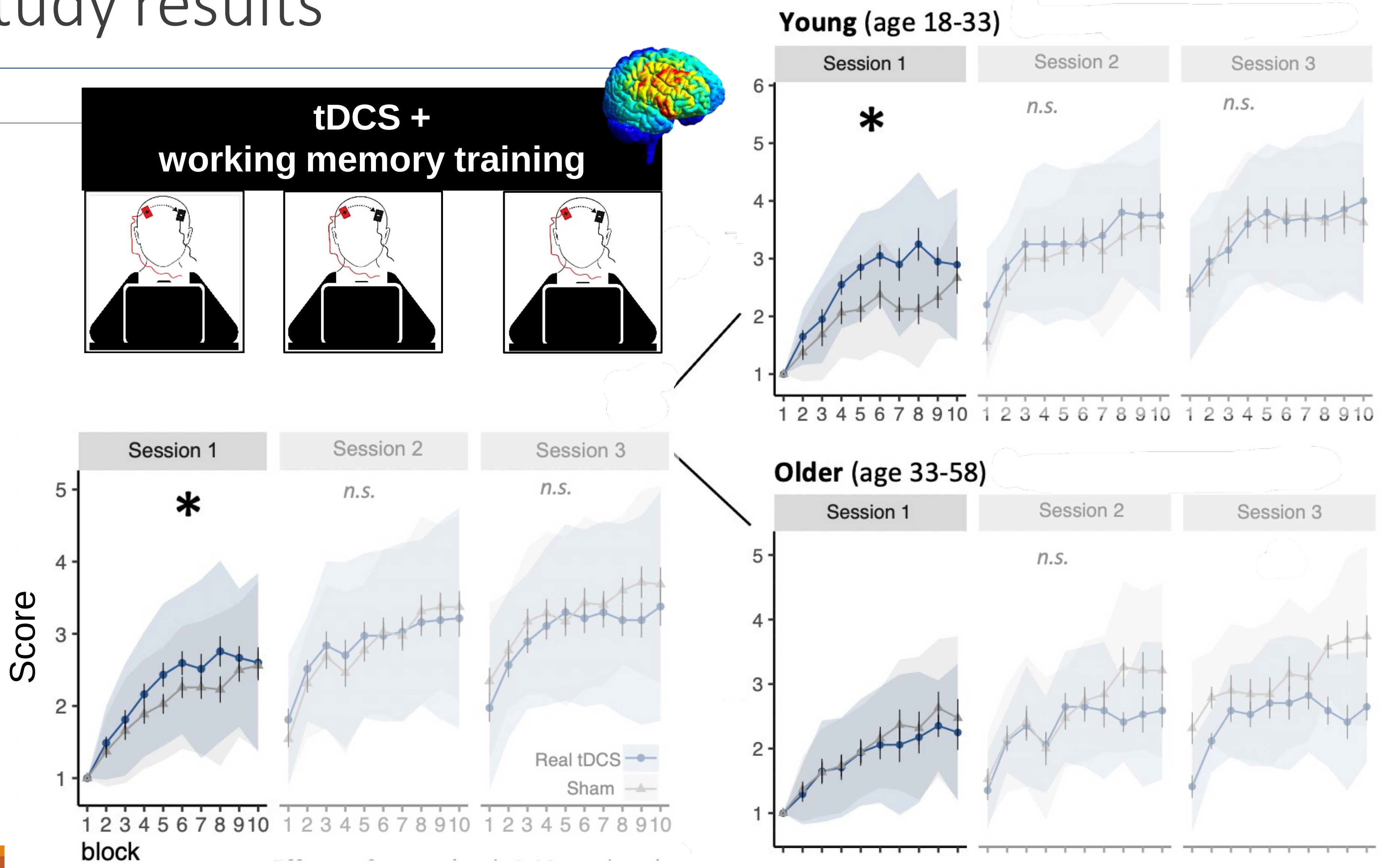
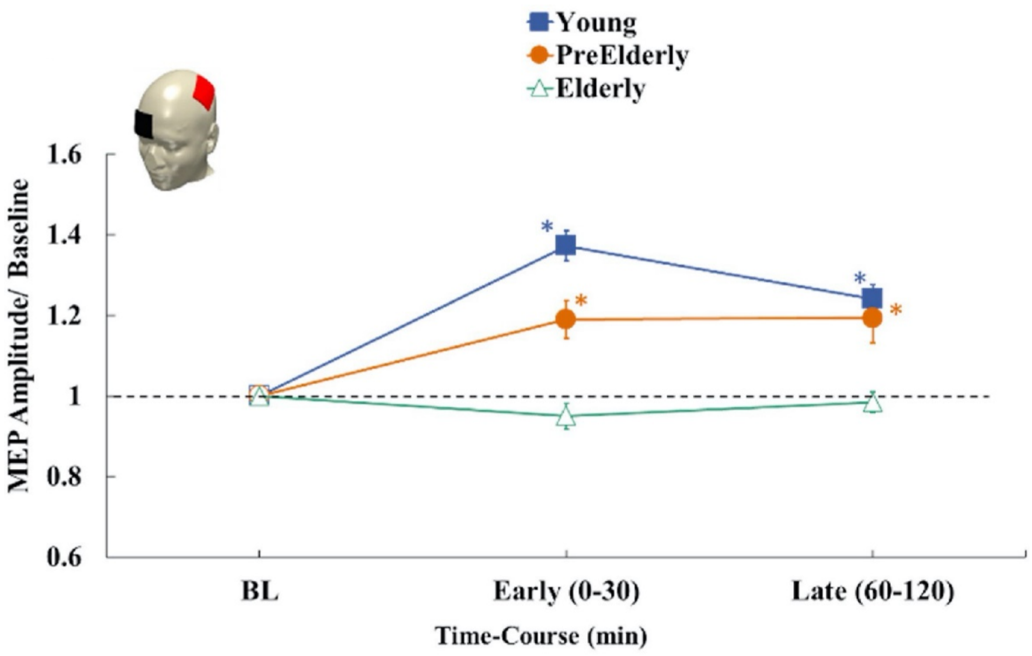
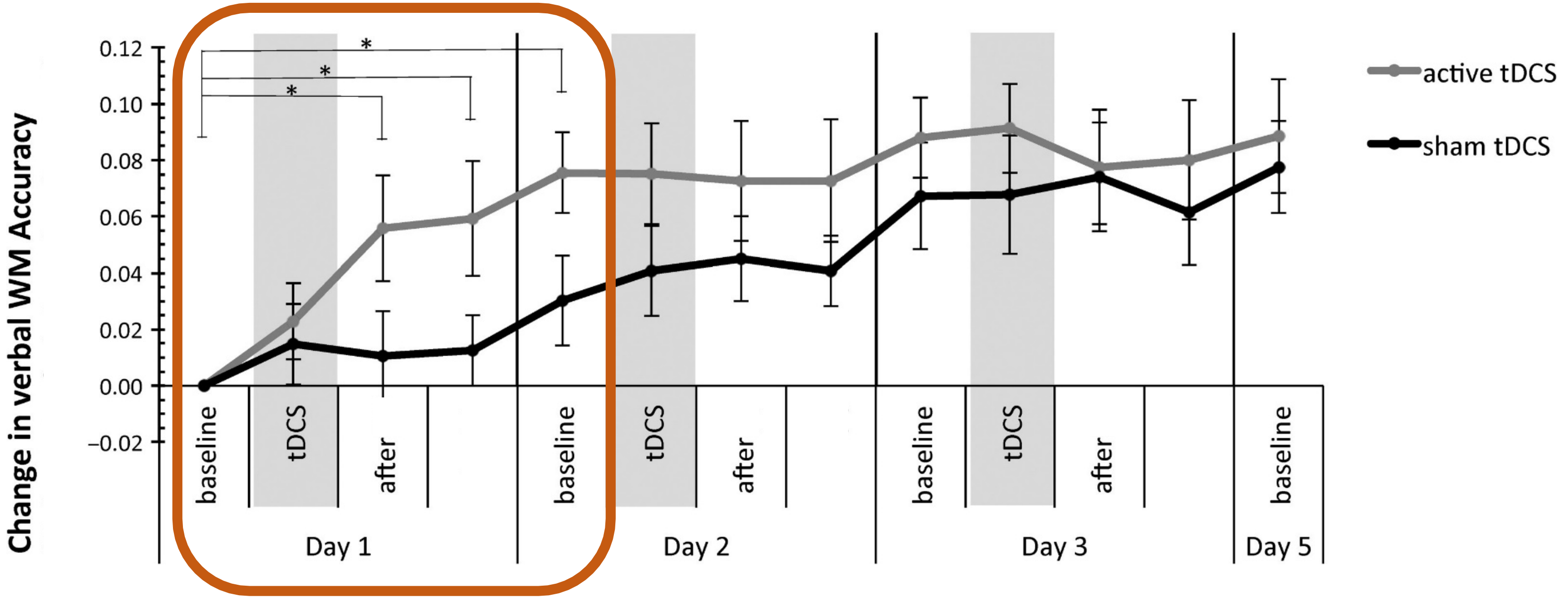


Discussion: age



Ghasemian-Shirvan et al. 2020

Discussion: early stage effect



Talsma et al. 2017

Conclusion

Brain Research and Innovation Centre

Is it useful to stimulate your brain? (with tDCS)

Conclusion

Is it useful to stimulate your brain? (with tDCS)

- Promising aspects
- Not yet ready
- Encouraging research avenues

Conclusion

Is it useful to stimulate your brain? (with tDCS)

- Promising aspects
  - Not yet ready
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Special thanks to:

Ministry of Defence (NL)
Brain Research and Innovation Centre
Dr. Elbert Geuze

Utrecht University
Prof. Dr. Dennis Schutter

All participants

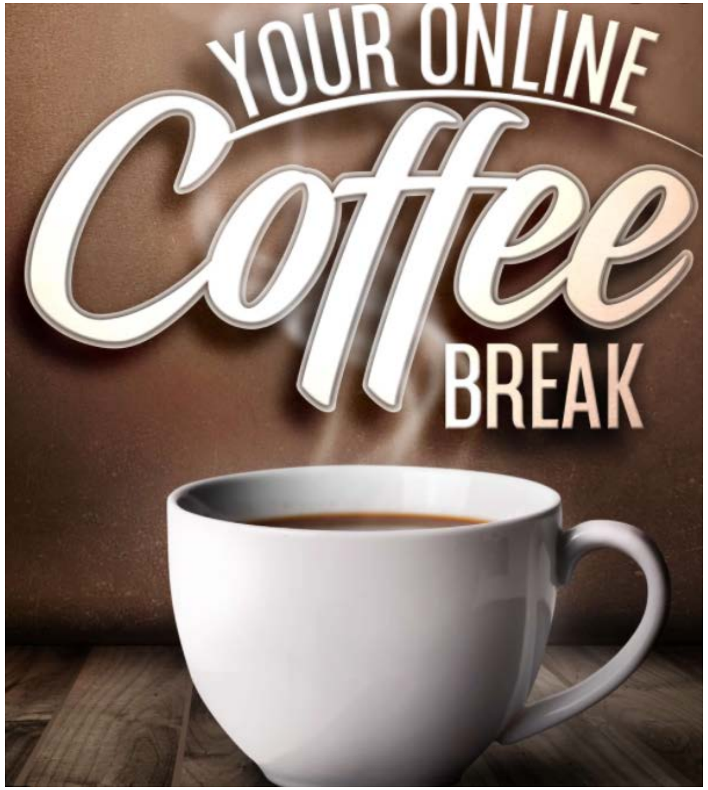
Joint Support Command
Ministry of Defence

UMC Utrecht

Utrecht University

6 Coffee Break

SEE YOU IN 20 MINUTES



Application of Novel Techniques to Enhance Cognitive Performance

Gorana Pobric & Johan Hulleman
The University of Manchester

HFM-334 Symposium Rome

11.10.2021.

Why Transcranial Electrical Stimulation (tES)?

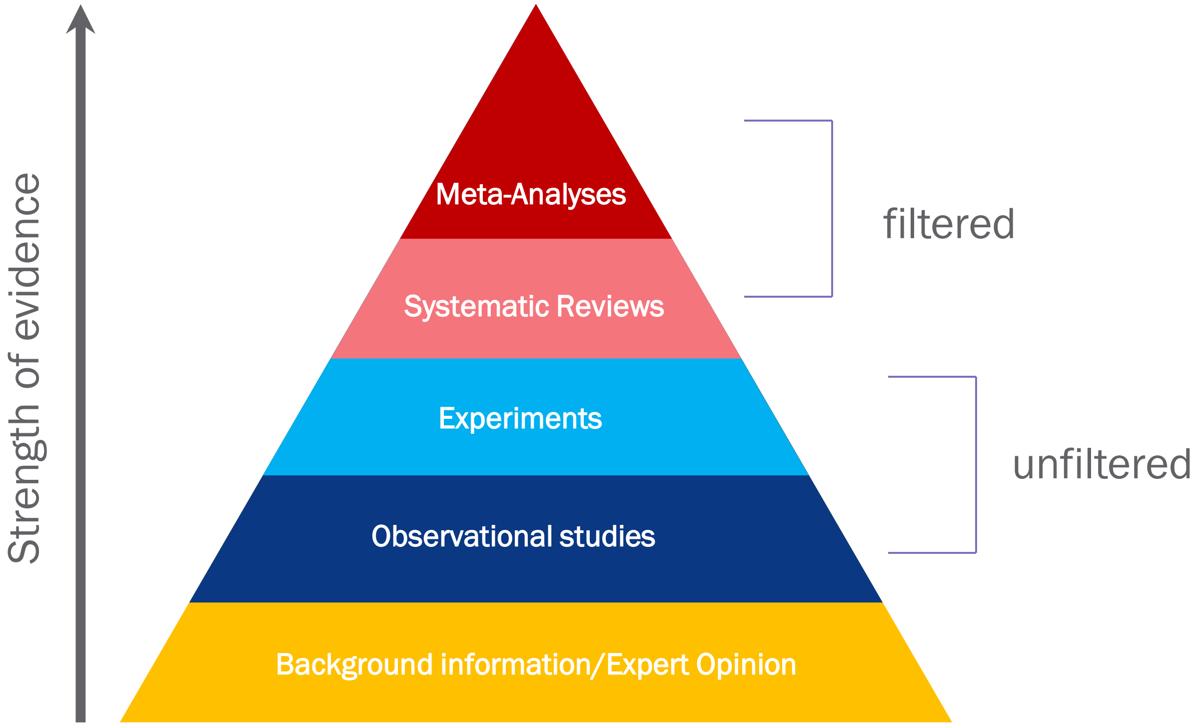
- Brain stimulation technologies, such as tES, demonstrate the potential to enhance both cognitive and physical performance.

- However, there are inconsistencies in evidence supporting their utility; stemming from methodological variation and a lack of standardised practices in this area.

Human Social Science Research Capability

Technical approach

Meta-analysis is a *statistical method* that creates a robust estimate of effectiveness by summarising data from multiple sources and helps to plan research and frame guidelines



Strengths
- objective estimate of intervention
- prescribed protocol
- systematic and documented in great detail

Weaknesses
- Time consuming and arduous
- Mixing high and low quality studies
- Mixing studies that are too different

Technical approach

Gap Analysis

Aims

- Identify perceptual and cognitive domains investigated by tES in healthy participants that could have implications for D&S applications

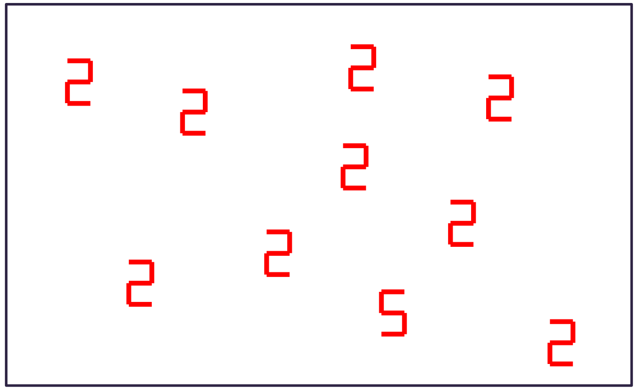
- Select the most promising domains for in-depth meta-analysis

- Perform a meta-analysis for the selected domains, focusing on parameters that could yield the most successful results in terms of efficacy and effectiveness of tES application in environments relevant to D&S

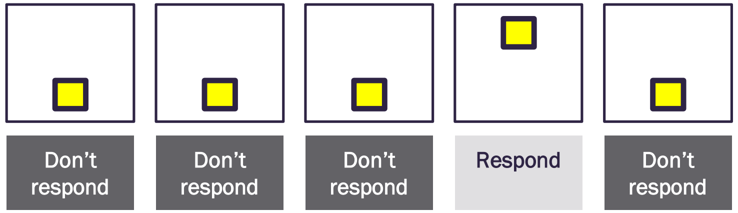
Cognitive Domains

Detailed analyses

Visual search

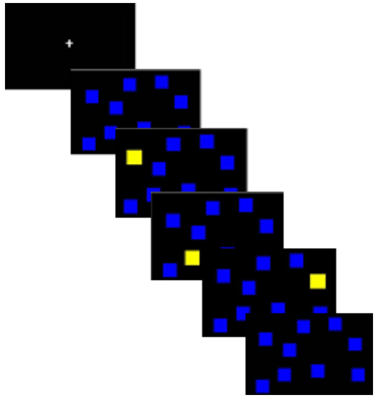


Vigilance/Sustained attention

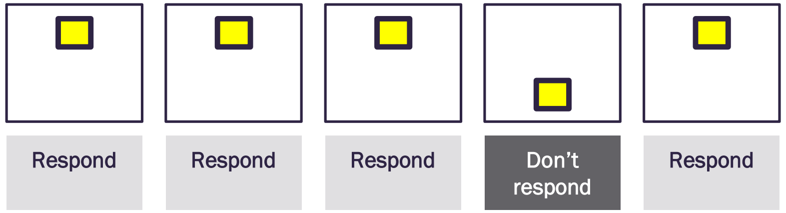


Subset analyses

Working memory



Inhibition/impulsivity



Human Social Science
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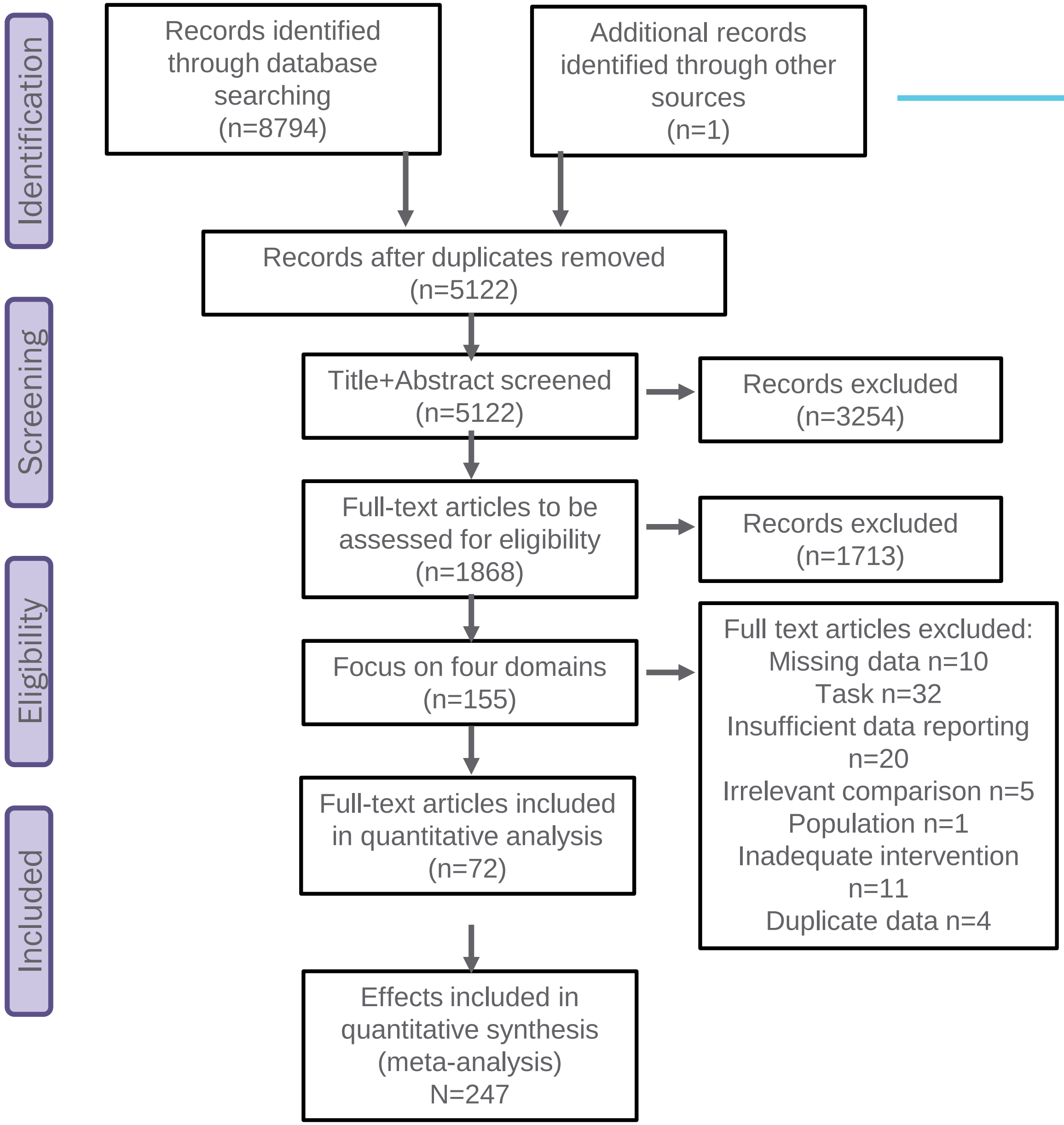
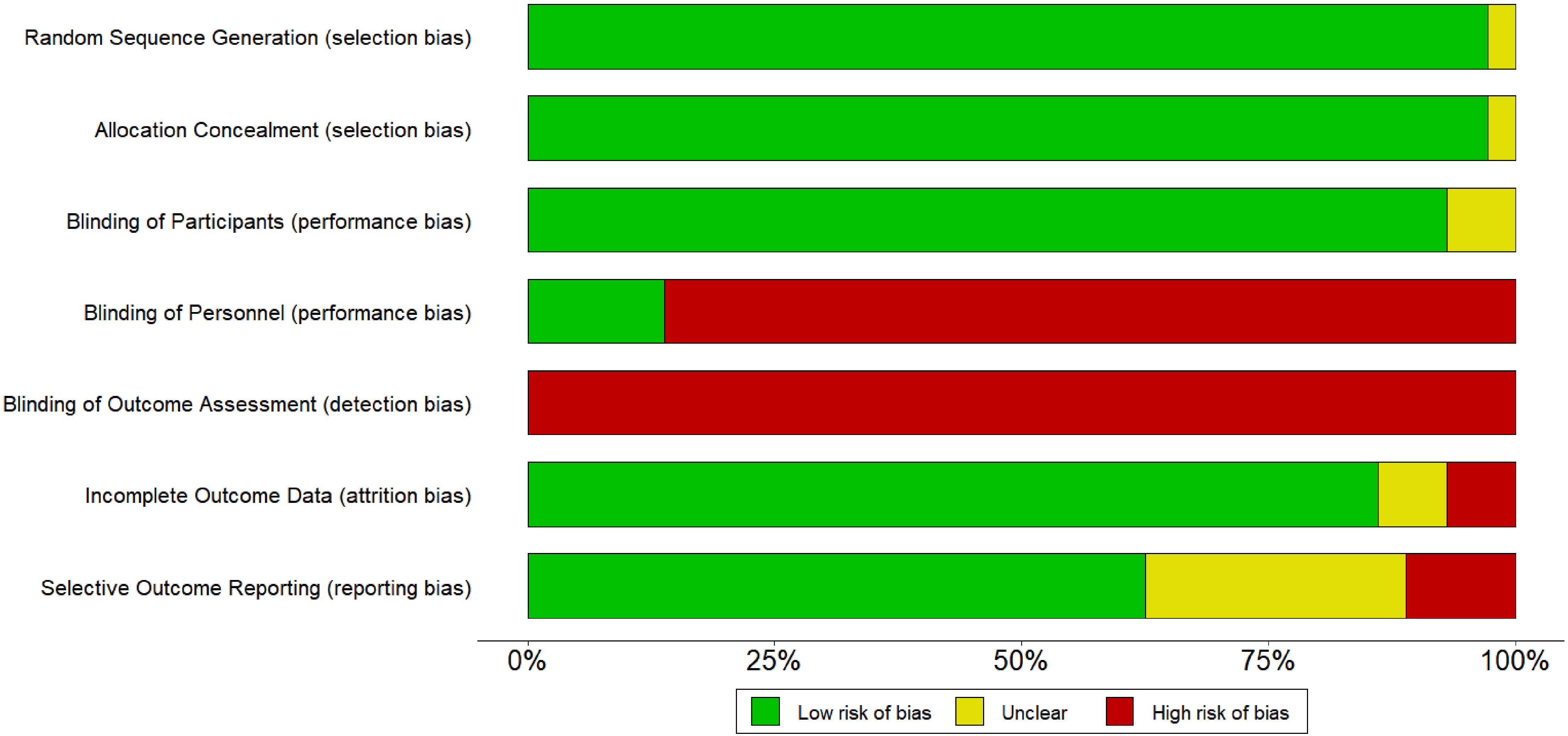
PRISMA Flowchart



Human Social Science Research Capability

Study Quality Assessment



Notes on Data Extraction

Overview of diversity of tasks used across the four domains

Domain	Task	n studies	N effects
Working Memory	n-back	4	16
	Digit span	2	4
	Cued Learning	1	4
Vigilance	Psychomotor Vigilance Task	4	6
	Sustained Attention to Response Task	2	8
	Mackworth Clock Task	3	4
	Other Tasks	21	49
Inhibition	Flanker	5	20
	Go/No Go	7	15
	Stop Signal Task	5	10
	Stroop	3	6
	Cognitive Reflection Test	2	6
	Iowa Gambling Task	2	3
	Other tasks	8	43
Visual Search	Conjunction Search	4	11
	Contextual Cueing	2	11
	Configuration Search	3	10
	Compound Search	3	5
	Search for a red pick-up truck	2	3
	Other tasks	6	15

Quantitative Approach and Analyses

A three-level meta-analytic model was used (Assink and Wibbelink, 2016)

- 1st level deals with the variance of all extracted effect sizes
- 2nd level deals with the variance between the effect sizes extracted from the same study
- 3rd level deals with the variances between studies

The three-level structure was defined by the inclusion of two random intercepts:

1. one for each individual effect size (the level at which the variance of the effect sizes from individual studies are distributed)
2. one for each individual study (the level at which the variance of individual studies is distributed)

Human Social Science
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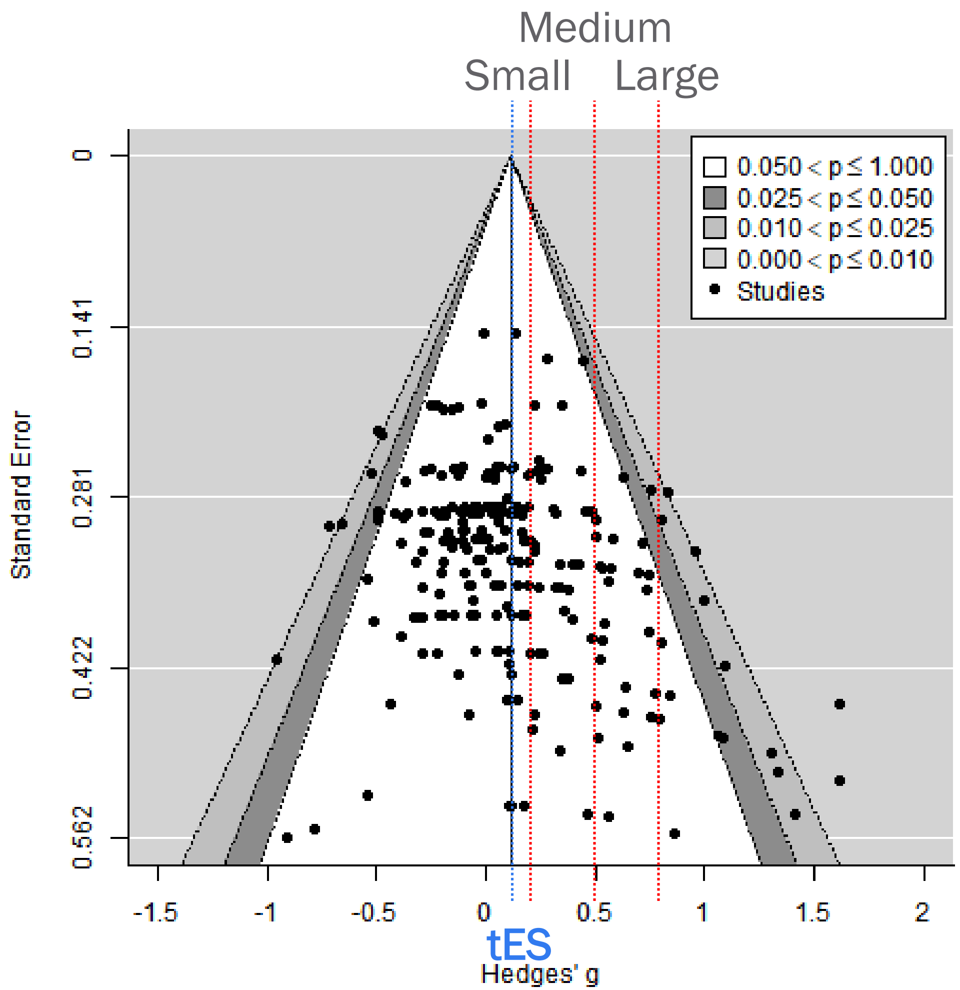
Overall effect of tES

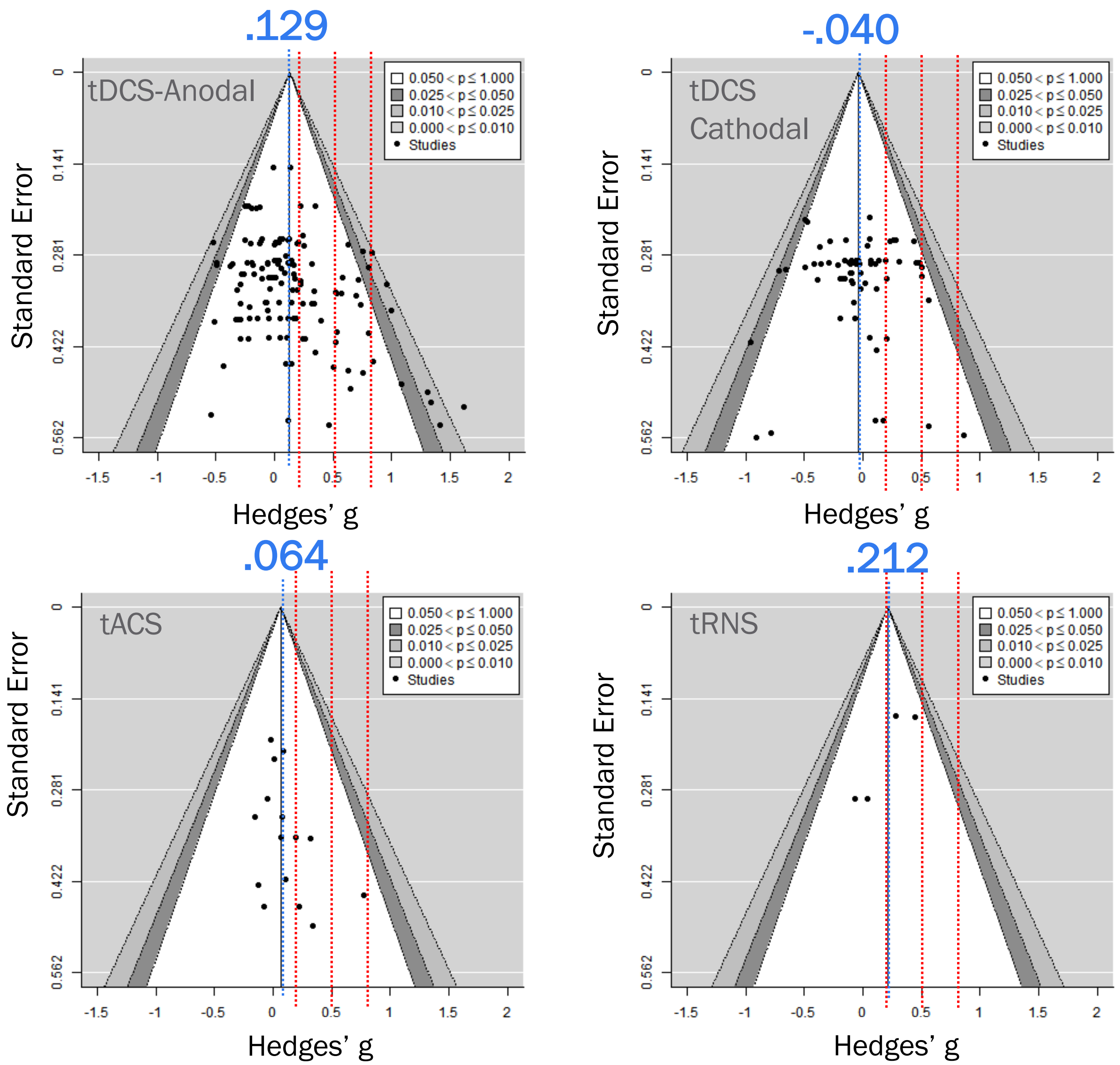
Funnel plots of the overall effect of tES protocols

Hedges' g=.112



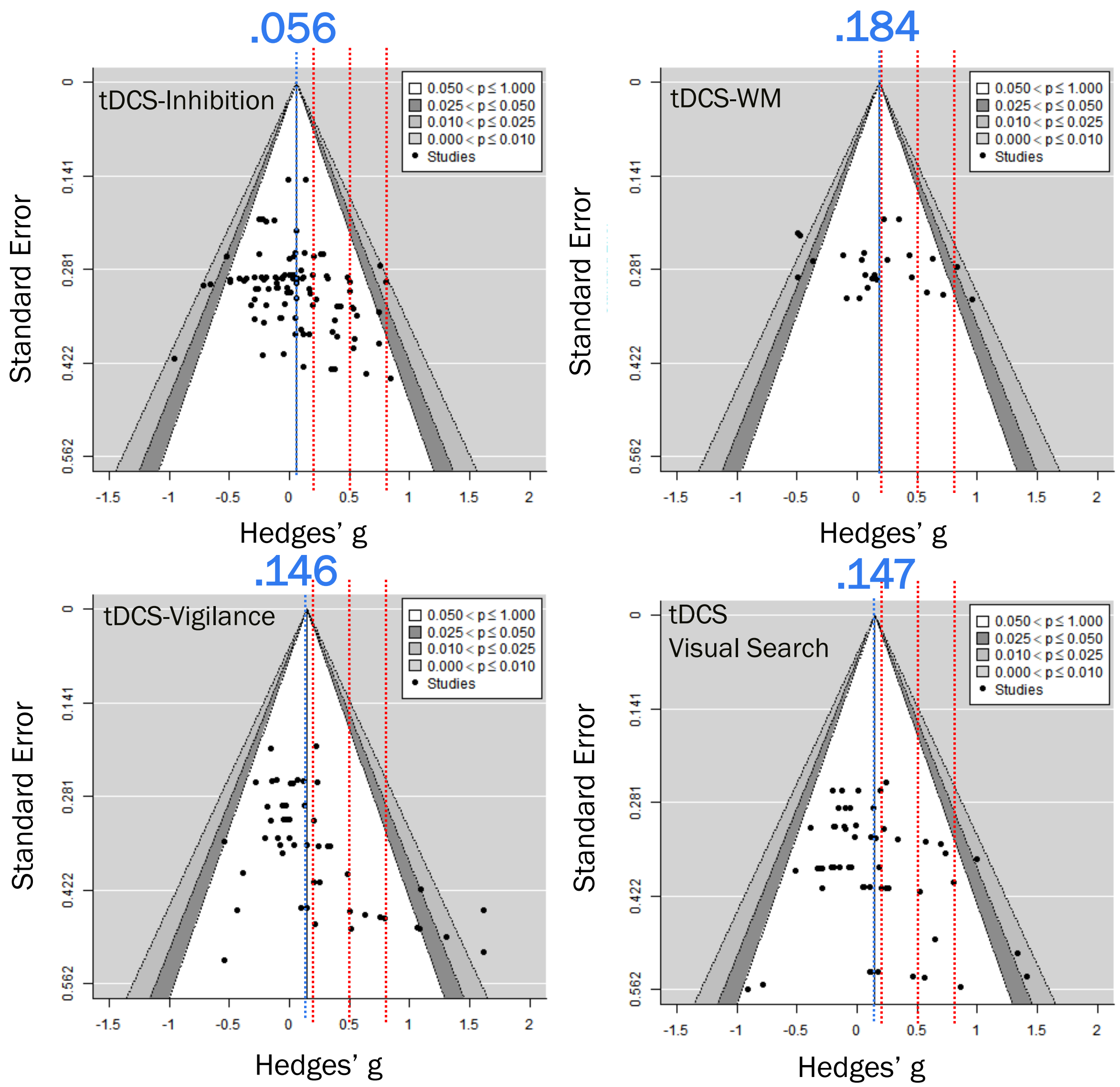
Human Social Science Research Capability

Effect of tES – stimulation paradigms

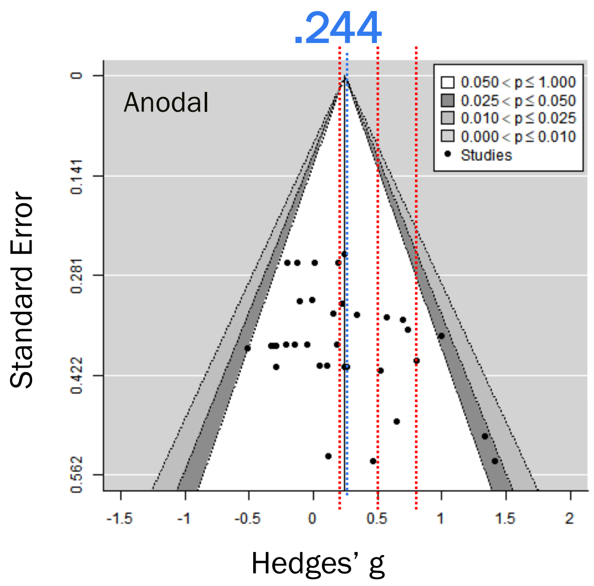


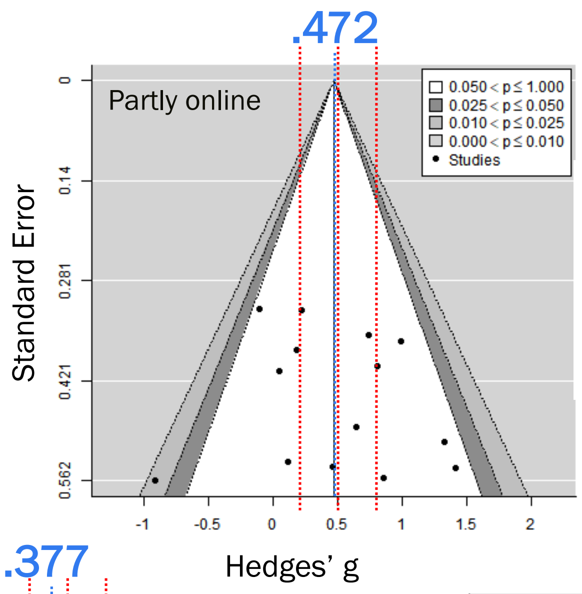
Human Social Science Research Capability

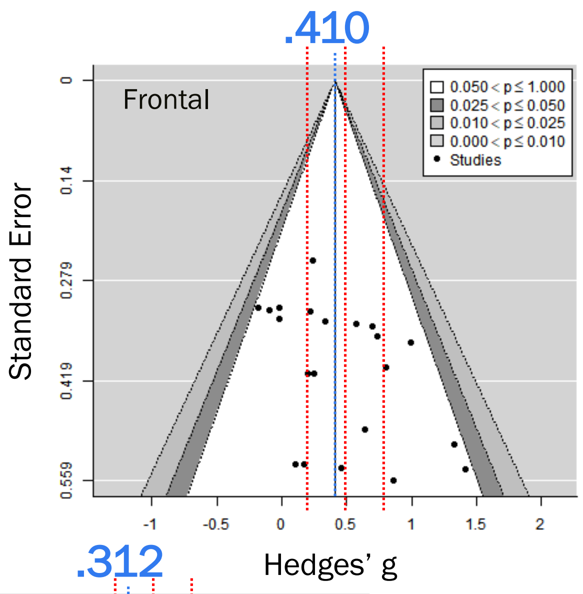
Overall results – tDCS by domain

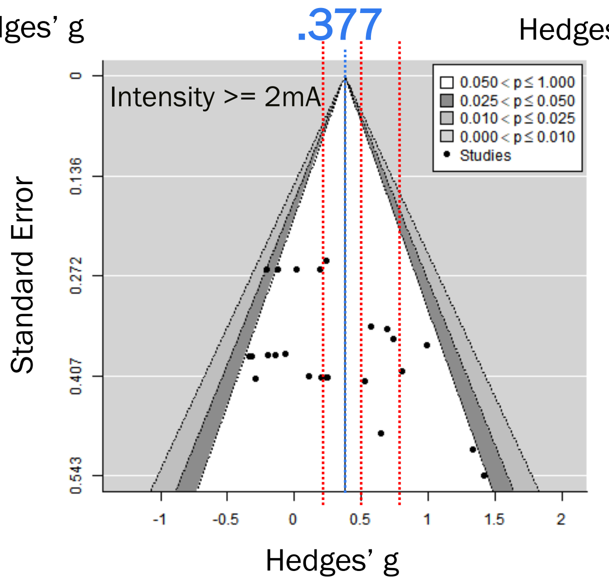


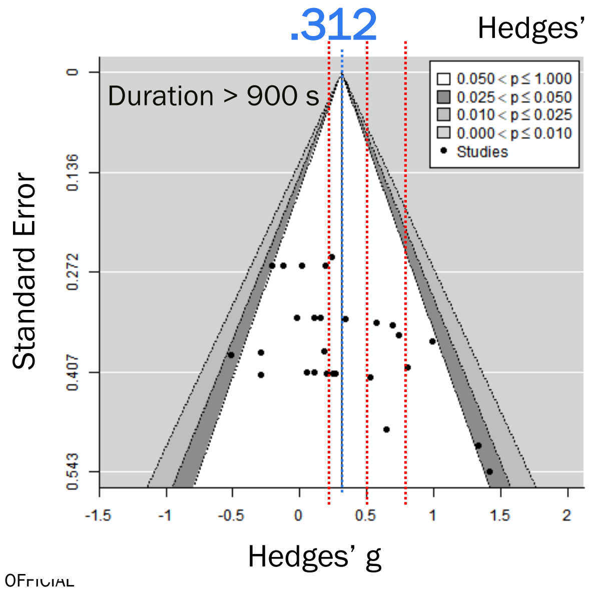
Results – Visual Search parameters











Findings – parameter selection

- Anodal stimulation
- Stimulation is partly online (stimulation ends before task ends)
- Stimulation of frontal brain regions, in particular lateral prefrontal cortex
- Stimulation intensity of 2 mA
- Stimulation duration that is longer than 900 seconds (1200 seconds)
- Between-subjects design
- Training paradigm (skill acquisition over a prolonged period of time, possibly over multiple sessions)

Human Social Science Research Capability

Limitations

- Heterogeneity in the studied domains is prevalent: there is variability within the study designs, study task and most importantly outcome measures

- Small (underpowered) sample sizes and inadequate control conditions were all too frequent

- Inter-individual variability in response to tES. anatomical , neurochemical concentrations, baseline individual differences in various cognitive domains have not been studied/addressed sufficiently

- Highly abstract tasks that have limited ecological validity

Human Social Science Research Capability

Conclusions

- tES does have the potential to enhance cognitive performance in healthy populations. However, the overall effect is rather small
- Significant larger effects were found when stimulation was applied while participants were engaged in a task, when lateral frontal parts of the brain were stimulated, and when a between-subject design was used
- A minority of the reviewed studies employed a training paradigm, these studies did find large effects, irrespective of domain
- More work is needed to understand whether lab-based effects transfer to real-life tasks that often draw upon several cognitive processes at once
- There is a need for the replication of studies, more systematicity in outcome reporting, and the necessity for large, well-powered studies prior to application of tES in D&S settings

Thank you

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Accelerating Image Analyst Training With Transdermal Vagal Nerve Stimulation (TVNS)

R. ANDY MCKINLEY / LEAD, COGNITIVE AND PHYSICAL PERFORMANCE

AIRMAN SYSTEMS DIRECTORATE 9/28/2021

Targeted Neuroplasticity for Training (TNT)

DARPA TNT – enhancing cognitive skill learning

Vision: enhancing cognitive skill learning in healthy adults by using noninvasive peripheral neurostimulation to promote synaptic plasticity in the brain

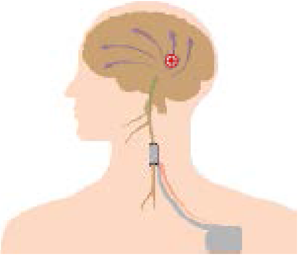
Cognitive Training Protocols

© US Army

Engage task-specific brain regions

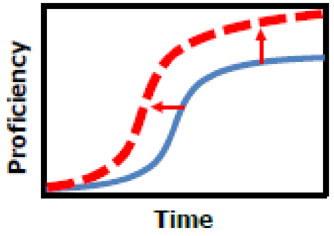
+

Peripheral Nerve Stimulation



© Fotosearch.com

Engage neuromodulatory circuitry

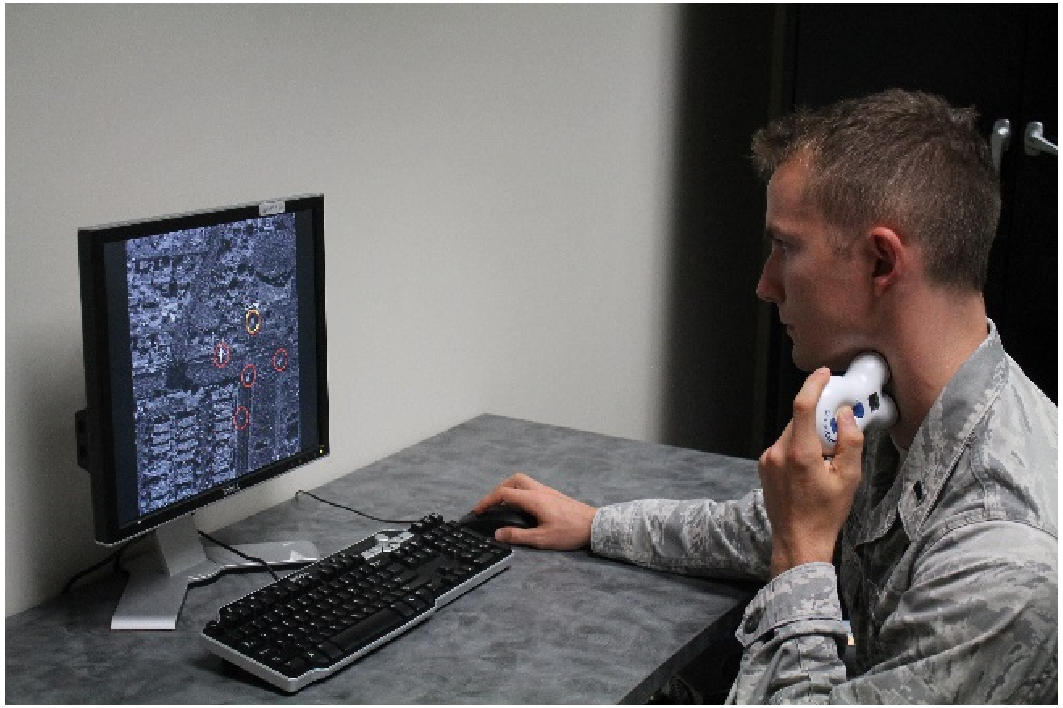


Result:
Train personnel **faster** & with **superior** cognitive abilities

Approved for Public Release, Distribution Unlimited

Background

- Vagus stimulation shown to alter locus coeruleus (LC) activity
  - LC modulates attention, wakefulness, arousal, and involved in learning
    - Shown to enhance memory retention
- gammaCore device – Non-invasive method to stimulate vagus nerve
  - FDA approved for cluster headaches
  - Only requires 2 minutes of stimulation



Learning through Electrical Augmentation of Plasticity

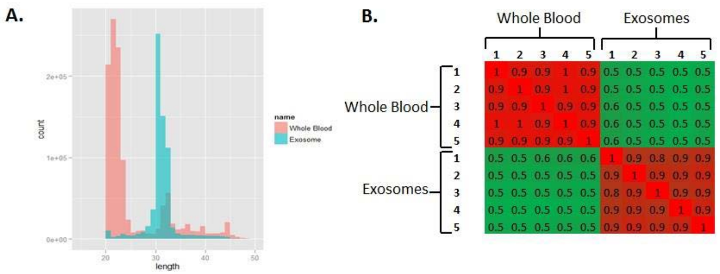
SAR imagery training & testing

Two tasks:
1) target search
2) change detection

Measures:
- Performance
- Learning rate
- Retention
- Eye metrics

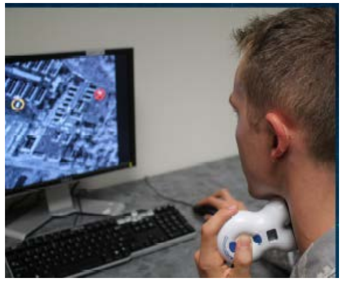

Courtesy of Lindsey McIntire

Goal: Elucidate mechanisms & optimize tVNS response through biomarker profiling



- Epigenomic signatures in blood
- SNP analysis
- Integrative bioinformatics

Stimulation: transdermal vagus nerve (tVNS)


Courtesy of Dr. Andy McKinley

gammaCore-R

>3,500 patients worldwide
0 serious adverse events

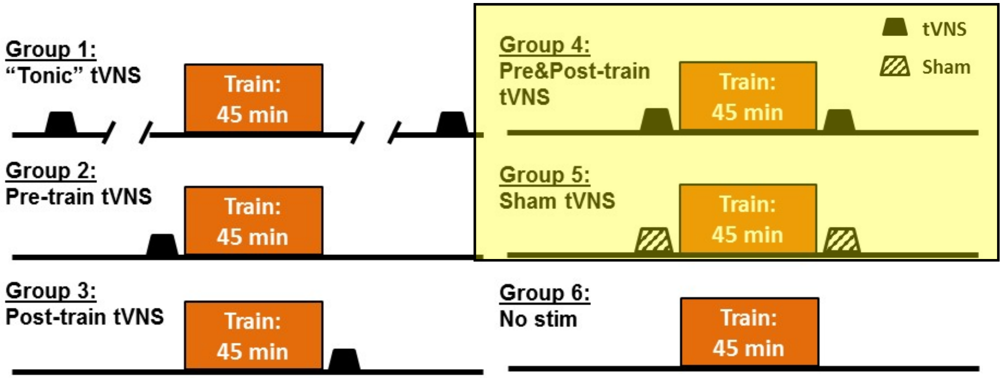
Validated via comparison with invasive VNS

Constant voltage output

Minimal off-target effects

Easy to self-administer

Parameter exploration: stimulus timing & frequency



Synthetic Aperture Radar (SAR) Training Task

Target Identification

Courtesy of Dr. Andy McKinley

Image Presentation

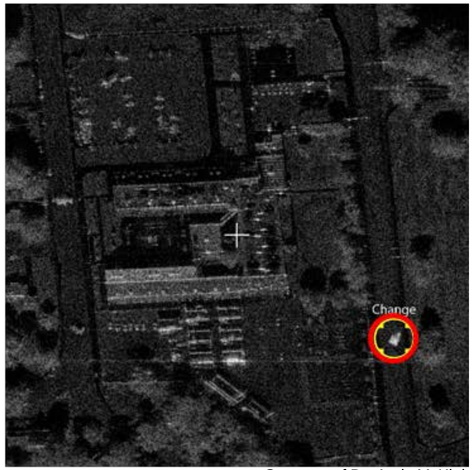
Courtesy of Dr. Andy McKinleyv

Find Target(s)

Target Change Detection

Courtesy of Dr. Andy McKinley

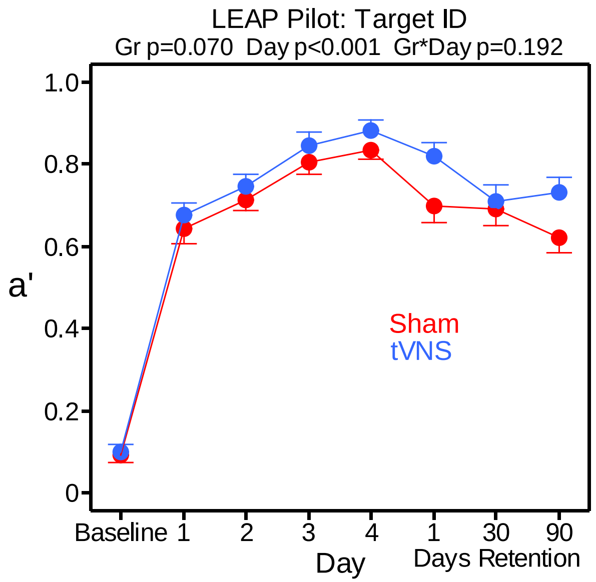
Change in Target

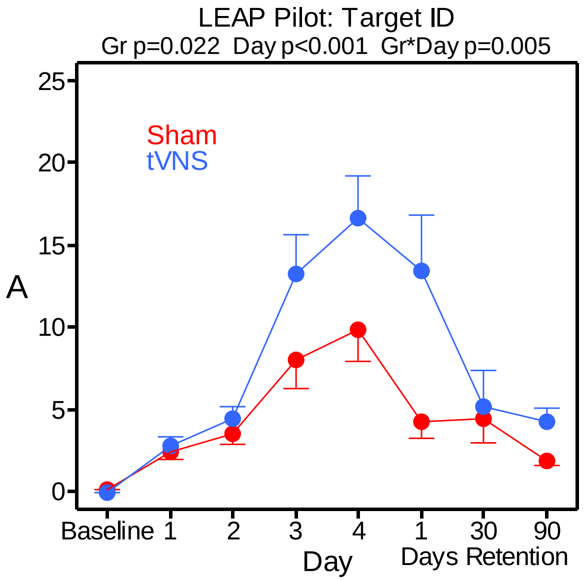


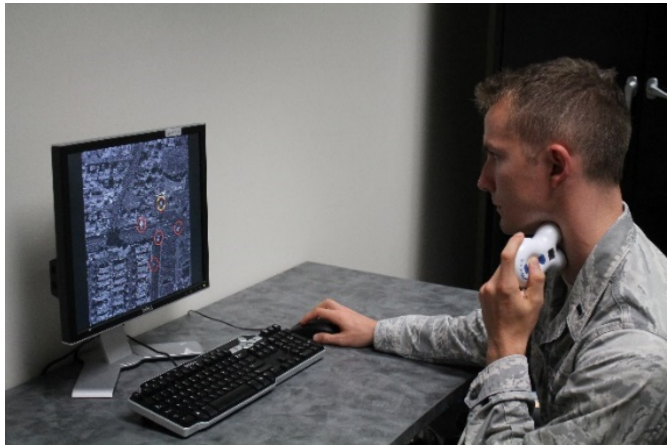
Courtesy of Dr. Andy McKinley

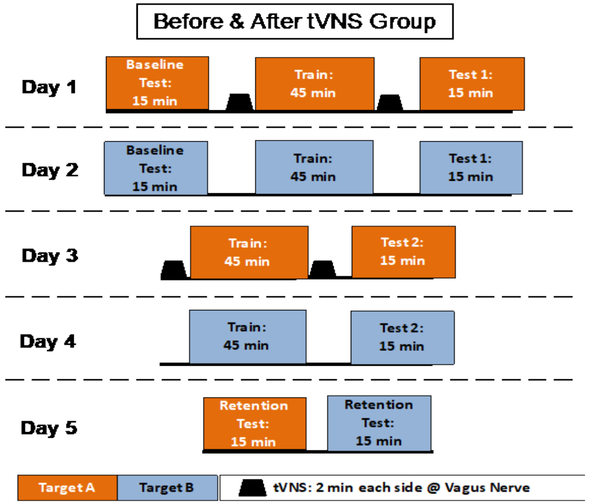
Find Change

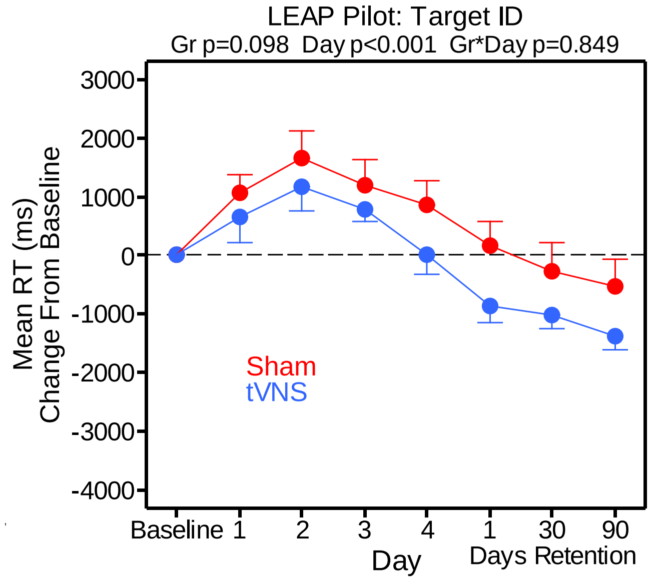
Results – Target Identification







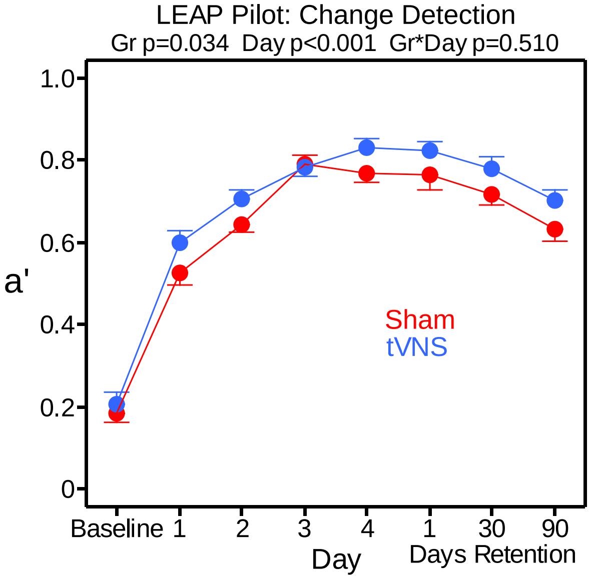


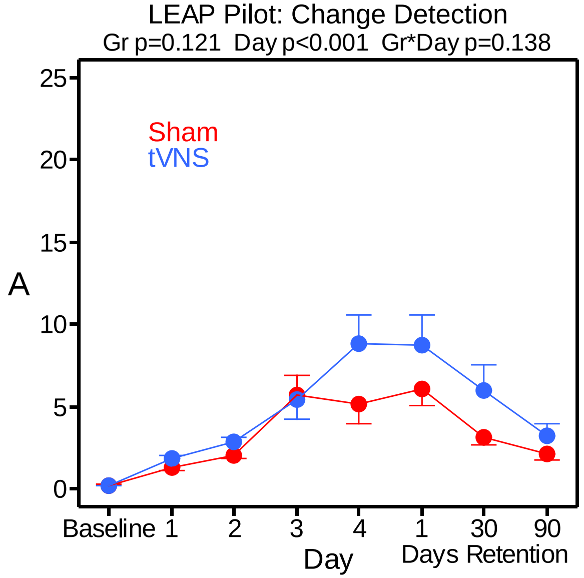


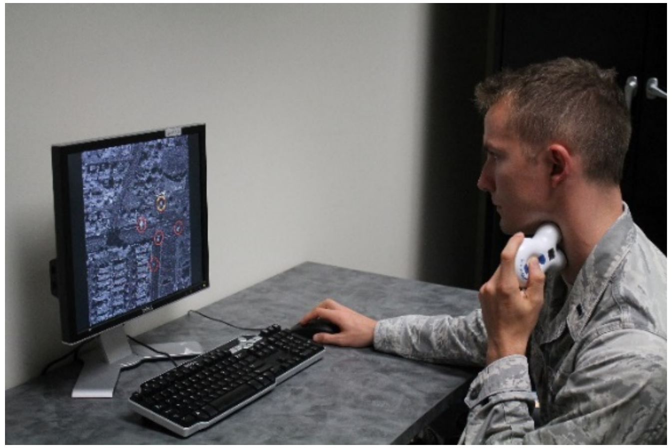
$$a' = hits/(hits + FAs + misses)$$

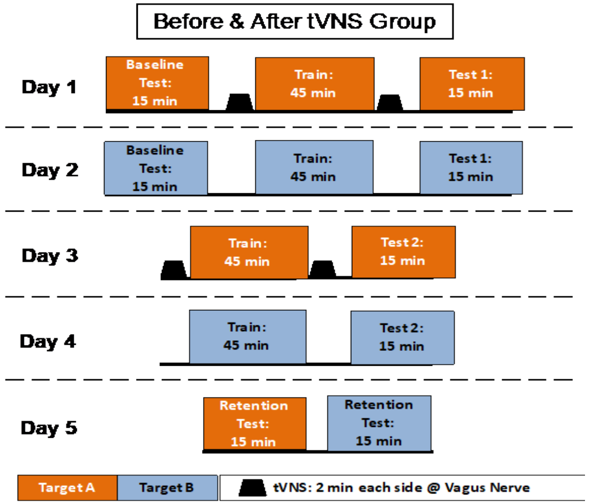
$$A = hits/(FAs + misses)$$

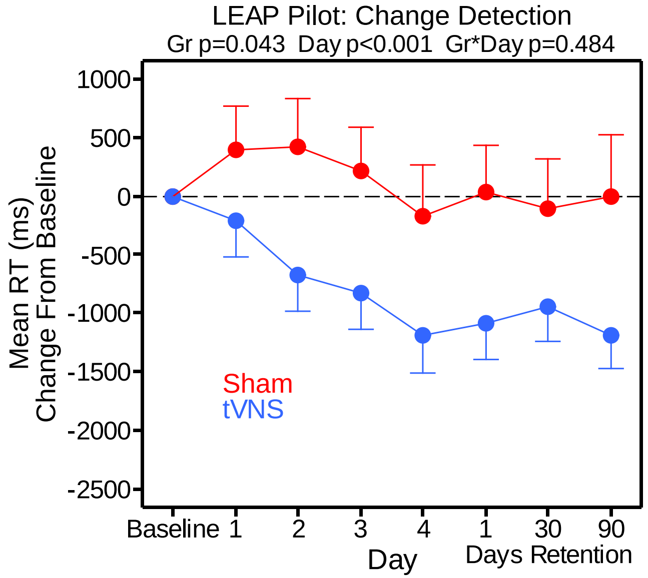
Results – Change Detection







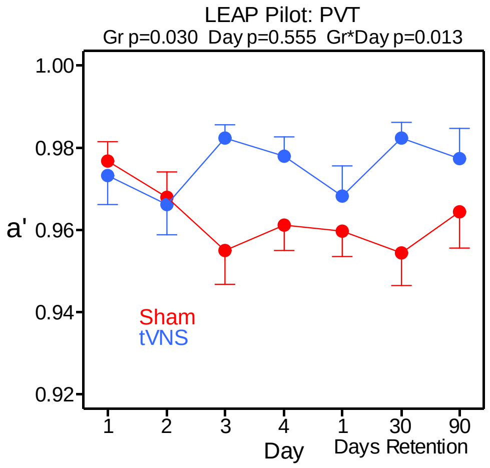


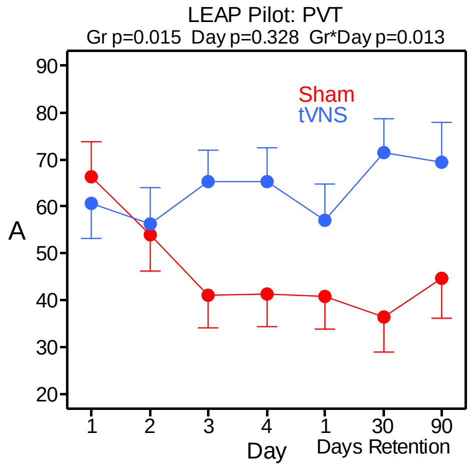


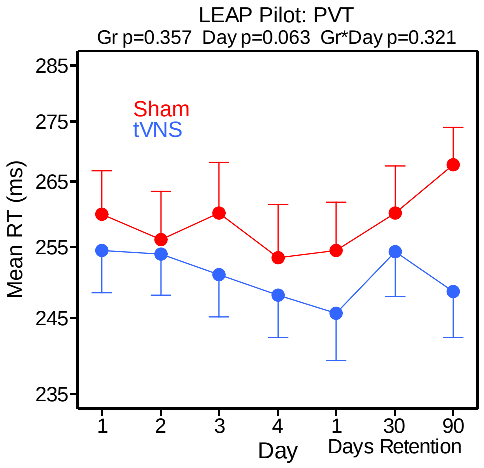
a' = hits/(hits + FAs + misses)

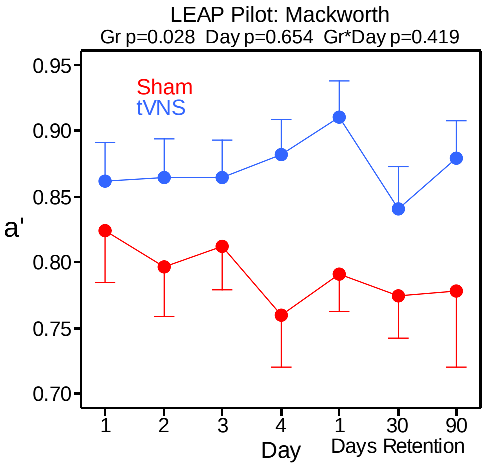
A = hits/(FAs + misses)

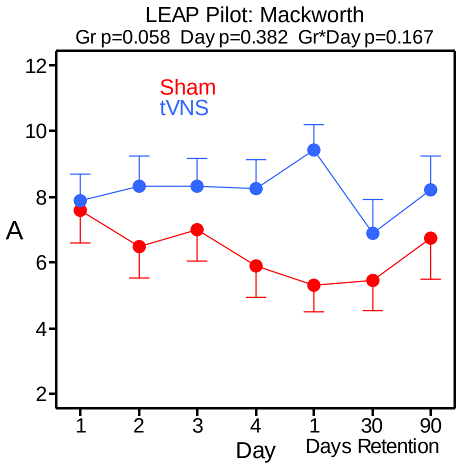
Results – Attention and Arousal

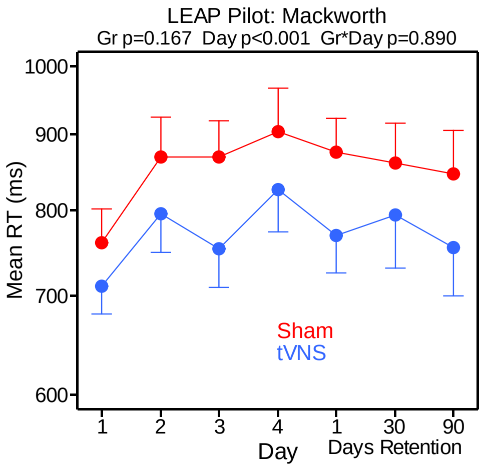


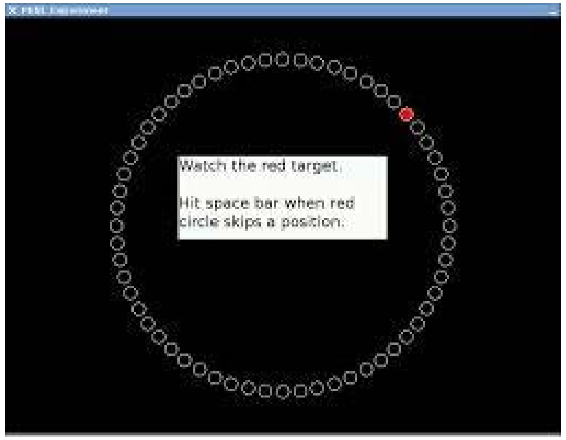












Discussion

- **Conclusions and impact of results:**

- Results suggest enhancement of Target Detection Accuracy for Active tVNS (~200% improvement from sham) during 24-hour retention test
  - Effect has largely diminished by the 30-day follow-up test
  - No significant effects on performance for tests occurring immediately following training, although data is trending that direction for tests following tVNS.
- Analyses revealed tVNS improved response time ~15-20% for both target identification and change detection
  - These improvements are retained 90 days post-stimulation
- Significant improvements in performance observed for off-target tasks
  - Improvements in errors/lapses/accuracy, but not response time in arousal test (PVT)
  - tVNS improved attention test accuracy metrics (Mackworth Clock), and data is trending in a manner that suggests a modest effect may be detected in additional tests with more data
    - Ceiling effect may be partly concealing tVNS effect, particularly in percent hits and accuracy measures.
- Little to no effect of tVNS on pupil diameter in main subject cohort
  - Data on a separate, more targeted study shows significant increases in pupil diameter with tVNS
  - Effects may be reduced in main cohort due to several possible factors including subjects may have amplitude too low, subject movement during stimulation, and influence of cognitive load from SAR tests.

Questions?

8

Session 2 –Enabling Technology Methods

Paper 8 - BCI Innovation at the Intersection of Restoration, Augmentation, and Intelligent Systems: Dr. Anne-Marie Brouwer

Paper 9 - Vagus Nerve Stimulation-Induced Cognitive Enhancement In Rats Is Associated With Enhanced Expression Of Brain-Derived Neurotrophic Factor In The Hippocampus: Dr. Candice Hatcher-Solis

Paper 10 - Using SocialXR to measure social cognitive performance to address isolation associated with deployment and post-traumatic life events: Dr. Christopher Stapleton

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

Mike Wolmetz
Clara Scholl

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Anne-Marie Brouwer, PhD
Judith Dijk

TNO

Brief History of TNO BCI/mental state monitoring Research

2008: Tactile p300 BCI ('active' BCI)

'passive' BCI/mental state monitoring out of the lab

Psychophysics

including (non-obtrusive) modalities besides brain measures

Brief History of JHU/APL BCI Research

Anthropomorphic Control

Beyond Anthropomorphic Control

Human–AI Partnership

Non-Invasive Brain Interfaces

A New Paradigm of Brain-Computer Interface (DARPA Colloquium, 2019)

Current Chronic Implant Research

Next-Generation Optical BCI

Outline

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

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 R&D to **augment** the performance of healthy individuals.

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

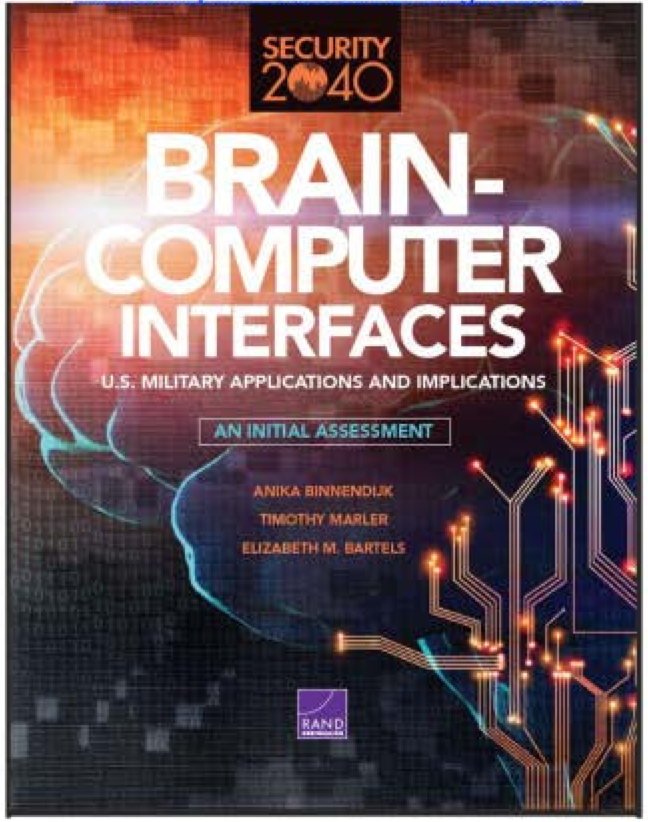
Objective

FIGURE 1
BCI Toolbox for National Security Game

2030 — 2040 — 2050

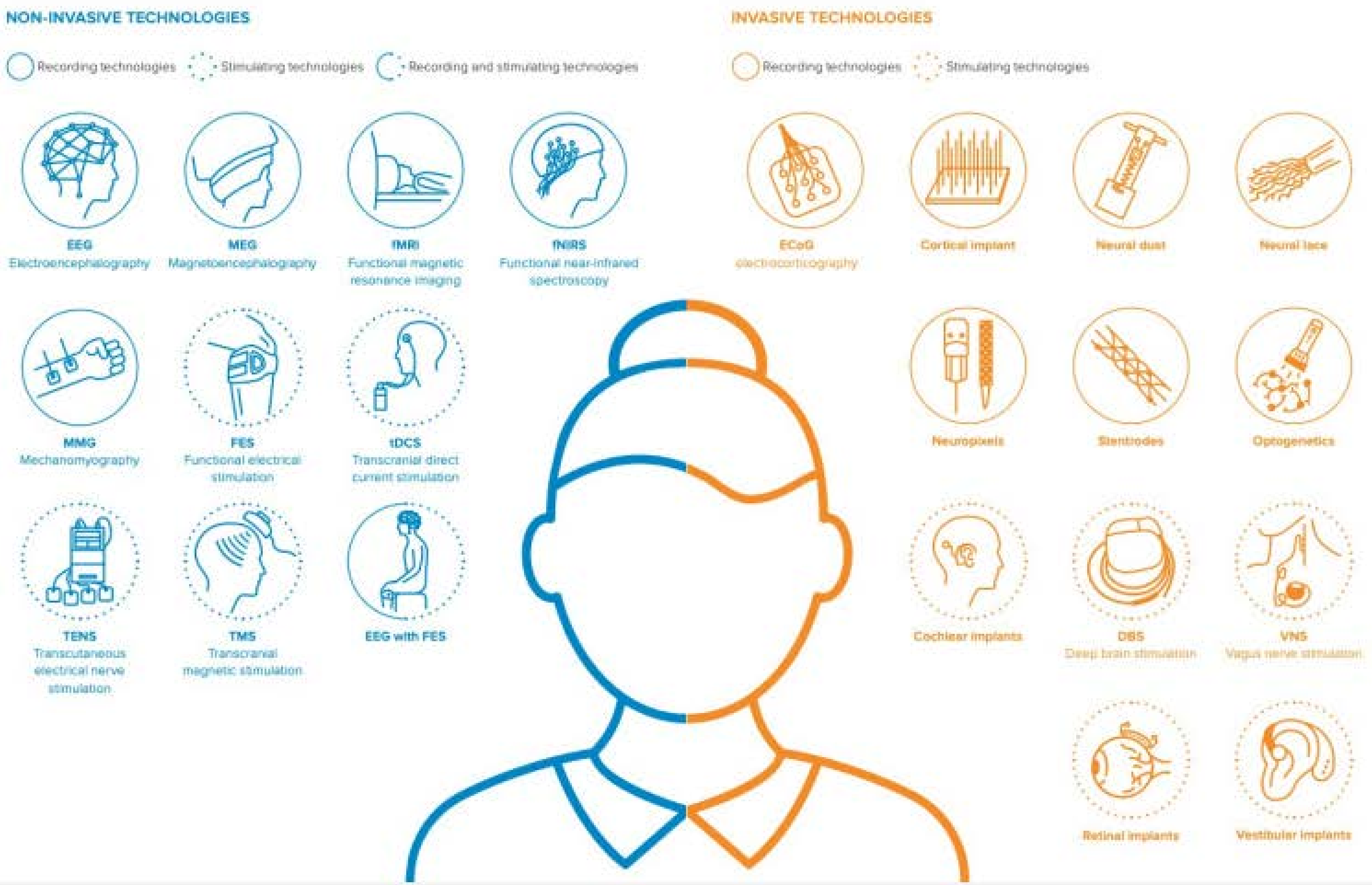
BCI tool	Near-term capabilities	Long-term capabilities
1) Human-machine decisionmaking	• Immediate transfer of operational risk • Faster decisions to deploy weapons • Shorter preparation cycle with faster feedback from occurrences in battlespace (collapse OODA loop) • Increased speed and accuracy of 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."

Invasive and non-invasive neurotechnologies



Active and passive BCI

Active and passive BCI

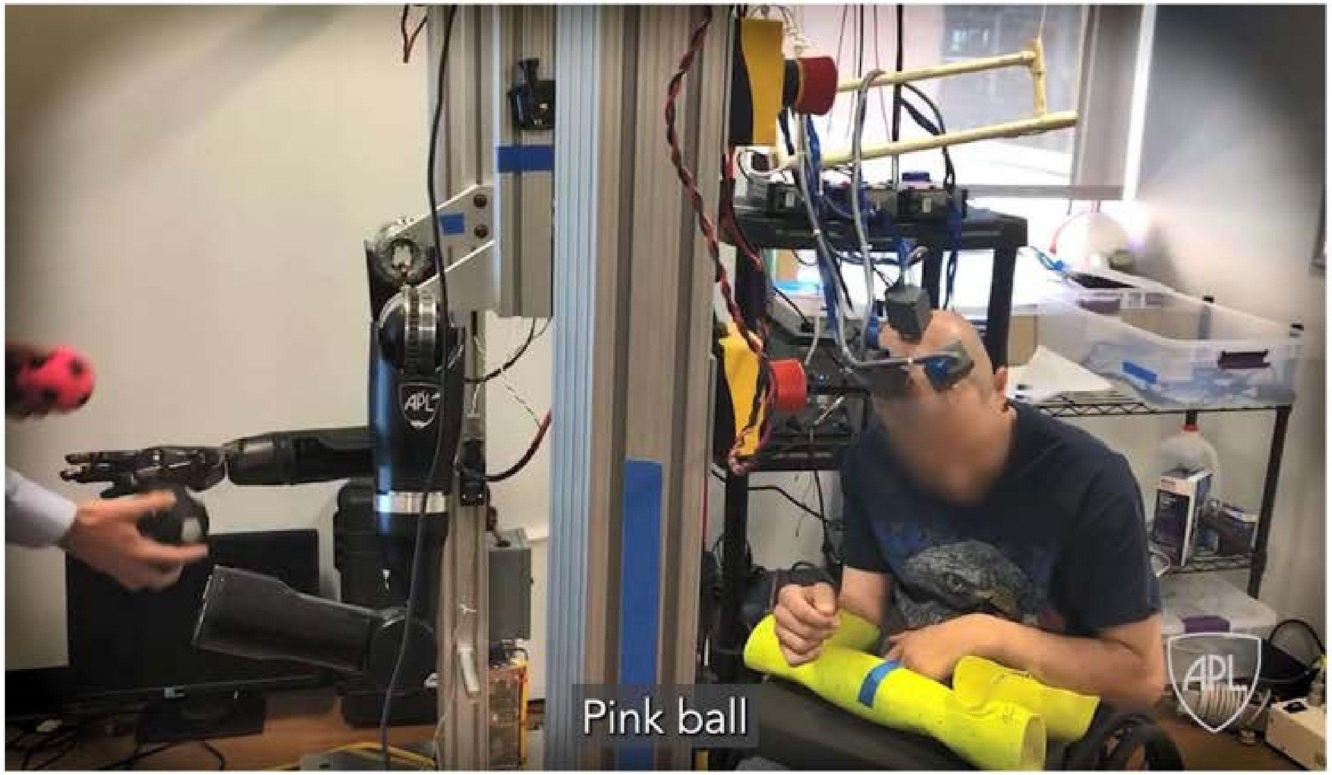


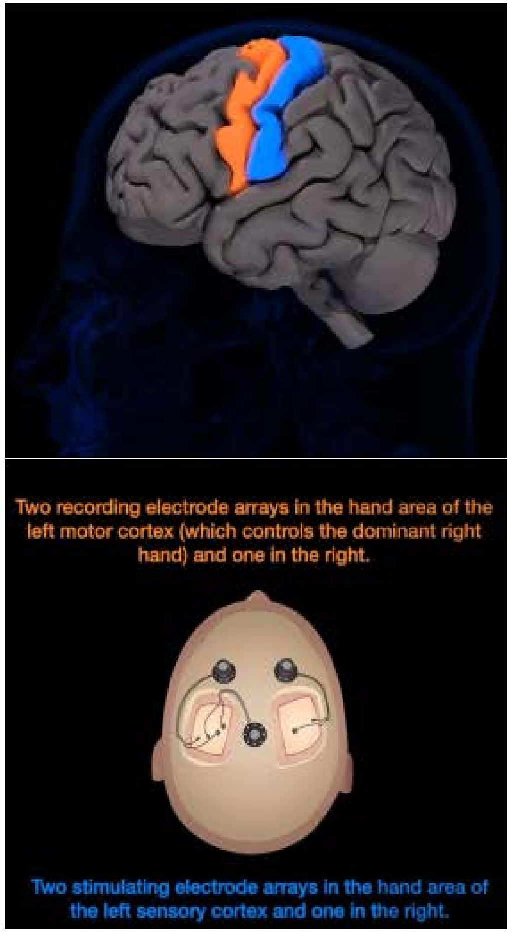
Restoration: active BCI

↕

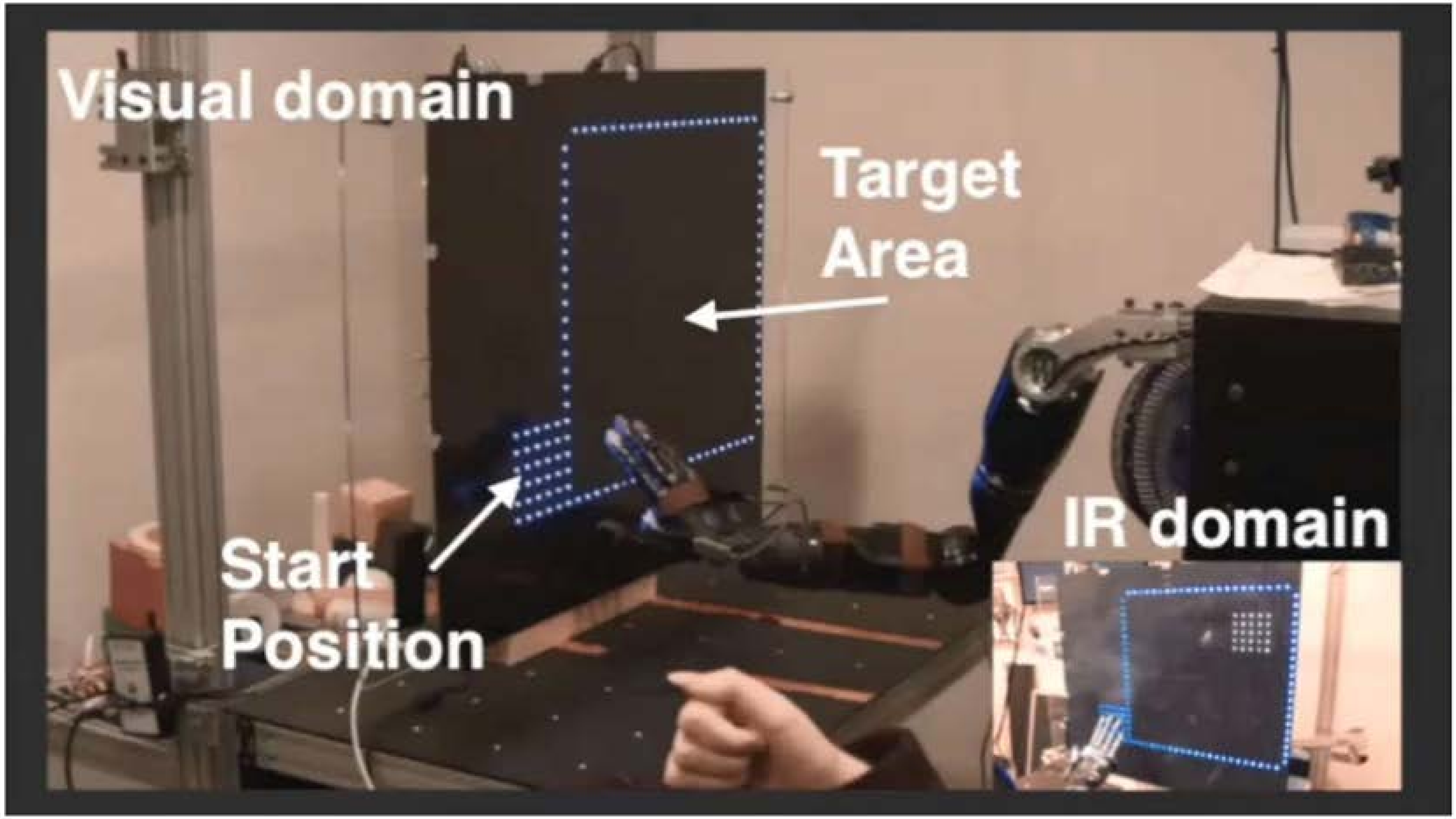
Augmentation: passive BCI

Anthropomorphic Perception & Control

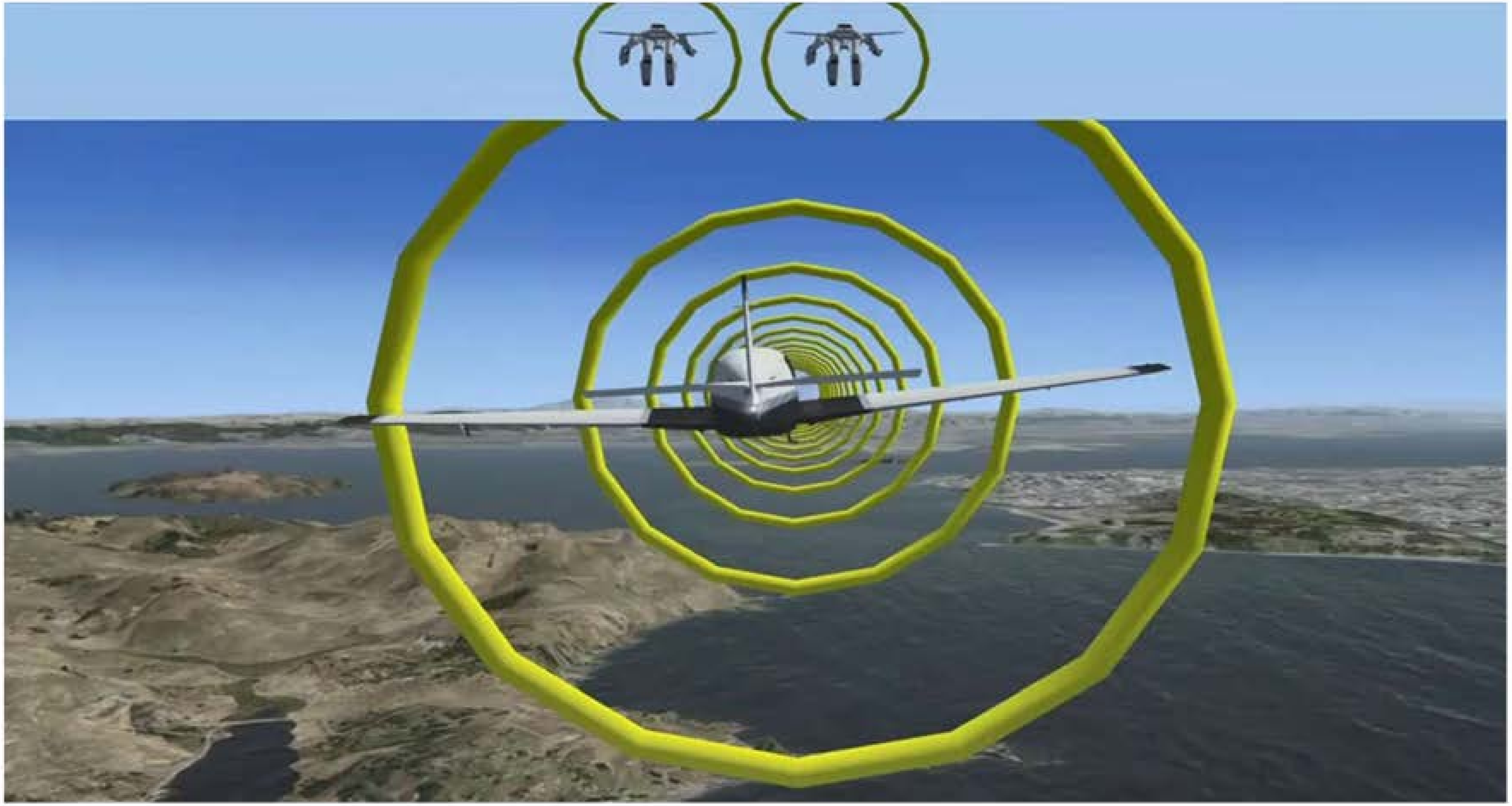




Beyond Anthropomorphic Perception



Beyond Anthropomorphic Control

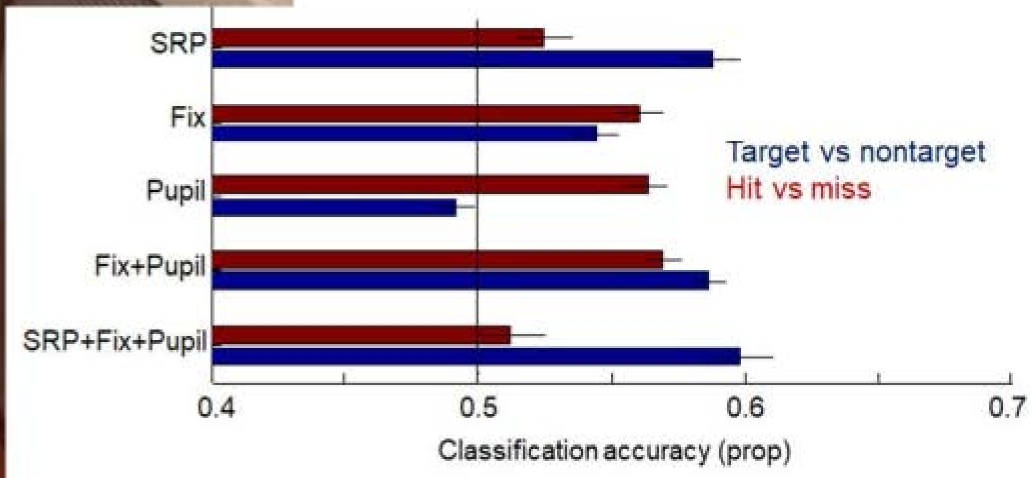


Neural multiplexing

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

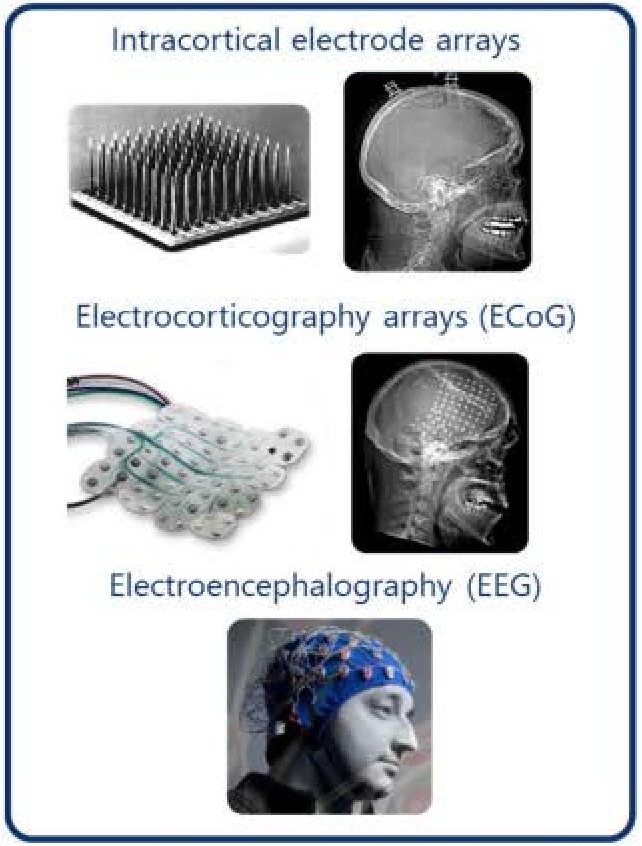
Towards augmentation?

Peripheral measures

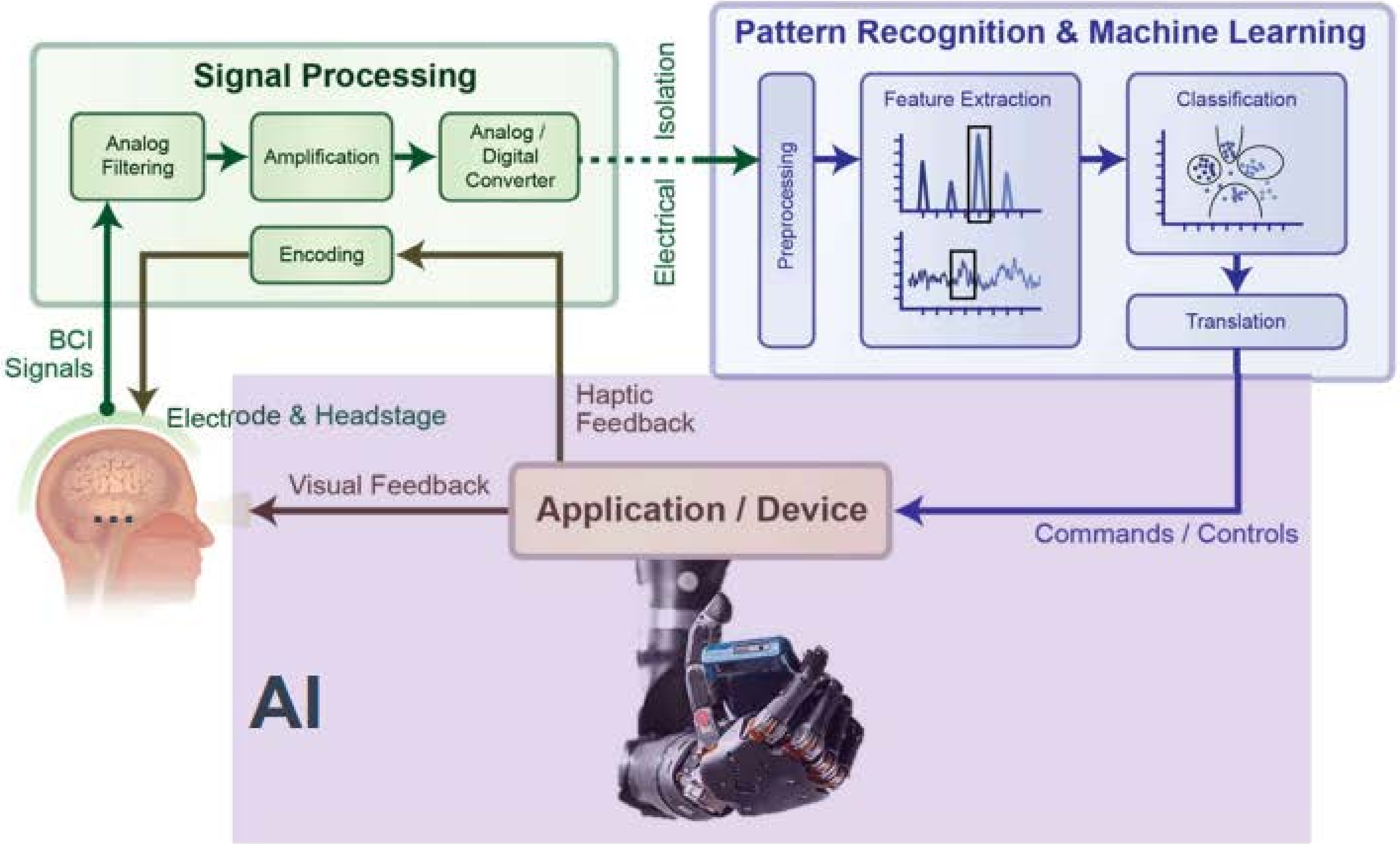


Integration with intelligent systems

Multiple BCI modalities

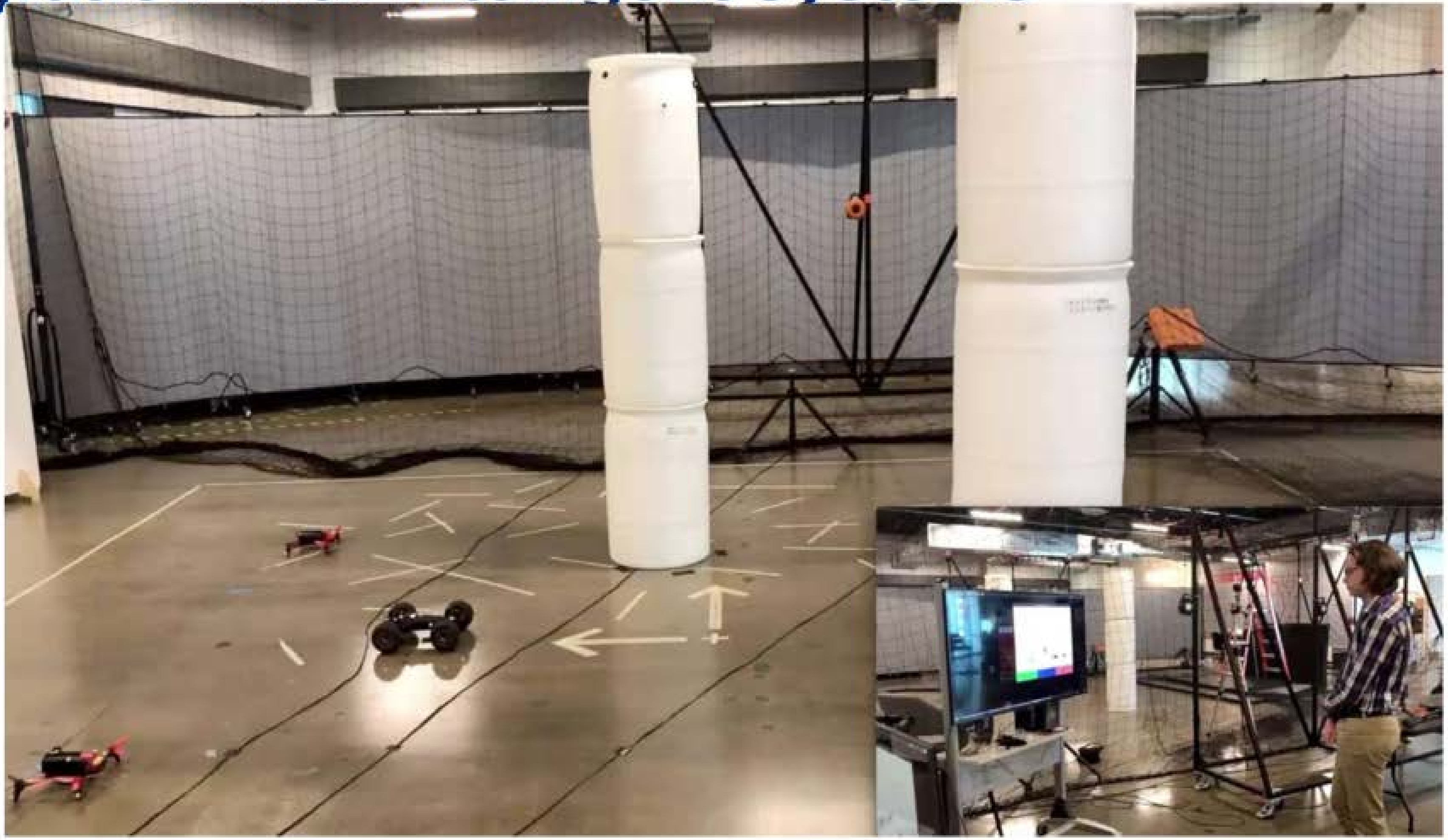


Blackrock, Albany Medical College

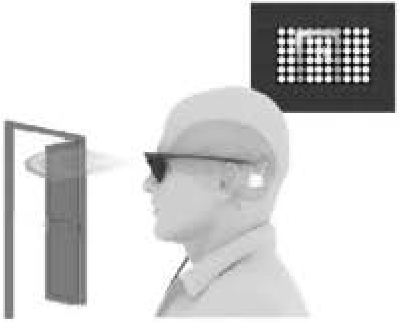


Integration with intelligent systems

Integration with intelligent systems



Integration with intelligent systems



Summary and Discussion

Invasive and non-invasive neurotechnologies

Invasive research provides invaluable inputs for non-invasive concepts and modalities. Emerging minimally-invasive surgical and high-resolution non-surgical techniques will enrich this landscape.

Active and passive neural interfacing

ITR will continue to be a critical metric in evaluating the relative research goals and value propositions for active and passive BCI across restoration and augmentation use cases.

Anthropomorphic and non-anthropomorphic perception, control, and embodiment.

When does a prosthetic, tool, or complex system start to feel like a genuine extension of the user, an to what effect? Invasive research suggests BCI may provide a unique tool to enable embodiment across anthropomorphic and non-anthropomorphic needs and restoration and augmentation use cases, from prosthetics to teleoperation.

Neural multiplexing

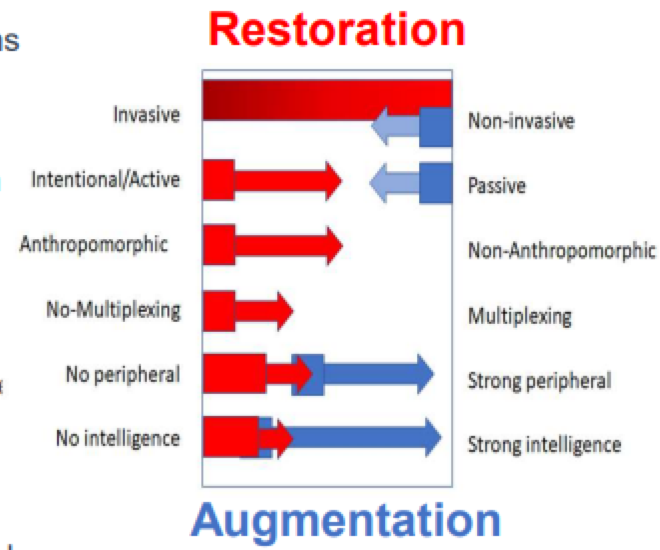
The ability to use the brain's natural mode of operation with the senses and muscles at the same tim as a direct neural interface is critical for augmentation and many emerging functional restoration use cases.

Peripheral measures

These measures can supplement or complement neural measures as less-obtrusive alternatives, and as sources of critical contextual information (e.g., linking neural signals to gaze) for both restoration and augmentation applications.

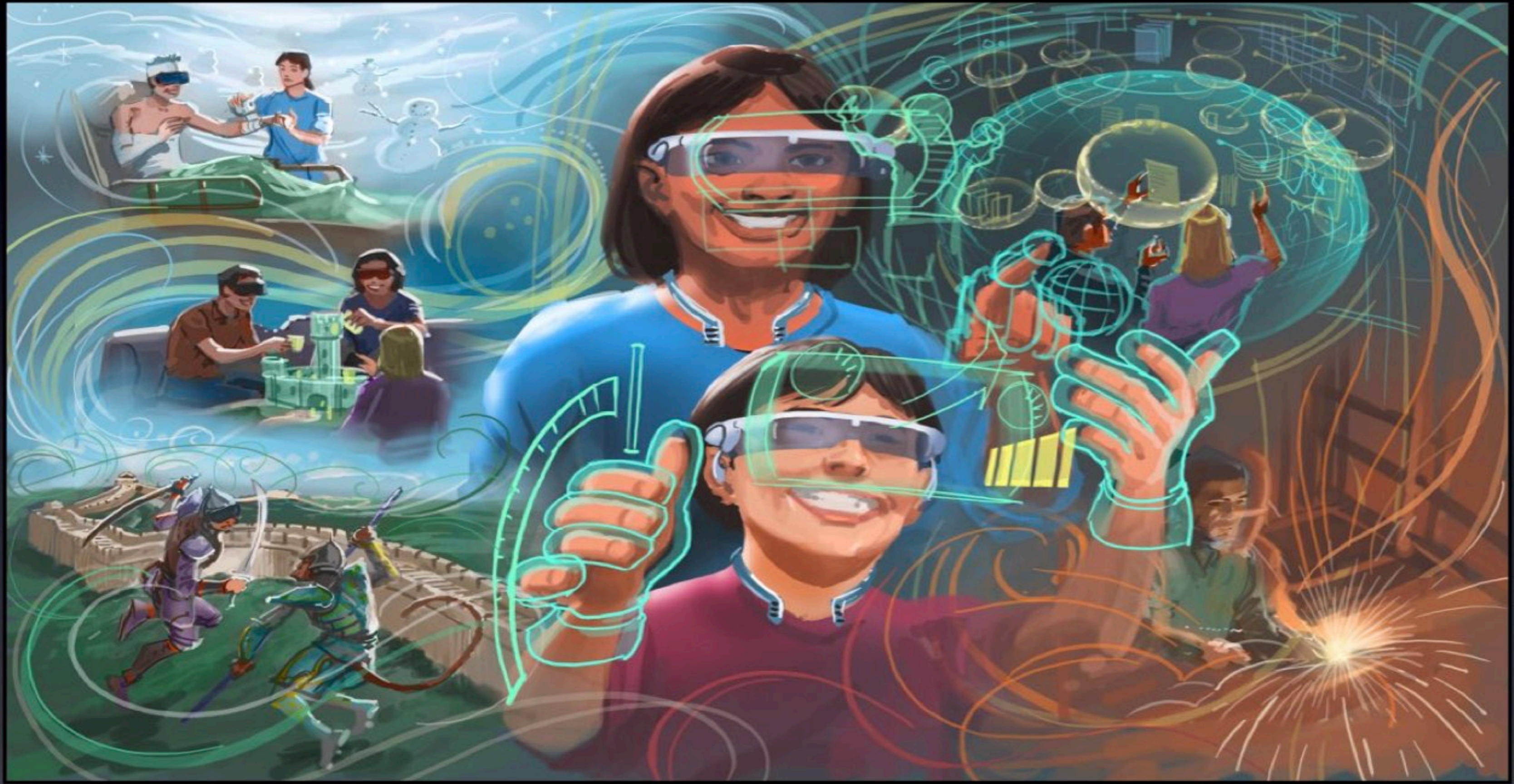
Integration with intelligent systems.

AI-enabled BCI helps to make the most of limited neural information, and offers new approaches to human-machine teaming at the speed of thought.



Using Social XR to Measure Social Cognitive Performance

to Address Isolation Associated with deployment & Post-Traumatic Life Events



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SIMIOSYS eXpanding Reality (XR) in Therapy & Enterprise

Christopher Stapleton, CEO

 christopher@Stapleton.net (407) 697.0381

Softcare Studios eXpanding Reality (XR) in Hospitals

Valentino Megale, CEO

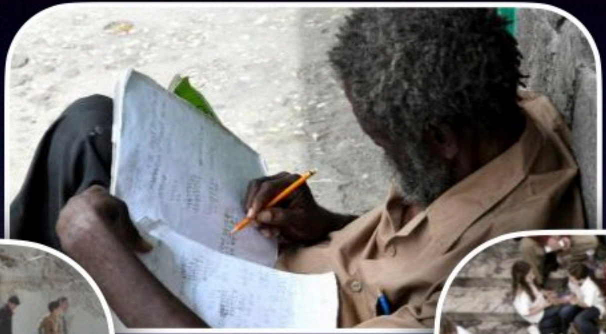
 v.megale@softcarestudios.com

eXpanding Reality (XR) in Isolation

Invisible populations at-risk for adverse effects of social isolation

Addiction

Poverty



Depressed

Displaced

Prejudice

Disenfranchised

Secondary Trauma

Beliefs

Aging

Hospitalized

Deployed

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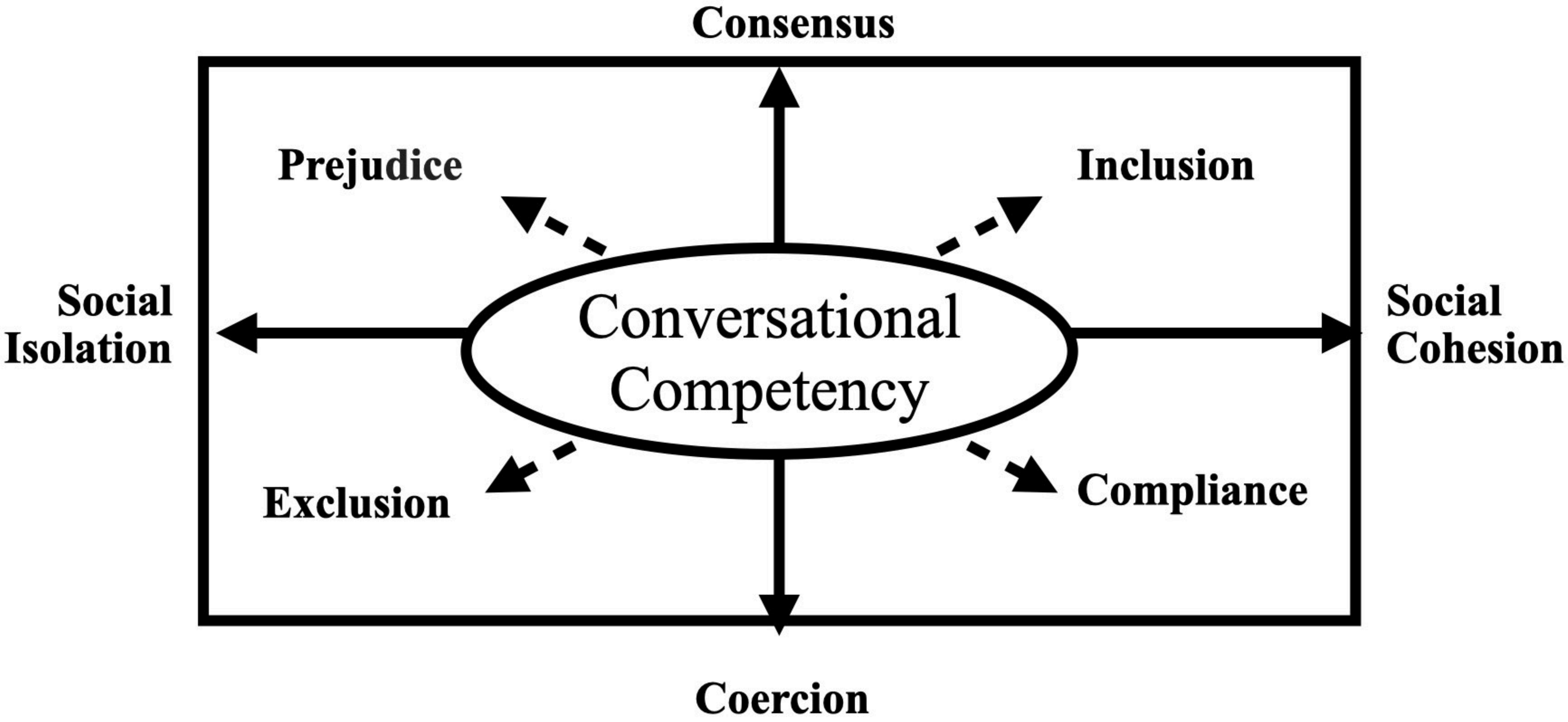
Sociality Continuum



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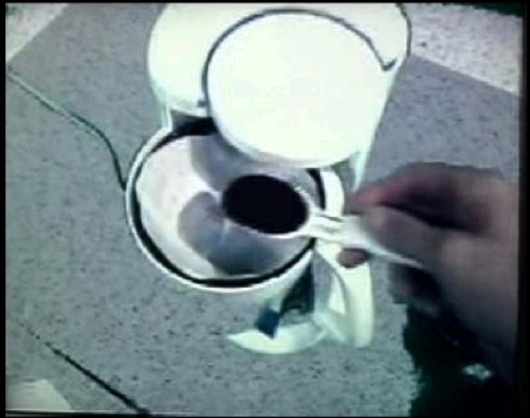
XR Human Experience Modeling of TBI Cog Rehab

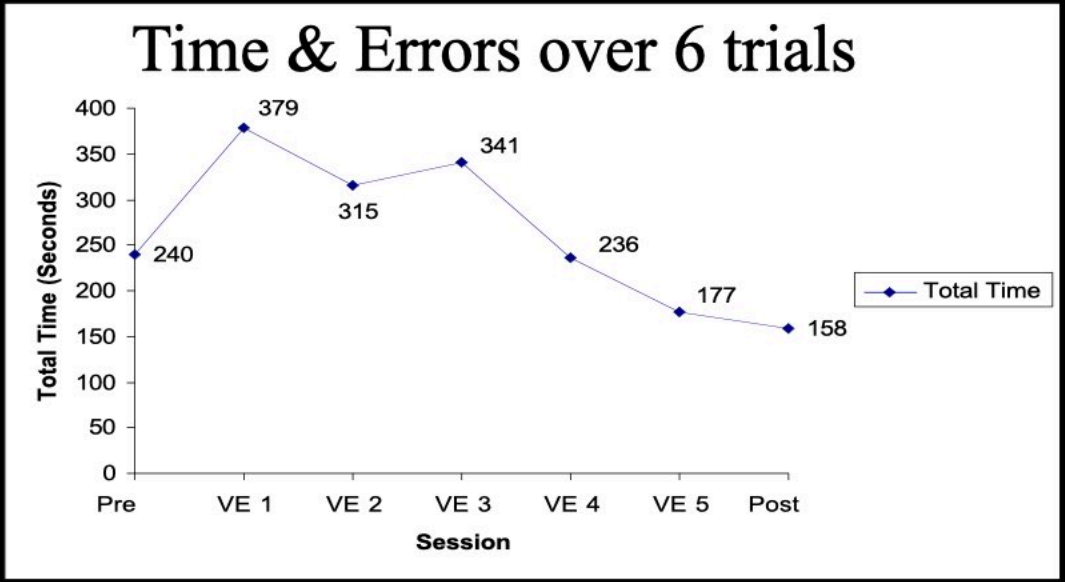
Home Kitchen

Clinic Kitchen

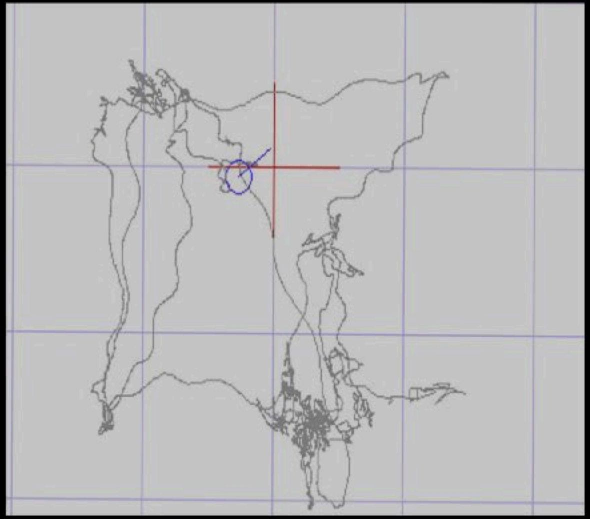
XR Kitchen

Subject View

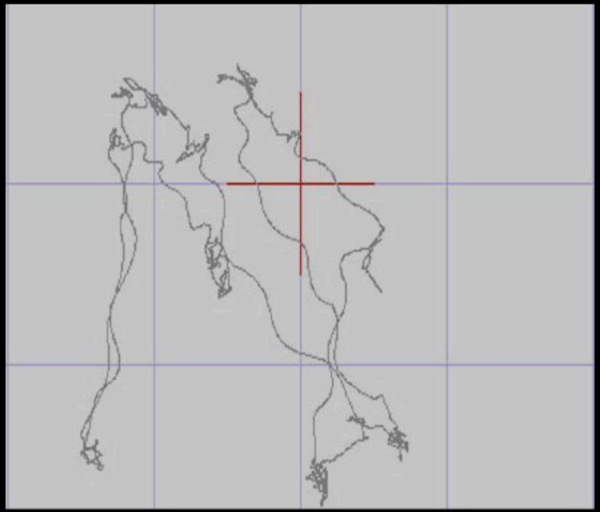




First Trial



Sixth Trial



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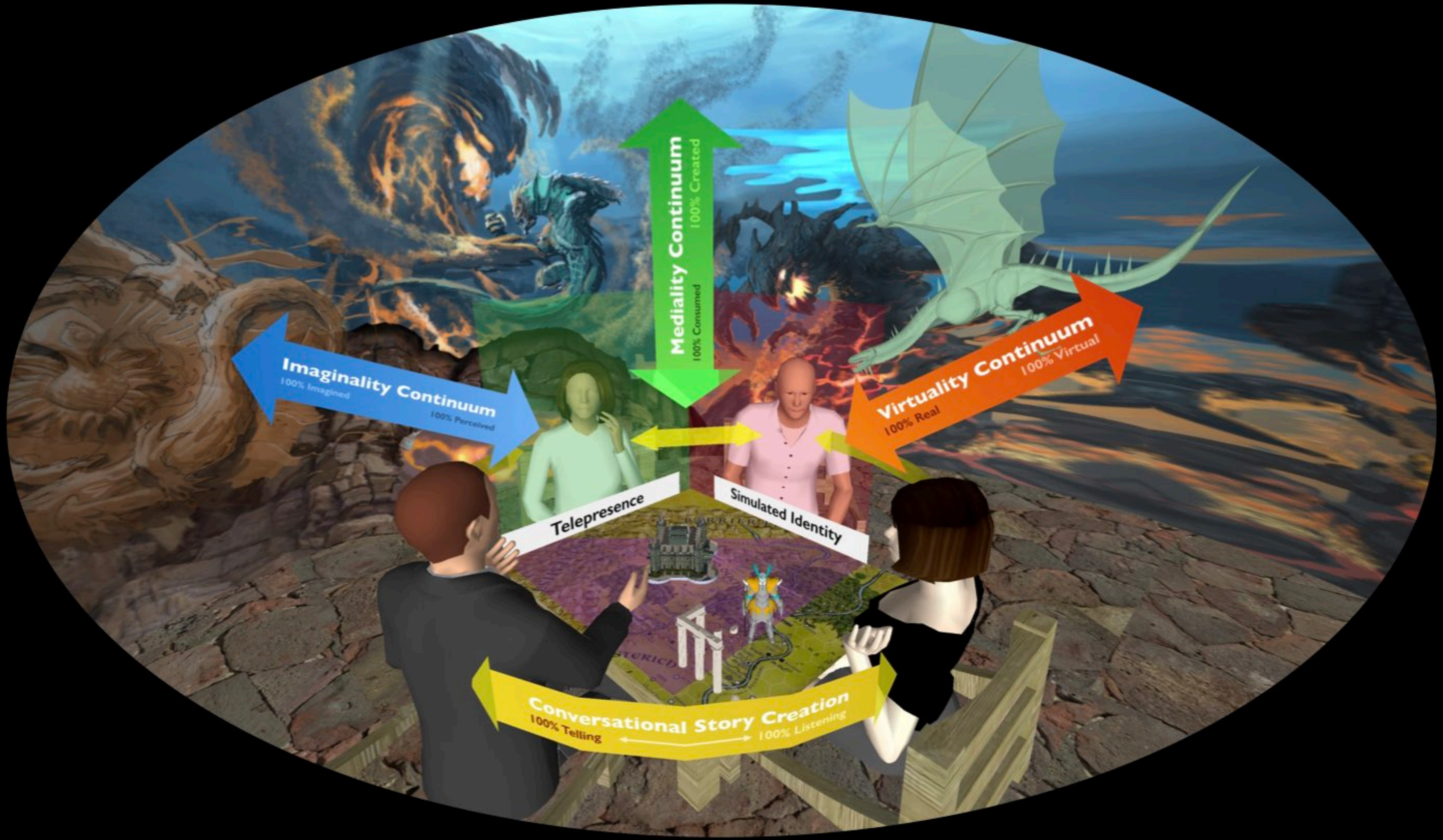
XR Human Experience Modeling of Therapy & Training



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Paradigm Shift: Measuring Social Cohesion

Integrating Human Reasoning with Machine Cognition

Isolation ⟷ Social Cohesion

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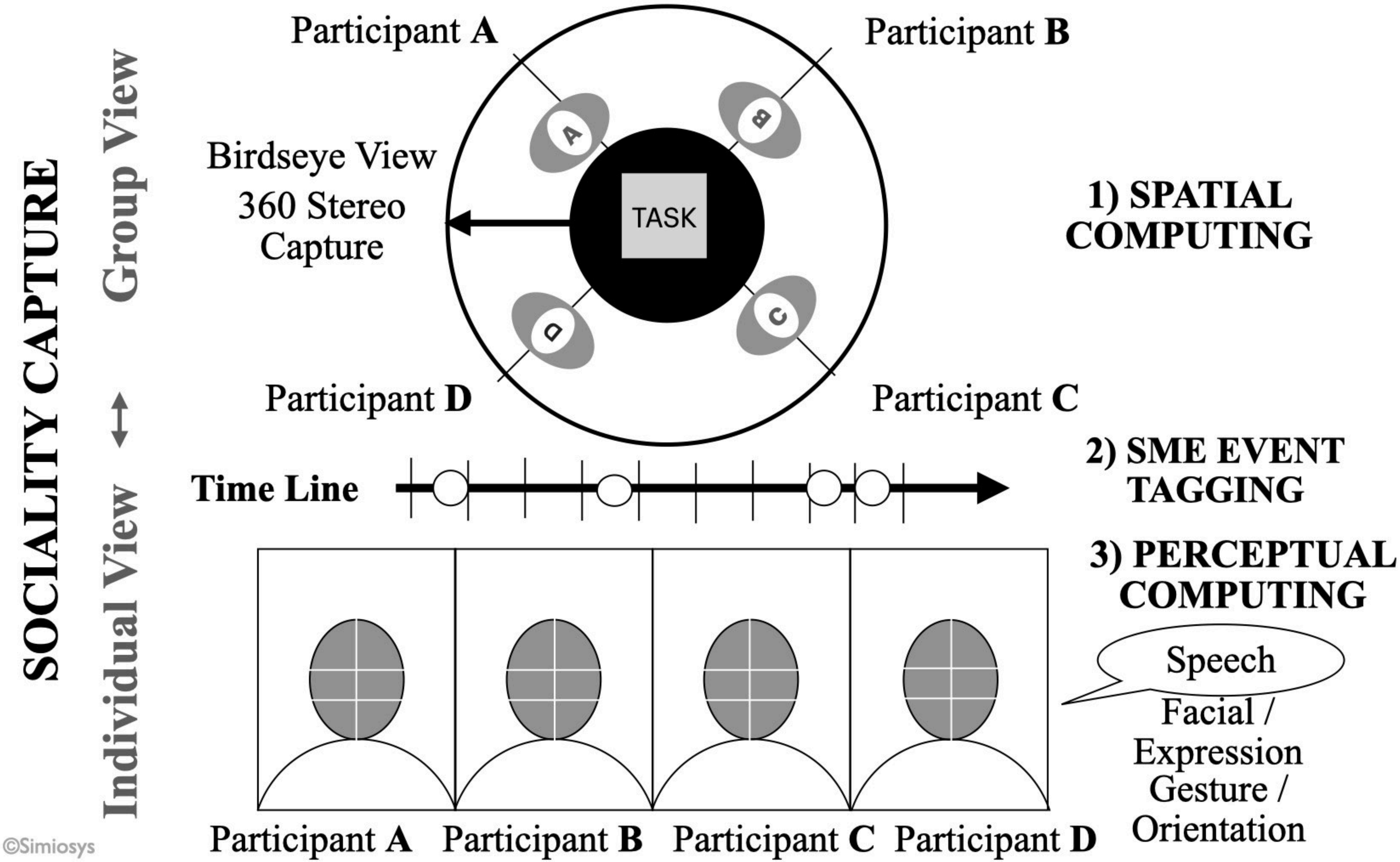
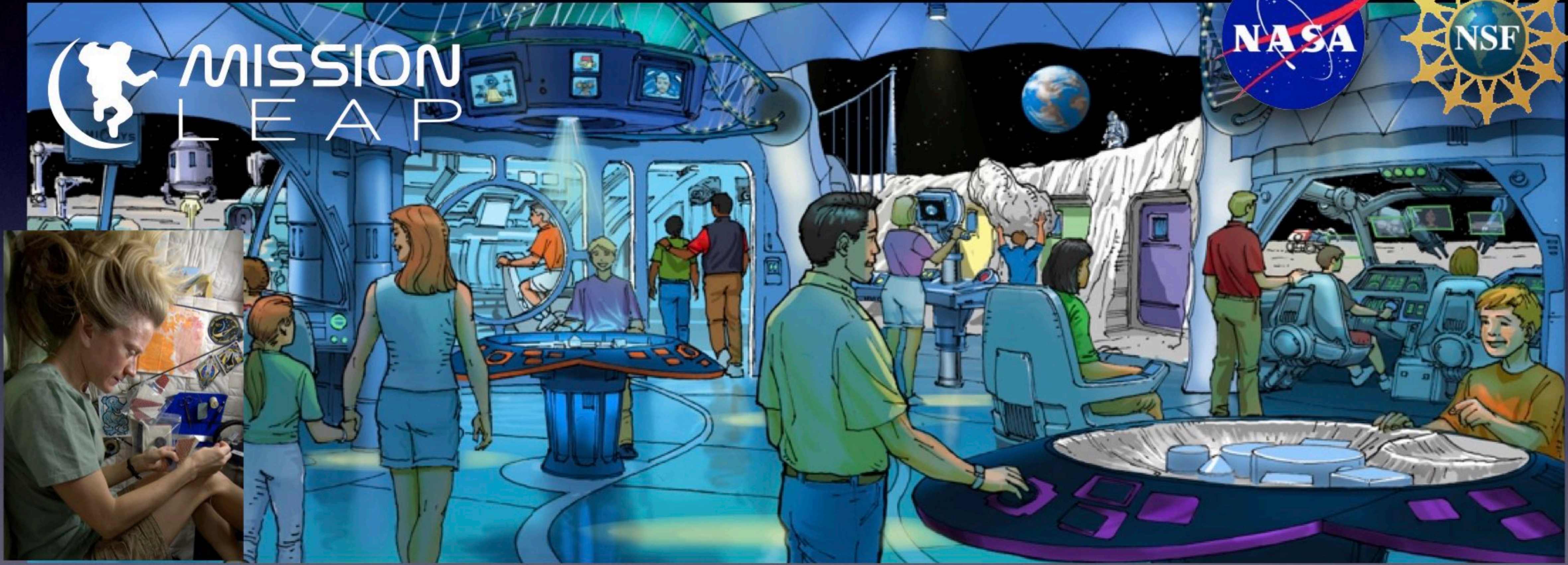

SOCIALITY CAPTURE
Group View
Individual View
Participant A
Participant B
Birdseye View
360 Stereo
Capture
TASK
A
B
C
D
Participant D
Participant C
1) SPATIAL
COMPUTING
2) SME EVENT
TAGGING
Time Line
3) PERCEPTUAL
COMPUTING
Speech
Facial /
Expression
Gesture /
Orientation
Participant A
Participant B
Participant C
Participant D

Consequence: Human Habitation on Mars



Transcending time and space for human connection…

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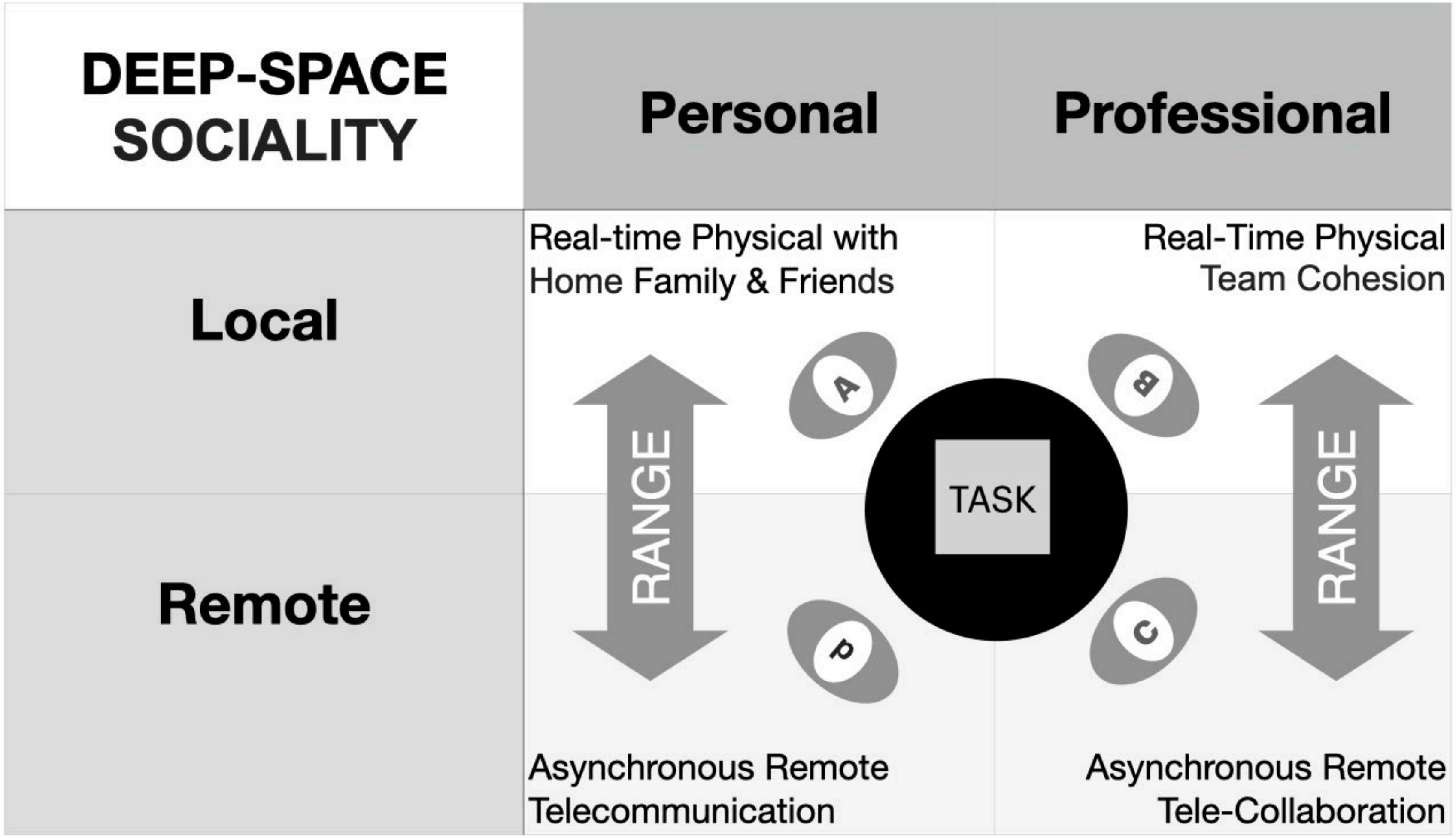
Social XR Transcending Time & Space



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Innovation: Three Dimensions of XR

Reality, Virtuality, Imaginaligy as one world…

- **Virtuality** Continuum
100% Real— 100% Virtual

- **Imaginality** Continuum:
100% Percieved —- 100% Imagined

- **Sociality** Continuum:
100% Passive consumption —- 100% Group Contribution

- **Conversational** Story Creation
Storytelling —- Story Listening

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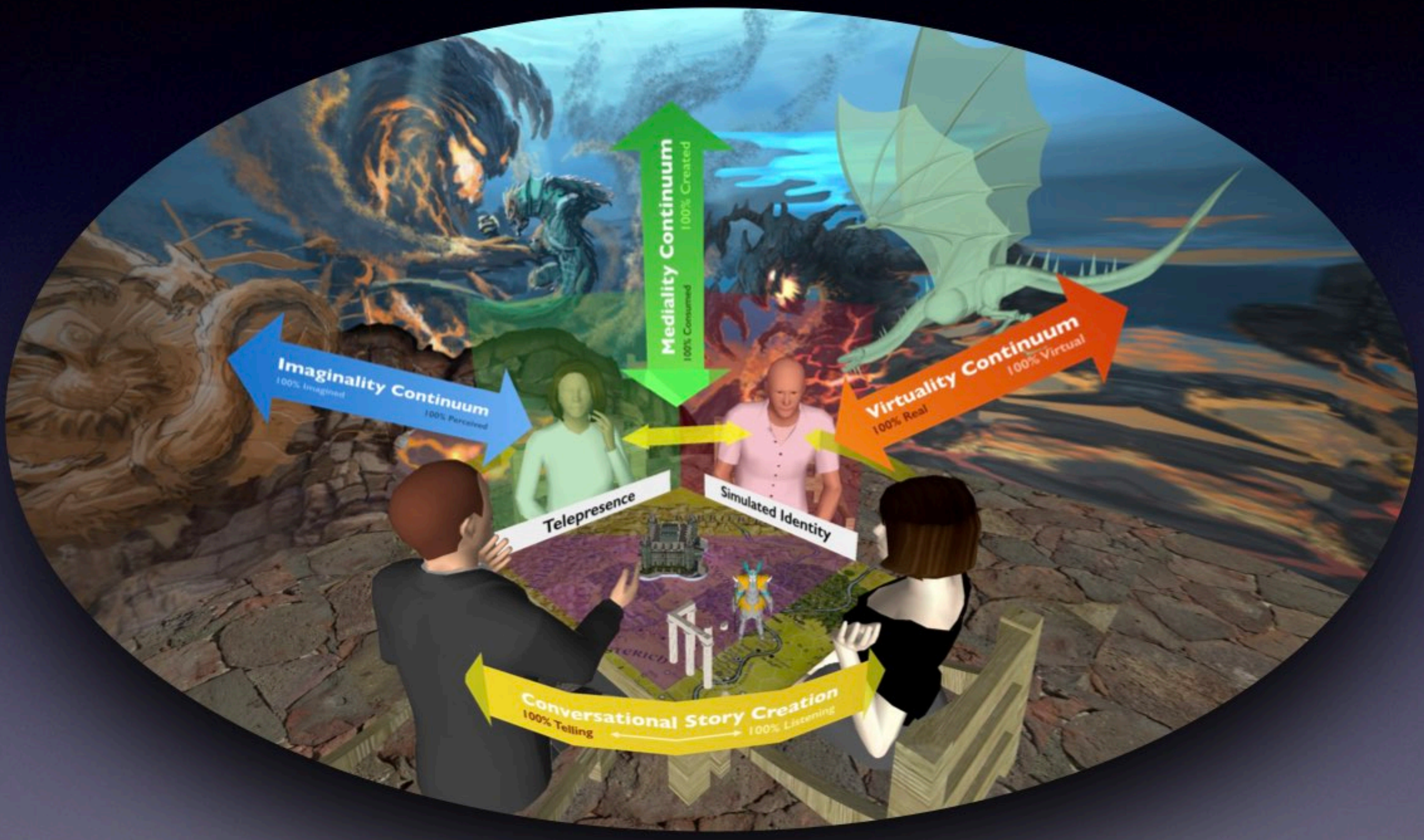
Dream: Reverse the Epidemic of Isolation

What is your vision for the future and why?



Social XR: anytime, anywhere, anyone

Augmented Imagination
Melting Boudaries using all senses, in all dimensions, all directions and all realities.

Overcoming obstacles to social cohesion by enhancing human connection, social engagement, expercising the imagination.

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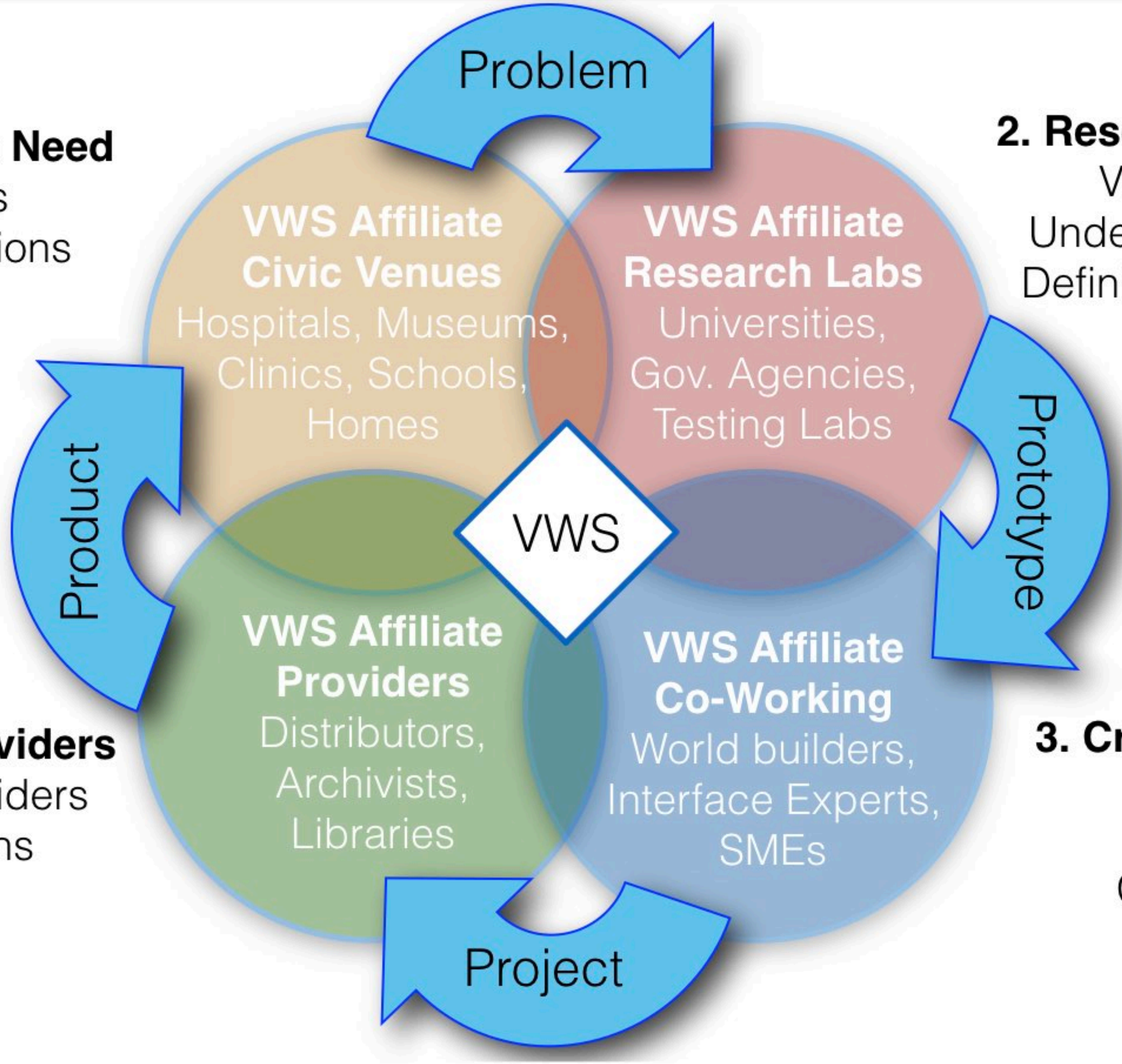
Call to Action: Stimulating Innovation for those who need it most

1. Communities in Need
Vast Problems
Looking for Solutions

2. Research Communities
Vast Expertise in
Understand Problems &
Defining Solution Criteria



3. Creative Communities
Vast Talent and
Technology to
Create Innovative
Solutions

4. Community of Providers
Vast Network of Providers
Delivering Solutions

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Thank You!

Would you like to collaborate?

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9 Closure – End of Day 1