



CHIST-ERA Conference 2020

Improving the sensitivity of the BCIs to users diversity

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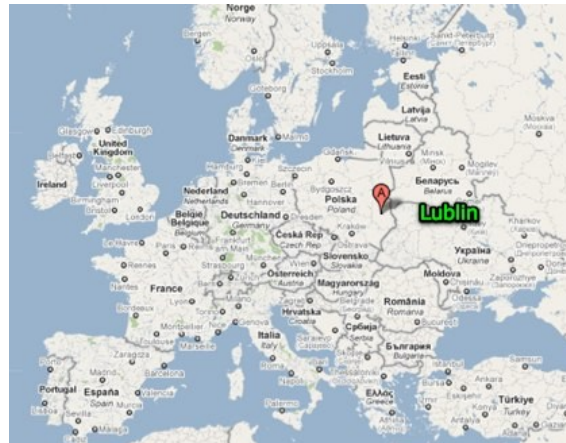
Perception & Cognition Lab Department of Experimental Psychology

<https://www.kul.pl/laboratory.22774.html>

<https://www.researchgate.net/lab/Perception-Cognition-Lab-Piotr-Francuz>

Research topics:

- Motor imagery
- SMR-EEG based BCI
- Haptic interaction
- fNIRS hyperscanning



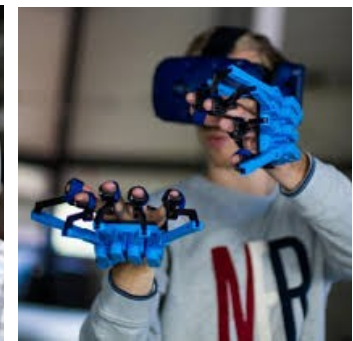
EEG



fNIRS



Eyetracking



VR & haptic
interfaces

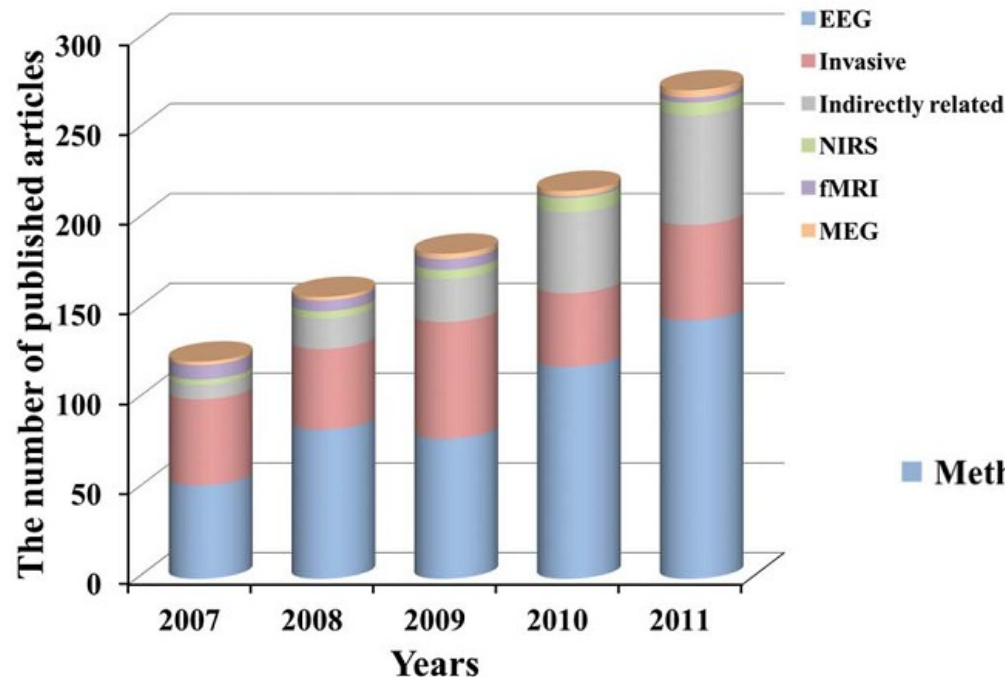
Speech plan

(1) Current and past projects on individual differences in BCI control from a psychological perspective.

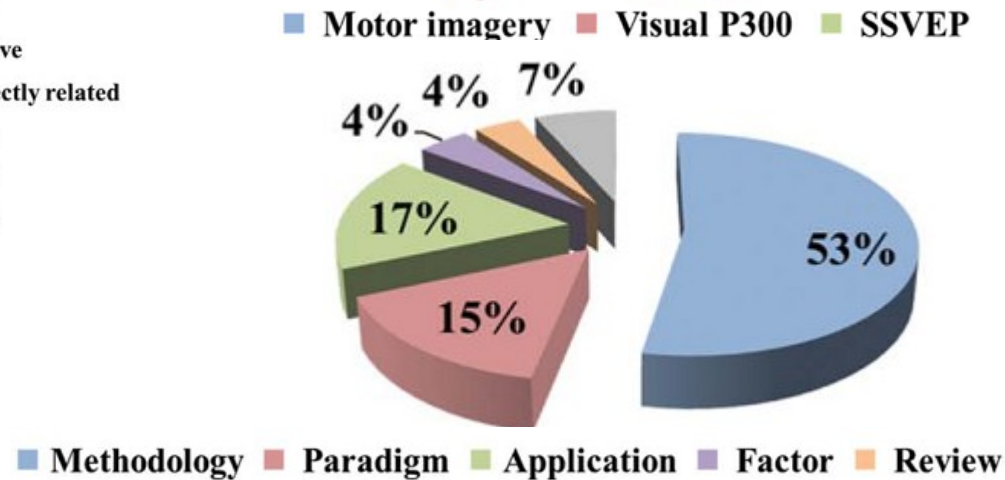
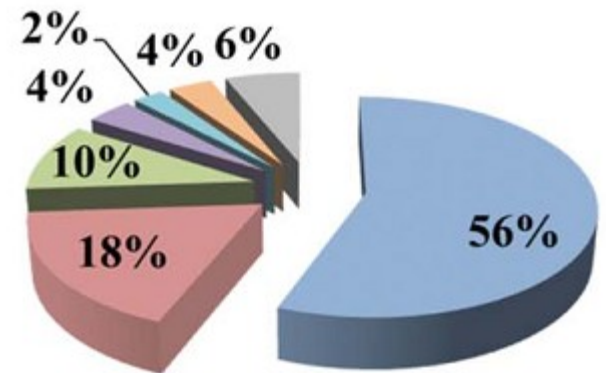
(2) A proposal for an ecological approach to study variations of BCI performance.

Why individual factors are so important in MI-BCI efficacy studies?

Hwang, H. J., Kim, S., Choi, S., & Im, C. H. (2013). EEG-based brain- computer interfaces: a thorough literature survey. *International Journal of Human-Computer Interaction*, 29(12), 814-826.



2007 - 2011



Most BCIs studies concern the signal processing methods for motor imagery EEG-BCIs



Most Popular Signal Processing Methods in Motor-Imagery BCI: A Review and Meta-Analysis

Piotr Wierzgała¹, Dariusz Zapala², Grzegorz M. Wojcik^{1*} and Jolanta Masiak³

Wierzgała, P., Zapala, D., Wójcik, G. M., & Masiak, J. (2018). Most popular signal processing methods in motor-imagery BCI: A review and meta-analysis. *Frontiers in Neuroinformatics*, 12, 78.

Research Questions

Q1: What is the average effectiveness of signal processing in the most popular types of MIBCI?

Q2: Was there a significant increase in effectiveness of signal processing over the relevant period?

Q3: Do methods of signal recording and processing (e.g., number of channels, spatial filtering, method of classification) influence the effectiveness of MIBCI control?

Q4: Do the research findings show that the applied techniques enable signal classification which is sufficient for effective use of the interfaces?

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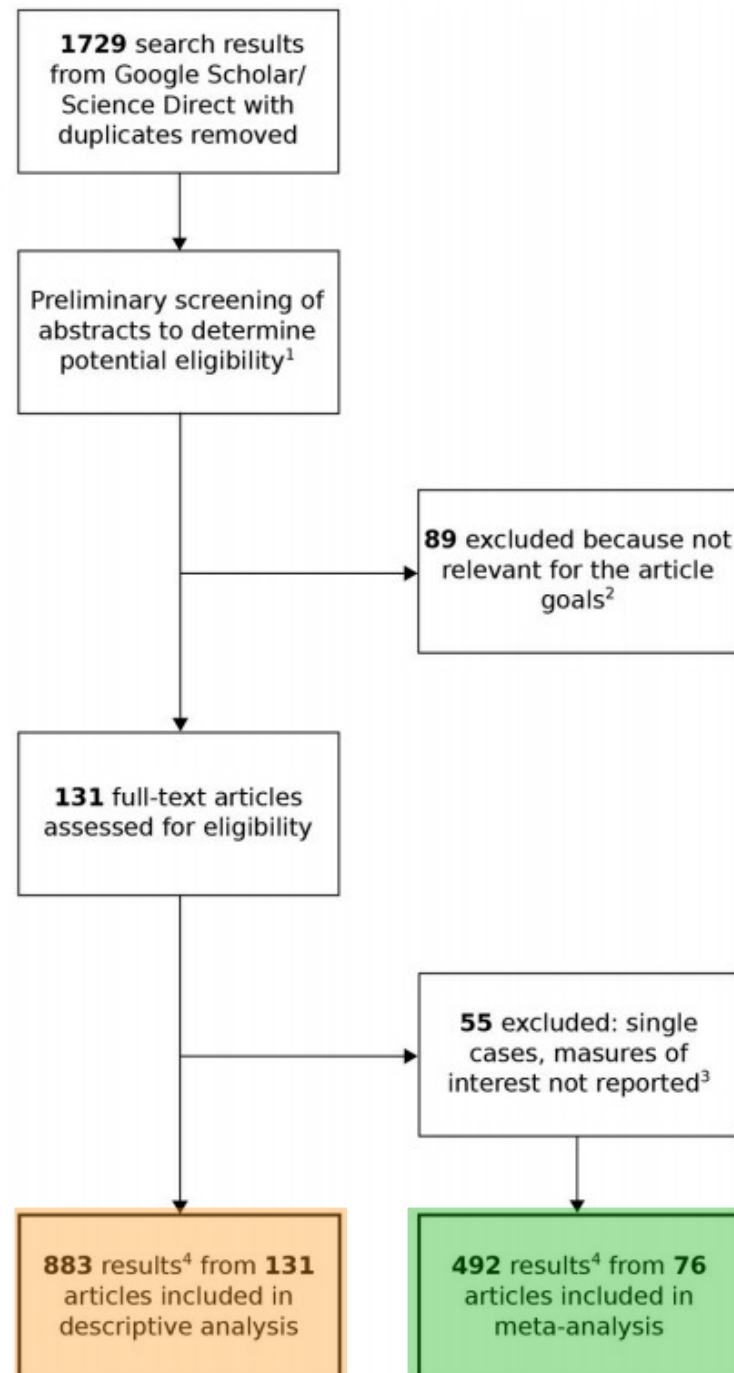
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From 1997 to 2017 20 years of BCI study

FIGURE 2 | Flow diagram for identifying articles for the meta-analysis and descriptive analysis. (1) A total of 1,503 studies were excluded because of their irrelevance (e.g., reviews, gray literature, theoretical articles, reports from cognitive experiments), (2) based on criteria (studies without motor imagery condition; other than EEG analysis), (3) and which did not provide sufficient statistics, such as means, standard deviations and size, to drive meta-analysis. (4) A majority of the articles contained results of more than one analysis. Each variant of data processing was examined as a separate result/BCI design.



Unification of the results

Classification Accuracy (CA) mean of correct clasifications reported in the article

Level of Chance (LC) level of CA that can be reached by chance:
 $LC = 100\% / \text{number of targets}$ (Marchetti and Priftis, 2015).

Corrected CA (CCA) = $(CA - LC) * 100 / (100 - LC)$ by Marchetti and Priftis (2015)

It is sufficient for effective use of the BCIs?

CCA higher than the **60% threshold rate for effective control** (Guger et al., 2003) **was achieved in 37%** of the studies and the **result exceeded 70%** (Brunner et al., 2010) **in only 16.6% of the studies.**

In the group of 14 studies analysing real-time BCI control, CCA was **below the threshold value of 60% in four cases (28.6%)** although the CCA in this group of results still differed from LC [$t(13) = 8.13, p < 0.001$].

Do we have a progress in MI-BCIs area?

No correspondence was observed between the reported CCA and the year in which the results were published. During the period in question the accuracy of the solutions examined decreased significantly!

year; $B = -0.97$, CI 95%: -1.26 to -0.68 ; $p = 0.005$

BCI Meeting

1999 NY – 22 research groups from 6 countries

2013 Albany – 165 research groups from 29 countries

Intra and inter individual differences in MI- BCIs

User training

Journal of Motor Behavior, Vol. 0, No. 0, 2015
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RESEARCH ARTICLE

Short-Term Kinesthetic Training for Sensorimotor Rhythms: Effects in Experts and Amateurs

Dariusz Zapała¹, Emilia Zabielska-Mendyk¹, Andrzej Cudo¹, Agnieszka Krzysztofiak¹,
Paweł Augustynowicz^{1,2}, Piotr Francuz¹

¹Department of Experimental Psychology, The John Paul II Catholic University of Lublin, Poland. ²Institute of Economics and Finance, Maria Curie-Skłodowska University, Lublin, Poland.

Feedback form

Appl Psychophysiol Biofeedback
DOI 10.1007/s10484-017-9383-z



The Impact of Different Visual Feedbacks in User Training on Motor Imagery Control in BCI

Dariusz Zapała¹  · Piotr Francuz¹ · Ewelina Zapała¹ · Natalia Kopiś¹ ·
Piotr Wierzgała² · Paweł Augustynowicz^{1,3} · Andrzej Majkowski⁴ · Marcin Kołodziej⁴

Intra and inter individual differences in MI - BCIs

Personality traits

Article



Temperament Predictors of Motor Imagery Control in BCI

Dariusz Zapata¹, Monika Matkiewicz², Piotr Francuz¹, Marcin Kołodziej³, and Andrzej Majkowski³

Real-life experience

**SCIENTIFIC
REPORTS**

nature research

The effects of handedness on sensorimotor rhythm desynchronization and motor-imagery BCI control

Dariusz Zapala^{*}, Emilia Zabielska-Mendyk, Paweł Augustynowicz, Andrzej Cudo, Marta Jaśkiewicz, Marta Szewczyk, Natalia Kopiś & Piotr Francuz

Conclusions:

1. BCI research focuses mainly on developing signal processing methods, less on differences between users.
2. In most studies, there is no precise control over the participants' mental strategies during BCI performance.
3. Too little attention is paid to the context in which BCI is used, e.g., body position, social interactions, motivation, etc.
4. The visual feedback dominates in MI-BCI, although kinesthetic stimulation is more natural for the motor imagery.

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CONTEXT

TYPES OF WIDE COGNITION



Source: Miłkowski, M., Clowes, R., Rucińska, Z., Przeglasińska, A., Zawidzki, T., Krueger, J., ... & Stjernberg, F. (2018). From wide cognition to mechanisms: A silent revolution. *Frontiers in Psychology*, 9, 2393.

TYPES OF WIDE COGNITION

DISTRIBUTED COGNITION:
Cognitive systems may encompass multiple individual agents and artifacts

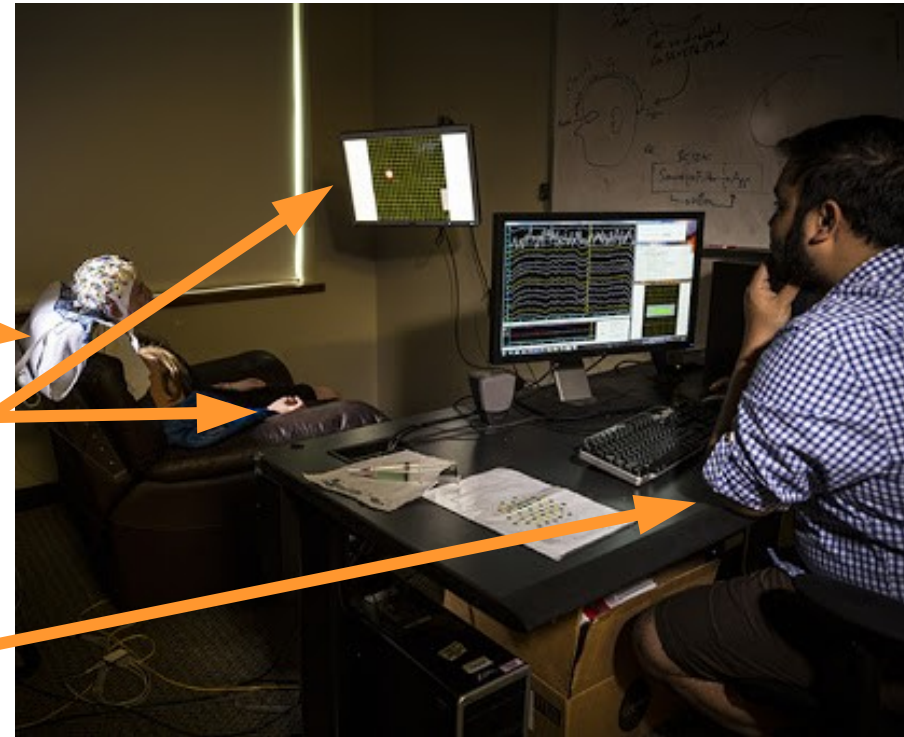
SITUATED AND EMBEDDED COGNITION
Extra-bodily context constrains and enables cognition

EMBODIED COGNITION:
The physical body of an agent is constitutively relevant to cognition

EXTENDED COGNITION:
Cognitive processes are not necessarily brain-bound and can incorporate external resources

ENACTIVE COGNITION:
Inter-dependency between an autonomous agent and the world it inhabits

Wide cognition in BCI experiments



Source:

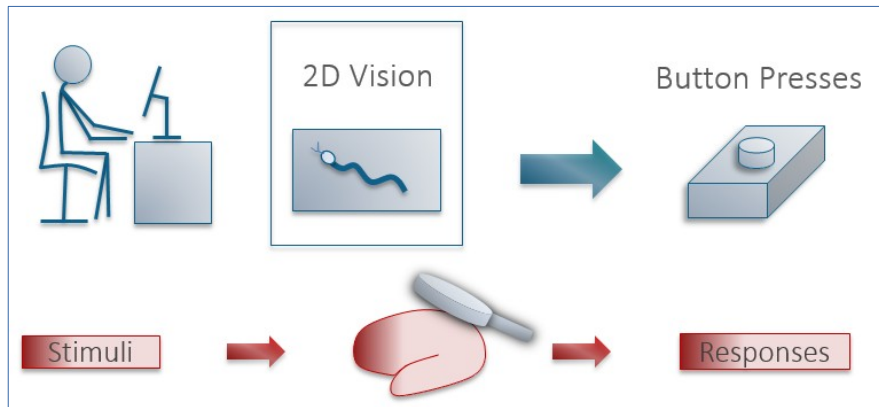
<http://www.centerforneurotech.org/engage-enable/post/investigating-how-learning-use-brain-computer-interface-impacts-connectivity>

[Access: 24-09-2020]

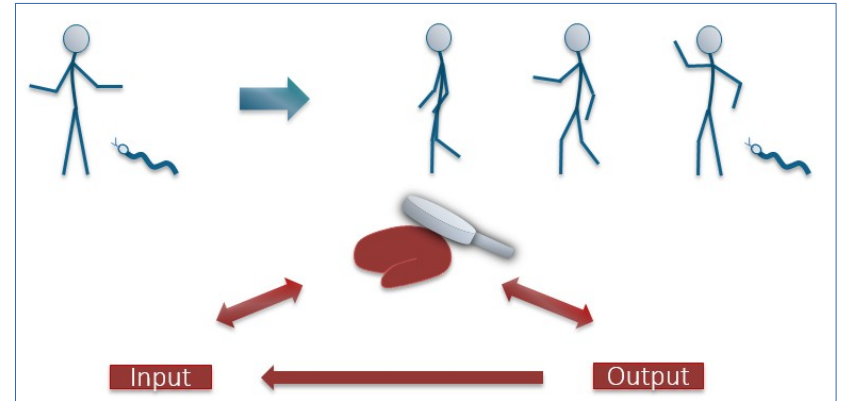
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Mobile Brain / Body Imaging (MoBI)

Classical Experimental Setup



MoBI Real World Experimental Setup



Source: https://blogs.tu-berlin.de/bpn_bemobil/ [Access: 24-09-2020]

Real-Life Neuroscience



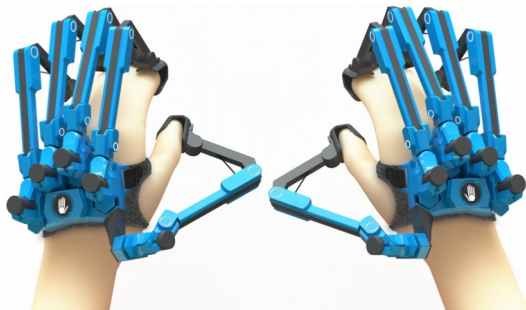
Ecological Validity

Source: Shamay-Tsoory, S. G., & Mendelsohn, A. (2019). Real-life neuroscience: an ecological approach to brain and behavior research. *Perspectives on Psychological Science*, 14(5), 841-859.

MENTAL STRATEGIES & KINESTHETIC STIMULATION

Table 1. Comparison of the most popular paradigms in the study of motor imagery

Name	Intentionality	Measure of correctness	Separation of modalities (e.g. KMI, VMI)	Main advantages/ disadvantages
Imagery movement of body parts (e.g. Graz BCI [6])	Explicit	Only chronometry	Only by instruction (explicit)	(+) easy to apply; (-) poorly engaging; lack of a correctness criterion
Imagery finger tapping [4]	Implicit	Accuracy and chronometry	Only by instruction (explicit)	(+) provides an indication of correctness (-) task can be executed without the involvement of motor imagery, e.g. by counting
Mental rotation task (e.g. hand laterality test/judgment task) [7]	Implicit	Accuracy and chronometry	Only by instruction (explicit)	(+) provides an indication of correctness (-) task may engage visual or spatial processes more than sensori-motor
Imagery comparison task	Implicit	Accuracy and chronometry	Yes (implicit)	(+) separates types of imagery on the basis of their modality (-) requires the use of additional devices, e.g. haptic interfaces



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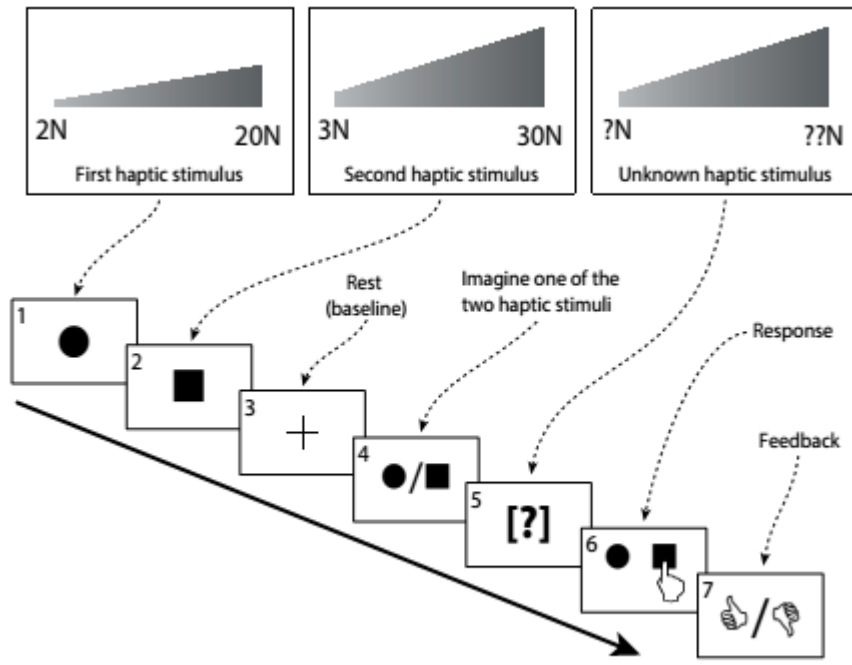
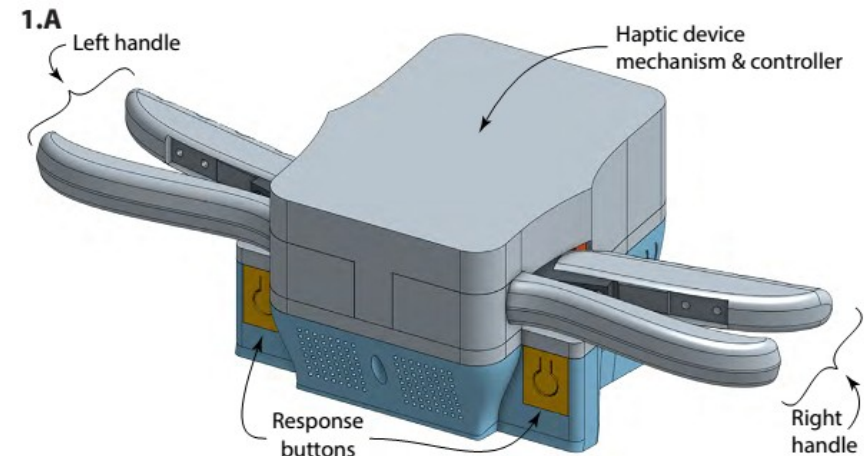


FIG. 2: Outline of the experimental procedure



1.B



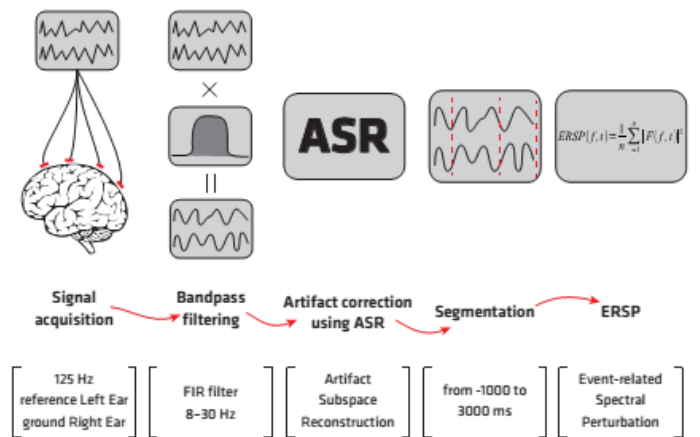


FIG. 3: Signal processing pipeline

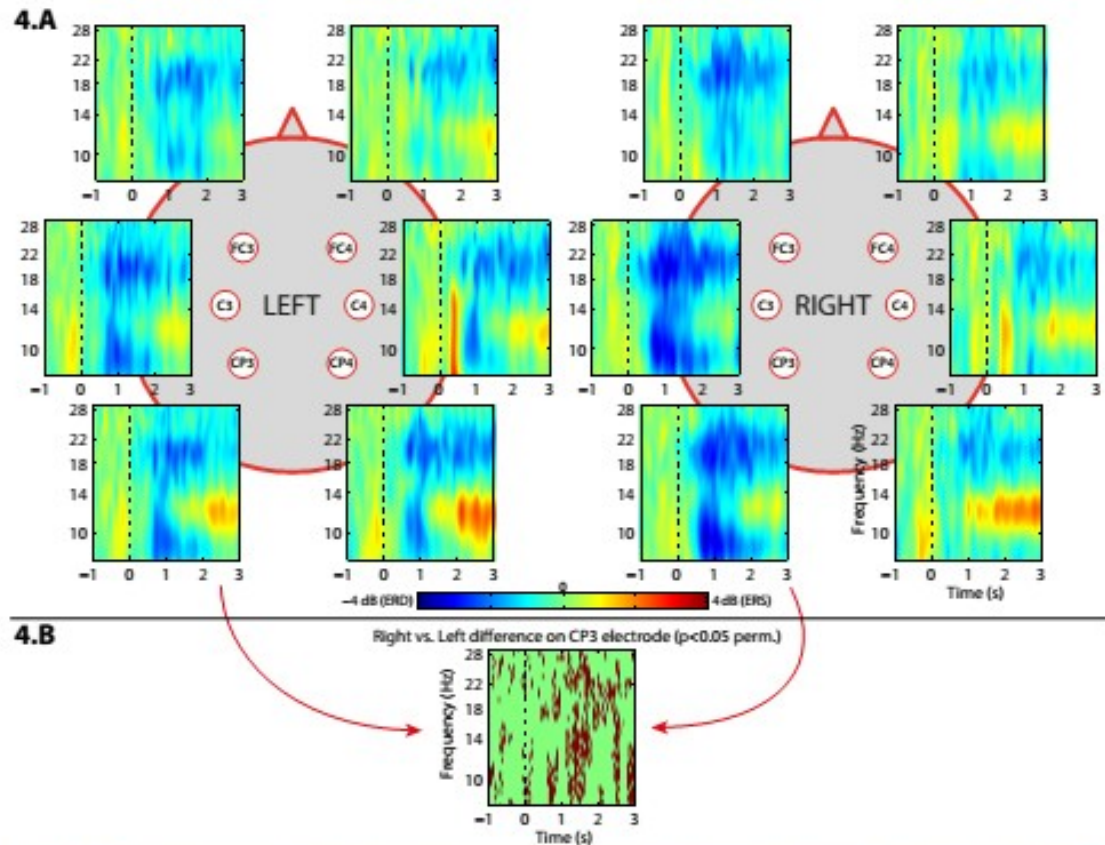


Fig. 4. A - The averaged time-frequency maps on six central electrodes (FC3; FC4; C3; C4; CP3; CP4) under KMI tasks. The dotted-line was marked at the onset of the task, the blue color indicates the ERD phenomenon; **B** - The area of statistical differences ($p < 0.05$ perm.) between the right and left-hand imagery movement on the CP3 electrode.

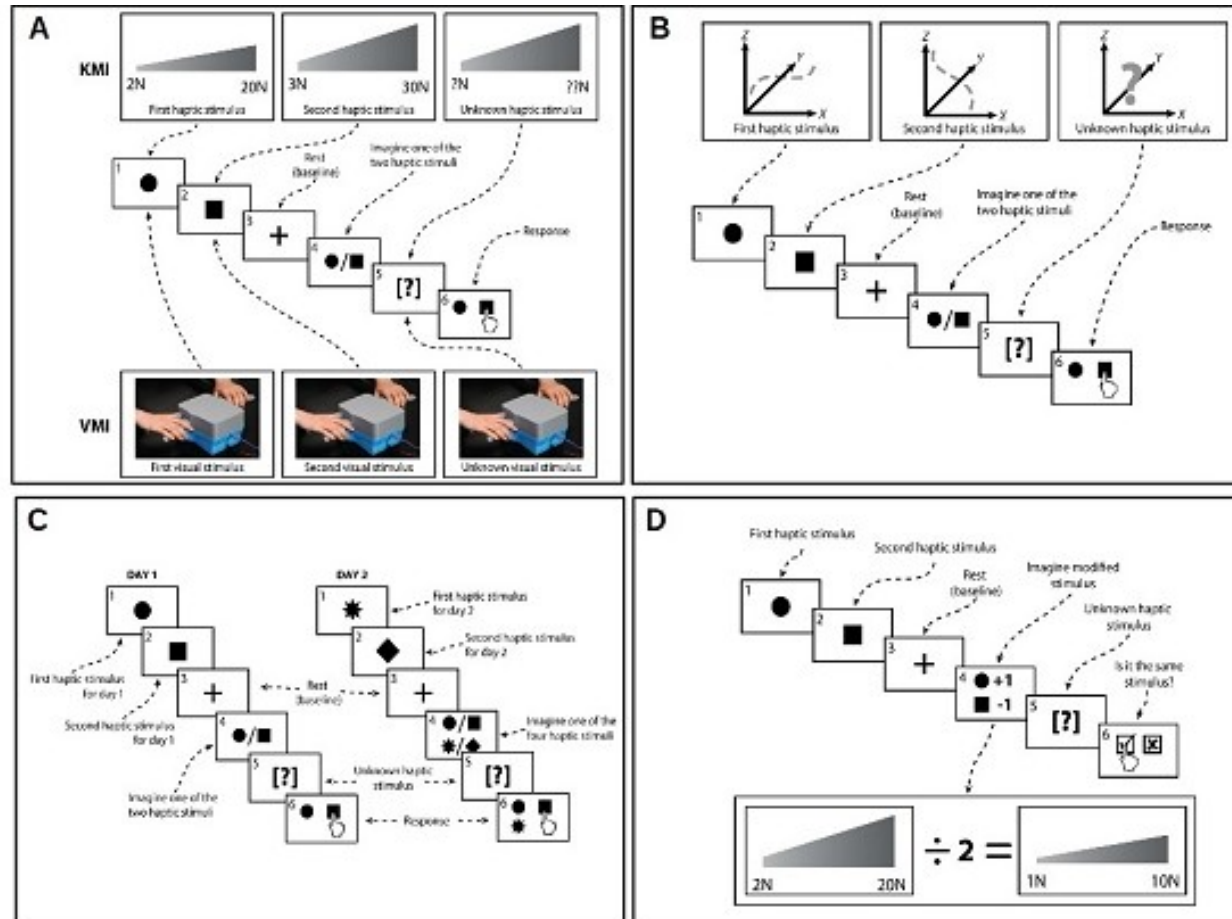


Fig. 7. A: Comparison of KMI and VMI conditions in Study 1. In the VMI condition, the stimuli are videos with recording of motion at different speeds. **B:** In the Study 3 haptic stimuli provide different resistance to movement in 3D space. **C:** Learning haptic stimuli on the first day and comparing them with new stimuli on the second day of Study 4. **D:** Recalling the known movement and creating new images on its basis in Study 5.

PROJECT PROPOSAL

MoBI BCI

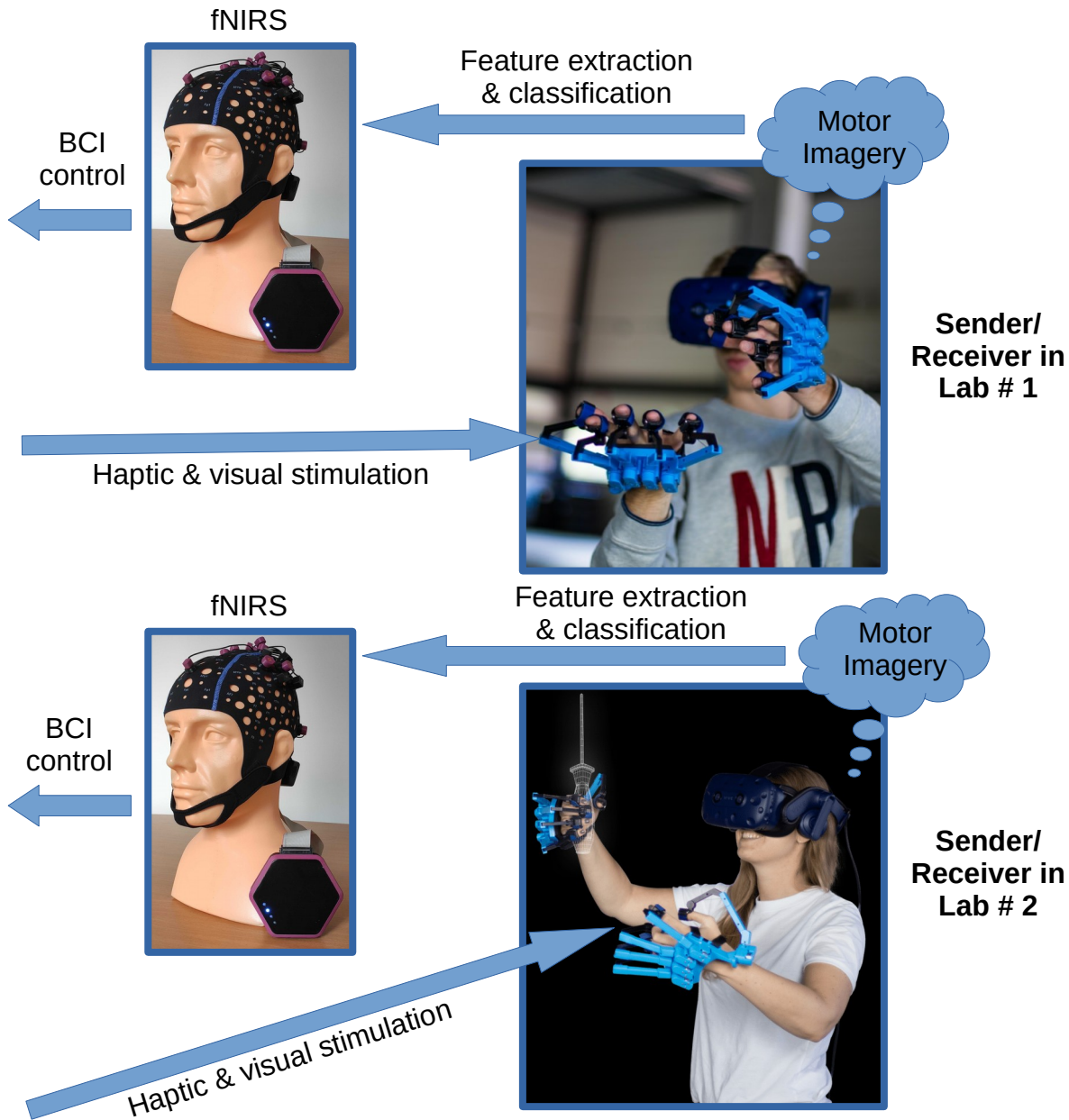
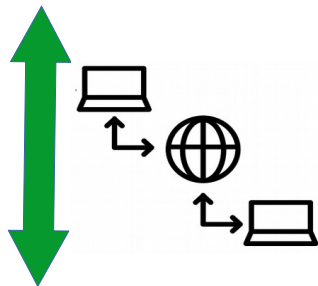
Project goal: to design a experimental framework to study individual differences in BCI control in compliance with the 'Real-Life Neuroscience' principles.

Assumptions:

- use of realistic feedback (VR environment and haptic/kinaesthetic stimulation)
- combining different research tools (EEG, fNIRS, Mo-Cap), e.g., using LSL protocol
- applying experimental procedures that provide an objective measure of mental strategies
- study of multidirectional brain-computer, brain-brain, and human-human interaction
- evoking natural social interactions, e.g., communication, entertainment, cooperation



Interaction in VR
environment



Major challenges:

- 'real-time' fNIRS signal processing tools
- intuitive software for developing haptic stimuli
- synchronization of signals recorded simultaneously in multiple locations
- proper control over the influence of interfering variables in 'real-life experiments'.

Possible applications:

- online neurorehabilitation (therapist as a sender, patient as a receiver)
- remote training of manual skills
- experimental framework for 'wide cognition' studies

Thank you for your attention!

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<https://scholar.google.pl/citations?user=r1W32eMAAAAJ&hl=pl>