chist-era

A user-centred approach to unlock the potential of non-invasive BCIs:

An unprecedented international translational effort -

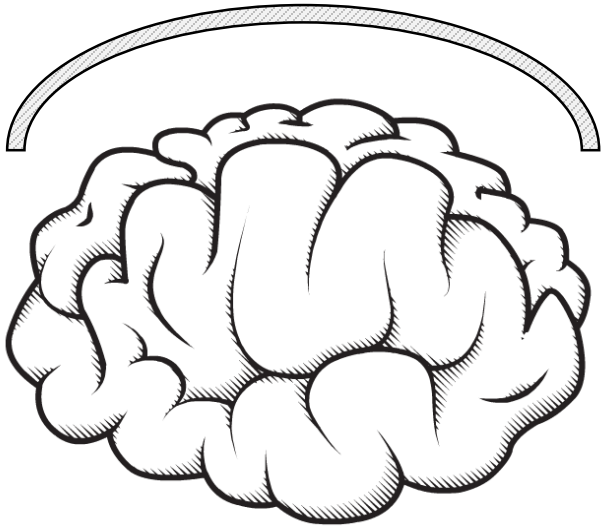
C. Jeunet, C. Benaroch, F. Cabestaing, R. Chavarriaga, E. Colamarino, M.-C. Corsi, D. Coyle, F. De Vico Fallani, S. Enriquez-Geppert, P. Figueirédo, M. Grosse-Wentrup, S. Kleih, S. Kober, A. Kübler, F. Lotte, E. Maby, D. Mattia, J. Mattout, G.R. Müller-Putz, S. Perdikis, L. Pillette, A. Riccio, S. Rimbert, A. Roc, R. N. Roy, R. Scherer, P. Seguin, H. Si-Mohammed, T. Tanaka, M. Tangermann, L. Tonin, A. Vourvopoulos, A. Vuckovic, G. Wood, S. Wriessnegger

Contact:

camillejeunet.wordpress.com
camille.jeunet@univ-tlse2.fr

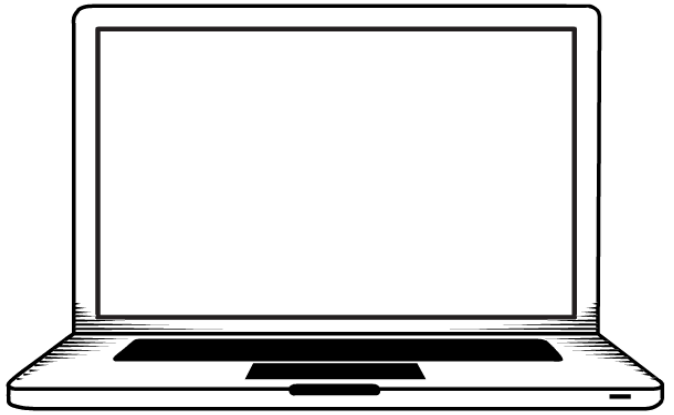
MT-BCIs, Mental Task-based BCIs

Human / / Machine



EEG patterns associated with a specific mental task

Feedback



For control applications:

MT-BCIs to control assistive technologies, video games & many others

[ImmersiveTech @ EPFL “Brain Controlled Wheelchair”]

[Inria Rennes - Project OpenViBE]

Beyond control applications:

Neurofeedback training to improve or recover cognitive / motor abilities

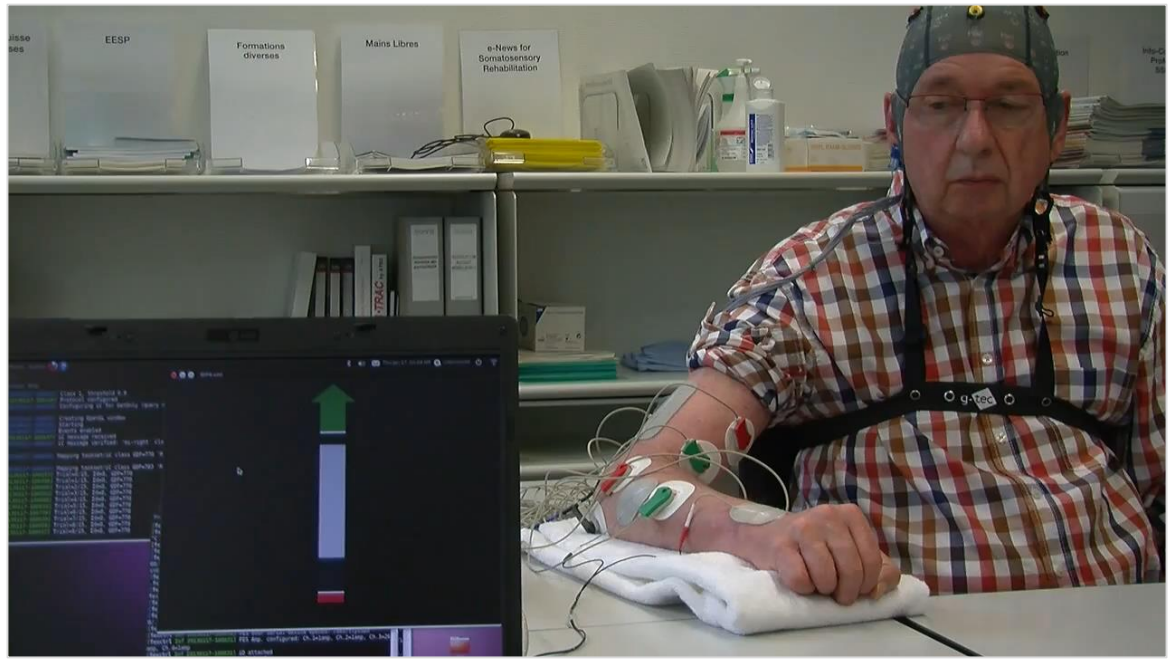
The New York Times

Olympians Use Imagery as Mental Training

Emily Cook, of the United States freestyle ski team, visualizes each aerial jump as part of her training for the Olympics. Javier Soriano/Agence France-Presse — Getty Images

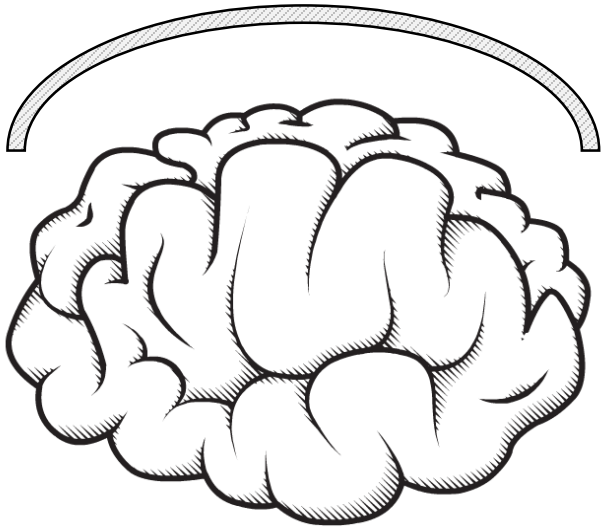
By Christopher Clarey

Feb. 22, 2014



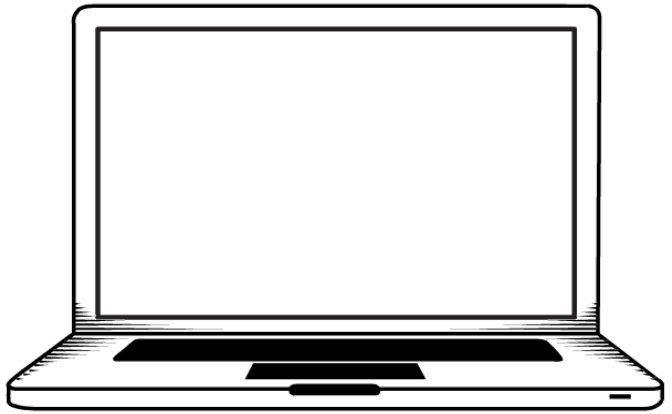
[EPFL News]

Human / / Machine



EEG patterns associated with a specific MI task

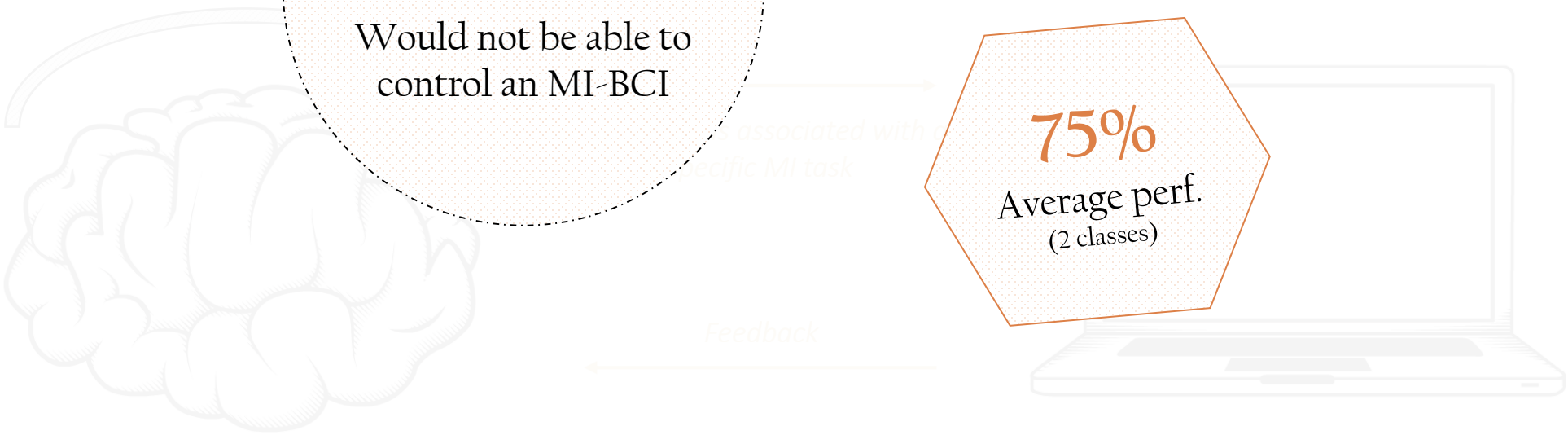
Feedback



Remain barely used: reliability issues

10-30%

Would not be able to control an MI-BCI



75%

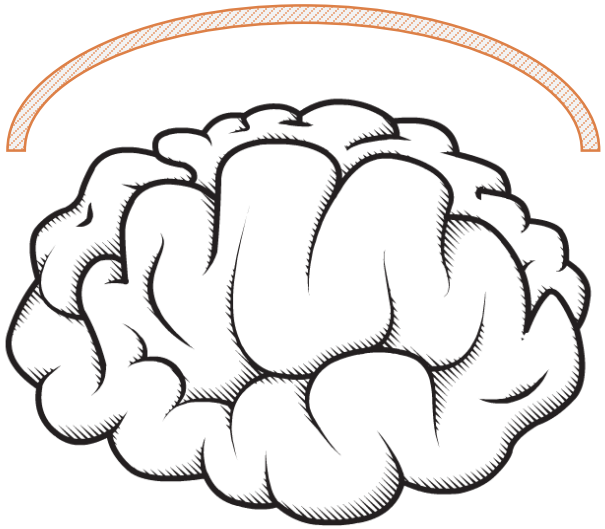
Average perf.
(2 classes)

[Allison & Neuper (2010)]

Remain barely used: reliability issues

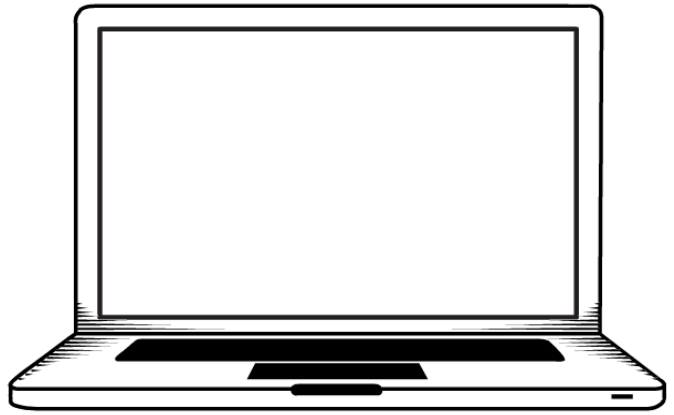
Human /

/ Machine



EEG patterns associated with a specific mental task

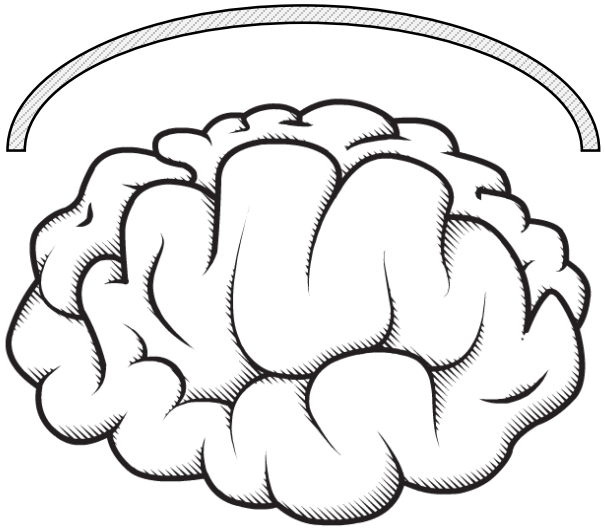
Feedback



Remain barely used: reliability issues

Human /

/ Machine



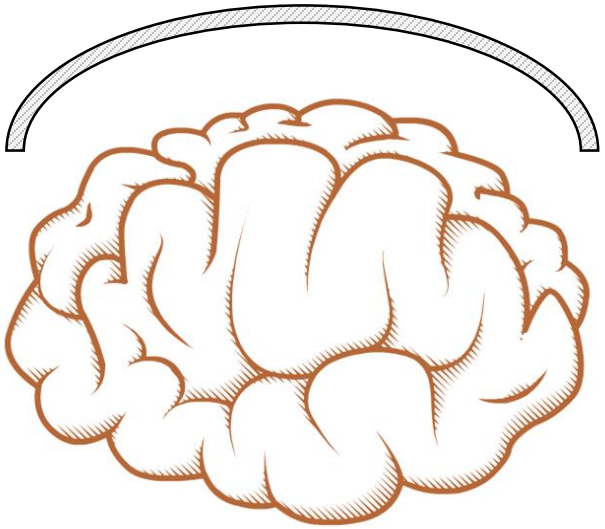
EEG patterns associated with a specific mental task

Feedback

Remain barely used: reliability issues

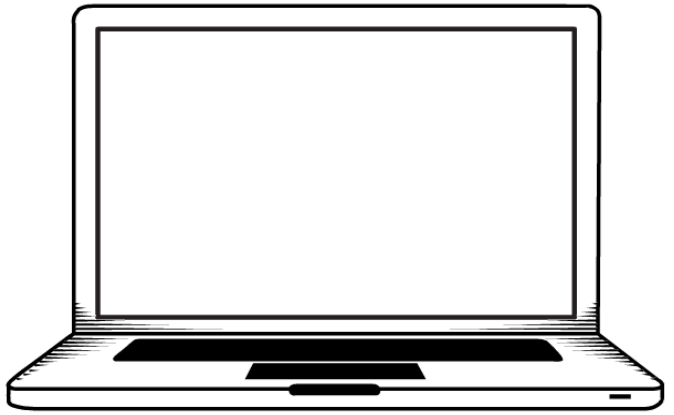
Human /

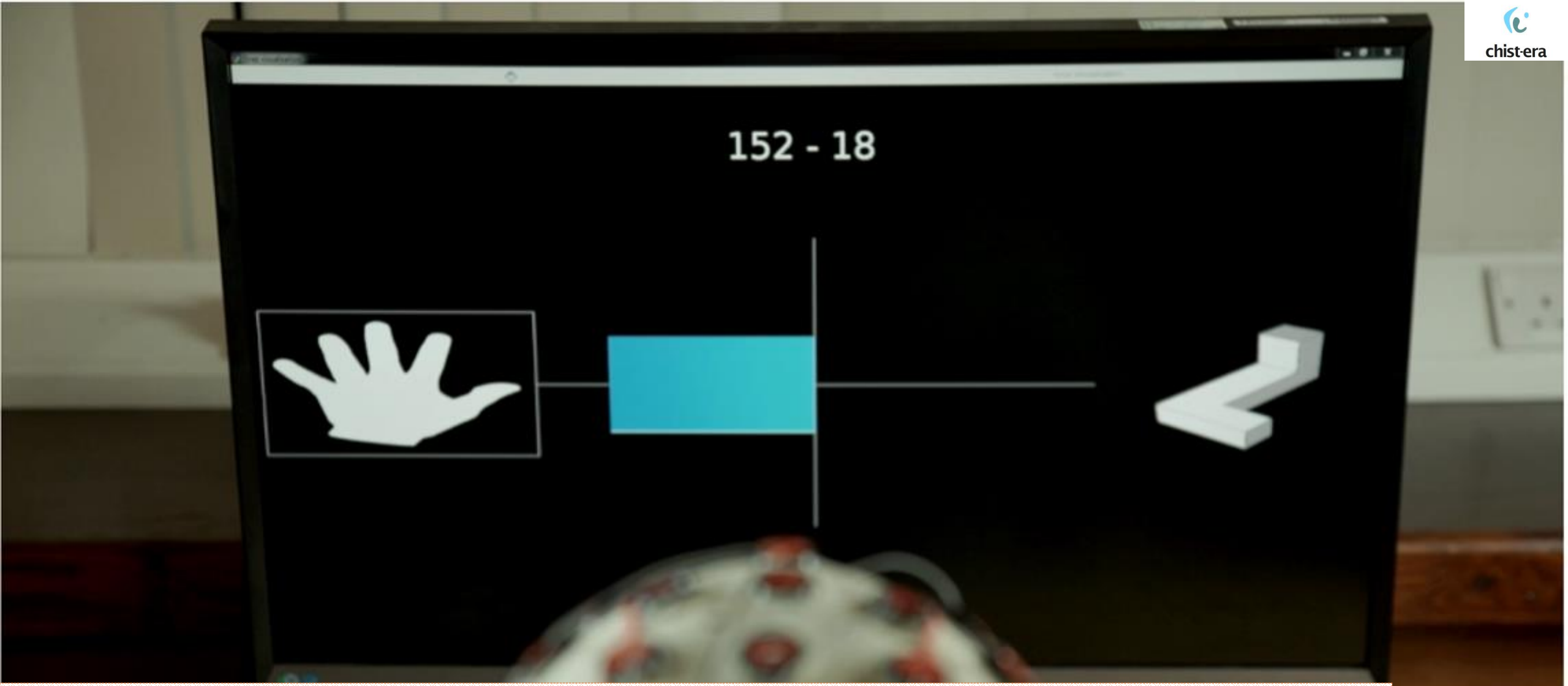
/ Machine



EEG patterns associated with a specific mental task

Feedback





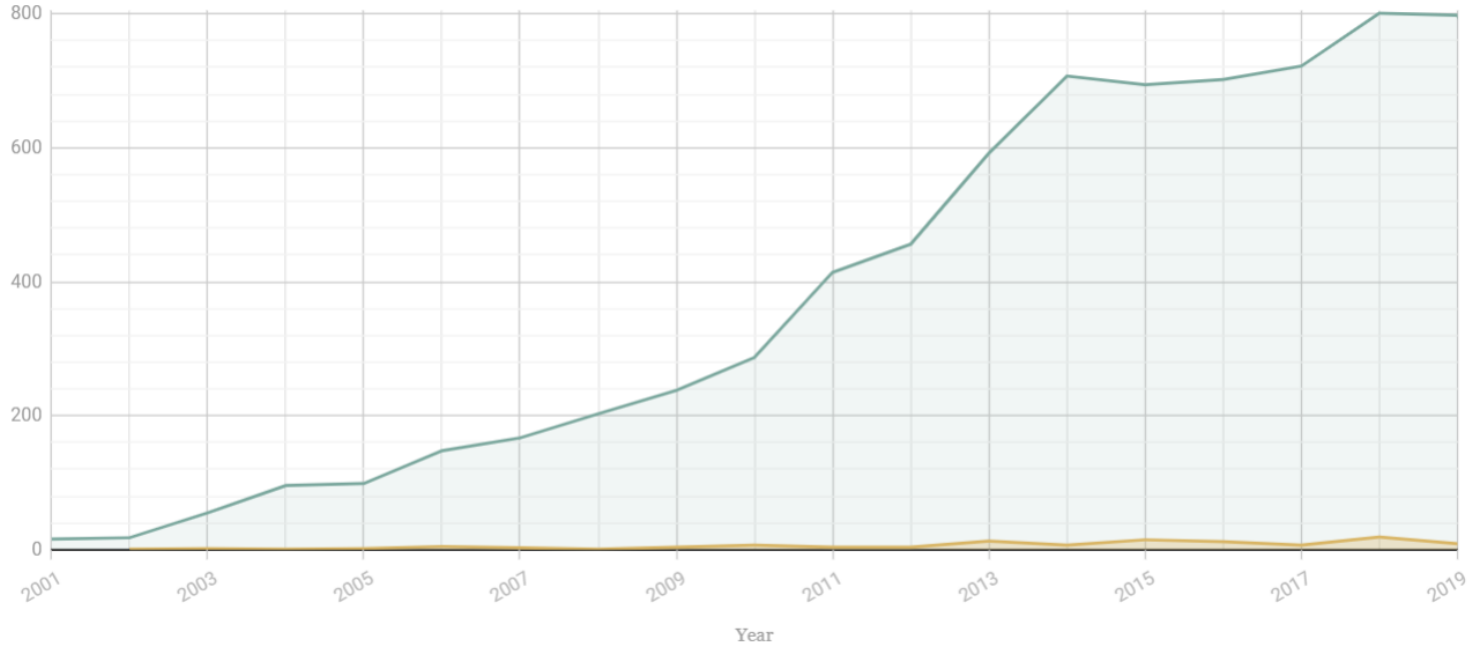
PROBLEM - do not enable MT-BCI users to reach adequate levels of performance

CHALLENGE - improving end-user training

Major challenge

Understanding BCI learning mechanisms and improving end-user training.

Yet, only a very small proportion of BCI research is dedicated to this primordial aspect.



Graph made by **Aline Roc**, representing the number of PubMed entries (including title and abstract) per year for:

- "BCI" [Brain computer interface(s) V brain machine interface(s) V direct neural interface(s)]
- "BCI" & "user learning" [User/human/participant training/learning V user/human/participant profile/trait(s) V learning curve V inefficiency V illiteracy]

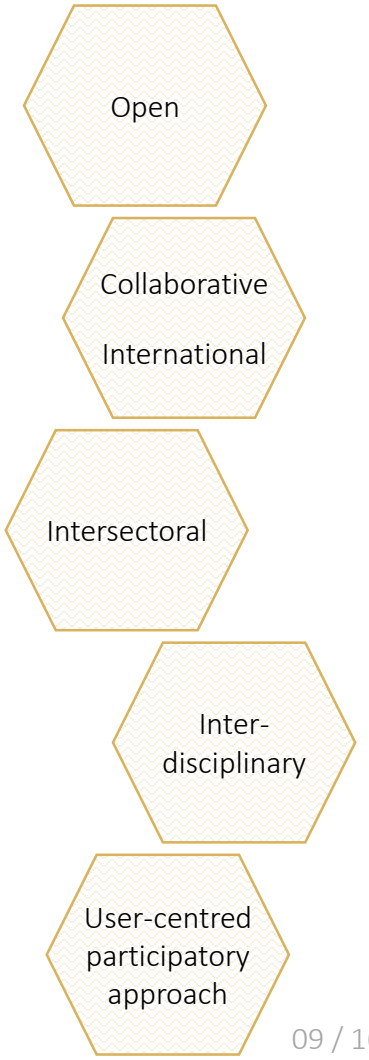
Objectives

Deepen our understanding of MT-BCI learning mechanisms

Design, implement and evaluate innovative MT-BCI training procedures (based on virtual reality and intelligent tutoring systems)

Improve the efficiency and reliability of MT-BCIs

Make MT-BCIs **useful, usable** and actually **used** for real-world, clinical and non-clinical, applications.



Objectives

METHODS

i. Design a rigorous MT-BCI training procedure based on the literature

ii. Collect a large database (100+ part., 20 sessions/part.)

iii. Analyse MT-BCI performance and learning, and their determinants

iv. Propose innovative and efficient training procedures (VR, ITS)

v. Apply in real-world applications

Deepen our understanding of MT-BCI learning mechanisms

↓

Design, implement and evaluate innovative MT-BCI training procedures (based on virtual reality and intelligent tutoring systems)

↓

Improve the efficiency and reliability of MT-BCIs

↓

Make MT-BCIs **useful, usable** and actually **used** for real-world, clinical and non-clinical, applications.

Open

Collaborative

International

Intersectoral

Inter-disciplinary

User-centred participatory approach

Consortium

AUSTRIA	Univ. Graz	Silvia Kober, Guilherme Wood
	Graz Univ. of Technology	Gernot Müller-Putz , Selina Wriessnegger
	Univ. Vienna	Moritz Grosse-Wentrup
FRANCE	CNRS Toulouse - Bordeaux	Camille Jeunet (project leader)
	Inria Bordeaux	Fabien Lotte
	Inria Paris	Fabrizio de Vico Fallani
	INSERM Lyon	Jérémie Mattout
	ISAE-Supaero Toulouse	Raphaëlle Roy
	Univ. Lille	François Cabestaing, Hakim Si-Mohammed
	Univ. Lorraine	Laurent Bougrain
GERMANY	Univ. Berlin	Benjamin Blankertz
	Univ. Oldenburg	Stefan Debener, Cornelia Kranczioch
	Unvi Würzburg	Sonja Kleih, Andrea Kübler
JAPAN	Tokyo Univ. of Tech. & Agr.	Toshihisa Tanaka
ITALY	Santa Lucia Roma	Donatella Mattia
	Univ. Padova	Luca Tonin
PORTUGAL	Univ. Lisbon	Patricia Figueiredo, Thanos Vourvopoulos
SWITZERLAND	Univ. Zürich	Ricardo Chavarriaga
THE NETHERLANDS	Univ. Groningen	Stefanie Enriquez-Geppert
	Donders' Institute	Michael Tangermann
UNITED KINGDOM	Univ. Essex	Reinhold Scherer, Simis Perdikis
	Univ. Glasgow	Aleksandra Vuckovic
	Univ. Ulster	Damien Coyle

We are happy to welcome new collaborations !

First steps

METHODS

i. **Design a rigorous MT-BCI training procedure based on the literature**

ii. Collect a large database (100+ part., 20 sessions/part.)

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v. Apply in real-world applications

Consultation of the consortium:

. Which research questions would each member of the consoritum like to tackle through the shared protocol?

. Rating of each question by each member of the consortium

. Ranking of the questions

First steps

METHODS

i. **Design a rigorous MT-BCI training procedure based on the literature**

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SUMMARY OF THE HIGHLIGHTED RESEARCH QUESTIONS: AVERAGE RATING, RATING DISTRIBUTION & PRIORISATION

Reminder: 1= priority ; 2 = interesting to consider, if possible ; 3 = cannot/should no be tackled in this protocol ; 4 = already (partially) answered or not relevant

Red = questions rated as a priority ; Blue = questions rated as less relevant or not a priority for this protocol

	MEAN	STD	Number of votes for each rating value:
---- USER LEARNING ---- (NF/BCI dose-response curve)	1,00	0,00	
What does the NF/BCI dose-response curve look like?	1,06	0,24	
How stable is performance within and between sessions?	1,32	0,58	
Does "BCI-illiteracy" really exist if we train the subjects long enough?	2,11	0,88	
How do ERD/ERS evolve with training, as a function of performance and progression?	1,53	0,77	
How could learning outcome be predicted? How many channels are needed?	1,74	0,73	
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)	1,58	0,67	
How do mental-imagery strategies relate to NF/BCI performance and learning success?	1,16	0,37	
Can they be used to predict/explain future performance?	2,21	0,85	
Do they influence the degree of lateralisation of measured EEG activity?	2,79	0,98	

...

A full description of the results is available in App. 1

First steps

METHODS

i. **Design a rigorous MT-BCI training procedure based on the literature**

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. Ranking of the questions

. Identification of the protocol requirements so that the most important questions can be rigorously investigated

First steps

METHODS

i. **Design a rigorous MT-BCI training procedure based on the literature**

ii. Collect a large database (100+ part., 20 sessions/part.)

iii. Analyse MT-BCI performance and learning, and their determinants

iv. Propose innovative and efficient training procedures (VR, ITS)

v. Apply in real-world applications

Identification of design requirements as a function of the different questions, rated as "first-order" and "second-order" priorities

	FIRST-ORDER QUESTIONS		*Requirements regarding the design to investigate this question*	*Design Specifications*
	---- USER LEARNING ---- (NF/BCI dose-response curve)	*1,00*		
1	What does the NF/BCI dose-response curve look like?	1,06	. Large number of sessions	. N-sessions = ~10 with 2 sessions per week (survey : 20 sessions = ok for half, too high for half)
2	How stable is performance within and between sessions?	1,32	. Large number of sessions, and runs / session	. N-runs/session = total duration of the BCI training: ~45-60min
4	How do ERD/ERS evolve with training, as a function of performance and progression?	1,53	. Performance and progression metrics	. *Offline analyses*
5	How could learning outcome be predicted? How many channels are needed?	1,74	. "Predicting factors"	. *Offline analyses*
	---- COGNITIVE STRATEGIES ---- (mental imagery strategies)	*1,58*		
6	How do mental-imagery strategies relate to NF/BCI performance and learning success?	1,16	. Record / Collect mental strategies	. Phenomenological interviews, at the beginning and end of the training procedure? + Frequent video recordings & verbalisation of the strategies (random experiment sampling?)

...

	SECOND-ORDER QUESTIONS		*Can be answered through the design chosen to answer the first-order questions:*	*Should we modify the design to investigate specifically this question? If yes, how?*
	---- USER LEARNING ---- (NF/BCI dose-response curve)	*1,00*		
3	Does "BCI-illiteracy" really exist if we train the subjects long enough?	2,11	. YES (large number of sessions - Q1 & Q2)	-
	---- COGNITIVE STRATEGIES ---- (mental imagery strategies)	*1,58*		
7	Can they be used to predict/explain future performance?	2,21	. YES (the cognitive strategies are collected - Q6)	-
8	Do they influence the degree of lateralisation of measured EEG activity?	2,79	. YES (the cognitive strategies are collected - Q6) . But specific to motor imagery	-

A full description of the results is available in App. 2.1 and 2.2

First steps

METHODS

i. **Design a rigorous MT-BCI training procedure based on the literature**

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Consultation of the consortium:

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. Rating of each question by each member of the consortium

. Ranking of the questions

. Identification of the protocol requirements so that the most important questions can be rigorously investigated

Constitution of a design group and thematic subgroups:

. Based on the general outline of the protocol, we are now working on assessment (**A. Kübler***), instructions (**S. Enriquez-Geppert***), machine learning (**R. Scherer***), interface (**F. Lotte***) and transfer (**D. Coyle***) aspects of the protocol.

* sub-group leaders

Next steps

METHODS

i. *Design a rigorous MT-BCI training procedure based on the literature*

ii. Collect a large database (100+ part., 20 sessions/part.)

iii. Analyse MT-BCI performance and learning, and their determinants

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WE NEED SUPPORT:

. To strengthen our consortium still further

. To implement the protocol and open database

. To include participants in all the partners' labs

. To analyse the data and extract from them innovative research avenues in terms of MT-BCI training procedures

. To foster international, interdisciplinary and intersectoral collaborations

. To transfer this new and indispensable knowledge to real-world applications and promote MT-BCI technologies

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Thank you!

A user-centred approach to unlock the potential of non-invasive BCIs:

An unprecedented international translational effort -

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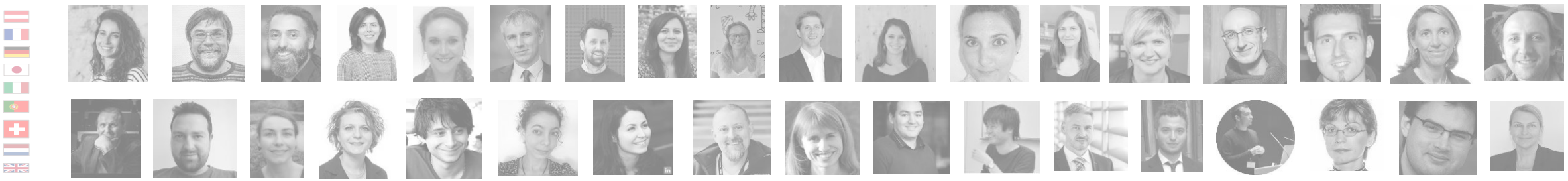
camillejeunet.wordpress.com // camille.jeunet@univ-tlse2.fr

MAJOR CHALLENGE

Collaborating using an **open-science** and **interdisciplinary** approach in order to deepen our understanding of MT-BCI **user learning mechanisms** and to design **innovative and efficient training procedures**.

This step is essential for BCIs to be **useful, usable and actually used** out-of-the-lab, both for clinical and non-clinical applications.



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How do ERD/ERS evolve with training, as a function of performance and progression?	1,53	0,77	
How could learning outcome be predicted? How many channels are needed?	1,74	0,73	
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)	1,58	0,67	
How do mental-imagery strategies relate to NF/BCI performance and learning success?	1,16	0,37	
Can they be used to predict/explain future performance?	2,21	0,85	
Do they influence the degree of lateralisation of measured EEG activity?	2,79	0,98	
Do MI strategies (and underlying EEG features) relate to the states of the user?	1,89	0,74	
Can BCI operation automatise? (i.e., proceduralisation)	2,32	0,82	
---- USER PROFILE ---- (demographical, psycho, cog & neurophy factors)	1,33	0,49	
How does the user profile relate to BCI/NF performance?	1,53	0,70	
Does it (partly) explain between-subject variations in terms of performance and learning abilities?	1,47	0,70	
---- MACHINE LEARNING ----(decoder/classifier/performance metrics)	2,17	0,58	
Is it more relevant/efficient to fixate the classifier or to regularly update it?	2,06	0,73	
Are classifiers actually efficient to favour learning? How to ensure that they are?	1,89	0,76	
Are the classifier's features robust to variations of the user's state (fatigue, workload)?	2,28	0,67	
How to design/train decoders that are stable across subjects and sessions?	1,72	0,57	
How, when, how often to retrain the classifier? (stability/flexibility tradeoff, coadaptation)	2,39	0,61	
What are the most suitable metrics for characterising BCI/NF performance and skill acquisition?	1,39	0,50	
Would transfer-learning approaches enable a faster user learning?	2,44	0,62	
---- TRAINING PROCEDURE ---- (instructions, tasks, training environment, fb)	1,91	0,70	
Does the design of the training procedure influence BCI/NF performance and learning?	2,00	0,88	
What kind of instructions should be provided?	1,67	0,84	
In there any gain in BCI performance/learning/user-experience from the step-wise approach ?	2,17	0,62	
Do VR/AR-based training environments favour learning?	3,22	0,81	
Is multimodal better than unimodal feedback?	2,89	0,90	

Identification of design requirements as a function of the different questions, rated as "first-order" and "second-order" priorities

FIRST-ORDER QUESTIONS			*Requirements regarding the design to investigate this question*	*Design Specifications*
---- USER LEARNING ---- (NF/BCI dose-response curve)		*1,00*		
1	What does the NF/BCI dose-response curve look like?	1,06	. Large number of sessions	. N-sessions = ~10 with 2 sessions per week (survey : 20 sessions = ok for half, too high for half)
2	How stable is performance within and between sessions?	1,32	. Large number of sessions, and runs / session	. N-runs/session = total duration of the BCI training: ~45-60min
4	How do ERD/ERS evolve with training, as a function of performance and progression?	1,53	. Performance and progression metrics	. *Offline analyses*
5	How could learning outcome be predicted? How many channels are needed?	1,74	. "Predicting factors"	. *Offline analyses*
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)		*1,58*		
6	How do mental-imagery strategies relate to NF/BCI performance and learning success?	1,16	. Record / Collect mental strategies	. Phenomenological interviews, at the beginning and end of the training procedure? + Frequent video recordings & verbalisation of the strategies (random experiment sampling?)
---- USER PROFILE ---- (demographical, psychological, cognitive & neurophysiological factors)		*1,33*		
11	How does the user profile relate to BCI/NF performance?	1,53	. Assessment of the user profile	. Psychometric questionnaires : we will use some, to be determined later
12	Does it (partly) explain between-subject variations in terms of performance and learning abilities?	1,47	. Assessment of user traits	. What, when, how? (fatigue, perceived difficulty, ...), also to be determined later
---- MACHINE LEARNING ----(decoder/classifier/performance metrics)		*2,17*		
16	How to design/train decoders that are stable across subjects and sessions?	1,72		. *Offline analyses*
18	What are the most suitable metrics to characterise BCI/NF performance & skill acquisition?	1,39	. Transfer task at the end > depending on the focus (learning vs	. Transfer task at the end (potentially 2 different ones) + *Offline analyses*
---- TRAINING PROCEDURE ---- (instructions, tasks, training environment, fb)		*1,91*		
21	What kind of instructions should be provided?	1,67	. Should be exactly the same for all the participants	. Definition of one instruction and translation into 4 languages (english french german italian)

SECOND-ORDER QUESTIONS			*Can be answered through the design chosen to answer the first-order questions:*	*Should we modify the design to investigate specifically this question? If yes, how?*
---- USER LEARNING ---- (NF/BCI dose-response curve)		*1,00*		
3	Does "BCI-illiteracy" really exist if we train the subjects long enough?	2,11	. YES (large number of sessions - Q1 & Q2)	-
---- COGNITIVE STRATEGIES ---- (mental imagery strategies)		*1,58*		
7	Can they be used to predict/explain future performance?	2,21	. YES (the cognitive strategies are collected - Q6)	-
8	Do they influence the degree of lateralisation of measured EEG activity?	2,79	. YES (the cognitive strategies are collected - Q6) . But specific to motor imagery	-
9	Do MI strategies (and underlying EEG features) relate to the states of the user?	1,89	. YES (te cognitive strategies are collected - Q6, together with the reported users' states - Q12)	-
10	Can BCI operation automatise? (i.e., proceduralisation)	2,32	. YES (the cognitive strategies are collected - Q6)	-
---- USER PROFILE ---- (demographical, psychological, cognitive & neurophysiological factors)		*1,33*		
---- MACHINE LEARNING ---- (decoder/classifier/performance metrics)		*2,17*		
13	Is it more relevant/efficient to fixate the classifier or to regularly update it?	2,06	. NO	. NO - *it is not the purpose of this experimentation*
14	Are classifiers actually efficient to favour learning? How to ensure that they are?	1,89	. NO	. NO - *it is not the purpose of this experimentation*
15	Are the classifier's features robust to variations of the user's state (fatigue, workload)?	2,28	. PARTIALLY - As we will regularly assess the users' states (Q12), we might be able to answer this question for the specific classifier that we will use	-
17	How, when, how often to retrain the classifier? (stability/flexibility tradeoff, coadaptation)	2,39	. NO	. NO - *it is not the purpose of this experimentation*
19	Would transfer-learning approaches enable a faster user learning?	2,44	. NO	. NO - *it is not the purpose of this experimentation*
---- TRAINING PROCEDURE ---- (instructions, tasks, training environment, fb)		*1,91*		
20	Does the design of the training procedure influence BCI/NF performance and learning?	2,00	. NO	. NO - Would require 2 groups - as the most important question is about the learning (and not about proving that one design is better than another) we will not investigate this question
22	Is there any gain in BCI performance/learning/user-experience from the step-wise approach ?	2,17	. NO	. NO - Would require a control group, not the main object (+ it would be too difficult to design the protocol for the control group)
23	Do VR/AR-based training environments favour learning?	3,22	. NO	. NO - *it is not the purpose of this experimentation- too specific*
24	Is multimodal better than unimodal feedback?	2,89	. NO	. NO - *it is not the purpose of this experimentation- too specific*