Cognitive Behavioral Assistive Technology

PRARIE Workshop at RIKEN AIP
March 20, 2023

Mihoko Otake,
Alexandra Wolf, Tomasz M. Rutkowski
RIKEN AIP, Japan

3 and 7 years-old sons, her husband, and herself got infected by flu…

Mihoko Otake

- Team Leader, Cognitive Behavioral Assistive Technology (CBAT) Team, RIKEN Center for Advanced Intelligence Project (AIP)

On behalf of the CBAT team, we, Ola and Tomek, present our works.

Otake Lab.

Interdisciplinary CBAT Team

Team Leader

Researchers

Technical Support and Part-timer

Names

Takata

Machida

Kumagai

Fukumori

Miyake

Kogure

Tamura

Taira

Murata

Suzuki

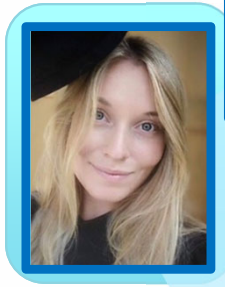
Iwata

Umemoto

Mizutani

Older Adults(8)

1. Conversation Supportive System



2. Analysis Methods

3. Evaluation of the Effects

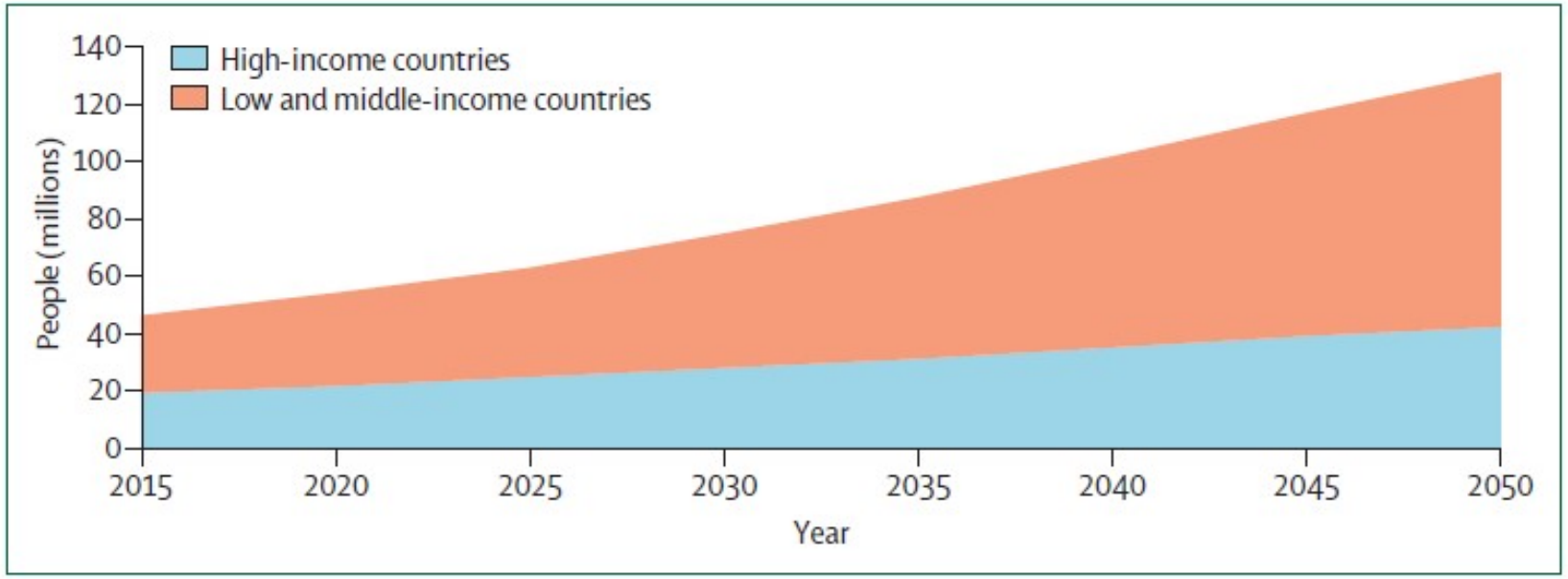
-2021fy

-2019fy

- Mathematical Biology, Mathematical Sociology, Software Engineering, Cognitive Neuroscience, Neural Technology, Public Health, Human Computer Interaction, Robotics, AI

CBAT Team

Significance



Livingston et al. 2017, Figure1

- The number of people with dementia is rising rapidly, primarily due to worldwide ageing populations, particularly in low and middle-income countries (LMICs).
- Mastering the challenges associated with aged societies in general, and those associated with age-related brain disabilities, is therefore of critical global importance.

Goal

- Cognitive Behavioral Therapy (CBT)

  +

- Assistive Technology (AT)

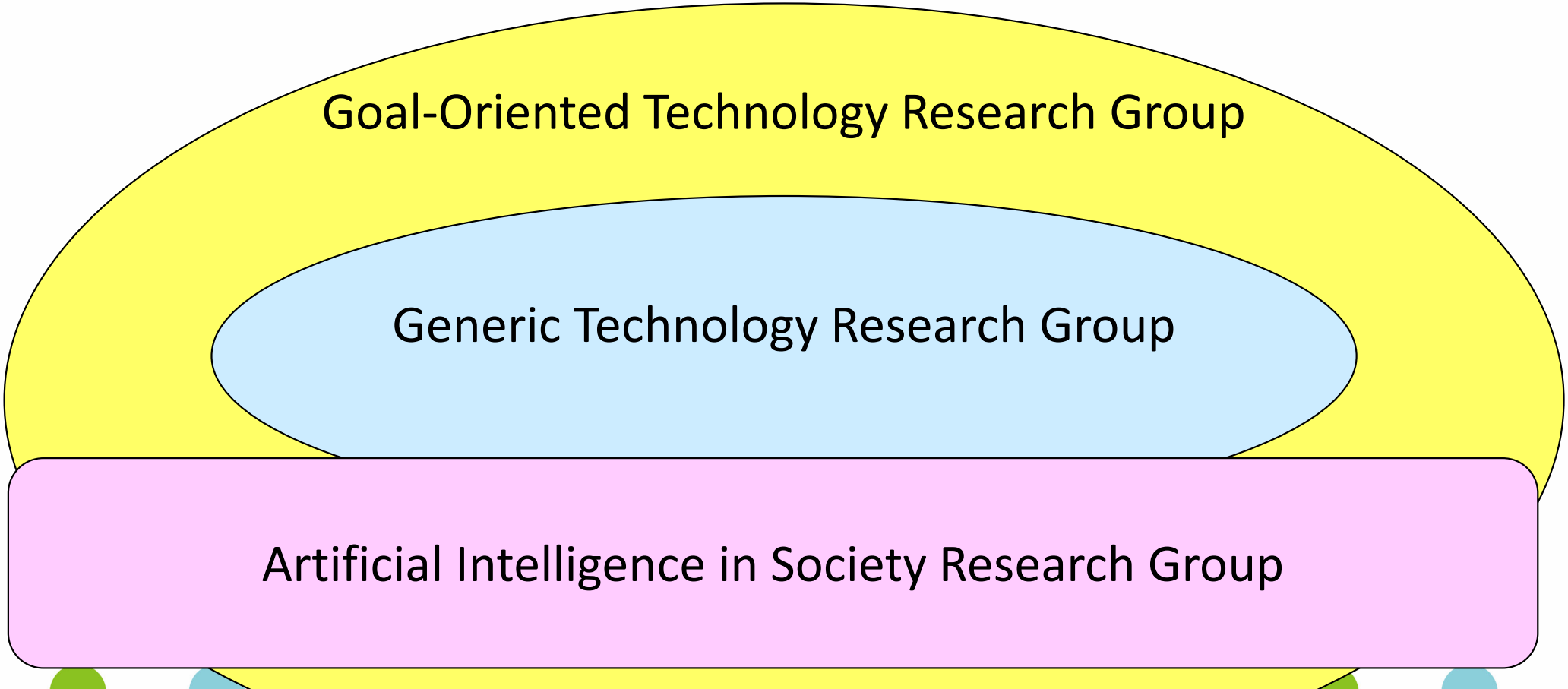
  =

Cognitive Behavioral Assistive Technology (CBAT)(2017-)

- To develop CBAT which promotes cognitive health for preventing cognitive decline and dementia among older adults which make it difficult for humans to function in society
- To develop technology for social activity intervention

RIKEN Center for Advanced Intelligence Project (AIP)

- AIP was founded in 2016 as a research center for the MEXT-AIP Project. I joined AIP in 2017.



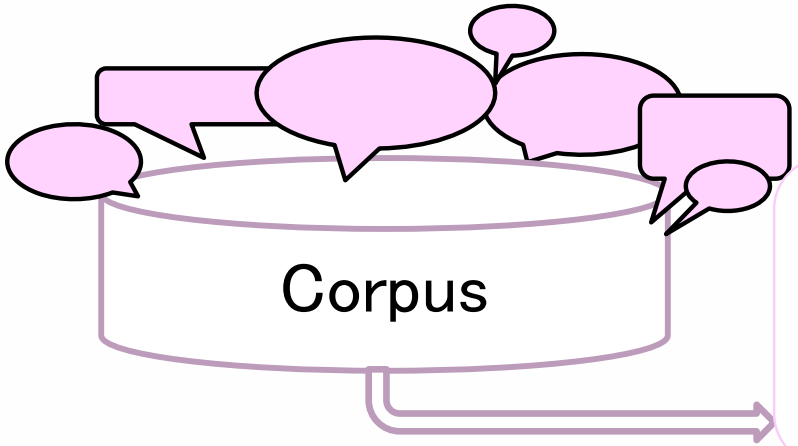
Impact

- While a systematic review found that social activity intervention may help maintain cognitive function among healthy older adults (Kelly et al., 2017), there are no global recommendations for social activity interventions related to cognitive health because evidence of the impact of such intervention is limited (World Health Organization, 2019).

- One major reason was the lack of technology for generating quantitatively and qualitatively consistent social activities necessary for cognitive intervention.

Cognitive Behavioral Assistive System with Conversational Assistive AI

Conversation data



Turn Taking Assistance

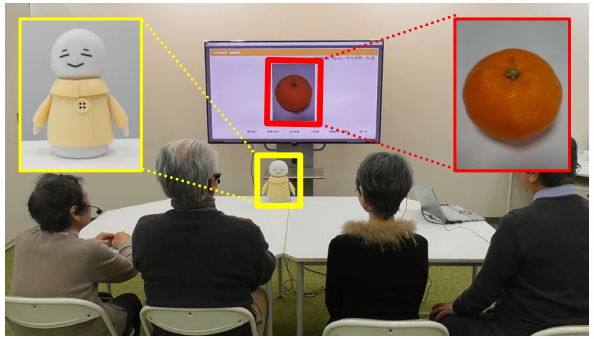
Laughter Assistance

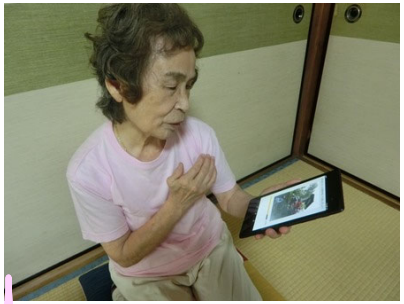
Web Server

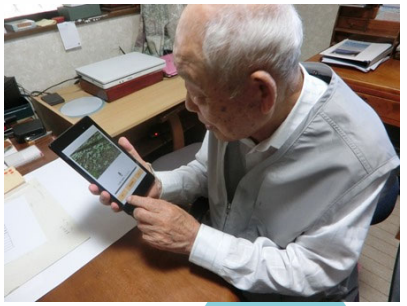
Conversational assistive AI

Application

COVID pandemic





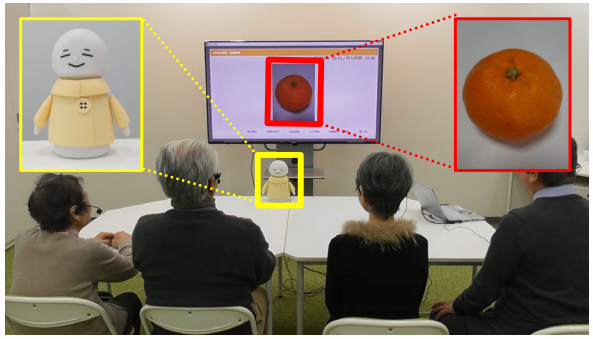


Group Conversation

Dialogue Robot

Remote Communication

Cognitive Intervention through Photo-Integrated Conversation Moderated by Robots (PICMOR) Program: A Randomized Controlled Trial (Otake-Matsuura et al. 2021)



frontiers in Robotics and AI

CLINICAL TRIAL
published: 12 April 2021
doi: 10.3389/frobt.2021.633076

Cognitive Intervention Through Photo-Integrated Conversation Moderated by Robots (PICMOR) Program: A Randomized Controlled Trial

Mihoko Otake-Matsuura[1]*, *Seiki Tokunaga*[1], *Kumi Watanabe*[1], *Masato S. Abe*[1], *Takuya Sekiguchi*[1], *Hikaru Sugimoto*[1], *Taishiro Kishimoto*[1,2] and *Takashi Kudo*[1,3]

[1]Center for Advanced Intelligence Project, RIKEN, Chuo-ku, Japan, [2]Department of Neuropsychiatry, School of Medicine, Keio University, Tokyo, Japan, [3]Department of Psychiatry, Graduate School of Medicine, Osaka University, Suita, Japan

OPEN ACCESS

Edited by:
Hidenobu Sumioka,

Social interaction might prevent or delay dementia, but little is known about the specific

- Otake-Matsuura M et al (2021)

  Frontiers in Robotics and AI, 8:633076.
  https://doi.org/10.3389/frobt.2021.633076

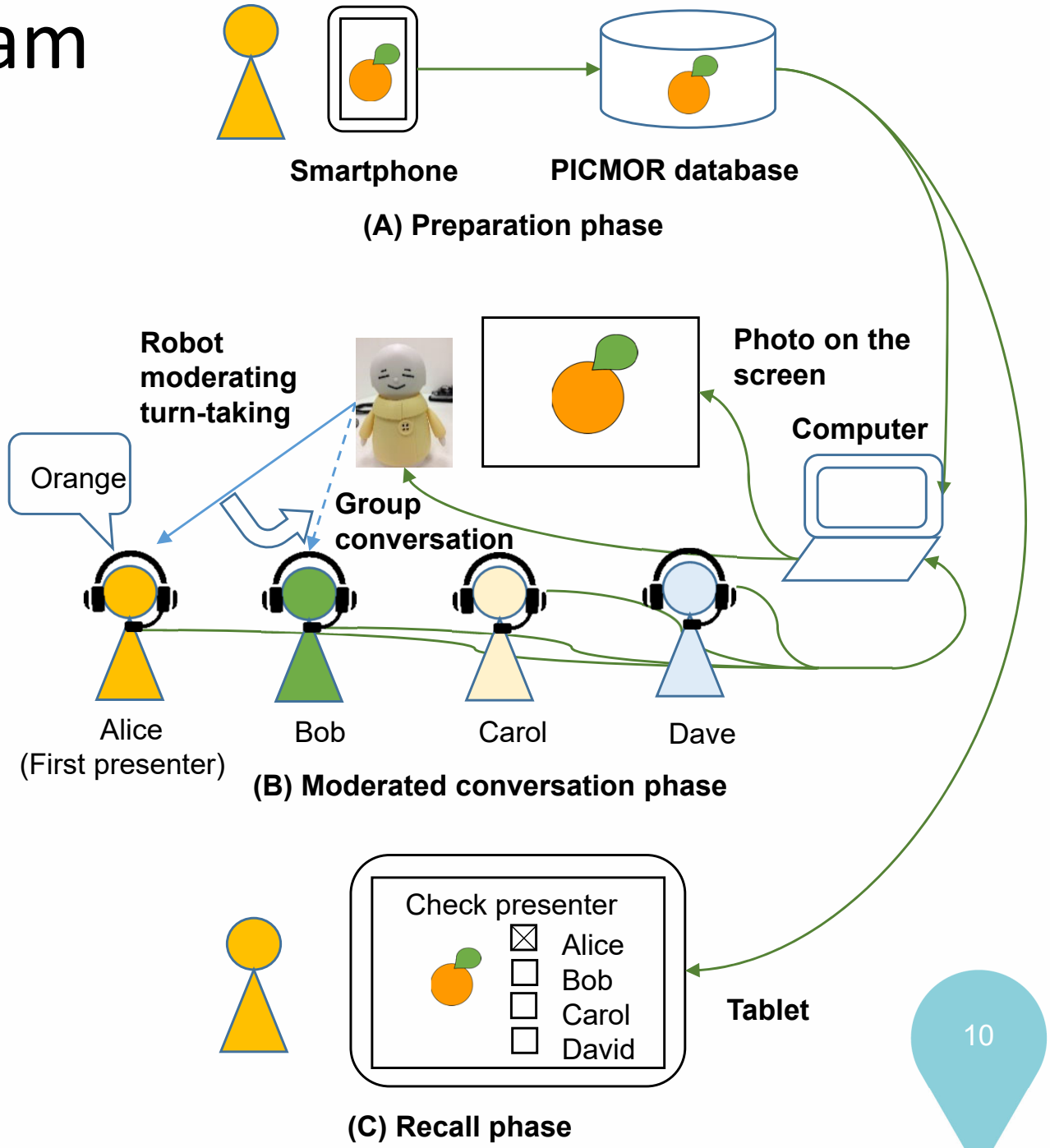
[Otake-Matsuura et al. 2021]

PICMOR Program (Fig. 2)

Preparation: Taking Photos based on Themes

Conversation: Talk and Q&A with Photos

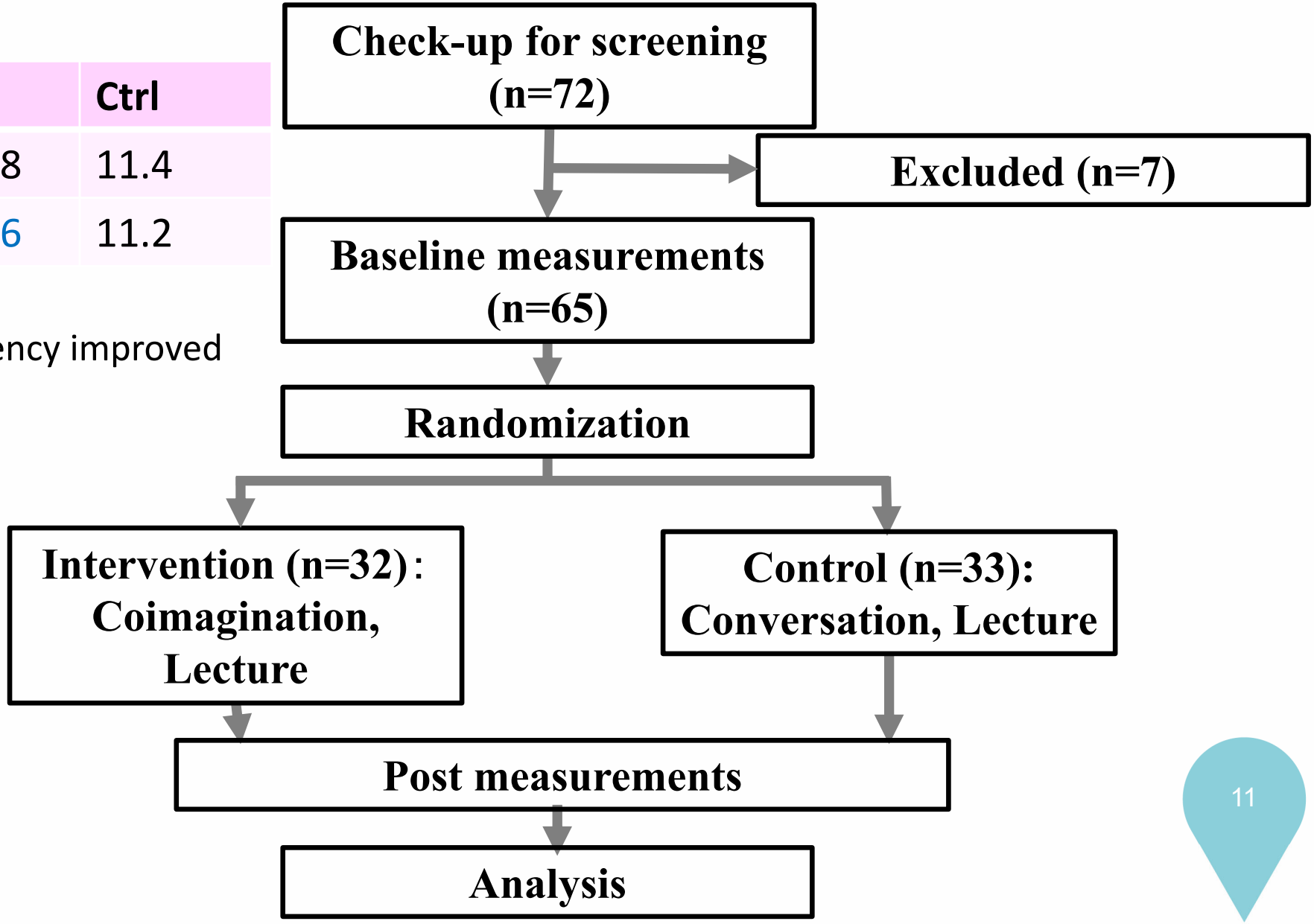
Recall: Immediate and Delayed the Photos and Talks



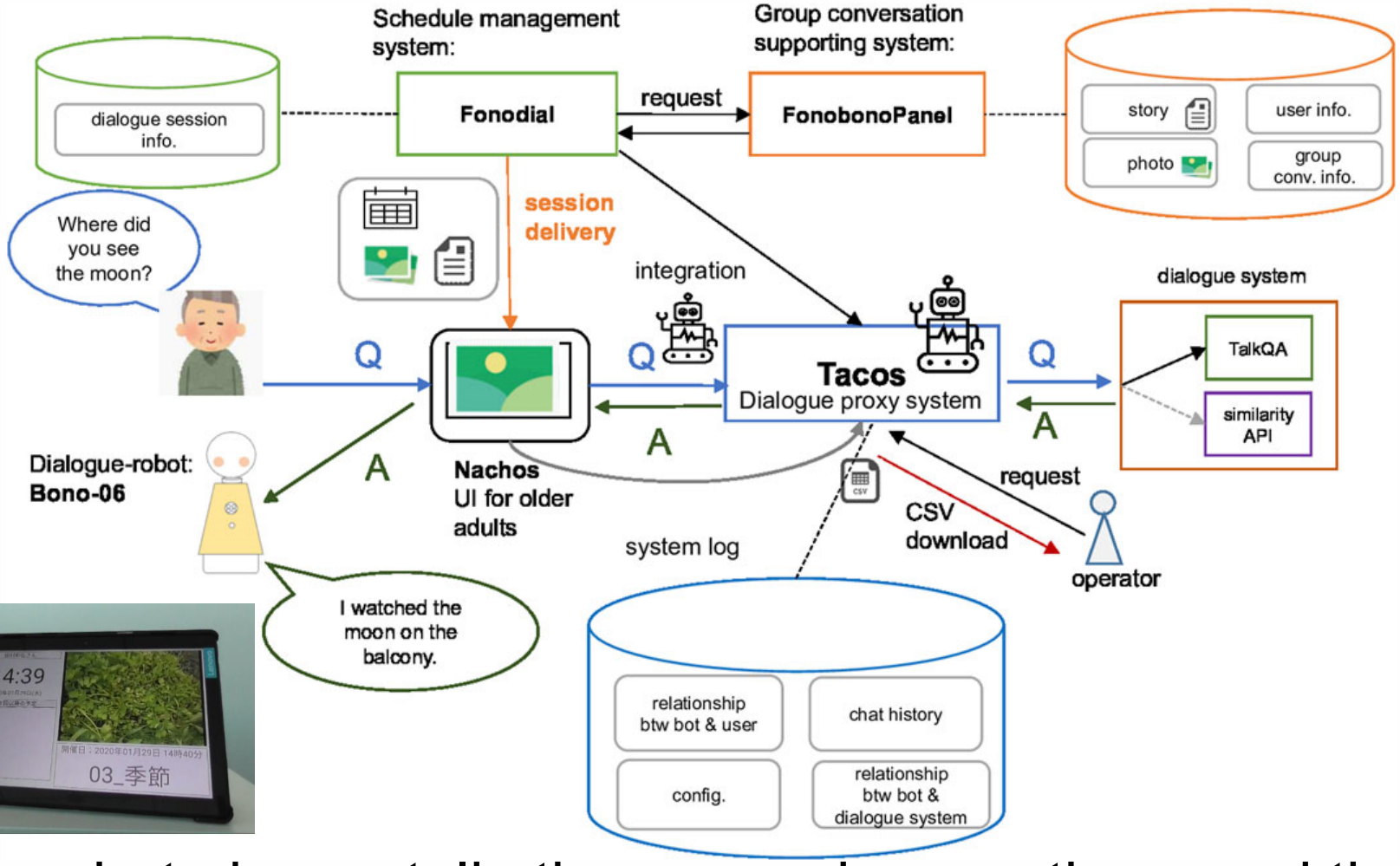
CONSORT Flow Diagram of RCT (Fig.1)

	Int	Ctrl
Pre	11.8	11.4
Post	13.6	11.2

Verbal fluency improved

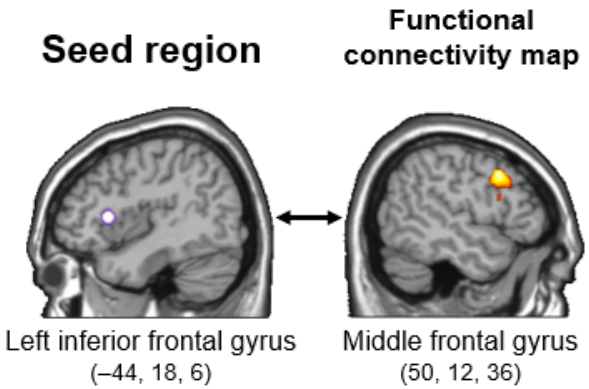


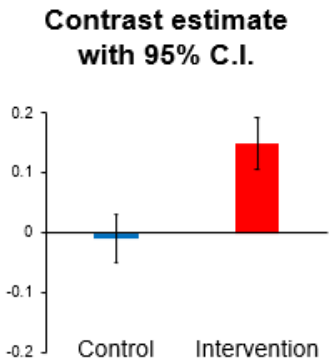
A Dialogue-Based System with Photo and Storytelling for Older Adults: Toward Daily Cognitive Training (Tokunaga, Tamura, Otake-Matsuura 2022)

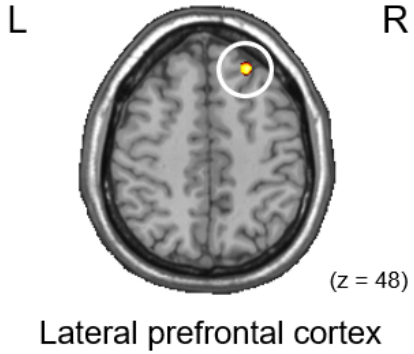


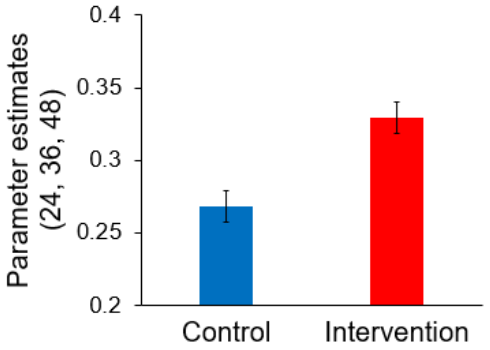
- The robot gives a talk, the user asks questions, and the robot answers for cognitive intervention through dialogue.

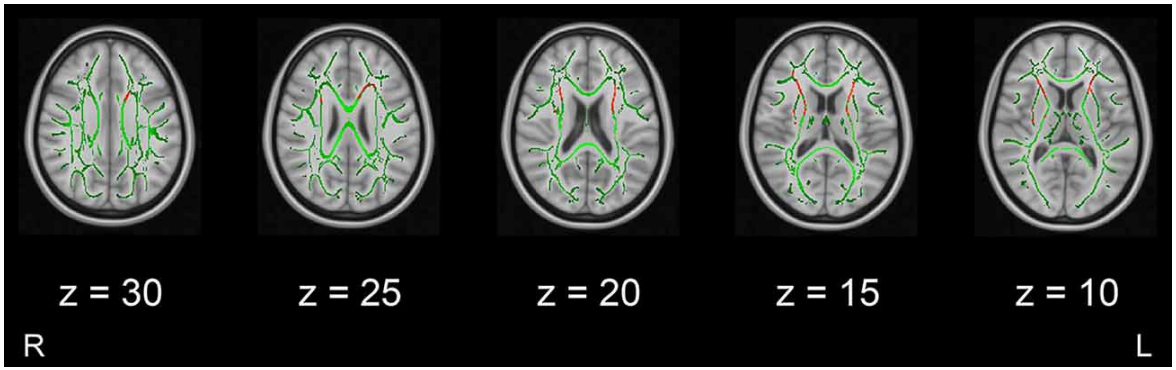
MRI Studies on the Effect of PICMOR









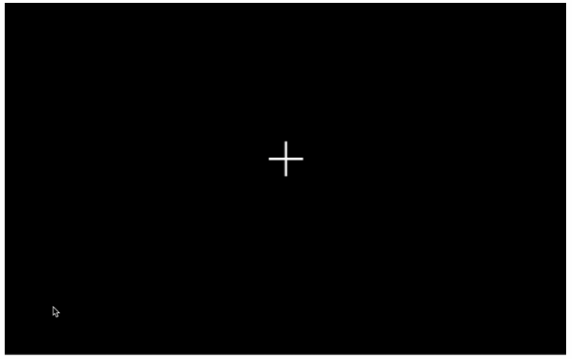


- Resting-state functional connectivity (2020)
- Voxel-based morphometry (2022)
- Tract-Based Spatial Statistics Analysis of Diffusion Tensor Imaging (2022)

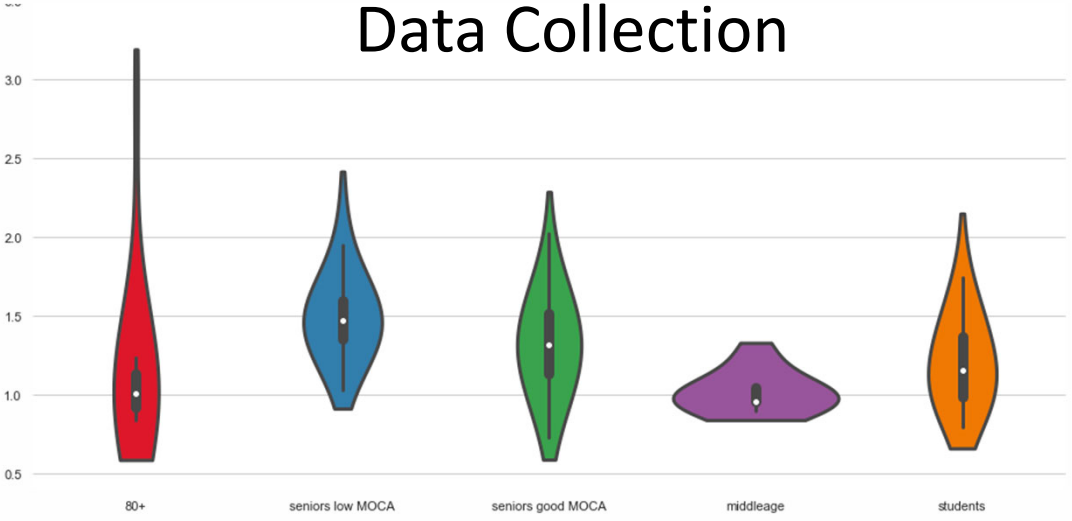
[Rutkowski et al. 2021]

Neurotechnology and Machine-learning Approaches to Early Dementia Onset Biomarker Development

- We develop a digital dementia biomarker for early-onset forecast.
- We have conducted EEG-wearable-based signal analysis and subsequent classification through the applications of machine learning (ML) methods.



Cognitive Task Design



Achievements

By 2023, we have succeeded in developing

- Novel technologies which enable cognitive intervention through social activities in older adults with evidence
- Novel technologies to predict cognitive functions from different modalities of behavioral and/or physiological data

AIP Open Seminar #43

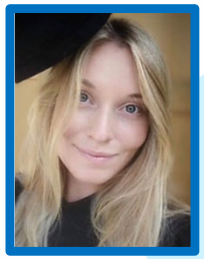
- Abstracts, references and movies related to today's talk
- https://aip.riken.jp/video/aip-open-seminar-43/

Call for Internship and Open Positions

Takata
Machida
Kumagai
Fukumori
Miyake
Kogure
Tamura
Taira
Murata
Suzuki
Iwata
Umemoto
Mizutani
Older Adults(8)

Team Leader
Researchers
Names
Technical Support and Part-timer

1. Conversation Supportive System



2. Analysis Methods

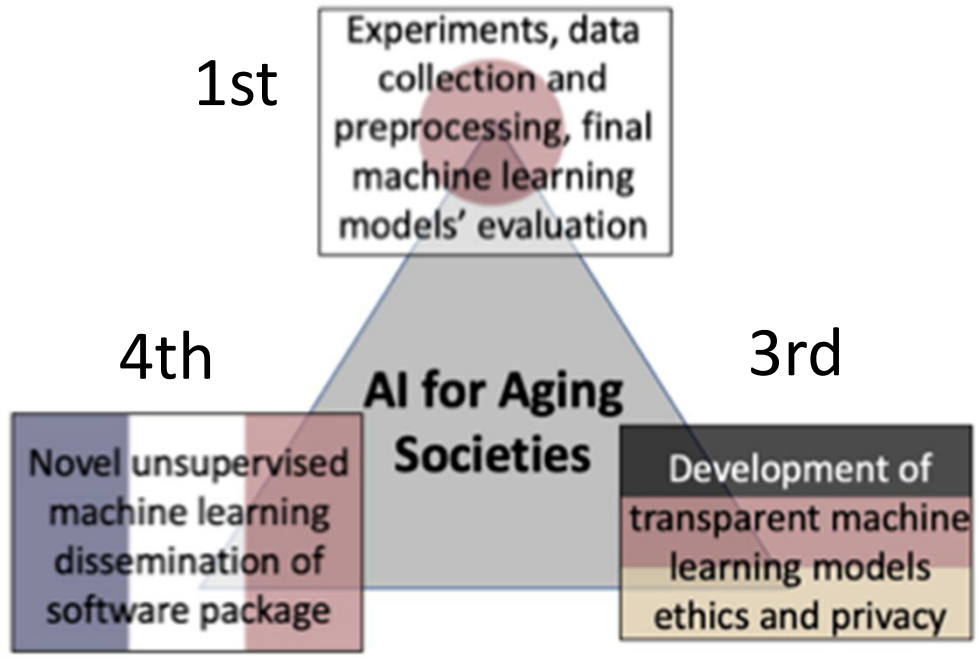
3. Evaluation of the Effects

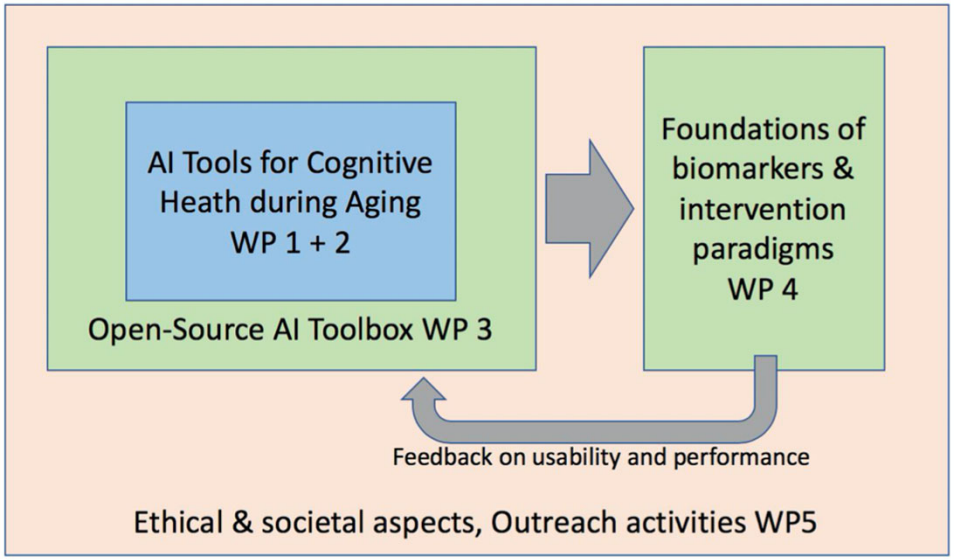
-2021fy

-2019fy

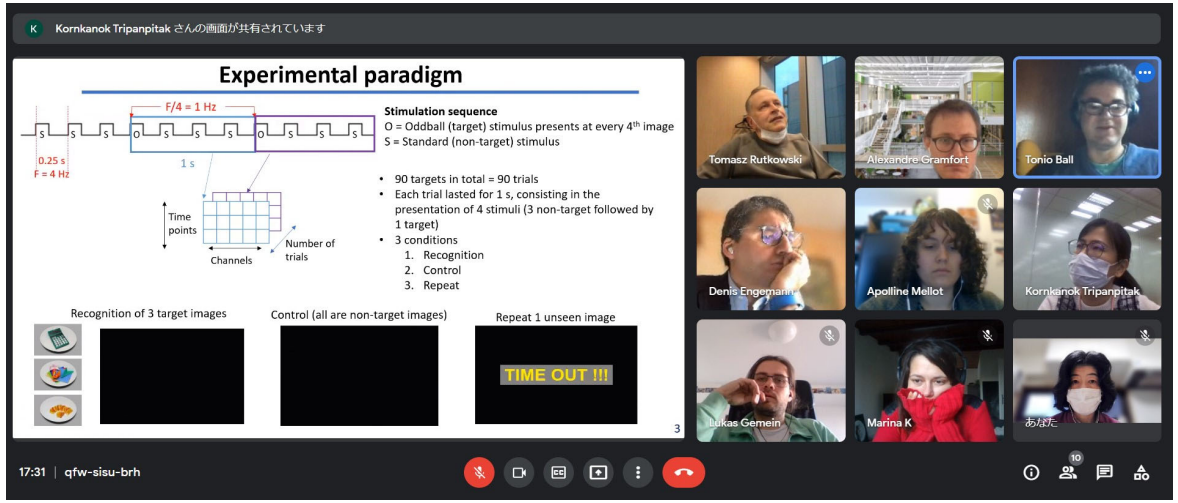
- Mathematical Biology, Mathematical Sociology, Software Engineering, Cognitive Neuroscience, Neural Technology, Public Health, Human Computer Interaction, Robotics, AI

Trilateral Project (2020-): AI for Aging Societies





Proportion of Aging Population



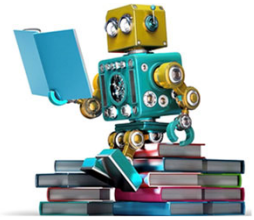
AI-Cog

Mihoko Otake[1], Tomasz M. Rutkowski[1],Tonio Ball[2],
Thomas Moreau[3], Alexandre Gramfort[3]
[1]Riken AIP Japan, [2]Uni. Freiburg Germany, [3]Inria France

Research objectives of AI-Cog

- Japan (#1), France (#3) and Germany (#4) belong to the top five countries worldwide with the ***highest proportion of people over the age of 65 years.***

- Identify ***machine-learning-driven biomarkers*** *to evaluate* ***cognitive interventions*** *as well as to* ***support personalized therapies*** *for* ***healthy aging***



- We use non-invasive recordings of brain activity (EEG)

Grant organization

Japan 🇯🇵

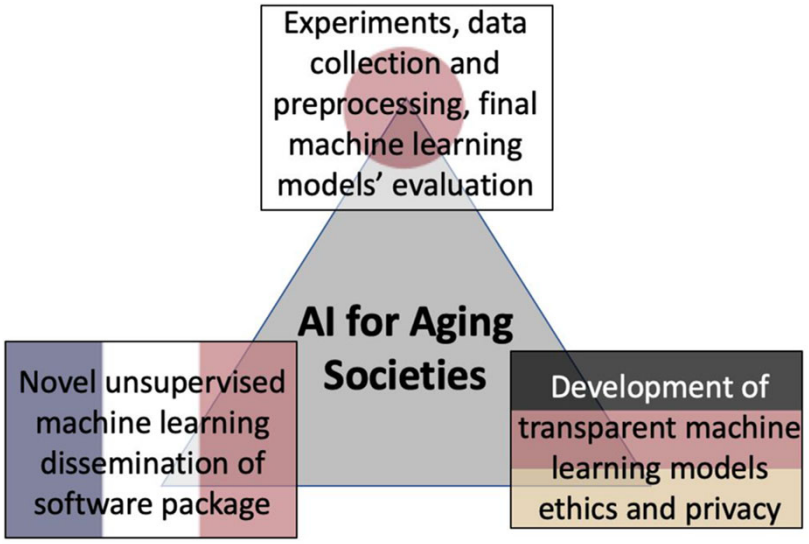
- EEG experiments in elderly & testing of cognitive intervention strategies
- the final evaluation of the ML methods developed i the present project

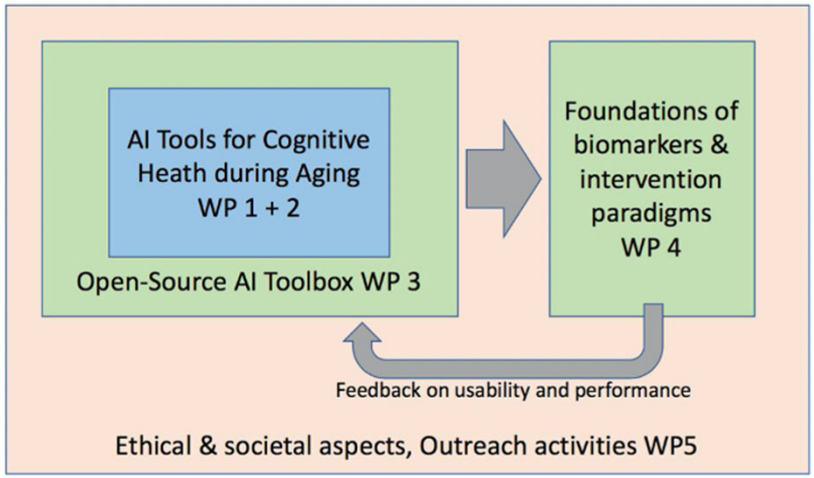
France 🇫🇷

- development of novel ML methods in the area of unsupervised learning, data augmentation, and domain adaptation
- making all ML methods publicly available and disseminating an open-source reference software package

Germany 🇩🇪

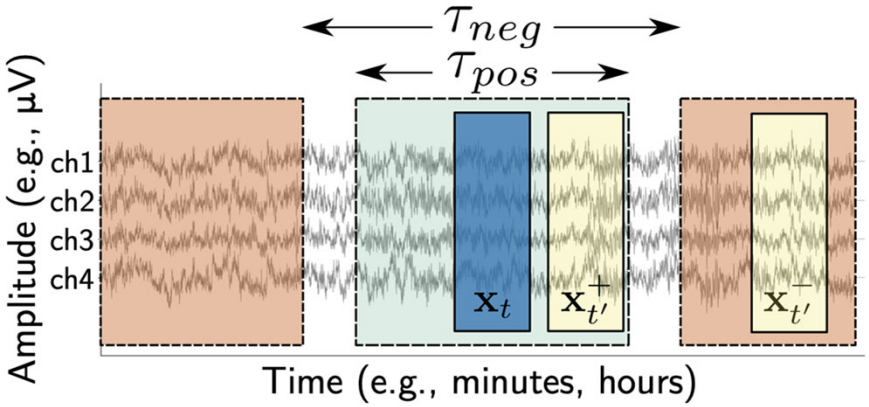
- promoting interpretable, human-transparent ML methods for the clinical analysis of brain signals
- organizing/conducting the ethical-societal aspects of the project, as well as of the outreach activities





Example: Aging in EEG during sleep

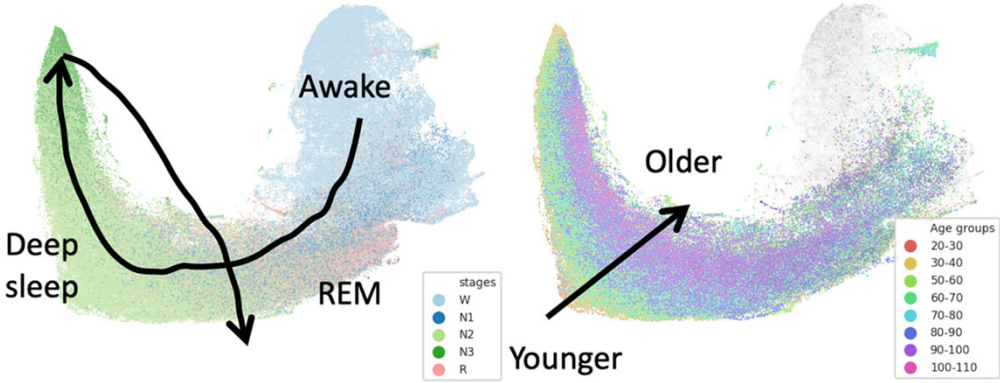
Self-supervised learning applied to sleep EEG: Relative positioning task with convolutional neural-network (CNN)



$$y_i = \begin{cases} 1, & \text{if } |t_i - t_i'| \leq \tau_{pos} \\ \text{-1}, & \text{if } |t_i - t_i'| > \tau_{neg} \end{cases}$$

[Banville et al. JNE 2021]

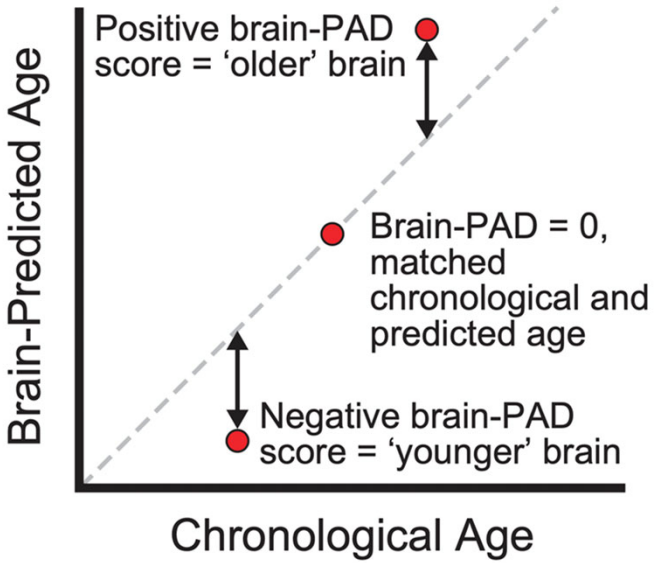
- 994 individuals
- 2D representation of 30s windows of EEG signals

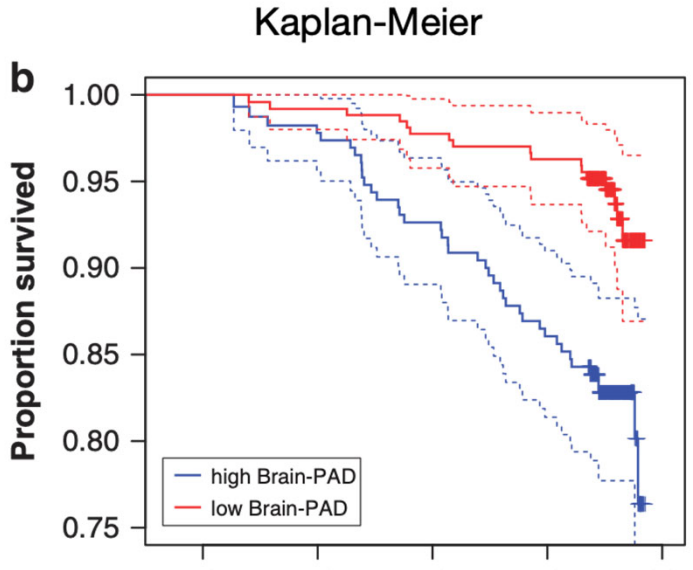


One can observe that one can learn without supervision sleep stages and aging trends

Example: How old is your brain?

Idea: Predict passport age from neuroimaging data using machine learning



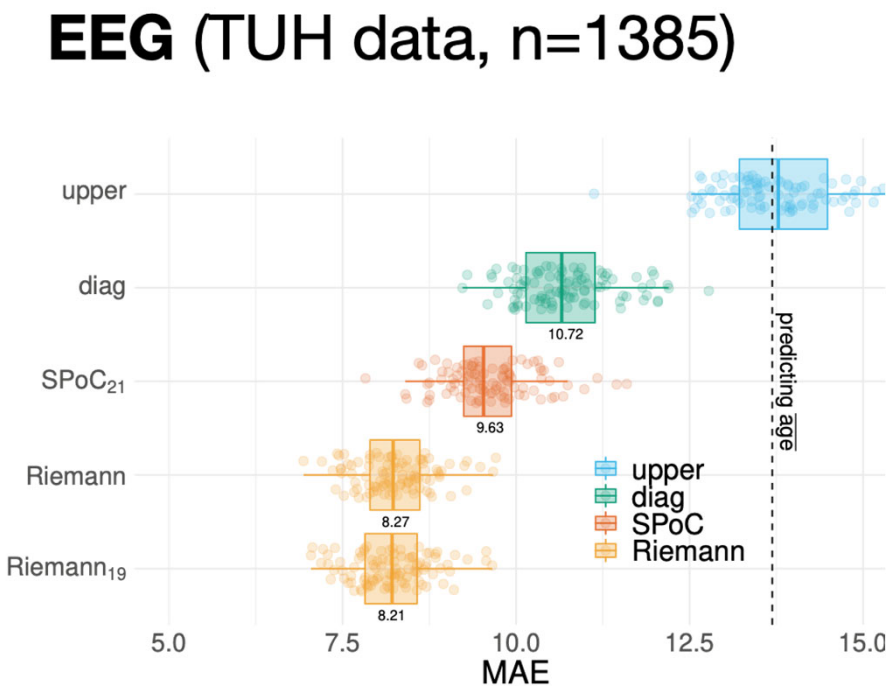


Idea:

If "brain age > true age" than you die earlier

[Cole et al. 2018]

Example: How old is your brain with EEG?



[Sabbagh et al. NeuIPS 2019, NeuroImage 2020]

Result: It is possible to predict the age of the brain from clinical EEG

Questions: Can we improve these models? Can we do it with consumer grade EEG for wider impact?

Research progress: Methods

Published as a conference paper at ICLR 2022

CADDA: Class-wise Automatic Differentiable Data Augmentation for EEG Signals

Cédric Rommel, Thomas Moreau, Joseph Paillard & Alexandre Gramfort
Université Paris-Saclay, Inria, CEA, Palaiseau, 91120, France
{firstname.lastname}@inria.fr

Data augmentation for learning predictive models on EEG: a systematic comparison

Cédric Rommel, Joseph Paillard, Thomas Moreau & Alexandre Gramfort
Université Paris-Saclay, Inria, CEA, Palaiseau, 91120, France
E-mail: {firstname.lastname}@inria.fr

Research progress: Applications

BIOMAG 2022
Birmingham UK

Dementia screening challenge

Organisers: Hokuto Hospital, Kumagaya General Hospital, and RICOH Company, Ltd., JAPAN.

Data providers: Hokuto Hospital, Kumagaya General Hospital, and Mihara Memorial Hospital, JAPAN.

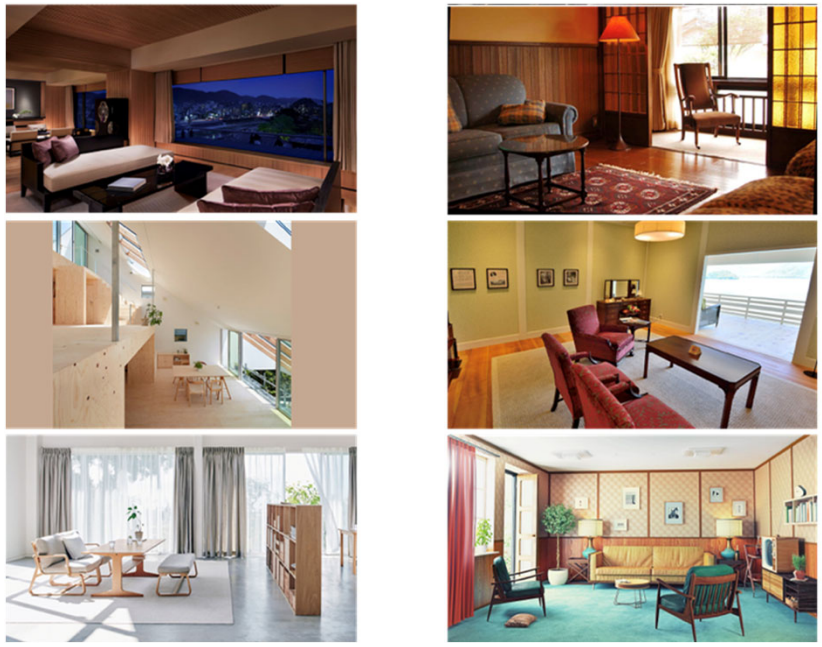
Contact: Yoshihito Shigihara MD PhD, **meaw.system@gmail.com**

Apolline Mellot, PhD student at Inria, funded by AI-Cog wins the “dementia screening challenge” at the international conference Biomag 2022

https://biomag2020.org/awards/data-analysis-competitions/

Research progress: Methods & Paradigms

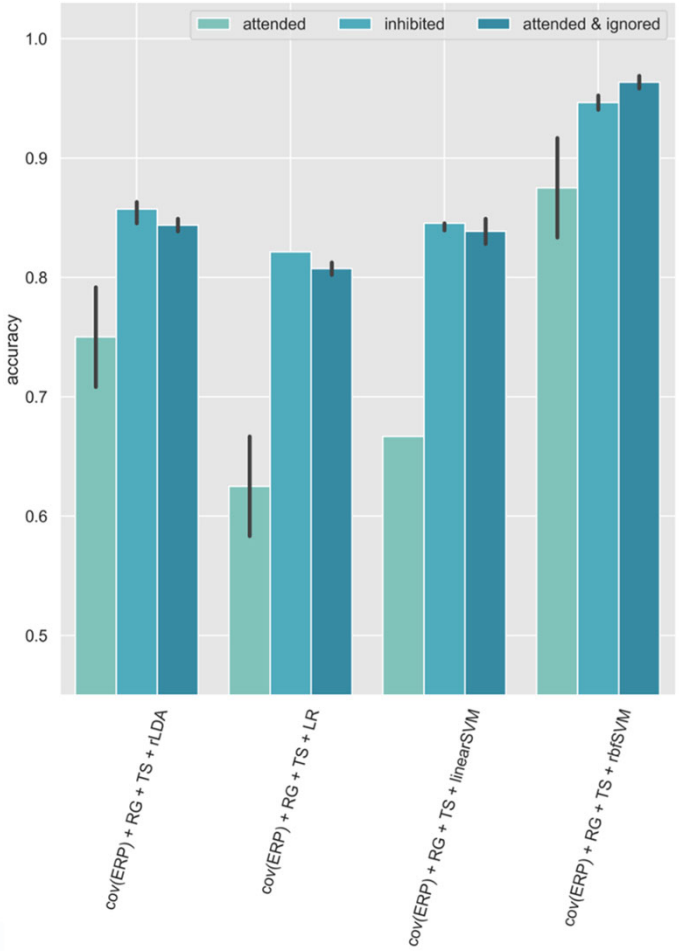
Paradigm: Show familiar or unfamiliar interior scenes



[Rutkowski et al. IEEE EMBC 2021, IEEE EMBC 2022, IEEE SMC 2022, IEEE SCIS & ISIS 2022]

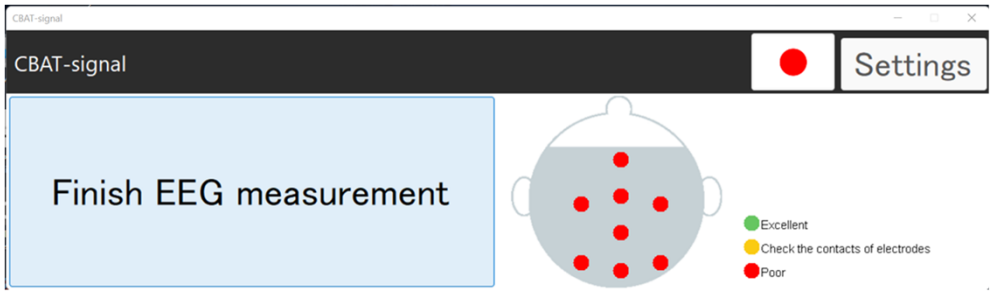
Classification: Predict from EEG if interior is familiar

Idea: Reveal neural correlates of memory impairment



Home–based EEG experiments with the elderly in Japan & Europe

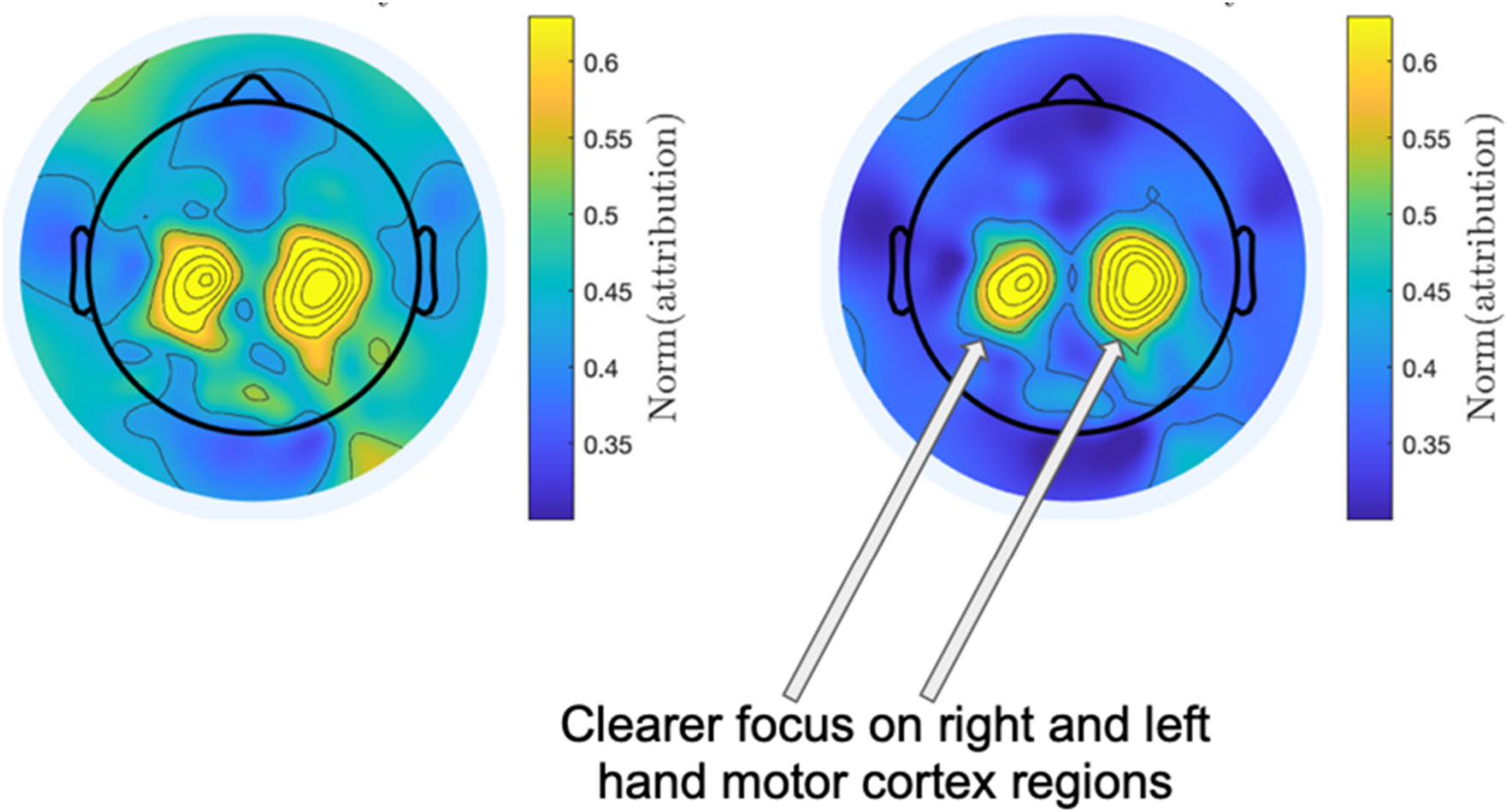
Application development to collect EEG data by elderly at home (cloud storing, video monitoring)



Research progress: Interpretability

Original Saliency Map

CC-Saliency Map



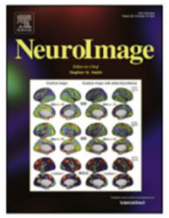
[Kapitonova et al., submitted]

Research progress: Methods

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage



A reusable benchmark of brain-age prediction from M/EEG resting-state signals

Denis A. Engemann [a,b,c,*], Apolline Mellot [b], Richard Höchenberger [b], Hubert Banville [b,d], David Sabbagh [b,e], Lukas Gemein [f,g], Tonio Ball [f,g,h], Alexandre Gramfort [b]

[a] Roche Pharma Research and Early Development, Neuroscience and Rare Diseases, Roche Innovation Center Basel, F. Hoffmann–La Roche Ltd., Basel, Switzerland
[b] Université Paris-Saclay, Inria, CEA, Palaiseau, France
[c] Max Planck Institute for Human Cognitive and Brain Sciences, Department of Neurology, D-04103, Leipzig, Germany
[d] InteraXon Inc., Toronto, Canada
[e] Inserm, UMRS-942, Paris Diderot University, Paris, France
[f] Neuromedical AI Lab, Department of Neurosurgery, Medical Center – University of Freiburg, Faculty of Medicine, University of Freiburg, Engelbergerstr. 21, 79106, Freiburg, Germany
[g] Neurorobotics Lab, Computer Science Department – University of Freiburg, Faculty of Engineering, University of Freiburg, Georges-Köhler-Allee 80, 79110, Freiburg, Germany
[h] BrainLinks-BrainTools Cluster of Excellence, University of Freiburg, Freiburg, Germany

Collaboration:

We evaluate state-of-the-art ML approaches (shallow and deep) on 4 large public datasets. Code is shared to replicate our findings.

https://github.com/meeg-ml-benchmarks/brain-age-benchmark-paper

Research progress: Novel experimental setups

A Modular, Adaptive, Deep-Learning-Based Brain-VR Interface

1st Maryna Kapitonova
Department of Neurosurgery
IMBIT
University of Freiburg, Germany
0000-0001-7206-9304

2nd Zacharias Häringer
Department of Neurosurgery
IMBIT
University of Freiburg, Germany
0000-0003-0958-3815

3rd Eric Bongk
Department of Neurosurgery
IMBIT
University of Freiburg, Germany
0000-0002-4226-3808

4th Tonio Ball
Department of Neurosurgery
IMBIT
University of Freiburg, Germany
0000-0002-4993-466X

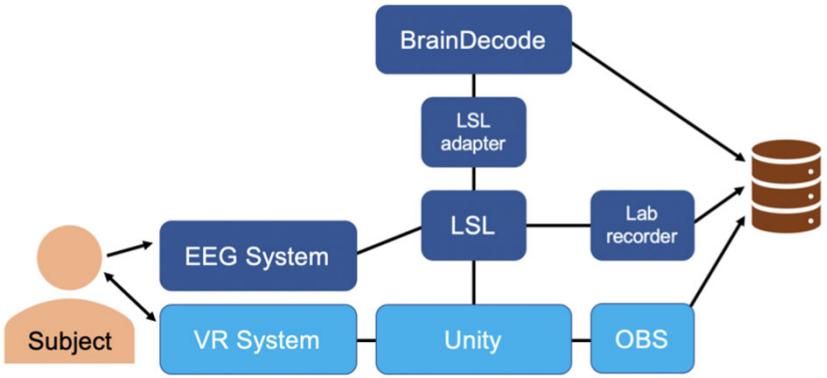
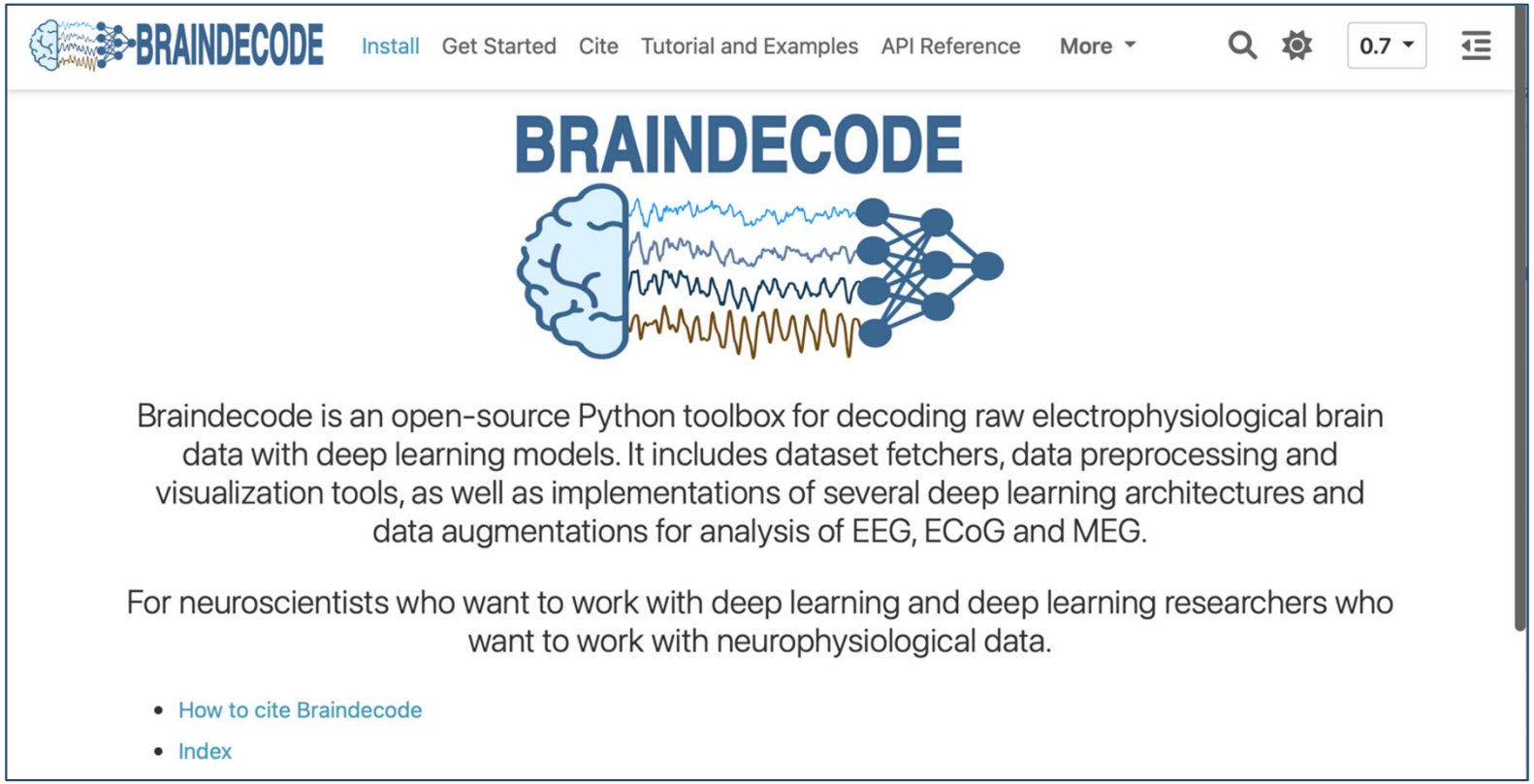


Fig. 1. Schematic of our modular BCI-VR set-up.

accepted for SCIS&ISIS 2022, Ise-Shima, Japan

Dissemination

https://braindecode.org/stable/index.html



Collaboration:

Latest release: 0.7 on Oct. 17 2022

Ongoing efforts and research plans

- *Pursue the development of state-of-the-art machine learning on EEG signals building on previous success using self-supervision and data augmentation*
- *Evaluate the models on new experiment using consumer grade EEG devices and demonstrate that early diagnosis of premature aging is possible at scale using EEG data.*
- *Share and disseminate the research outputs in open source packages (braindecode, MNE)*
- *Contribute to reproducible research efforts at the interface between ML and neuroscience*