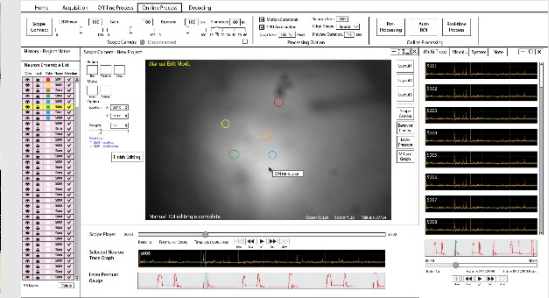
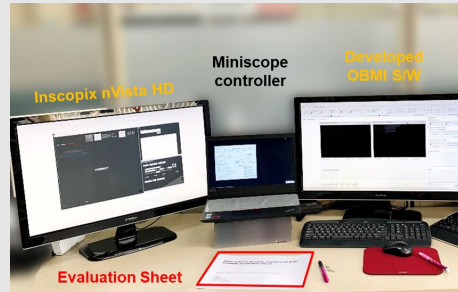
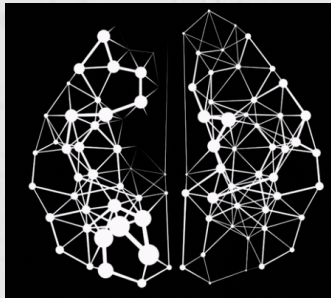


Development and Evaluation of UI Design for Ergonomic Optical Brain-Machine Interface (OBMI) System

광학적 뇌-기계 인터페이스 시스템의 UI 디자인 개발 및 평가



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한지아웨이⁴, 왕루이수에⁴, 유희천¹

¹포항공과대학교 산업경영공학과, ²장남대학교인공 지능 및 컴퓨터 과학 대학, ³한국과학기술연구원
기능커넥토믹스연구단, ⁴중국 저장대학교 의용 생체 공학과

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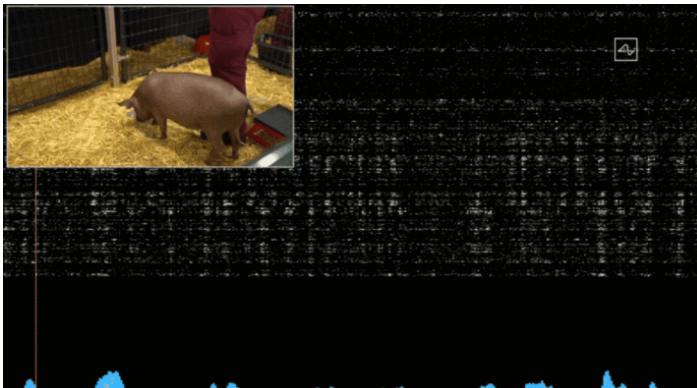
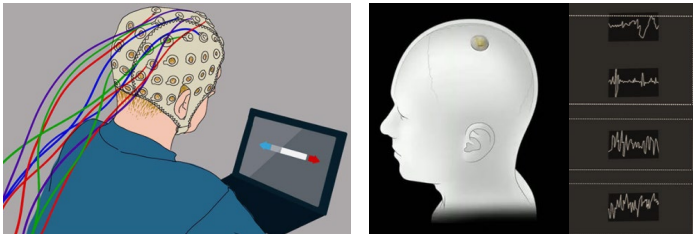
Contents

- **Introduction**
 - Background
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 - Objective of the study
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 - Study procedure
 - Simulation S/W
 - **Design Analysis**
 - **Information Architecture**
 - **UI Development**
 - **Evaluation of Proposed UI Design**
 - Methods
 - Results
 - **Discussion**
-

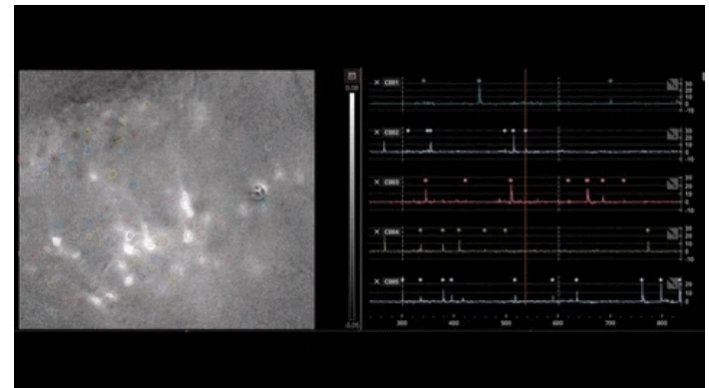
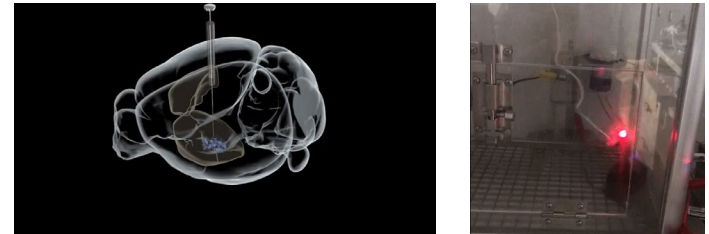
Background

- ❑ A **brain-machine interface (BMI)** is a device that translates **neuronal information** into commands capable of controlling an external device.
- ❑ Optical brain-machine interface (OBMI) research based on **calcium imaging technology** has shown great advantages in brain science.

Electrophysiology-based BMI systems



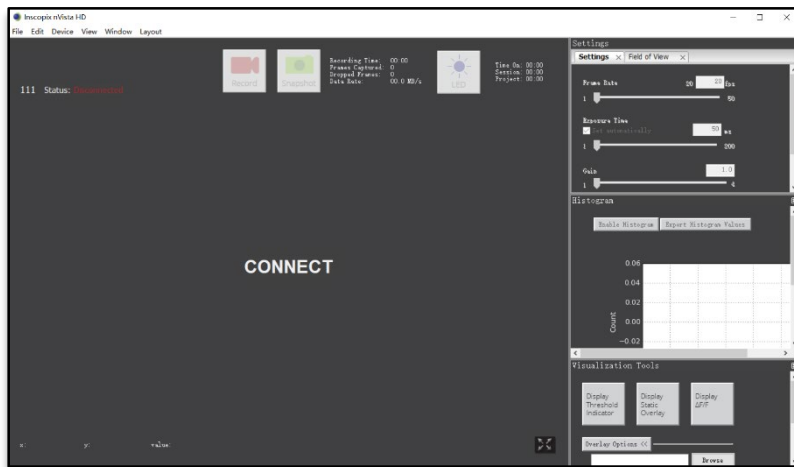
Calcium imaging-based BMI systems



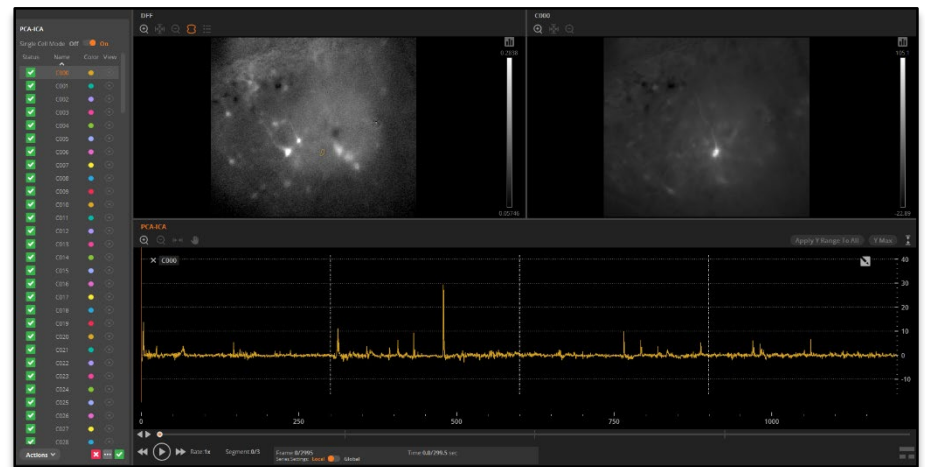
Limitations of Optical BMI

- ❑ **Few** OBMI S/W is developed for video acquisition, image processing, neuron extraction, and signal visualization.
- ❑ Limitations of existing OBMI S/W need to be improved.
 - Existing systems **cannot** realize **real-time processing** of neuron signals to control external devices.
 - Many **usage problems** (e.g., inconvenience of using independent modules) were complained by neuron scientists.

Examples of existing OBMI S/W



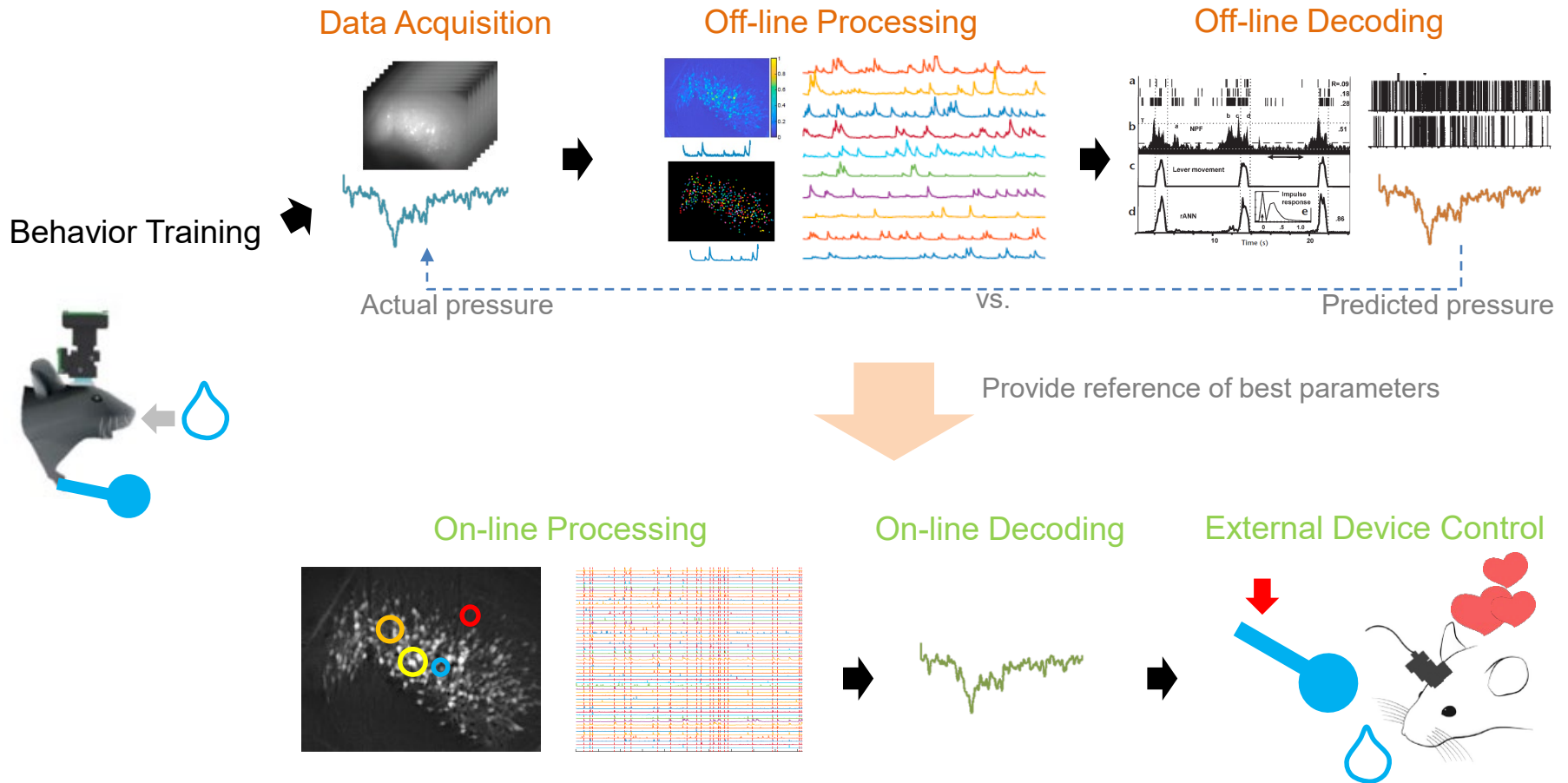
S/W for Signal acquisition
(Inscopix nVisata HD)



S/W for signal processing and
visualization (Inscopix)



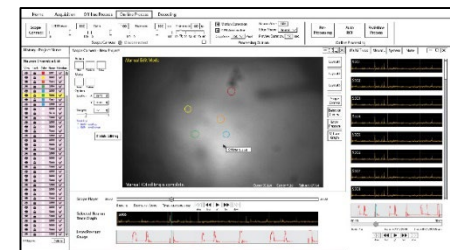
Experiment Procedure by Neuron Researchers



Objectives of the Study

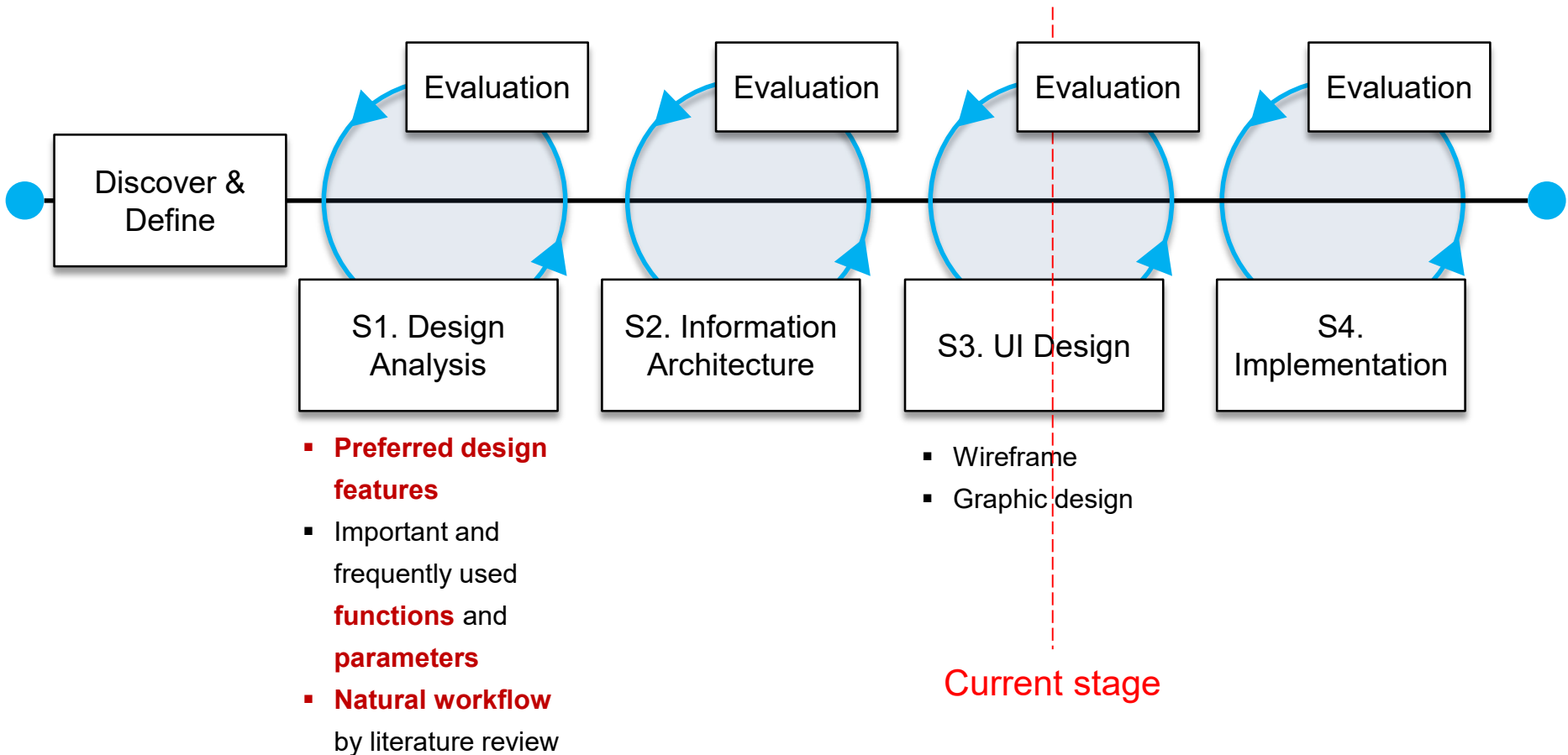
Development of **UI Design** for OBMI System with Improved Usability and Functionality

1. Analyze **design features** by literature review, benchmarking and a user survey
2. Develop the **information architecture**
3. Propose **UI wireframe**
4. **Evaluate** the proposed UI wireframe and proposed design improvements

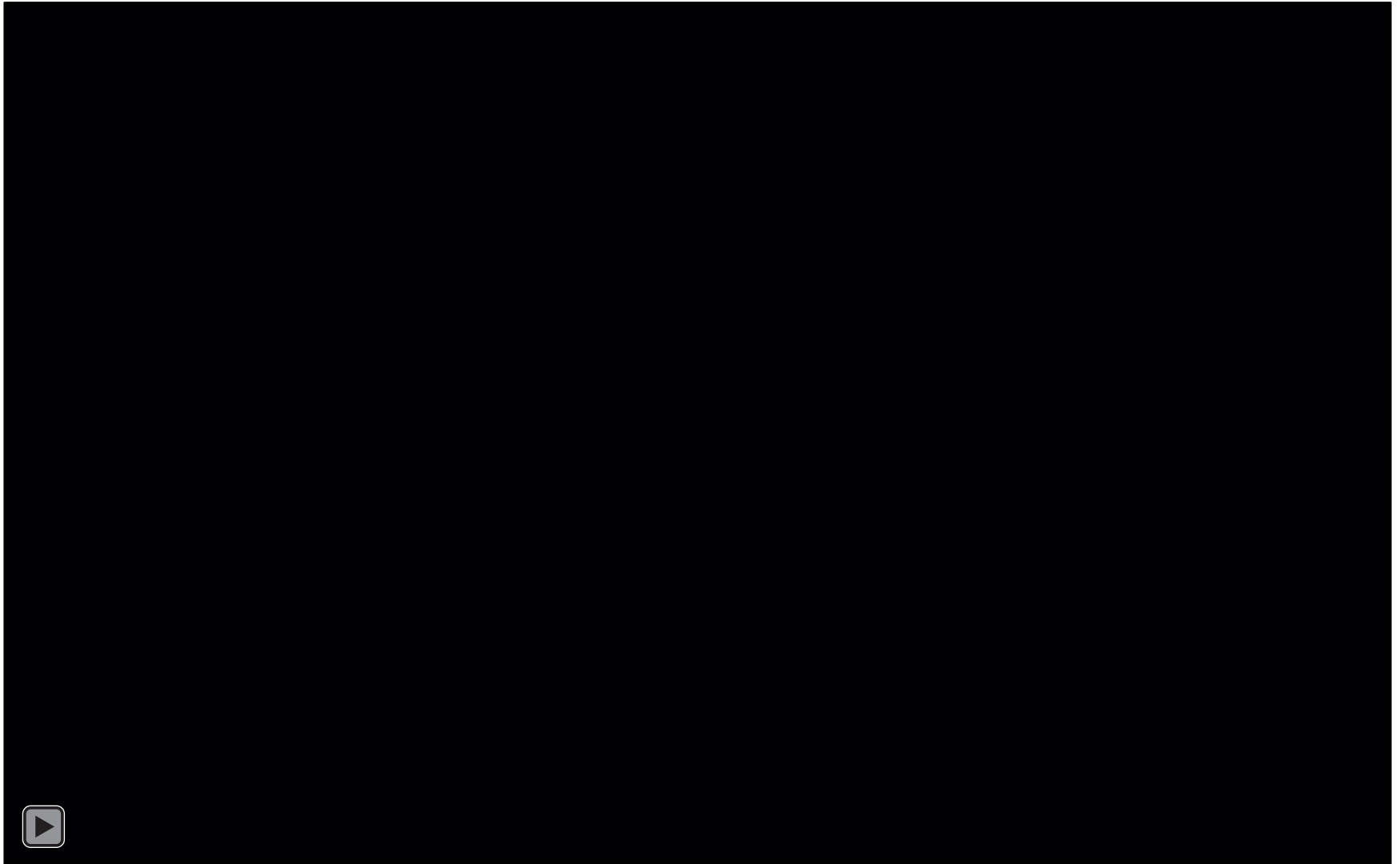


Research Procedure

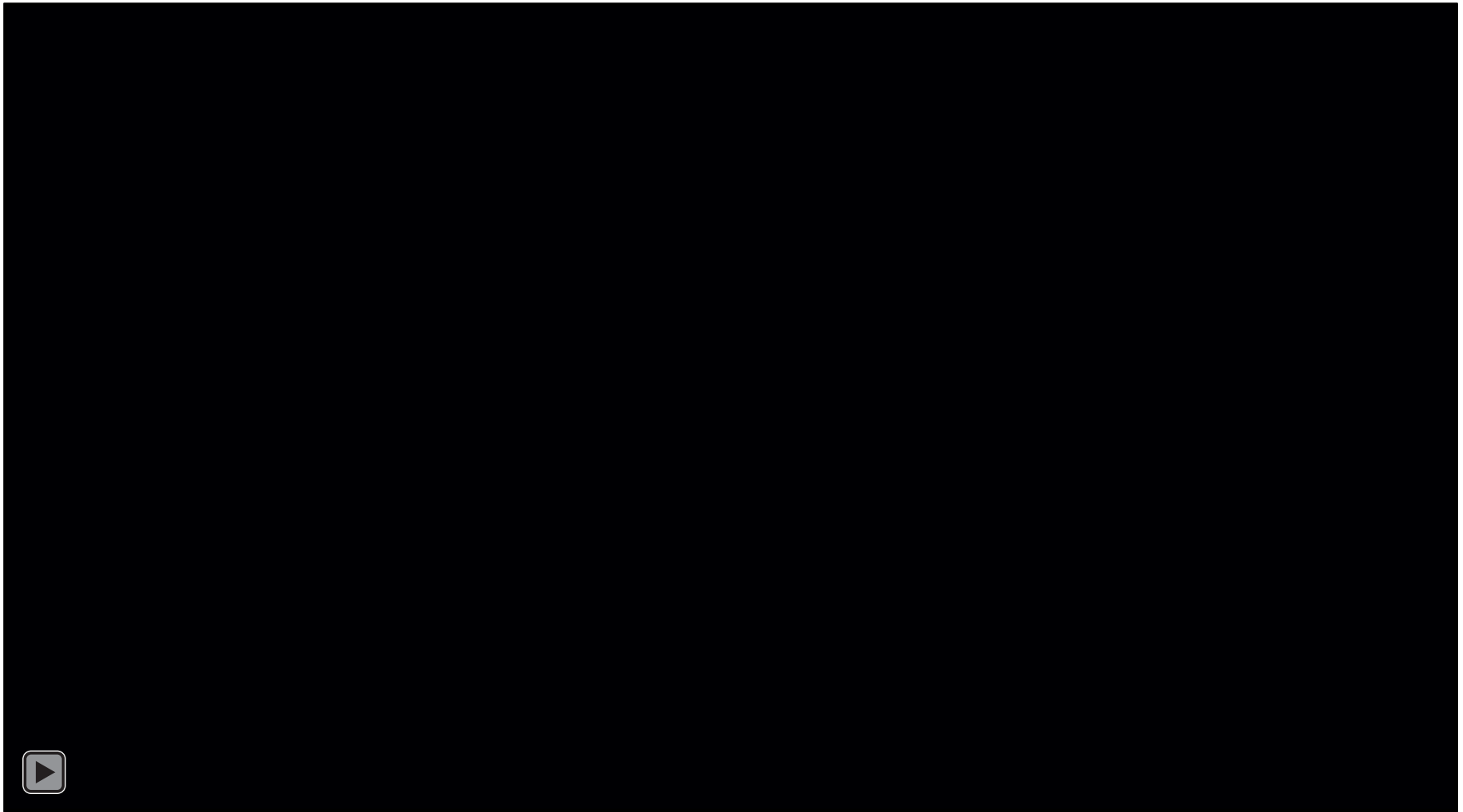
- An **iteration** design and evaluation process was conducted to develop OBMI UI.



Simulation S/W: Data Acquisition Module



Simulation S/W: Off-line/On-line Processing Module



S1. Design Analysis: Preferred Design Features (pre.)

- ❑ **Benchmarking** on seven existing BMI S/W and a **satisfaction survey** (7-point Likert scale) were conducted to **identify preferred design features**.

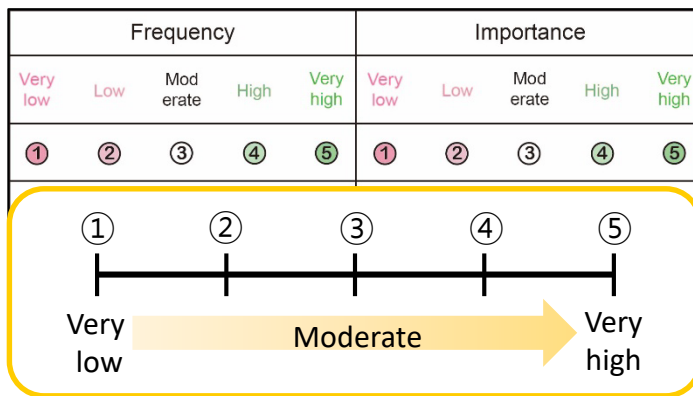
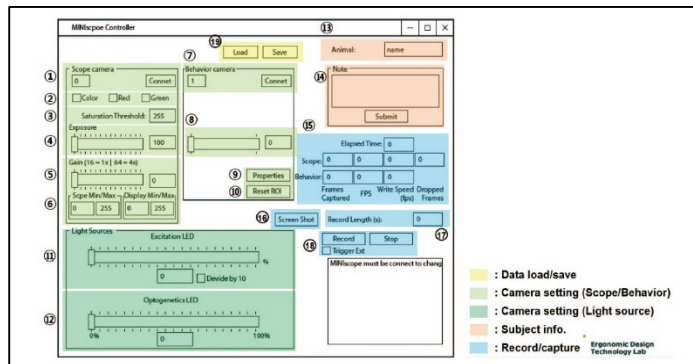
Preferred design features

Category	Attribute	Design Feature	Preferred Design Features by Design Type			
			Full freestyle (4.0)	Semi-freestyle (5.4) 😊	Fixed design (5.4) 😊	-
GUI Design Style (Static)	Layout	Overall Layout	Full freestyle (4.0)	Semi-freestyle (5.4) 😊	Fixed design (5.4) 😊	-
	Display	Status Info. Location	Separate (5.0) 😊	Combined (4.8)	-	-
Interaction Design Style (Dynamic)	Navigation	Function Navigation	Workflow-based (4.9)	Category-based (3.7)	Tiled navigation (5.3) 😊	-
	Output	Window Appearance Mode	Attached panel (6.0) 😊	Independent window (5.3)	Re-planned area (3.9)	Folded tag (4.9)
	Input	Parameters Input Mode	Standardized mode (5.5)	Customized mode (6.0) 😊	-	-
	Controllability	Trace Adjustment Mode	Button type (4.7)	Slider type (5.9) 😊	-	-
		Parameter Adjustment Mode	Property-based (5.7) 😊	Alphabet-based (3.9)	Frequency-based (3.7)	-

S1. Design Analysis: Functions and Parameters (pre.)

- Evaluation of **importance** and **frequency** of functions and parameters was performed to **develop the hierarchy** and **sequence of UI elements**.

5-point Likert scale evaluation method



Ranking of functions and parameters

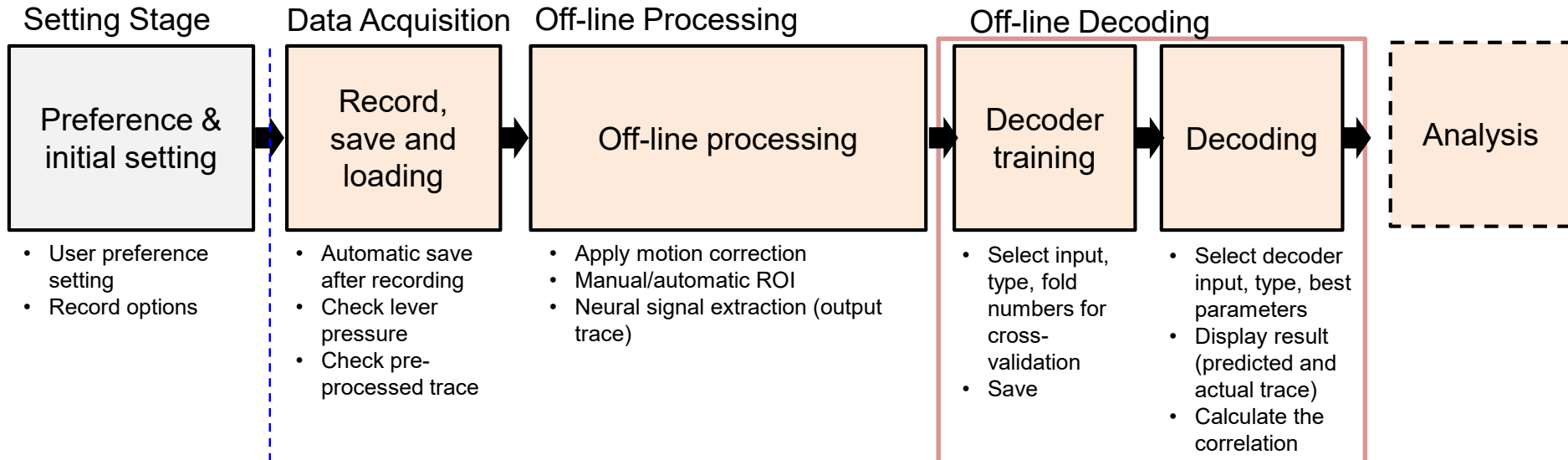
Status	Frequency (Mean)	Importance (Mean)
FPS	5.0	5.0
Exposure	5.0	5.0
Frames	5.0	5.0
Gain	5.0	5.0
LED Power	5.0	5.0
ROIs	5.0	5.0
Time	4.8	5.0
Dropped Count	4.8	5.0
Dropped	4.8	5.0
Recording Schedule Name	4.0	4.3
Files	4.0	4.0
Recording Started (computer clock time)	4.0	4.0
Recording Ended (computer clock time)	4.0	4.0
Triggered from External Hardware	4.0	4.0
Meta Data	4.0	4.0
Downsample	3.0	4.0
Version	3.0	3.0
Width	3.0	3.0
Height	3.0	3.0
Left	3.0	3.0
Top	3.0	3.0
LED Delay Value	3.0	3.0
LED Session	3.0	3.0
LED Project	3.0	3.0
Recording Schedule Batch ID	3.0	3.0
Recording Schedule Step	3.0	3.0
Recording Schedule Cycle	3.0	3.0
Camera Chip Version	3.0	3.0
Sensor Board Serial Number	3.0	3.0
Hardware Serial Number	3.0	3.0



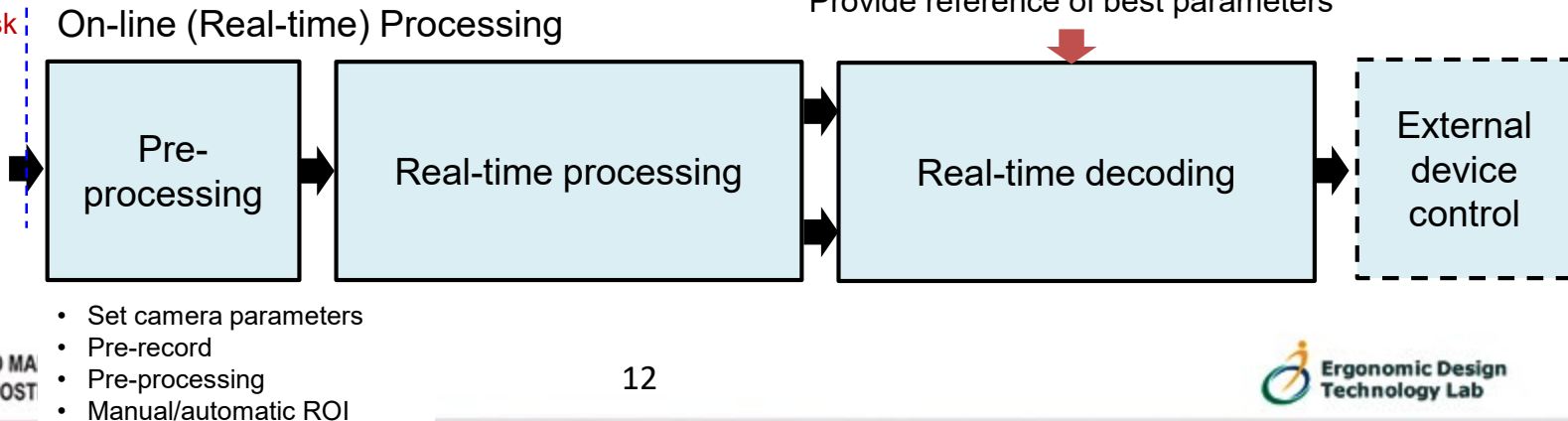
S1. Design Analysis: Workflow (pre.)

- Literature review, user interviews, and benchmarking on existing systems were conducted to identify the workflow of OBMI.

Off-line task



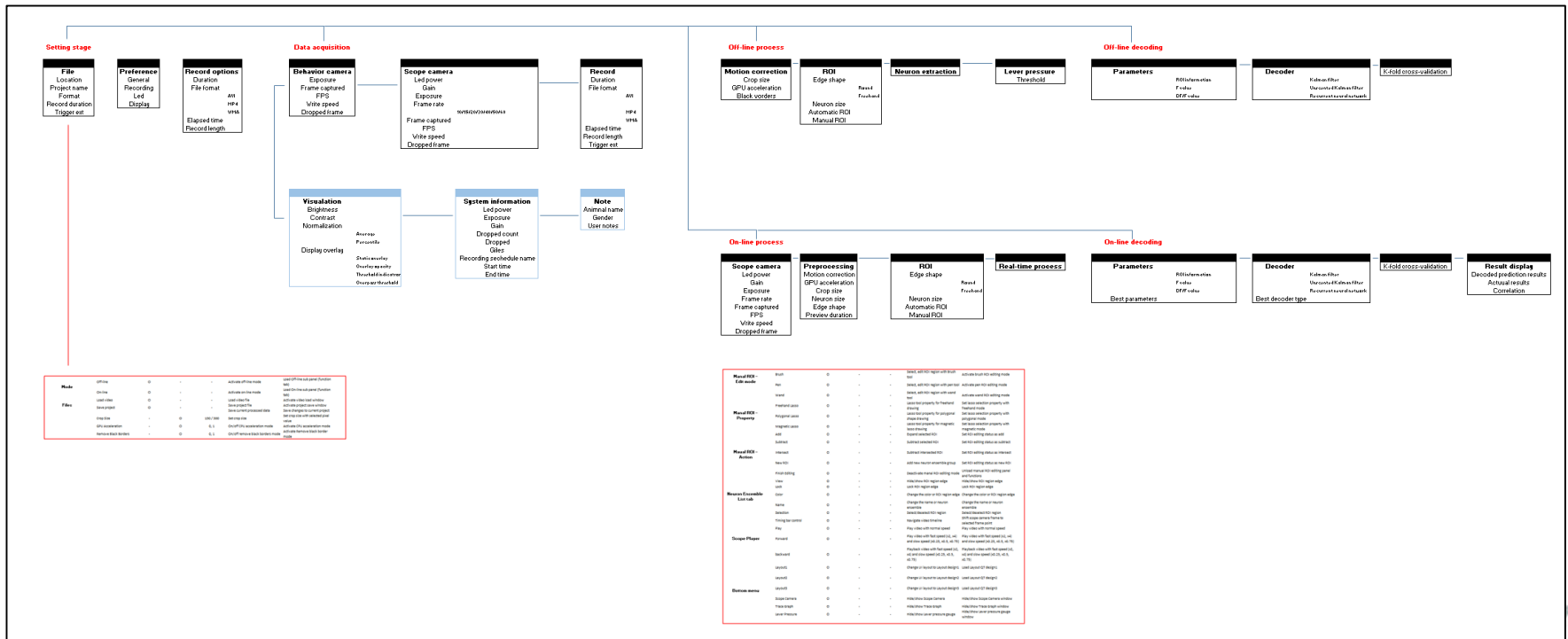
On-line task



S2. Information Architecture (IA)

- ❑ The **4 modules** were extracted from **OBMI workflow** including data acquisition, off-line process, on-line process, and decoding.
- ❑ **UI components, functions** with **hierarchy** and **sequence** were arranged from evaluation results in terms of **preference, frequency** and **importance**.

Information architecture



S3. Wireframe Design: Summary

- ❑ **Wireframe design** of ergonomic O-BMI system was developed based on **task-based design concept, preferred UI features and IA.**

Wireframe design of OBMI UI

The image displays a wireframe design of the OBMI UI, which is a software interface for data acquisition and processing. The interface is organized into several key sections:

- Navigation Bar:** Located at the top, it includes tabs for 'Home', 'Acquisition' (the active tab), 'Off-line Process', 'On-line Process', and 'Decoding'.
- Control Panels:** Below the navigation bar, there are two main control areas. The left panel, labeled 'Behavior Connect', features an 'Exposure' slider set to 255 and a 'Behavior Camera' status indicator showing 'Disconnected'. The right panel, labeled 'Scope Connect', includes sliders for 'LED Power' (100), 'Gain' (100), and 'Exposure' (100), along with a 'Frame rate' dropdown set to 60 fps and a 'Scope Camera' status indicator showing 'Disconnected'.
- Recording Options:** A 'Record' button is present, accompanied by a 'Duration' field set to 00:30, a 'File format' dropdown set to .avi, and a 'Recording Status' section showing 'Elapsed time: 0' and 'Record length: 0'.
- Camera Window:** A large central area labeled 'Camera Window' contains two video feeds: 'Behavior Camera' and 'Scope Camera'. Both feeds are currently dark, indicating they are disconnected. At the bottom of this window, status information is displayed: 'Frame Captured: 0', 'FPS: 0', 'Write Speed (fps): 0', and 'Dropped Frames: 0'.
- Visualization Panel:** On the right side, there is a 'Visualization' panel with several sub-sections: 'Brightness & Contrast' (sliders for both at 100%), 'Brightness Normalization (F0-value)' (radio buttons for 'Average' and 'Percentile' at 100%), and 'Display Overlay & Display Threshold' (checkboxes for 'Threshold indicator' and 'Overpass threshold').
- System Information Panel:** Below the visualization panel, a 'System Information' panel provides details such as 'LED Power: 70/100', 'Exposure: 50/100', 'Gain: 20/100', 'Dropped Count: 3,350', 'Dropped: 2,210', 'Files', 'Recording Schedule Name: 190820', 'Triggered', 'Start: 10:03 am', and 'End: 10:08 am'. It also includes an 'Export Log' button.
- Note Panel:** At the bottom right, a 'Note' panel contains the text 'Animal name: 190820_mice_trial_055' and 'Gender: male', with an 'Export Note' button.

S3. Wireframe Design: Preferred Features (1/4)

- ❑ The overall layout was designed to fixed components with several default layout options.

Layout options of data acquisition & on-line processing

The screenshot displays a software interface for data acquisition and on-line processing, organized into several functional areas:

- Navigation:** Home, Acquisition (selected), Off-line Process, On-line Process, Decoding.
- Behavior Control:** Behavior Connect, Exposure slider (0 to 255, set to 255), Behavior Camera status (Disconnected).
- Scope Control:** Scope Connect, LED Power slider (0 to 100, set to 100), Gain slider (0 to 100, set to 100), Exposure slider (0 to 100, set to 100), Frame rate slider (10 to 60, set to 60), Scope Camera status (Disconnected).
- Recording Options:** Record button, Duration (00:30 min), File format (.avi), Recording Status (Elapsed time: 0, Record length: 0).
- Camera Window:** Behavior Camera and Scope Camera viewports. Status at the bottom: Frame Captured: 0, FPS: 0, Write Speed (fps): 0, Dropped Frames: 0.
- Visualization Panel:** Brightness & Contrast (Brightness: 100%, Contrast: 100%), Brightness Normalization (FO-value) (Whole range, Selected range, Average, Percentile: 100%), Display Overlay & Display Threshold (Overlay Opacity: 100%, Threshold indicator, Static Overlay, Overpass threshold).
- System Information Panel:** LED Power: 70/100, Exposure: 50/100, Gain: 20/100, Dropped Count: 3,350, Dropped: 2,210 Files, Recording Schedule Name: 190820 Triggered, Start: 10:03 am, End: 10:08 am, Export Log button.
- Note Panel:** Animal name: 190820_mice_trial_055, Gender: male, Export Note button.

S3. Wireframe Design: Preferred Features (2/4)

- ❑ The navigation system was designed to tiled panel based on the conduction sequence of tasks, functions, and parameters.

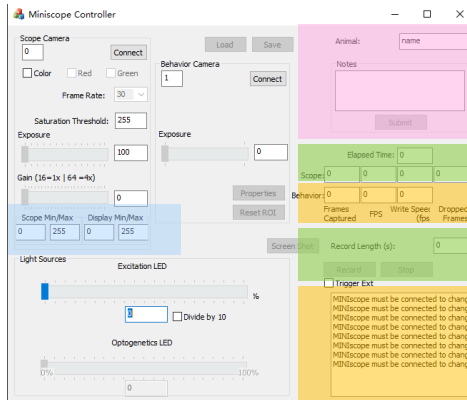
Navigation system

The image displays three horizontal panels representing different stages of a software navigation system. Each panel has a top navigation bar with tabs: Home, Acquisition, Off-line Process, On-line Process, and Decoding. The 'Acquisition' tab is highlighted in the first panel, 'Off-line Process' in the second, and 'On-line Process' in the third. A red arrow points from the 'Acquisition' tab in the first panel to the 'Off-line Process' tab in the second, and another red arrow points from the 'Off-line Process' tab in the second panel to the 'On-line Process' tab in the third. The 'Acquisition' panel includes controls for Behavior Camera (Exposure: 255), Scope Camera (LED Power: 100, Gain: 100, Exposure: 100, Frame rate: 60), and Recording Options (Duration: 00:30, File format: .avi). The 'Off-line Process' panel includes File operations (Load Video, Save Project), Motion Correction (Crop Size: 150 Pixel, GPU Acceleration, Remove Black Borders), and Neuron Extraction (ROI Selection Options: Edge Shape: Round, Neuron Size: 100, Auto ROI, Neuron Extraction). The 'On-line Process' panel includes Scope Camera controls (LED Power: 100, Gain: 100, Exposure: 100, Frame rate: 60), Processing Options (Motion Correction, GPU Acceleration, Crop Size: 150 Pixel, Neuron Size: 100, Edge Shape: Round, Preview Duration: 15 sec.), and Online Processing (Pre-Processing, Auto ROI, Real-time Process).

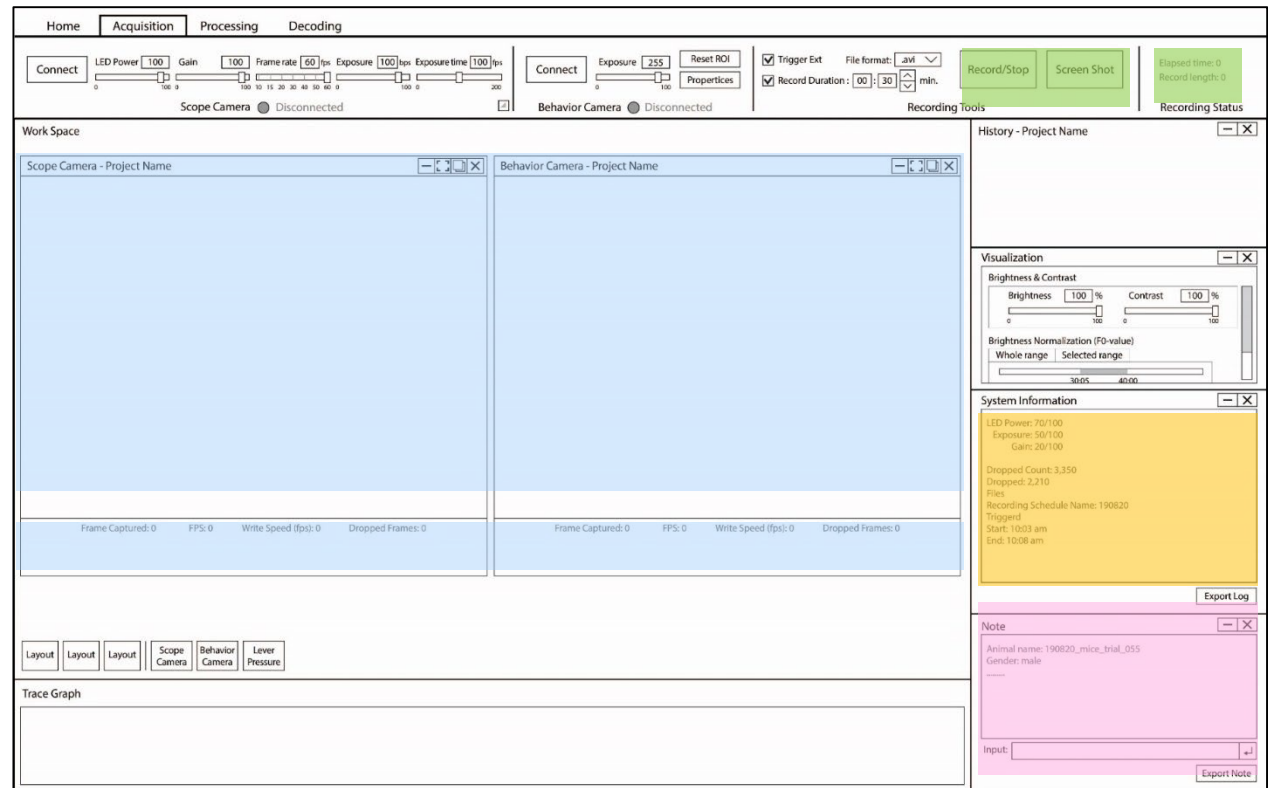
S3. Wireframe Design: Preferred Features (3/4)

- ❑ **Status information** was arranged next to modules with **high relevance**.

Existing S/W



OBMI system



Camera status

Recording status

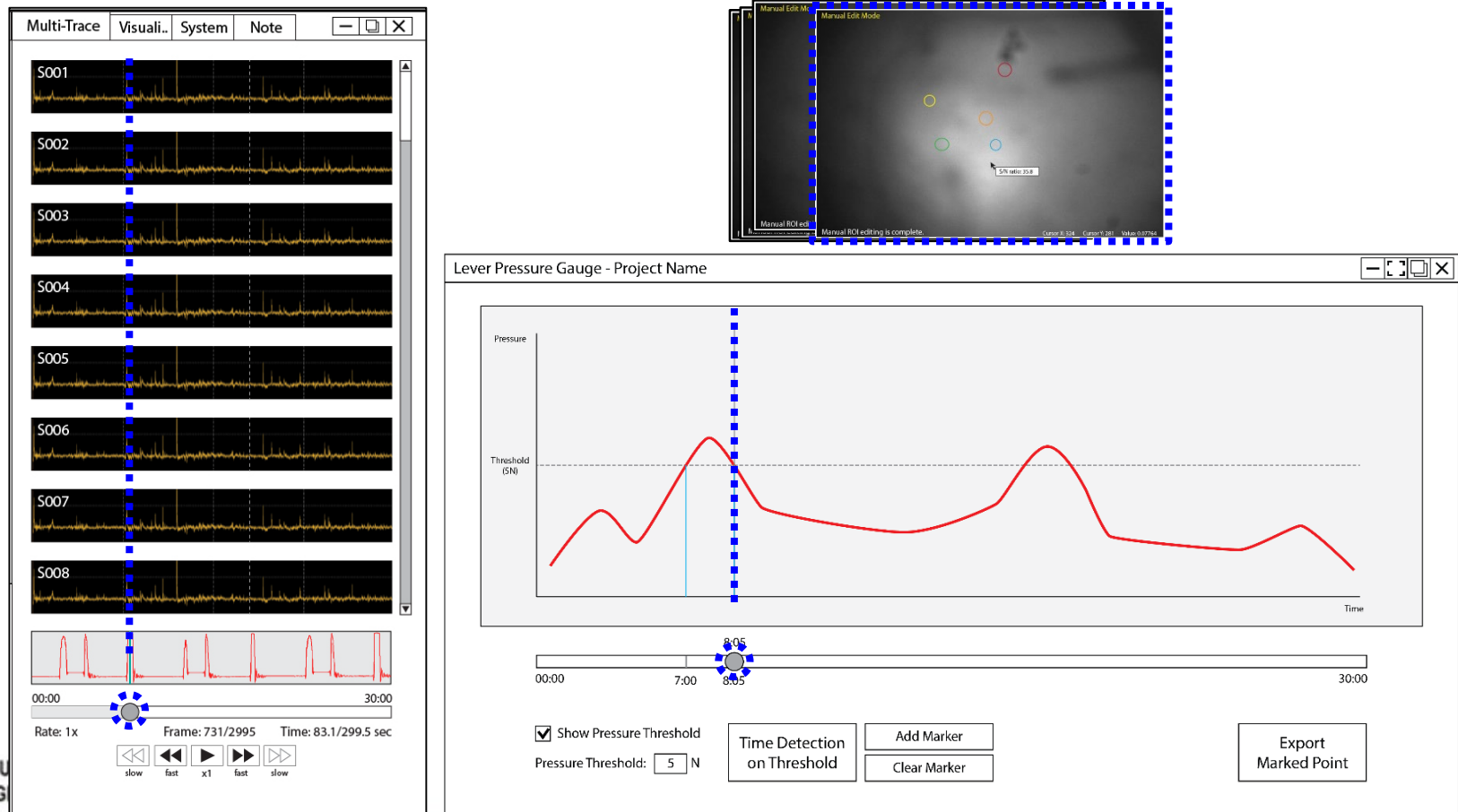
System information

User notes/animal information

S3. Wireframe Design: Preferred Features (4/4)

- ❑ **Controllability** and **feedback** between neuron signal trace, lever pressure graph, video and users was enhanced **slider operations**.

Trace of lever pressure and neuron signal

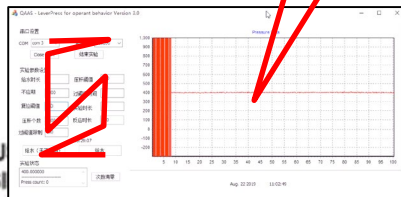
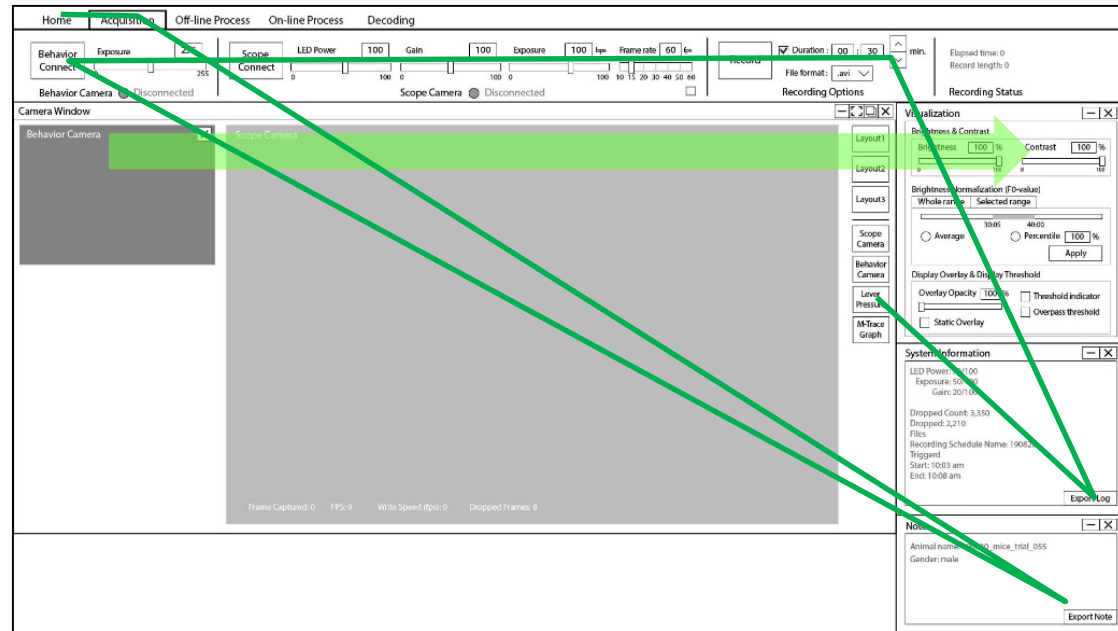
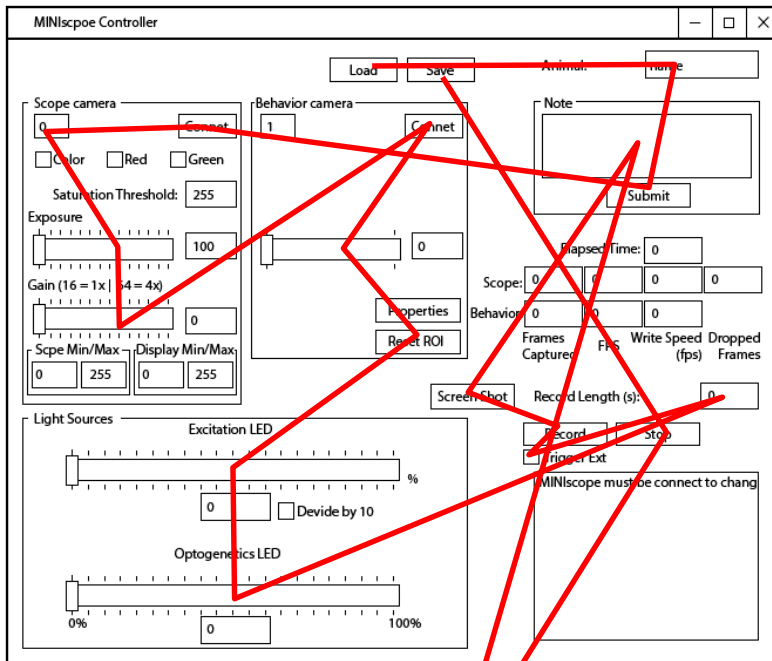


S3. Wireframe Design: Improved Usability and Functionality (1/3)

- ❑ Task sequence was improved by proposed navigation panel, and function panels.

Existing S/W (Miniscope)

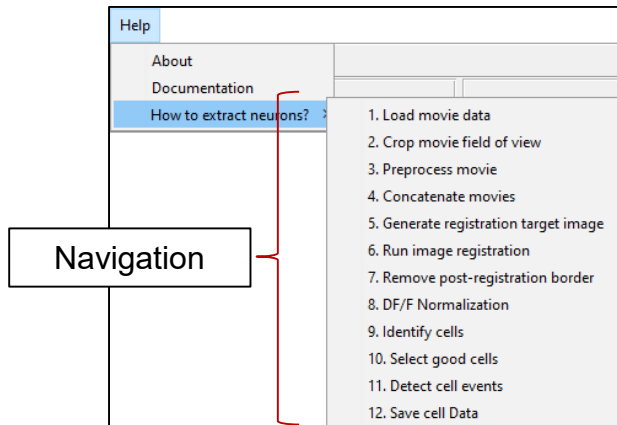
Proposed OBMI system



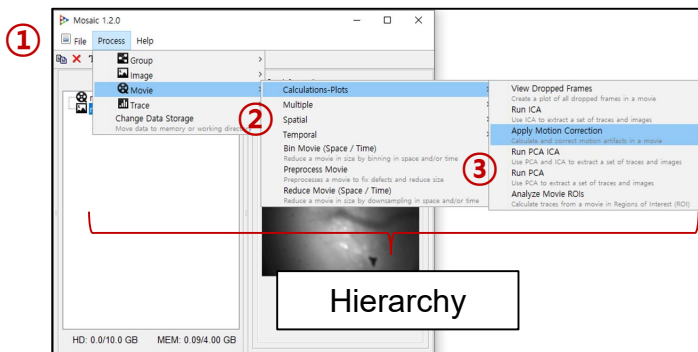
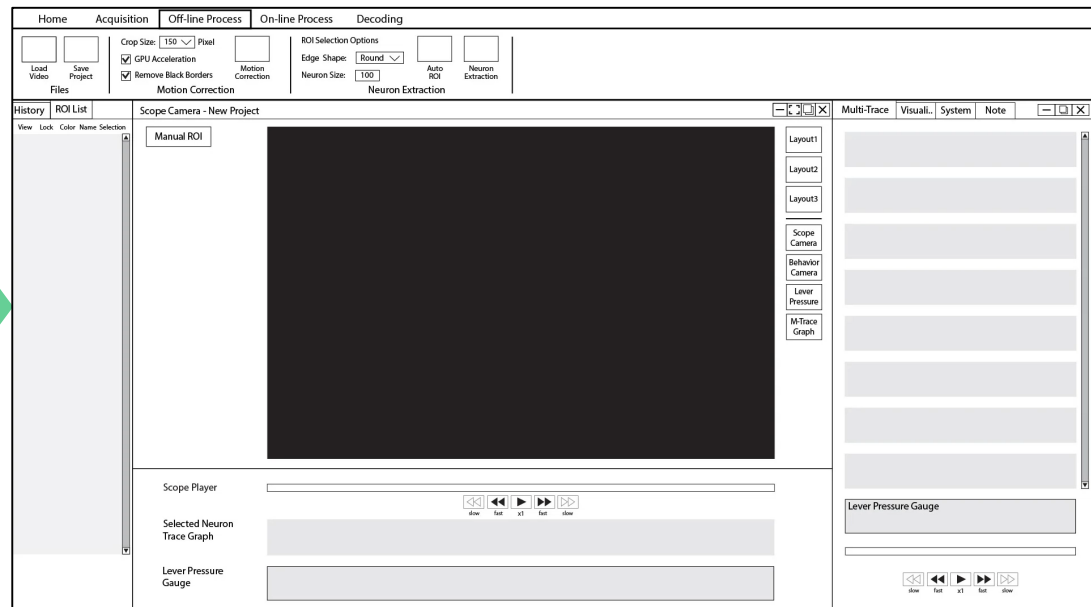
S3. Wireframe Design: Improved Usability and Functionality (2/3)

- Accessibility of function and learnability of task were improved by proposed task-based panel.

UI/UX of existing S/W (Mosaic)



UI/UX of proposed OBMI system



S3. Wireframe Design: Improved Usability and Functionality (3/3)

- ❑ On-line module with **real-time recoding** and **processing functions** was proposed.

On-line module of proposed OBMI system

The screenshot displays the software interface for the on-line module of the proposed OBMI system. The interface is organized into several functional areas:

- Navigation and Settings:** At the top, there are tabs for "Home", "Acquisition", "Off-line Process", "On-line Process" (which is currently selected), and "Decoding". Below these are various control panels. The "Scope Connect" panel includes sliders for "LED Power" (set to 100), "Gain" (set to 100), and "Exposure" (set to 100), along with a "Frame rate" dropdown set to 60 fps. The "Processing Option" panel includes checkboxes for "Motion Correction" and "GPU Acceleration", a "Crop Size" dropdown set to 150 Pixel, and a "Preview Duration" set to 15 sec. The "Online Processing" panel features buttons for "Pre-Processing", "Auto ROI", and "Real-time Process".
- Main Display Area:** The central part of the interface is a large black rectangle labeled "Manual ROI". To its left is a "History" and "ROI List" panel with columns for "View", "Lock", "Color", "Name", and "Selection". To the right of the main display is a vertical stack of buttons for "Layout1", "Layout2", "Layout3", "Scope Camera", "Behavior Camera", "Lever Pressure", and "M-Trace Graph".
- Playback and Monitoring:** At the bottom, there is a "Scope Player" with a progress bar and playback controls (slow, fast, x1, fast, slow). Below this are two "Selected Neuron Trace Graph" and "Lever Pressure Gauge" panels, each with its own playback controls.

S4. Evaluation on Wireframe Design

- ❑ **Subjective satisfaction evaluation** was conducted to test **usability** of the proposed wireframe design comparing with two existing S/W.
 - Evaluation scale: 7-point Likert scale (1: very dissatisfied, 4: moderate, 7: very satisfied)
 - Participant: 20 neuron researchers

Orientation (15 min)

Introduce of BMI background

Introduce of BMI tasks & features & UI

Explanation of evaluation method

Explanation of evaluation measures

Usability testing (40 min)

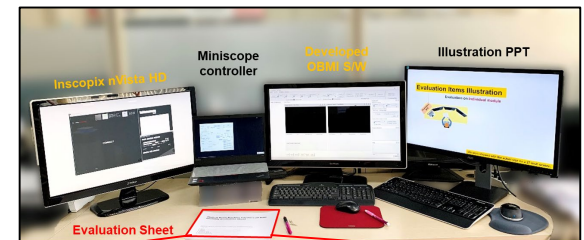
Individual component

Overall design

- Modules
- Components
- Fonts
- Color

- Style
- Layout
- Structure
- Overall system

Evaluation environment



Debriefing (5 min)

S1_1. Scope Camera Control Module

	Inscopix nVista HD	Miniscope DAQ	O-BMI
Location			
If Score <=	Where do you want to use this module?		
Size			
If Score <=	Where do you want to use this module?		

Overall duration:
1h/person

S4. Evaluation Target & Measures

- ❑ The **individual components** (location and size of modules, size of elements, size and typeface of fonts, color contrast of font and background) were evaluated by users' **satisfaction**.
- ❑ The **overall design** was evaluated using **ten evaluation attributes** (learnability, familiarity, simplicity, distinctiveness, visibility, informativeness, attractiveness, controllability, accessibility, overall preference) (Kim, 2015) (pre.).

Evaluation on individual components

S1_1. Scope Camera Control Module

	Inscopix nVista HD							Miniscope DAQ							O-BMI						
Location	Very Dissatisfied	Dissatisfied	Slightly Dissatisfied	Moderate	Slightly Satisfied	Satisfied	Very Satisfied	Very Dissatisfied	Dissatisfied	Slightly Dissatisfied	Moderate	Slightly Satisfied	Satisfied	Very Satisfied	Very Dissatisfied	Dissatisfied	Slightly Dissatisfied	Moderate	Slightly Satisfied	Satisfied	Very Satisfied
If Score < 4	Where do you want to use this module?							Where do you want to use this module?							Where do you want to use this module?						
Size	Very Dissatisfied	Dissatisfied	Slightly Dissatisfied	Moderate	Slightly Satisfied	Satisfied	Very Satisfied	Very Dissatisfied	Dissatisfied	Slightly Dissatisfied	Moderate	Slightly Satisfied	Satisfied	Very Satisfied	Very Dissatisfied	Dissatisfied	Slightly Dissatisfied	Moderate	Slightly Satisfied	Satisfied	Very Satisfied
If Score < 4	Very Small	Small	Slightly Small	Height	Slightly Large	Large	Very Large	Very Small	Small	Slightly Small	Height	Slightly Large	Large	Very Large	Very Small	Small	Slightly Small	Height	Slightly Large	Large	Very Large
	Very Small	Small	Slightly Small	Width	Slightly Large	Large	Very Large	Very Small	Small	Slightly Small	Width	Slightly Large	Large	Very Large	Very Small	Small	Slightly Small	Width	Slightly Large	Large	Very Large

Evaluation on overall design

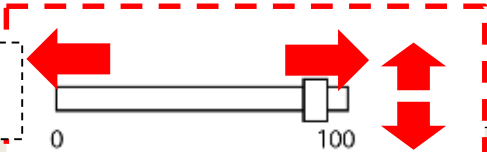
Category	Evaluation Dimensions	Descriptions
1	Style	Text style <ul style="list-style-type: none"> Typeface, size, color
2		Color style <ul style="list-style-type: none"> Colors of UI components
3		Overall style <ul style="list-style-type: none"> Appearance and atmosphere of the UI which is reflected by the visual elements
4	Layout	Distribution <ul style="list-style-type: none"> Orientation (horizontal/vertical) and arrangement way of the UI components
5		Spacing <ul style="list-style-type: none"> Free space between modules
6		Design concept <ul style="list-style-type: none"> The design concept about how to execute a function
7	Structure	Navigation system <ul style="list-style-type: none"> Hierarchy (depth and breadth)
8	Overall system usability	

S4. Results: Individual Modules

- ❑ 50% evaluation items of OBMI were preferred; others were not significantly different from the UI ranked 1st.
- ❑ Designs may need revision were selected base on principle: Mean < 5.0 / MD ≥ 0.3

Result of evaluation on individual components

No.	Category	Design Variable	Satisfaction (Mean)			MD
			A	B	C	
1	Location of module	Scope Camera Control Module	5.4	5.1	5.2	0.3
2		Behavior Camera Control Module	-	4.8	5.4	-
3		Record Control Module	5.7	4.6	5.2	0.5
4		Information Record Module	5.4	5.6	5.6	-
5		System Information Display Module	5.4	5.4	5.6	-
6		Camera Status Display Module	5.4	4.6	5.6	-
7		Record Status Display Module	5.8	4.9	5.2	0.6
8		Scope Camera Window	6.2	5.1	6.1	0.1
9	Size of module	Scope Camera Control Module	5.3	5.0	4.9	0.4
10		Behavior Camera Control Module	-	4.4	5.2	-
11		Record Control Module	5.5	5.0	5.1	0.4
12		Information Record Module	4.9	5.6	5.6	-
13		System Information Display Module	5.4	5.5	5.5	-
14		Scope Camera Window	6.0	4.8	6.1	-



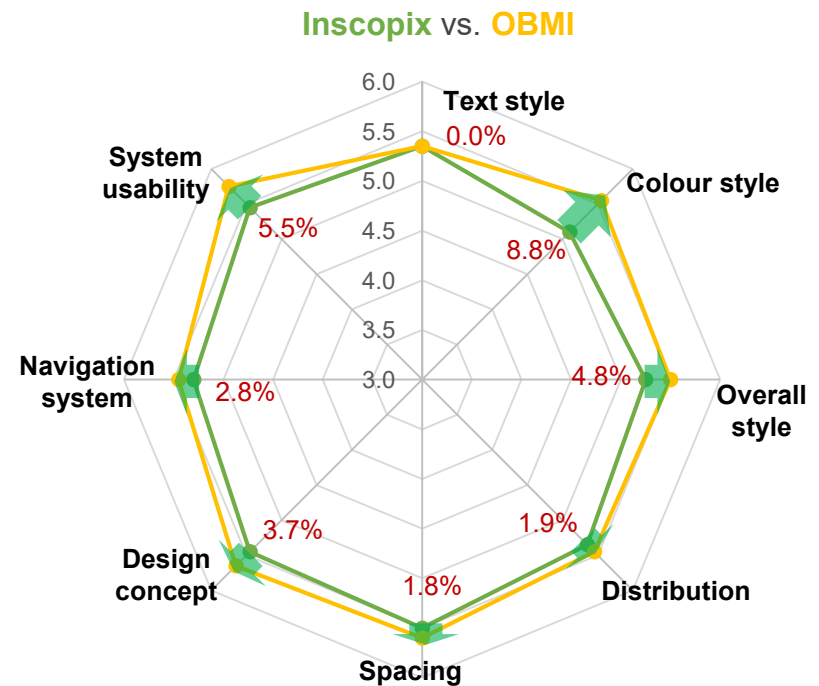
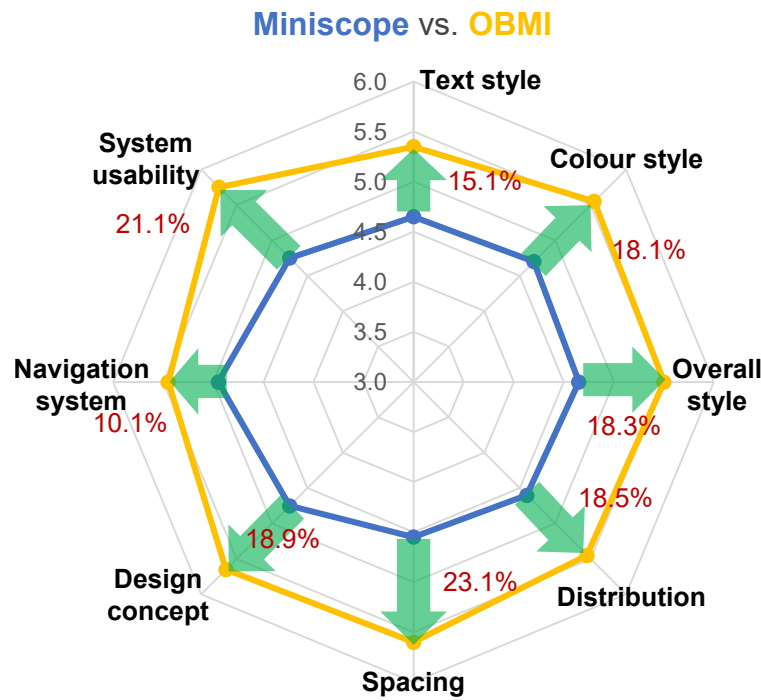
Improvement direction of slider & control widget size

No.	Category	Design Variable	A	B	C	MD
16	Record Button	5.5	4.8	5.3	0.2	
17	Slider	5.7	5.3	5.3	0.4	
18	Slider Control Widget	5.6	5.1	4.9	0.7	
19	Selector	5.1	5.0	5.3	-	
20	Spin Box	4.9	-	5.2	-	
21	Plus/Minus Controller	4.8	-	-	-	
22	Check Box	4.5	5.1	5.3	-	
23	Size of fonts	'Label 1'	5.5	5.3	5.4	0.1
24		'Label 2'	5.0	5.3	5.3	-
25		'Number 1'	5.2	5.4	5.4	-
25		'Number 2'	4.8	5.3	5.0	0.3
27	Typeface of fonts	'Record'	5.5	5.4	5.3	0.2
28		'Gain'	4.8	5.5	5.1	0.4

S4. Results: Overall System Usability (1/2)

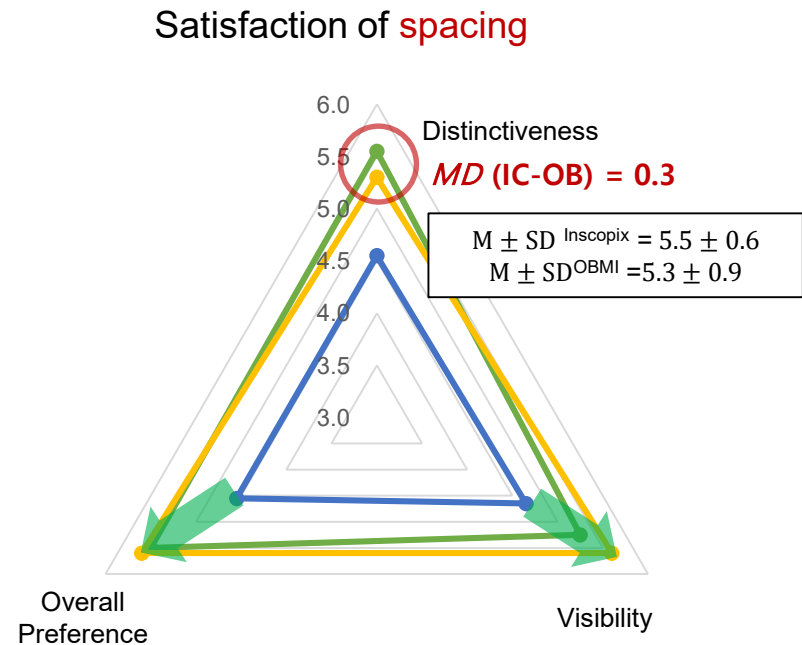
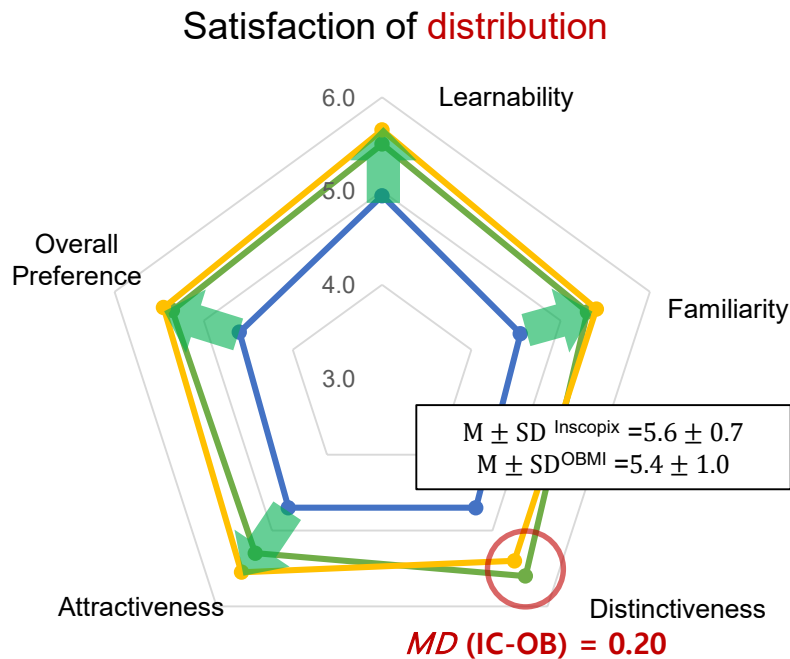
- Satisfaction of OBMI UI design has been improved by 0% ~ 8.8%, 10.1% ~ 23.1% compared to Inscopix and Miniscope, respectively.

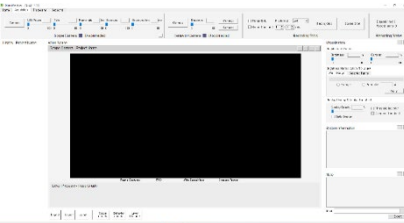

Mean overall preference of design aspects



S4. Results: Overall System Usability (1/2)

- ❑ The **distribution** and **spacing of UI** may need improvement in terms of **distinctiveness** ($MD \geq 0.2$).

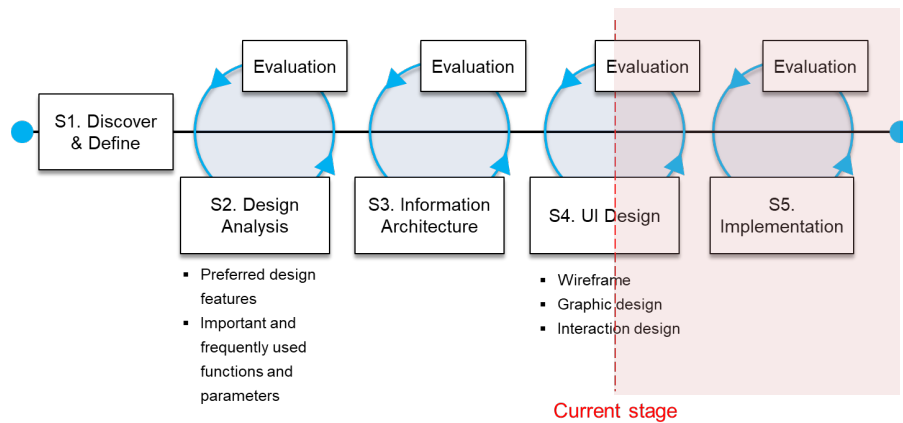


Evaluation Object	Description	OBMI	Inscopix
Distribution	Orientation and arrangement way of the UI components		
Spacing	Free space between modules		

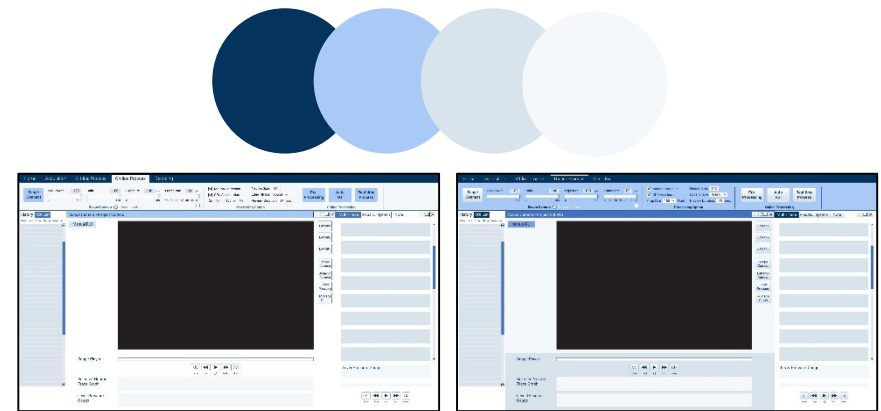
Discussion (1/2)

- ❑ The **wireframe** of the OBMI UI was proposed with **satisfying usability and functionality**.
- ❑ **Graphic design** need to be applied to the proposed wireframe.
- ❑ **Dynamic usability test** needs to be included in the future work.

Future UI development work



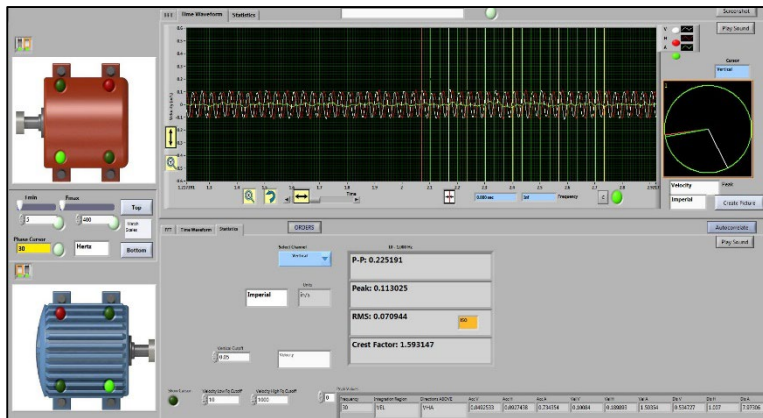
Color schemes of OBMI UI design



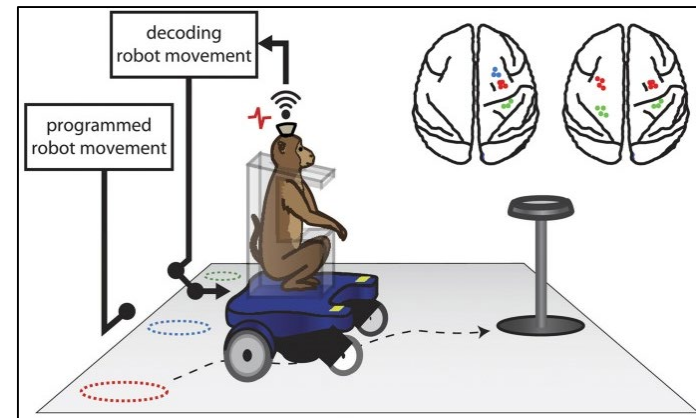
Discussion (2/2)

- ❑ The OBMI UI design can be referred to various systems with **similar UI design requirements** and be applied to **other types of BMI research**.

Vibration analysis S/W



Wireless Cortical BMI research for whole-body navigation in primates



경청해 주셔서 감사합니다.



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Appendix

Simulation S/W: On-line Module

