



**HAL**  
open science

# Multimodal data fusion for brain-computer interfaces: A literature review

Faustine Faccin, El-Hadi Djermoune, Pauline Guyot, Laurent Bougrain

## ► To cite this version:

Faustine Faccin, El-Hadi Djermoune, Pauline Guyot, Laurent Bougrain. Multimodal data fusion for brain-computer interfaces: A literature review. Journées CORTICO (Collectif pour la Recherche Transdisciplinaire sur les Interfaces Cerveau-Ordinateur), May 2024, Nancy, France. 2024. hal-04636122

**HAL Id: hal-04636122**

**<https://hal.science/hal-04636122v1>**

Submitted on 5 Jul 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License



# Multimodal Data Fusion for Brain-Computer Interfaces

## A literature review

Faustine Faccin<sup>1,2,3</sup>, El-Hadi Djermoune<sup>2</sup>, Pauline Guyot<sup>1</sup>, Laurent Bougrain<sup>3</sup>

<sup>1</sup>Noviga, Nancy, France, <sup>2</sup>Université de Lorraine, CNRS, CRAN, F-54000 Nancy, France, <sup>3</sup>Neurorhythms team, Université de Lorraine, CNRS, LORIA, F-54000 Nancy, France

### Context

Several factors have made medical progress in neurosciences possible, including optimization of the patient care:

- New **data acquisition technologies** combined with the multiplication of health data;
- A lot of different data to describe a patient's **physiological and physical state**;
- New algorithmic methods able to integrate these different **modalities**.

**Brain-Computer Interfaces** (BCI) usually take electroencephalograms (EEG) signals as single inputs. However, studies show that **hybrid systems** such as **Body-Computer Interfaces**, combining the advantages of different types of input signals, offer competitive results compared to conventional interfaces [3,5].

### Problematic and objectives

The purpose of this work is to **complement** current research on hybrid BCI [4].

**How to integrate different modalities at the scale of the algorithms in BCIs?**

The objectives are the followings:

1. Conduct a **literature review** focusing on multimodal data fusion methods that could be integrated in hybrid systems.
2. Identify relevant **combinations** of physiological signals for improving traditional BCI systems.
3. Compare above-mentioned methods.

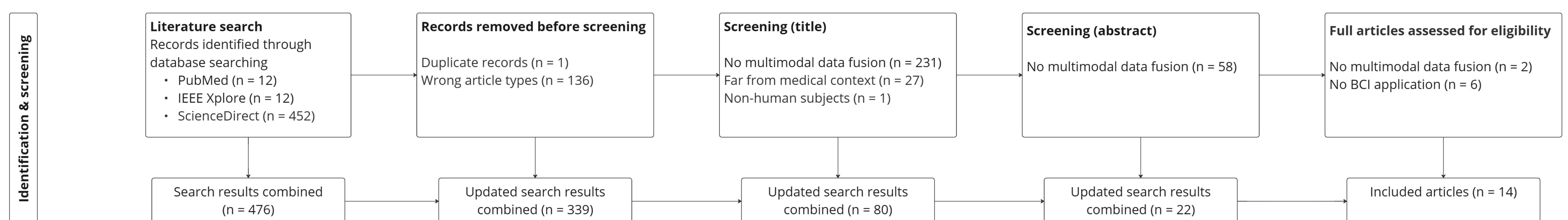
### Methods

This study is part of a comprehensive literature review, conducted according to PRISMA recommendations, on deep learning data fusion mechanisms. The review is currently being written.

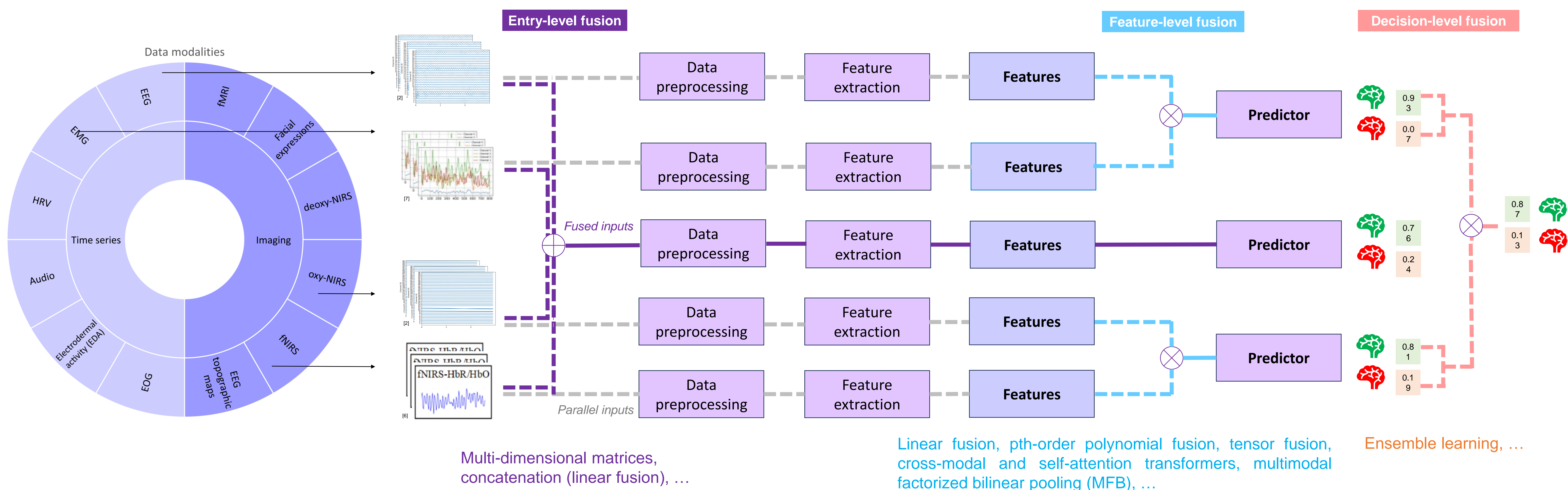
The comprehensive search depicted here was based on several databases. A total of 339 articles were screened.

The diagram below represents the contributions of this research, applied for BCI, adding 14 more articles.

### PRISMA diagram



### Different levels of fusion mechanisms



### Methods and limitations

- **Entry-level fusion**: a shared representation is learnt from a **multimodal single input** formed by the fusion of all data at the entry level of the network. **Non-linearity of correlations between data limits learning** [8].
- **Feature-level fusion**: multimodal features are **learnt independently then concatenated** at a deeper level to better learn correlations later. **Difficulties lie in the weight given to each feature, regardless of its dimension, as well as the size of the feature vector** [1].
- **Decision-level fusion**: **same independent decision-making** process for all data whose results are combined at the end-level. **However, final result is based on independent input processing without learning modalities correlations** [8].

### Conclusion

Different modalities can be interesting but complicated to integrate without complicating nor degrading the algorithms. Rationale behind fusion strategy highly depends on **relationship between data**. Relationship is given by the consistency of specific **patterns concomitant** with the occurrence of the target event of the BCI: thus, multimodal inputs must represent the same recording time at the same scale. Ideally, models should combine **independent and correlated analysis** of each normalized modality to accurately learn multi-modal patterns. Thus, **adapted feature-level fusion** seems the most appropriate. Such method showed promising results in motor imagery classification with a reported accuracy of 82.11% [6].

### References

- [1] LI, Yong, HE, Zihang, WANG, Heng, *et al.* CraftNet: a deep learning ensemble to diagnose cardiovascular diseases. *Biomedical Signal Processing and Control*, 2020, vol. 62, p. 102091.
- [2] SUN, Zhe, HUANG, Zihao, DUAN, Feng, *et al.* A novel multimodal approach for hybrid brain-computer interface. *IEEE Access*, 2020, vol. 8, p. 89909-89918.
- [3] AMIRI, Setare, FAZEL-REZAI, Reza, *et al.* ASADPOUR, Vahid. A review of hybrid brain-computer interface systems. *Advances in Human-Computer Interaction*, 2013, vol. 2013, p. 1-1.
- [4] PFURTSCHALLER, Gert, ALLISON, Brendan Z., BAUERNEFELD, Günther, *et al.* The hybrid BCI. *Frontiers in neuroscience*, 2010, vol. 4, p. 1283.
- [5] JIANG, Jun, ZHOU, Zongtan, YIN, Erwei, *et al.* Hybrid Brain-Computer Interface (BCI) based on the EEG and EOG signals. *Biomedical materials and engineering*, 2014, vol. 24, no 6, p. 2919-2925.
- [6] HE, Qun, FENG, Lufeng, JIANG, Guoqian, *et al.* Multimodal multitask neural network for motor imagery classification with EEG and fNIRS signals. *IEEE Sensors Journal*, 2022, vol. 22, no 21, p. 20695-20706.
- [7] DAS, Tanaya, GOHAIN, Lakhyajit, KAKOTY, Nayan M., *et al.* Hierarchical approach for fusion of electroencephalography and electromyography for predicting finger movements and kinematics using deep learning. *Neurocomputing*, 2023, vol. 527, p. 184-195.
- [8] MANOR, Ran, MISHALI, Liran, *et al.* GEVA, Amir B. Multimodal neural network for rapid serial visual presentation brain computer interface. *Frontiers in computational neuroscience*, 2016, vol. 10, p. 130.