脳機能の全容は巨大クロスワードの如く急速に解明されるかもしれない
The great crossword: Potential for rapid progress in understanding the function of the entire brain

田和辻 可昌[1,2], 布川 絢子[2], 荒川 直哉[2], 高橋 恒一[3,2,4], 山川 宏[5,2,6]

Yoshimasa Tawatsuji[1,2], Ayako Fukawa[2], Naoya Arakawa[2], Koichi Takahashi[3,2,4], Hiroshi Yamakawa[5,2,6]

1. 早稲田大学, 2. 全脳アーキテクチャ・イニシアティブ, 3. 理化学研究所, 4. 慶應義塾大学, 5. 東京大学, 6. 電気通信大学
1. Waseda University, 2. WBAI, 3. RIKEN, 4. Keio University, 5. The University of Tokyo, 6. The University of Electro-Communication

Introduction

- Previous studies focus on particular regions of the brain to understand its functions
- However, the functional decomposition approach [Yamakawa, 21] is also important in that function of a brain region should be allocated from the entire brain function

SCID (Structure-Constrained Interface Decomposition) method [Yamakawa 21]

- Method for extracting the operating principles necessary to reproduce the cognitive-behavioral functions of the brain based on the reference architecture of the brain

1. Anatomical structures around the brain region of interest (ROI) are investigated and registered as Brain Information Flow (BIF)
2. A valid ROI and the top-level function (TLF) it performs are determined
3. Possible HCDs (Hypothetical Component Diagrams) are listed and HCDs that are inconsistent with scientific findings are dismissed
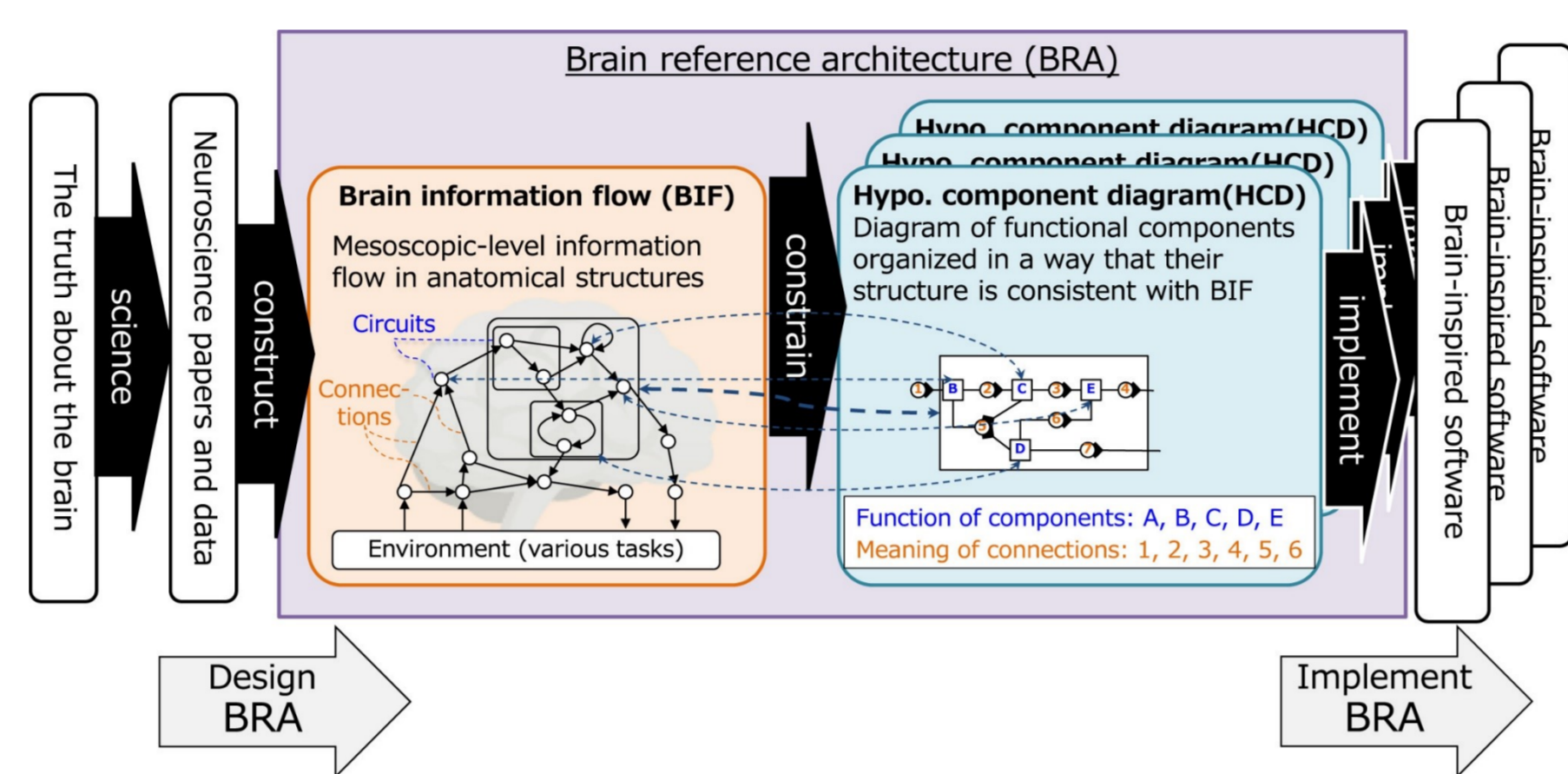
Summary

- The functional decomposition approach [Yamakawa, 21] is important in that function of a brain region should be allocated from the entire brain function
- In this approach, as the function allocation proceeds,
    - The constraints on possible function allocation pattern become stronger
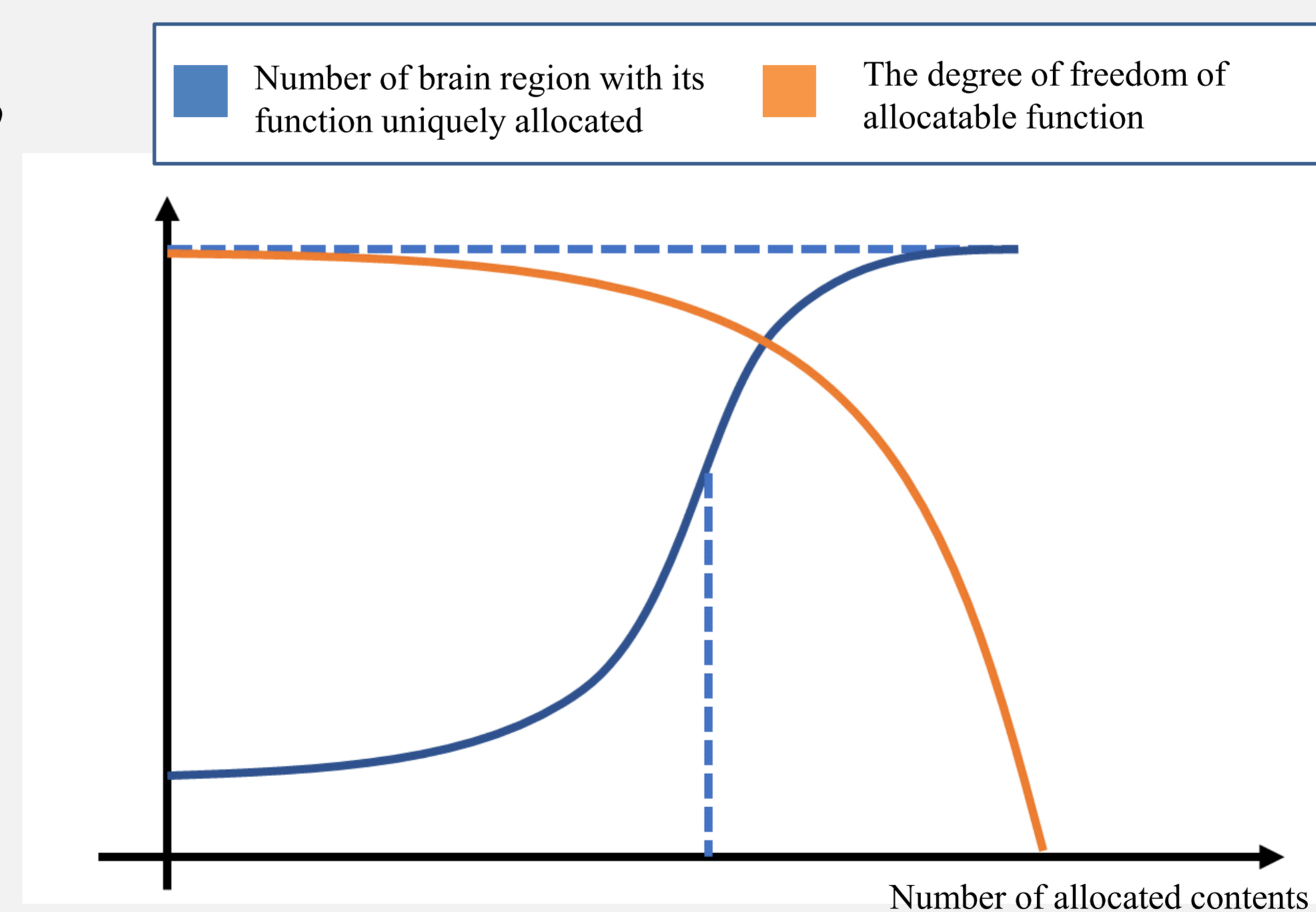   - The allocation problem becomes easier to be solved just like a crossword puzzle

The problem dealt in this method is quite similar with a crossword puzzle in the perspective of structure-constrained contents-allocating problem!

Correspondence between Crossword Puzzle Solving and Designing Reference Architecture of the Brain
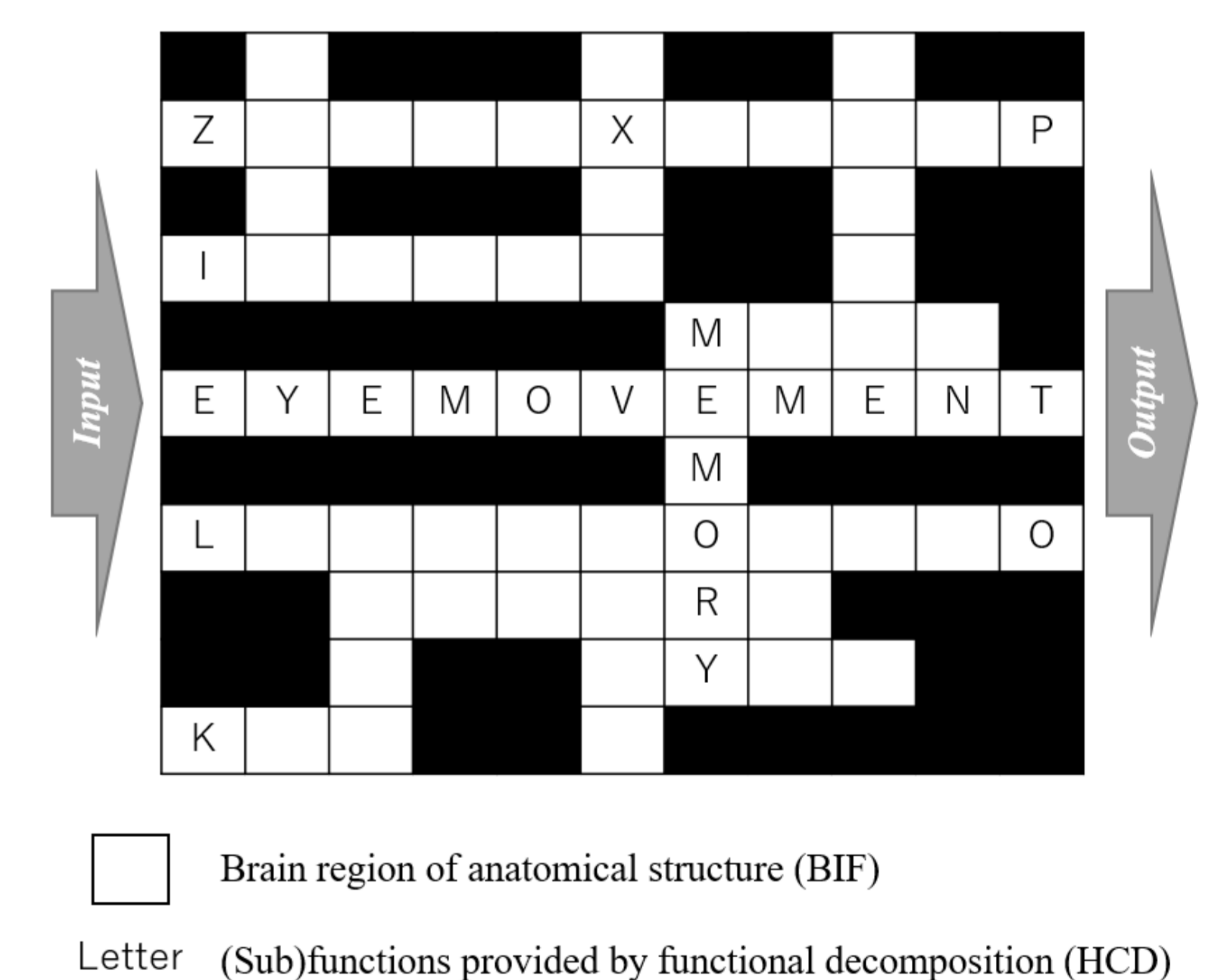
	Crossword puzzle	Reference Architecture of the Brain
Structure	**Puzzle framework** Squares and blanks	**(Mesoscopic) Neural Structure** Brain regions and connections
Contents	Letters allocated to each square	Subfunctions (provided by functional decomposition)
	Words	(Top level) Functions
Clue for which contents to be allocated	Clues ("across" and "down")	Neural behavior ("What information each region codes")

In the latter part of problem solving, allocating should rapidly progress

- Allocatable contents for one structure get restricted as the contents are allocated to the peripheral structure
- At the point of the allocating progress, the allocatable contents drastically decreases

Number of brain region with its function uniquely allocated / The degree of freedom of allocatable function / Number of allocated contents

"Crossfunction" puzzle

☐ Brain region of anatomical structure (BIF)
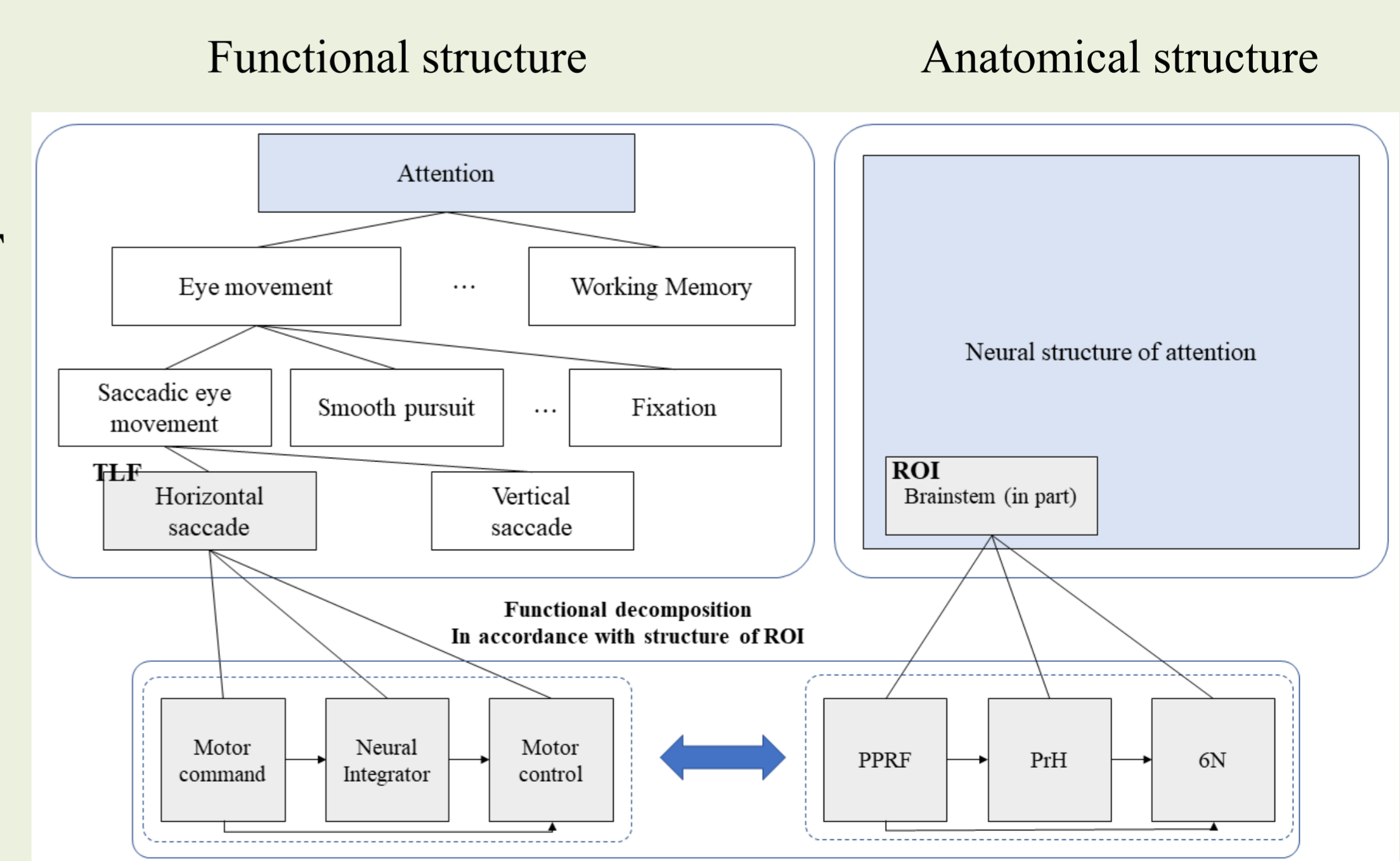Letter (Sub)functions provided by functional decomposition (HCD)

Discussion

ROI and TLF is set from the HCDs creator's own perspective. It causes the problem of integration of HCDs created separately. In this point, we would like to discuss:

1. How should we determine ROI and its TLF?
2. Is it possible to integrate HCD created in a distributed manner (see also: *Functional composition problem*)?

References:
Yamakawa, H.: The whole brain architecture approach: Accelerating the development of artificial general intelligence by referring to the brain, *Neural Network*, 144, 478–495 (2021)

Functional composition problem   *E.g. Eye movements*

- (Sub)functions of brain regions are determined under the functional decomposition of TLF (e.g. horizontal saccade)
- However, it does not guarantee that the function of a region should be same if allocated by decomposition of the higher function (e.g. "eye movement", or "(visual) attention")