Data for Brain Reference Architecture of YM24Amygdala

Yohei Maruyama[a*], Tatsuya Miyamoto[b], Yoshimasa Tawatsuji[ac], Hiroshi Yamakawa[ac]

[a]The Whole Brain Architecture Initiative, Tokyo, Japan

[b]Graduate school of Advanced Science and Engineering, Waseda University, Tokyo, Japan

[c]Graduate School of Engineering, The University of Tokyo, Tokyo, Japan

[*]Corresponding author: Yohei, Maruyama; info@wba-initiative.org

Abstract

The dataset covers fear conditioning in the amygdala, including Brain Information Flow (BIF) data related to the amygdala' s fear conditioning circuitry. The data was collected in alignment with anatomical and neural dynamics and reconstructed using functionally organized motifs for the construction of Functional Reference Graphs (FRG). By using motifs, it enables the identification of frequently observed patterns as functional modules within the amygdala. This facilitates a detailed analysis of the amygdala' s BIF circuitry from a bottom-up perspective, aiding in the construction of FRG graphs and enhancing our comprehension of the neural circuitry's overall function. This data is organized into brain reference architecture (BRA) format. The dataset is stored in the BRA Data Repository and is readily accessible for research purposes.

Keywords: motif; Funciton Realization Graph; Brain Information Flow; amygdala; fear conditioning;

Author roles:

Yohei Maruyama: Data curation, Methodology, Visualization, Writing – original draft;

Tatsuya Miyamoto: Investigation,Visualization, Supervision, Validation,Writing – review and editing;

Yoshimasa Tawatsuji: Investigation,Visualization, Supervision, Validation, Writing – review and editing;

Hiroshi Yamakawa: Conceptualization, Funding acquisition, Methodology,Project administration, Supervision,Visualization, Writing – review and editing

1 Context

Brain Reference Architecture (BRA) is the reference architecture for software that realizes cognitive and behavioral functions in a brain-like manner. The architecture primarily consists of the mesoscopic-level anatomical data of the brain and the data of one or more functional mechanisms that are consistent with that knowledge(Yamakawa, 2021). BRA consists of Brain Information Flow (BIF), which represents structural knowledge of the brain, and Hypothetical Component Diagram (HCD)/Funciton Realization Graph (FRG), which represent brain functionality.

The amygdala is a critical brain region for the processing of emotions, particularly fear (Maren, 2001). This paper provides data on the "amygdala's fear conditioning circuitry." The amygdala's fear conditioning circuitry refers to specific neural networks within the amygdala that are involved in the process of fear conditioning. Fear conditioning is the process by which an innocuous conditional stimulus is paired with a noxious unconditional stimulus, resulting in a fear response to the innocuous conditional stimulus (Maren, 2001). This circuitry includes various neurons and synaptic connections within the amygdala that mediate the learning and expression of conditioned fear responses. The lateral nucleus (LA) is responsible for the associative formation between the innocuous conditional stimulus and the noxious unconditional stimulus (Quirk, Repa, & LeDoux, 1995). This information is then transmitted to the basal nucleus (BA), where BA is involved in the formation (Sun, Gooch, & Sah, 2020). Consequently, the individual begins to exhibit a fear response to the previously noxious unconditional stimulus. Furthermore, this process is modulated by CA1, which processes contextual information (such as environmental cues, temporal context, and physiological state) to ensure that these fear responses are contextually appropriate.

In this dataset, the Brain Information Flow (BIF) data is reconstructed using motifs organized based on their functions to build the Function Realization Graph (FRG). This approach allows for constructing the FRG from the bottom up by incrementally integrating functional motifs, thereby enhancing our comprehension of the neural circuitry' s overall function. Additionally, this method can serve as a reference when deconstructing functions from the top down.

2 Method

Motif Definition and Organization

Motifs are patterns frequently observed within neural circuits that serve as fundamental building blocks of complex neural circuits and are thought to have specific functions. We referenced motifs that are frequently observed anatomically to compile a list of these motifs (Braganza & Beck, 2018; C. Alex Goddard & Knudsen, 2014; Luo, 2020, 2021). Motifs consist of neuronal nuclei, referred to as nodes, and the edges connecting them. In this study, most of the referenced motifs were used in their original form. However, some motifs were partially modified by adding or removing nodes and edges to refine their structure. These modifications were made with a focus on the capability of each motif. (Examples of these capabilities are shown in Figure 1.) If the capability was not compromised, nodes and edges were removed to minimize the motifs. Additionally, if removing nodes and edges resulted in different capabilities, these modified motifs were also included in the list. Furthermore, motifs were included in the list if their combination resulted in synergistic effects that exceeded the sum of their individual capabilities.

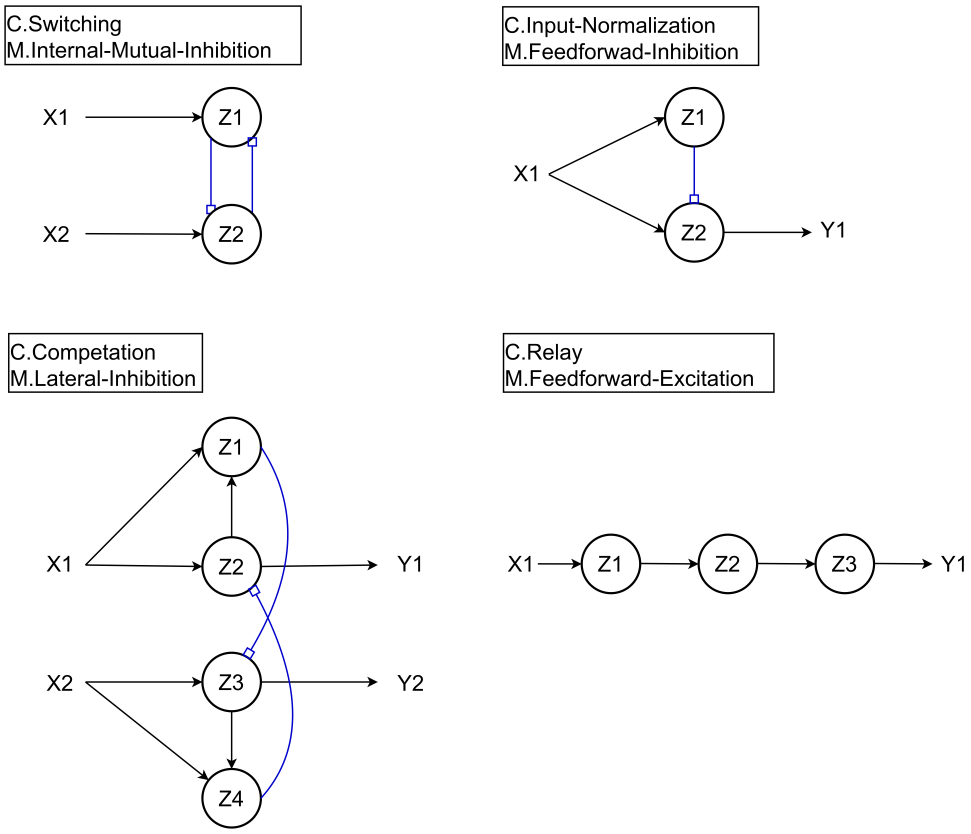

Figure 1: motif

Figure 1 illustrates several examples of motifs. Each motif is composed of nodes (Z1, Z2, Z3, ...) connected by edges. Inputs (X1, X2, X3, ...) propagate through these nodes and are output as (Y1, Y2, Y3, ...). Black edges indicate excitatory signals directed along the arrows, while blue edges represent inhibitory signals flowing in the same manner. The symbol M indicates the mechanism of the motif, whereas C represents the capability of the motif. For instance, the motif in the upper left of Figure 1 shows a mechanism where the nodes receive inputs and mutually inhibit each other, demonstrating a signal switching capability.

FRG construction based on Motif

In this study, we aim to construct the Function Realization Graph (FRG) from the bottom up by incrementally integrating motifs organized based on their functions, distinguishing this approach from the SCID method.

This paper presents Brain Information Flow (BIF) data on the amygdala's fear conditioning circuitry. The data on the amygdala's fear conditioning circuitry was collected in alignment with anatomical and neural dynamics and reconstructed using motifs. In the following paragraphs, we describe the process of reconstructing this BIF data using motifs to build the Function Realization Graph (FRG) from the bottom up.

Initially, to construct the FRG, we applied the compiled list of motifs to the created BIF data exhaustively. In applying the motifs to the BIF data, motifs were selected if their nodes and edges were generally contained within the regions of interest (ROI), and partial overlap between motifs was allowed.

Next, to practically construct the FRG, we assigned the corresponding capabilities of the motifs to a higher layer of nodes within the selected motifs. In the process of hierarchically assigning capabilities, we could optionally integrate the nodes and the motifs to create new motifs, and then assign the capabilities corresponding to the new motifs above the integrated nodes and motifs. This means that the process does not end with assigning capabilities to a higher layer of nodes corresponding to the motifs; we can further integrate these nodes and motifs and assign the capabilities corresponding to the new motifs above them.

Additionally, it is possible to combine the capabilities of different motifs and assign new capabilities to a higher layer. By repeating this process, we hierarchically constructed the FRG from the bottom up.

Sampling strategy
The dataset was created by the authors, including experts in anatomy, through the collection and integration of data from multiple publications. The selection criteria for the referenced publications were based on their inclusion in major academic journals related to anatomy. Detailed information about the referenced publications, such as titles, authors, journals, and publication years, is provided in the "References" sheet of the dataset. The motifs used to construct the FRG data were organized based on their functions, referencing the literature cited in this paper. some motifs were partially modified by adding or removing nodes and edges to refine their structure. These modifications were made with a focus on the capability of each motif.

3 Dataset Description

Repository location BRA Editorial System (BRAES) https://sites.google.com/wba-initiative.org/braes/data

Object name and versions Please refer to the "Project" sheet in the BRA data for the more detail of data summary.

Table 1: BRA DATA SUMMARY

BRA Data			
Object Name	Template	Including Content(s)	
		BIF	HCD/FRG
YM24Amygdala.bra	*version 2.0*	√	√

Table 2: BRA IMAGE SUMMARY

Graphic Files: BIF Image, HCD Image, FRG Image	
File Type	Object Name
BIF Image	YM24AmygdalaBIF.xml
HCD Image	YM24AmygdalaHCD.xml
FRG Image	YM24AmygdalaFRG.xml

Creation dates 2024-02-08 to 2024-06-30.

Language English.

License The open license under which the data has been deposited (CC-BY 4.0).

Publication date 2024-07-01.

4 Caveats for Data Usage

This dataset was compiled by the authors, including experts in anatomy, through the meticulous collection and integration of data from multiple publications. The motifs utilized to construct the Function Realization Graph (FRG) were organized based on the references cited in this paper. Some motifs were modified with a focus on their capabilities and used. The dataset is stored in the BRA Data Repository and is readily accessible for research purposes. This dataset is primarily applicable to the field of neuroscience. It is invaluable for the organization, understanding, and utilization of neural circuits based on their functions. The Brain Information Flow (BIF) data is constructed according to the latest research, reflecting the current state of knowledge. Consequently, the FRG constructed using these motifs is also based on the most up-to-date understanding.

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Competing interests

Yoshimasa Tawatsuji and Hiroshi Yamakawa are managers of BRAES but did not take part in the editorial process or decisions pertaining to this manuscript.

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