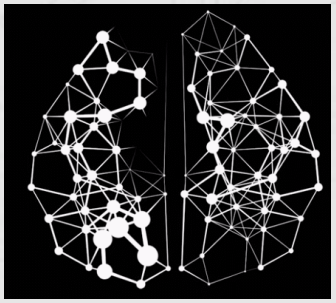
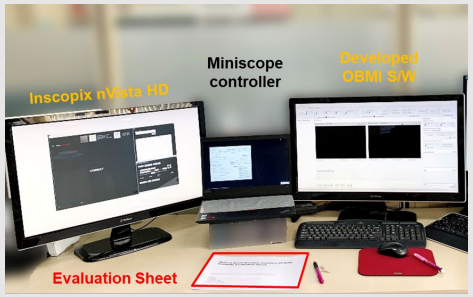
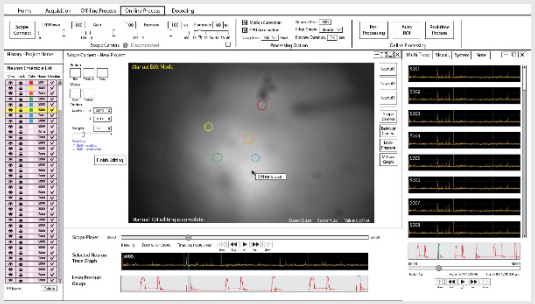
Development and Evaluation of UI Design for Ergonomic Optical Brain-Machine Interface (OBMI) System

광학적 뇌-기계 인터페이스 시스템의 UI 디자인 개발 및 평가







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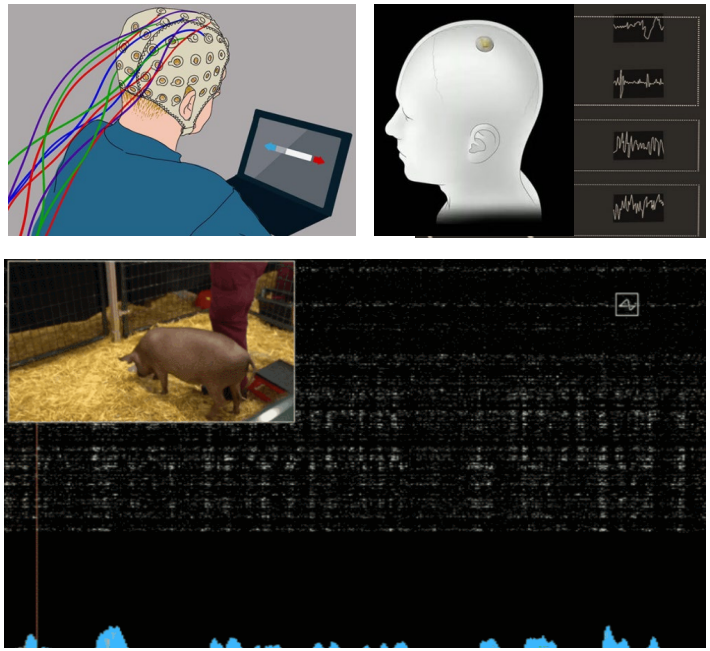
Contents

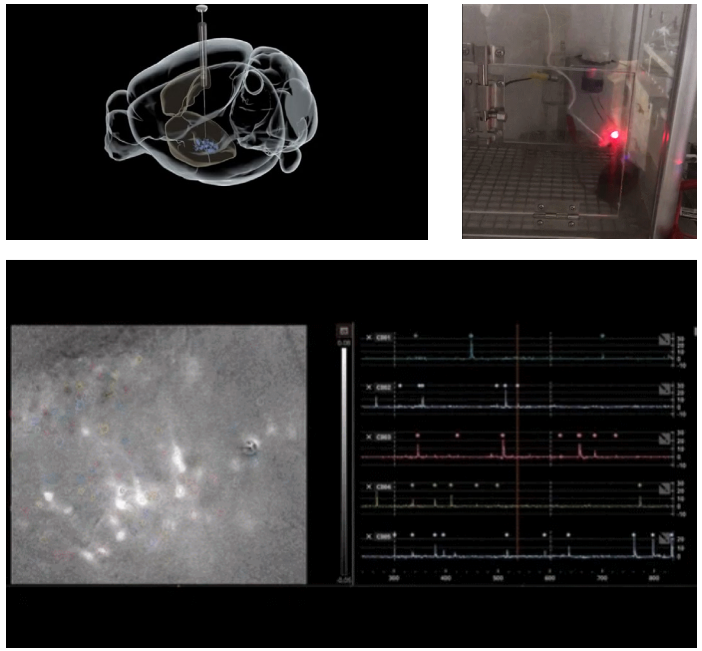
Background

- 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



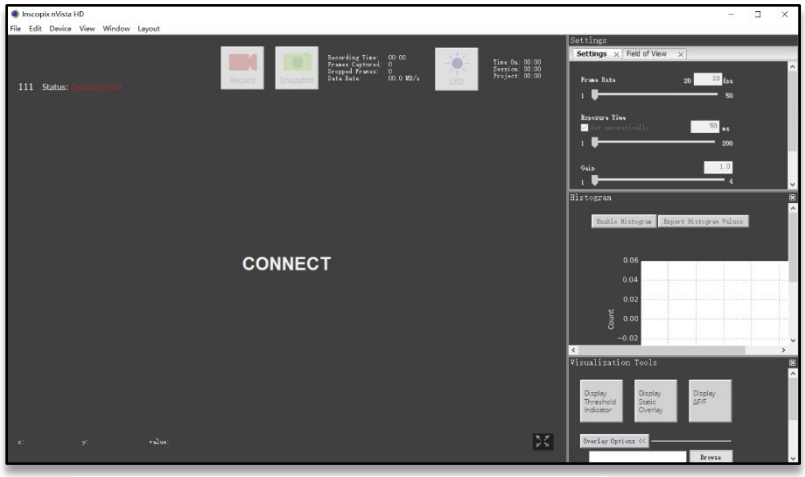
Calcium imaging-based BMI systems



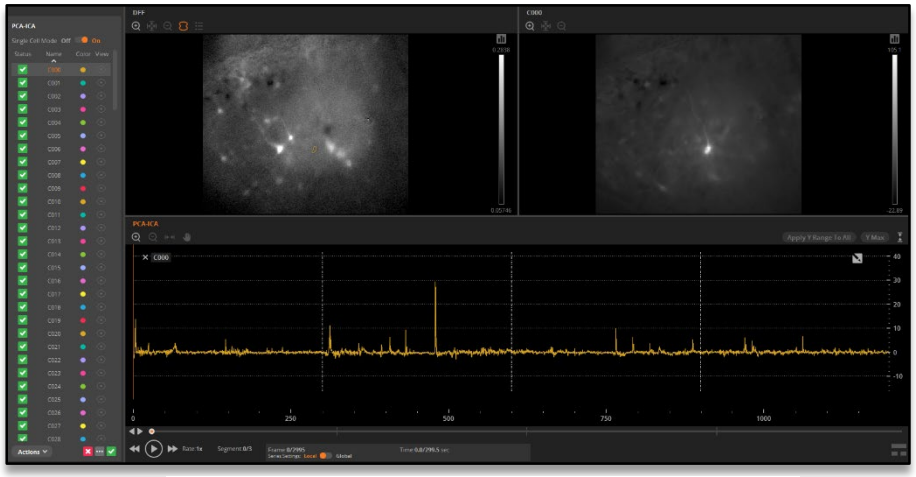
Limitations of Optical BMI

- 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)

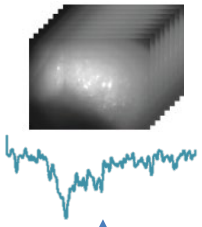
Experiment Procedure by Neuron Researchers

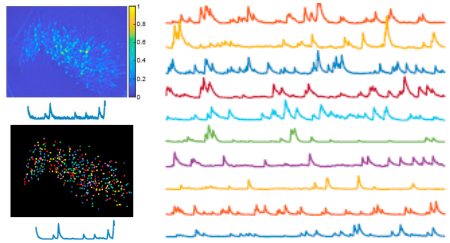
Data Acquisition

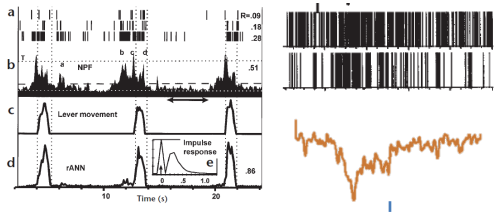
Off-line Processing

Off-line Decoding

Behavior Training



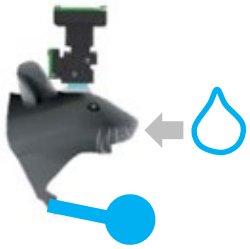




Actual pressure

vs.

Predicted pressure

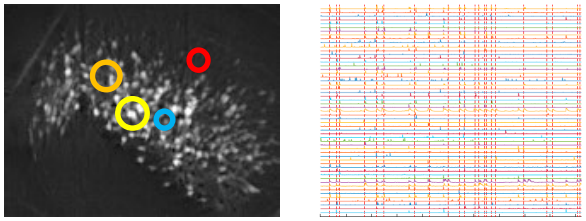


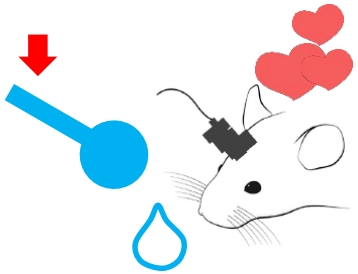
Provide reference of best parameters

On-line Processing

On-line Decoding

External Device Control

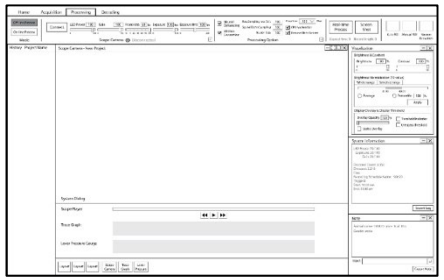


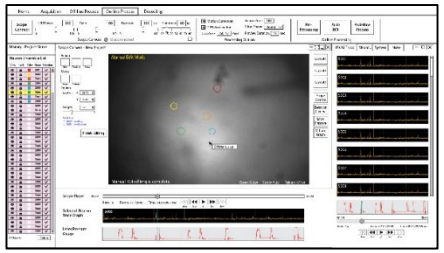


Objectives of the Study

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

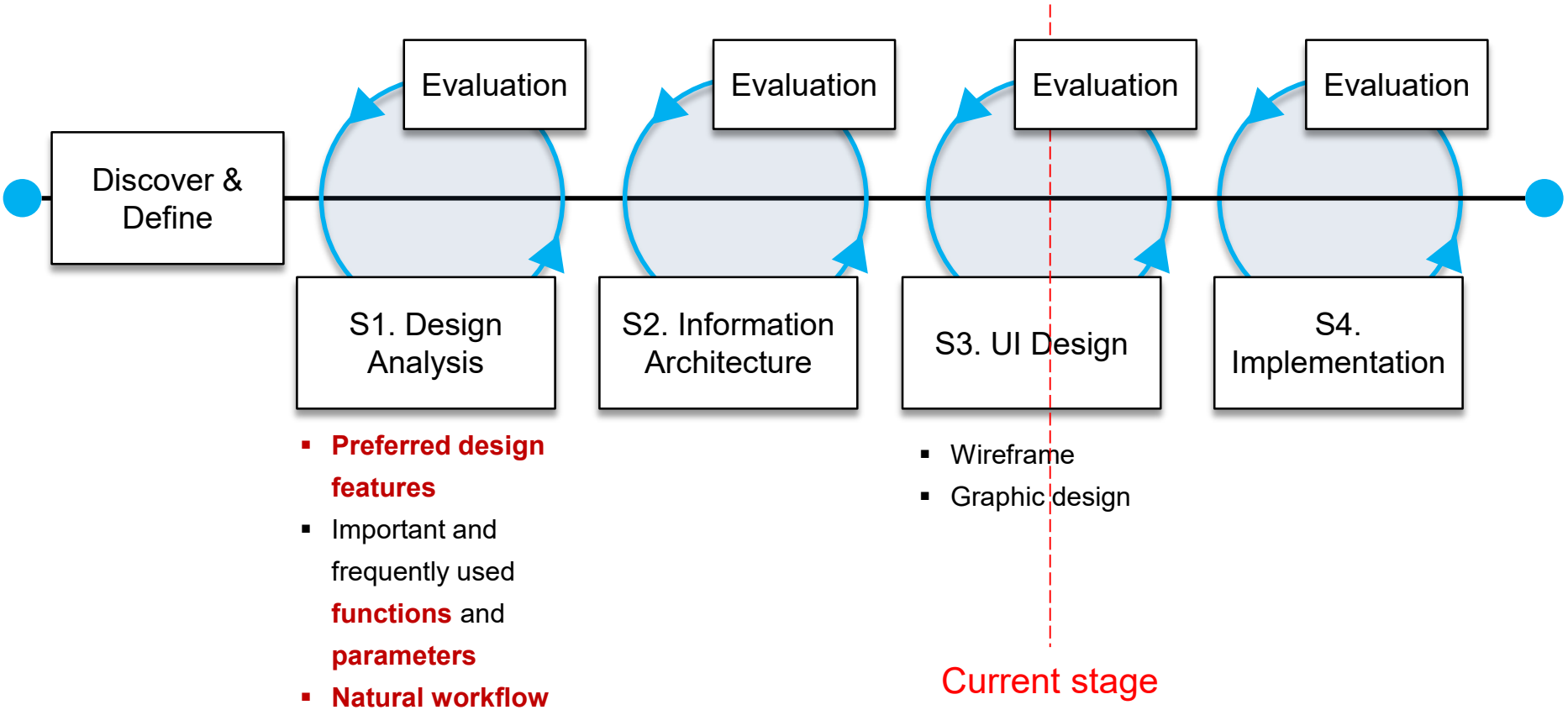
1. Analyze design features by literature review, benchmarking and a user survey
2. Develop the information architecture
3. Propose UI wireframe
4. Evaluate the proposed UI wireframe and proposed design improvements



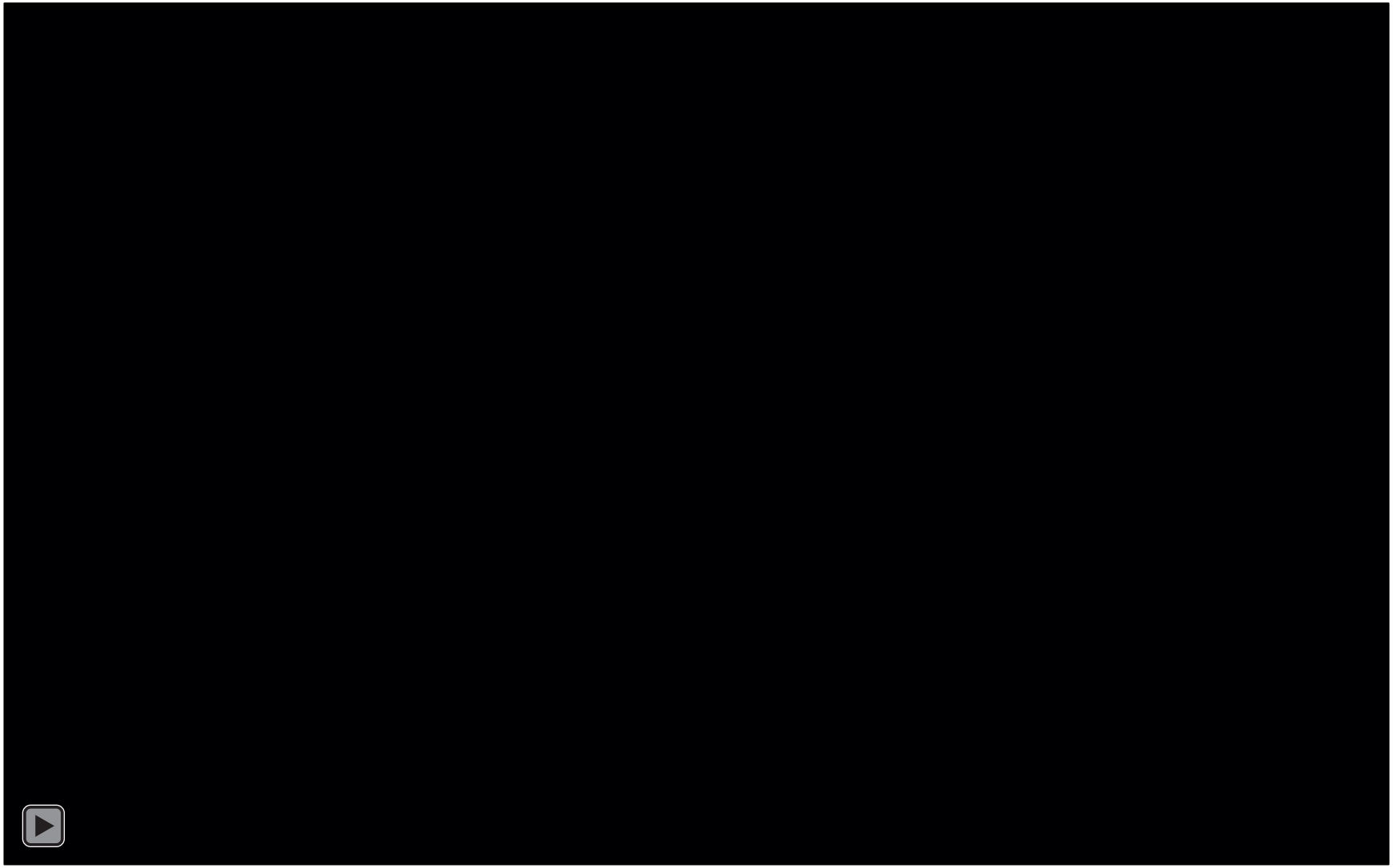


Research Procedure

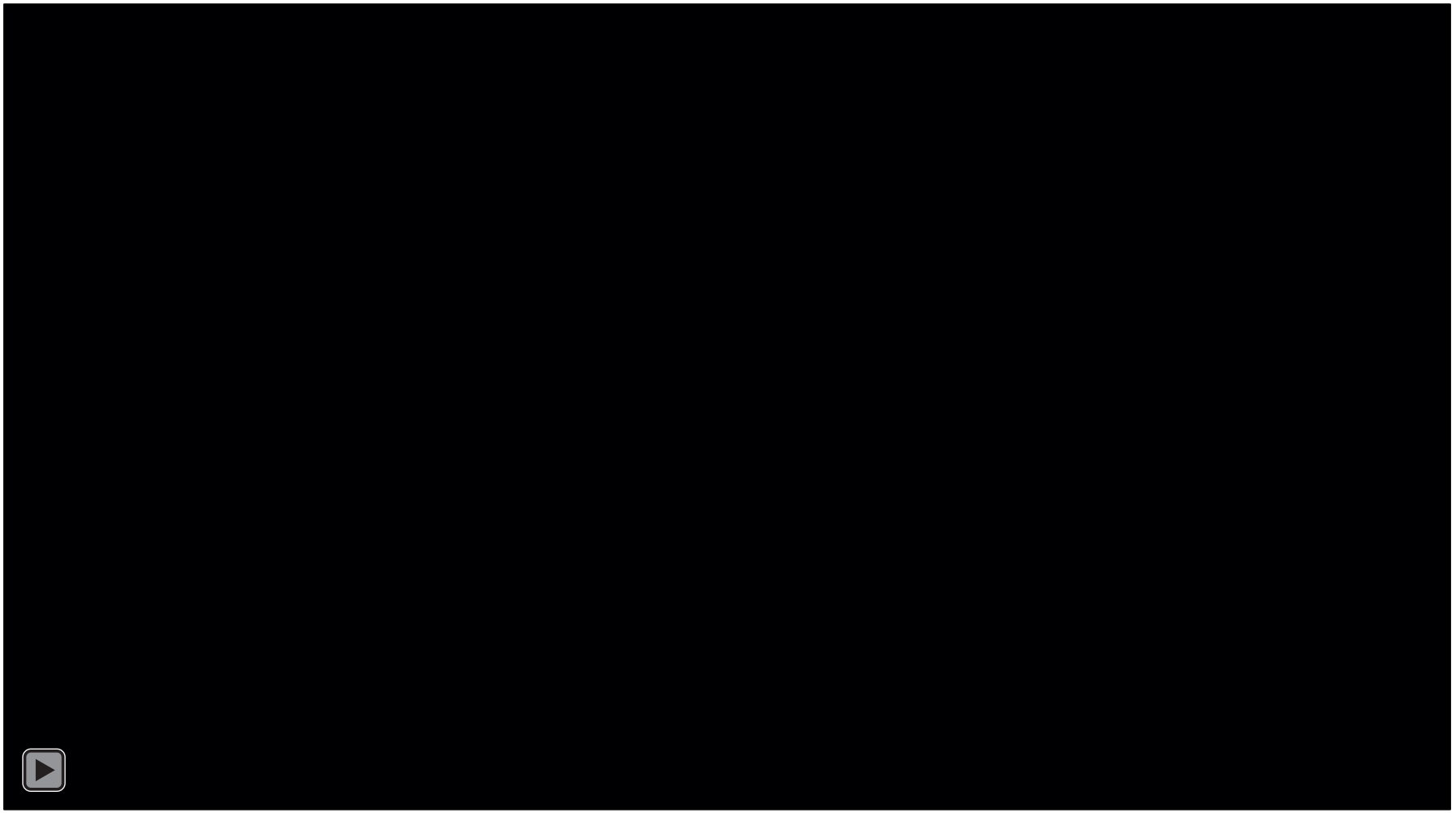
- An iteration design and evaluation process was conducted to develop OBMI UI.



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**.

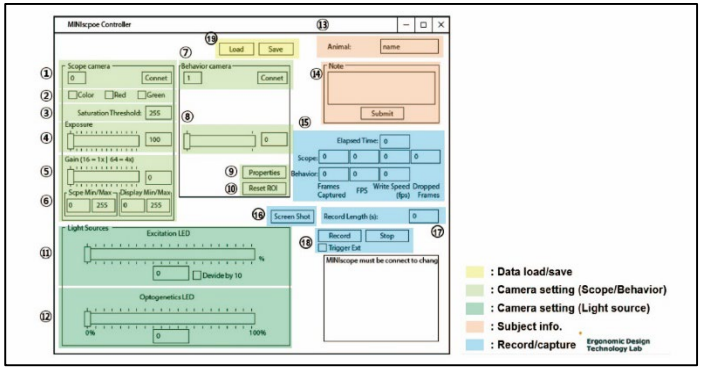
Preferred design features

Category	Attribute	Design Feature	Preferred Design Features by Design Type			
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)	-

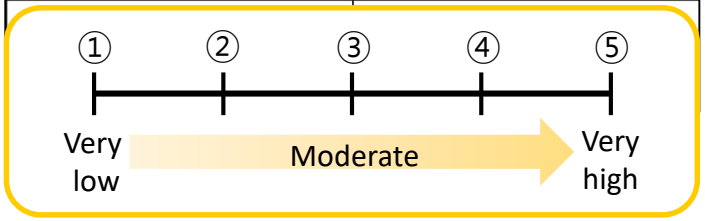
S1. Design Analysis: Functions and Parameters (pre.)

- 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



Frequency					Importance				
Very low	Low	Mod erate	High	Very high	Very low	Low	Mod erate	High	Very high
①	②	③	④	⑤	①	②	③	④	⑤

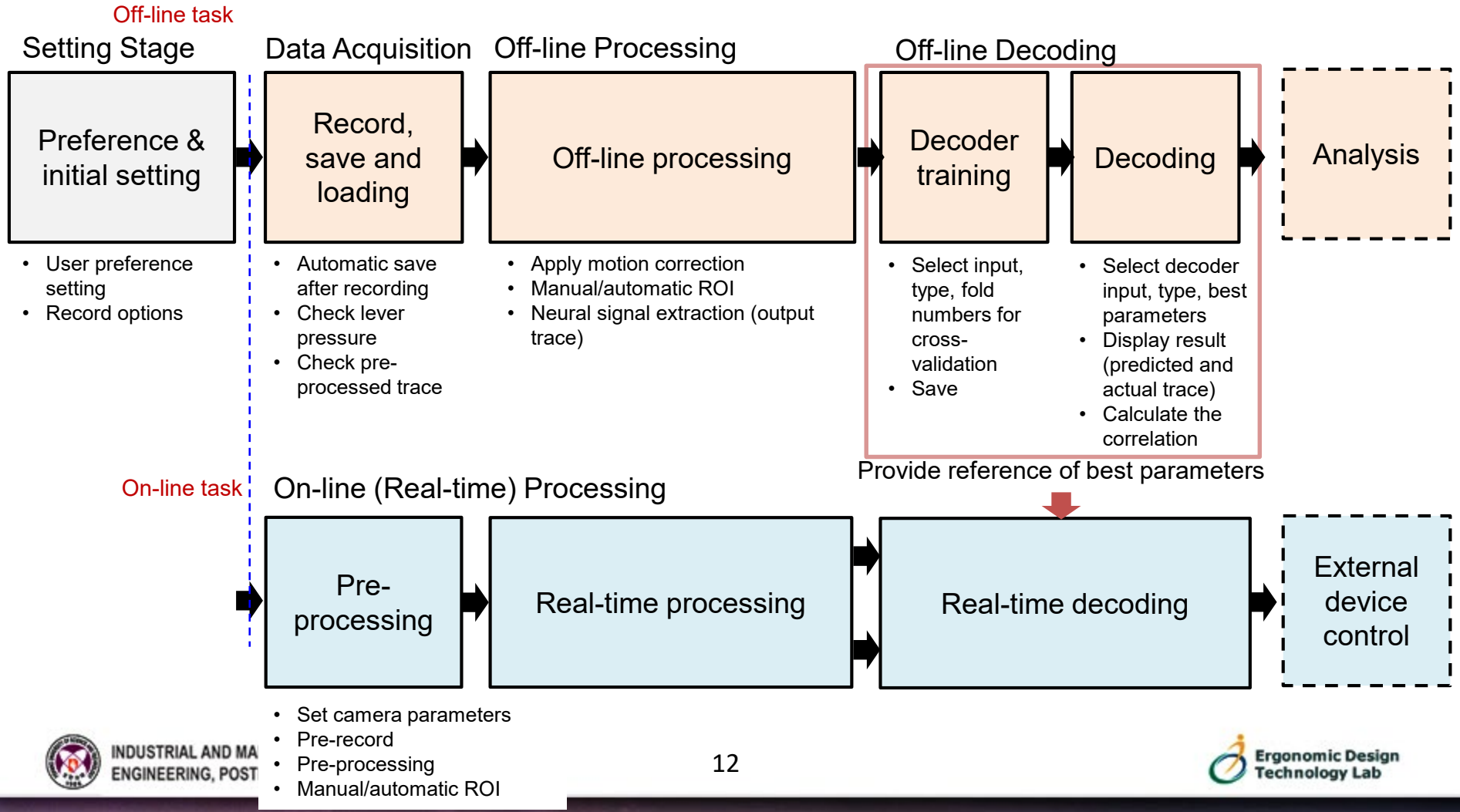


Ranking of functions and parameters

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.)

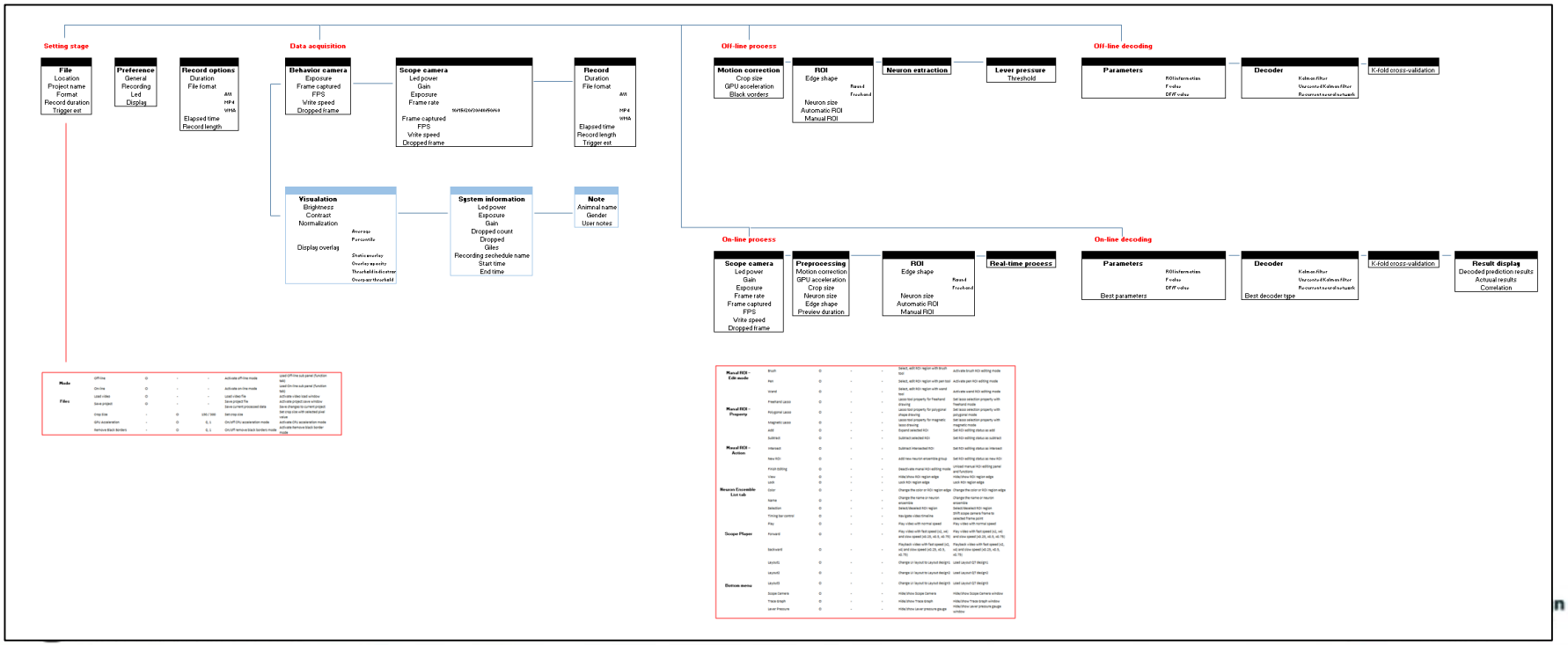
- Literature review, user interviews, and benchmarking on existing systems were conducted to identify the **workflow of OBMI**.



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.

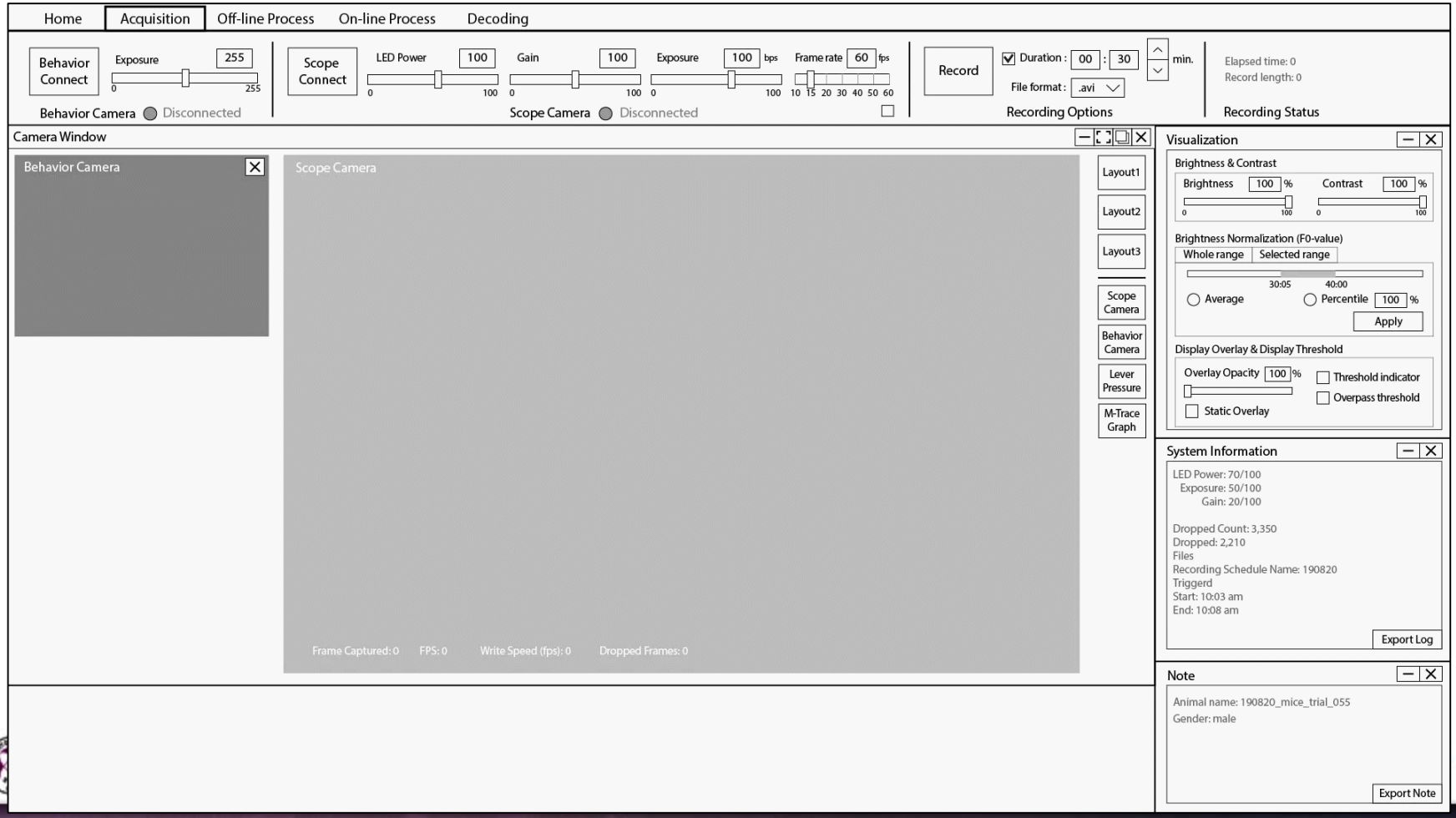
Information architecture



S3. Wireframe Design: Summary

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

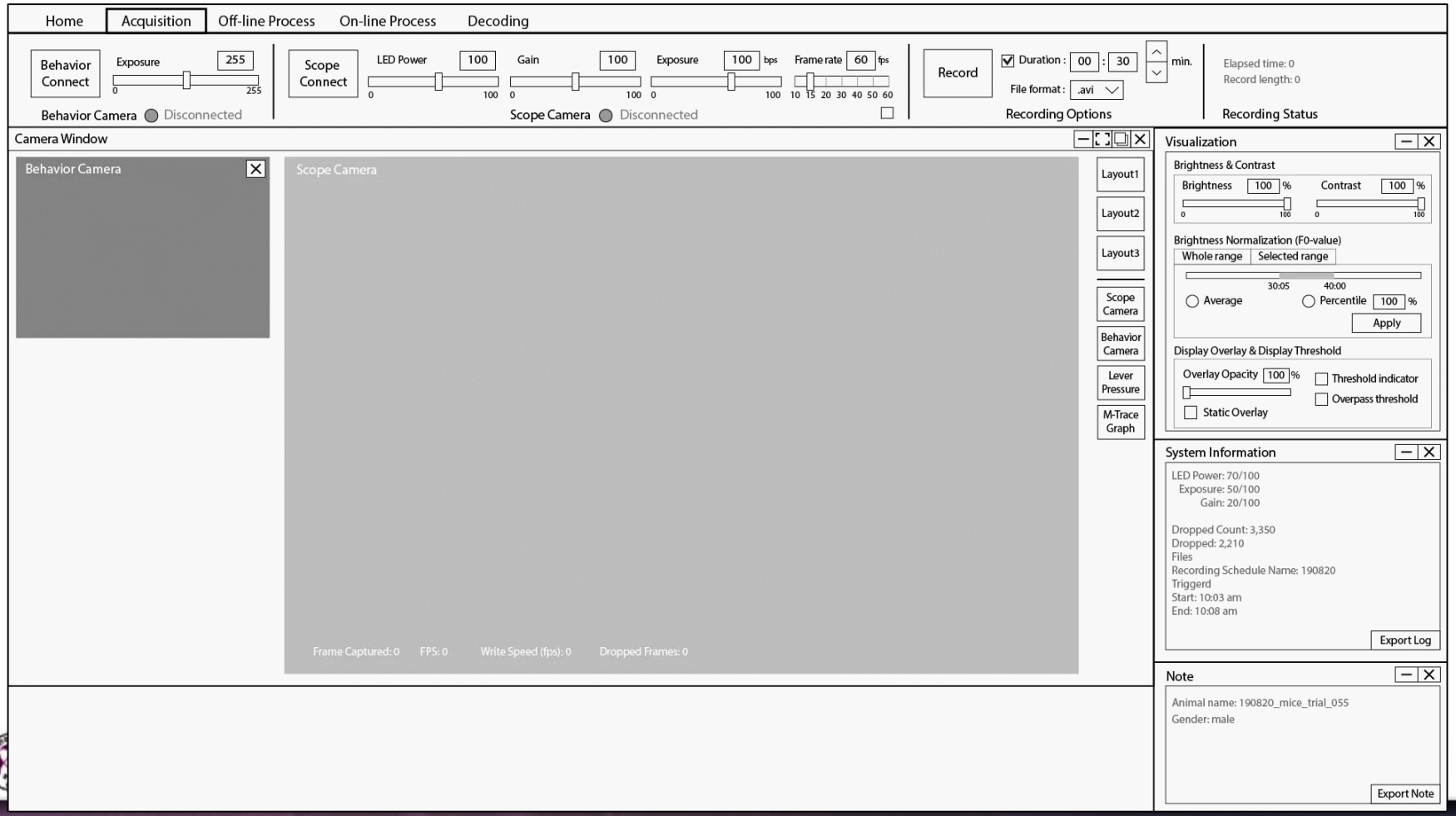
Wireframe design of OBMI UI



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

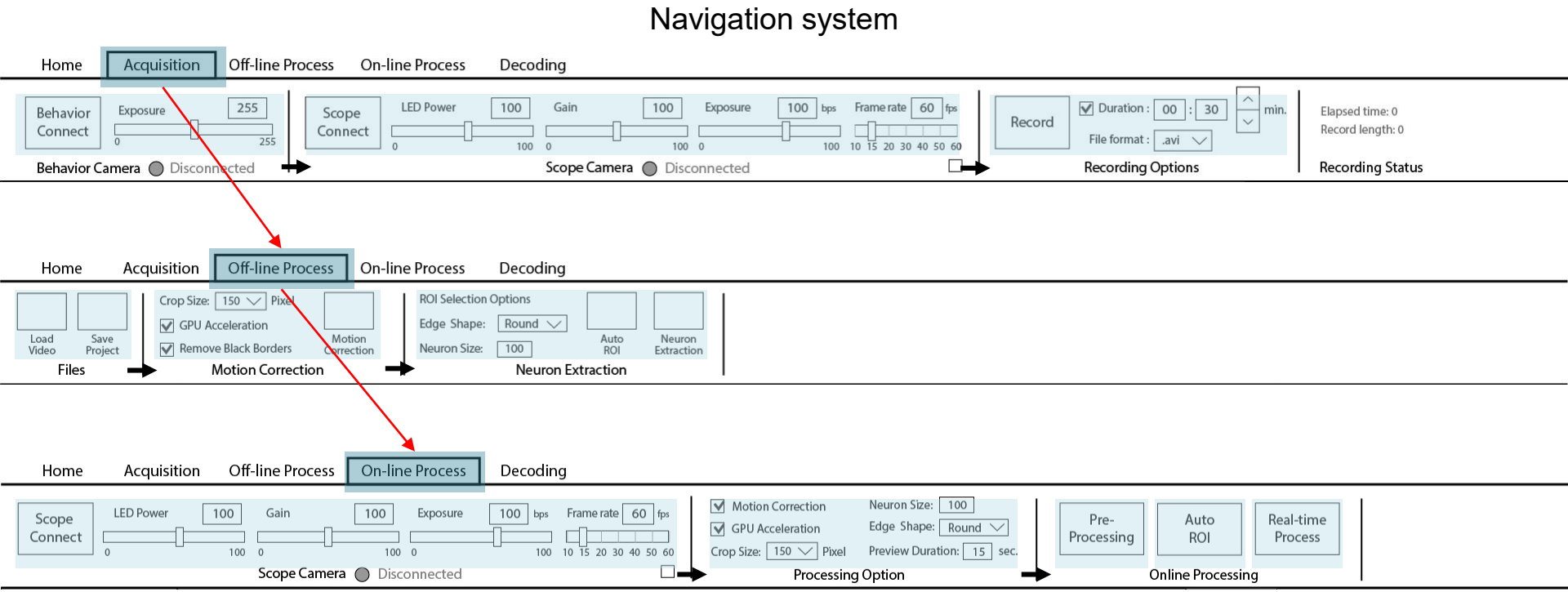
- The overall layout was designed to fixed components with several default layout options.

Layout options of data acquisition & on-line processing



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

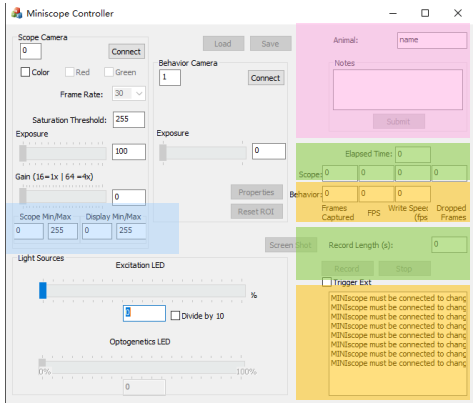
- The navigation system was designed to tiled panel based on the conduction sequence of tasks, functions, and parameters.

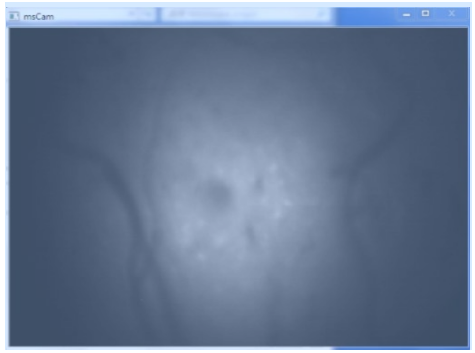


S3. Wireframe Design: Preferred Features (3/4)

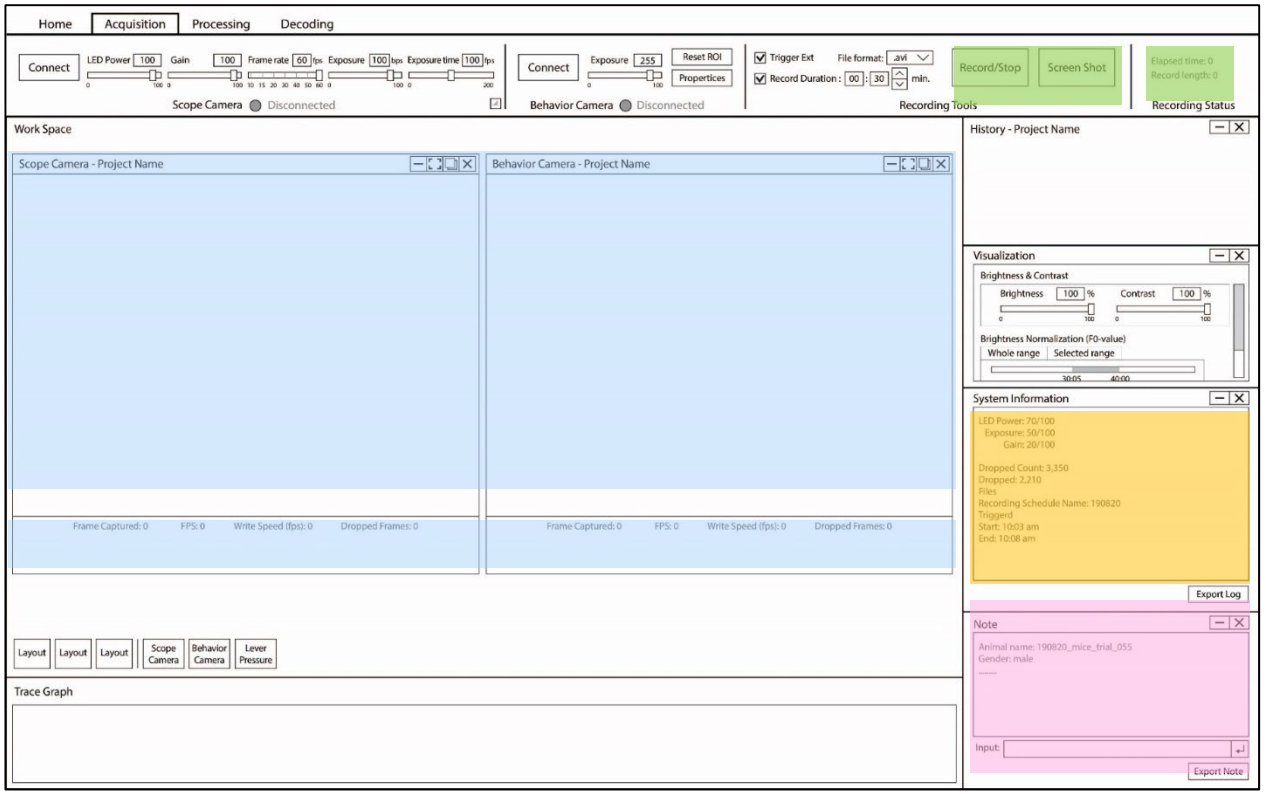
- Status information was arranged next to modules with high relevance.

Existing S/W





OBMI system

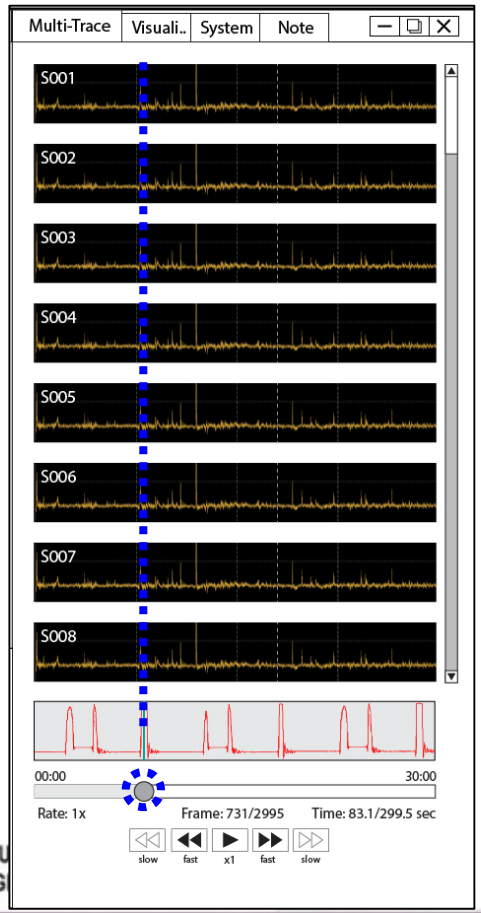


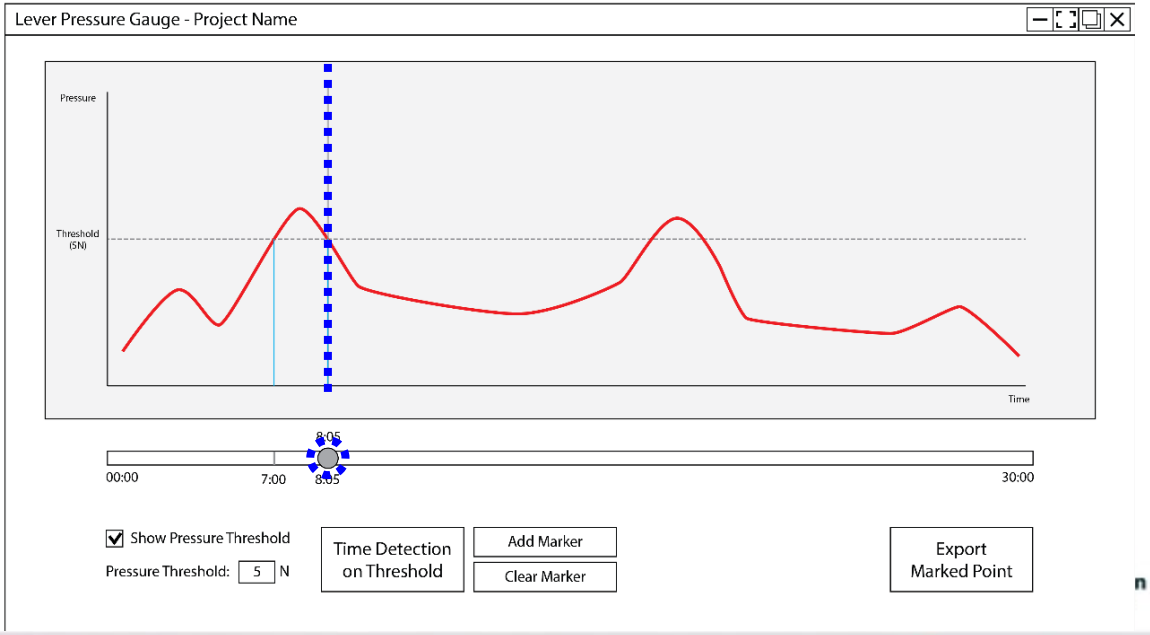
Camera status | Recording status | System information | User notes/animal information

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

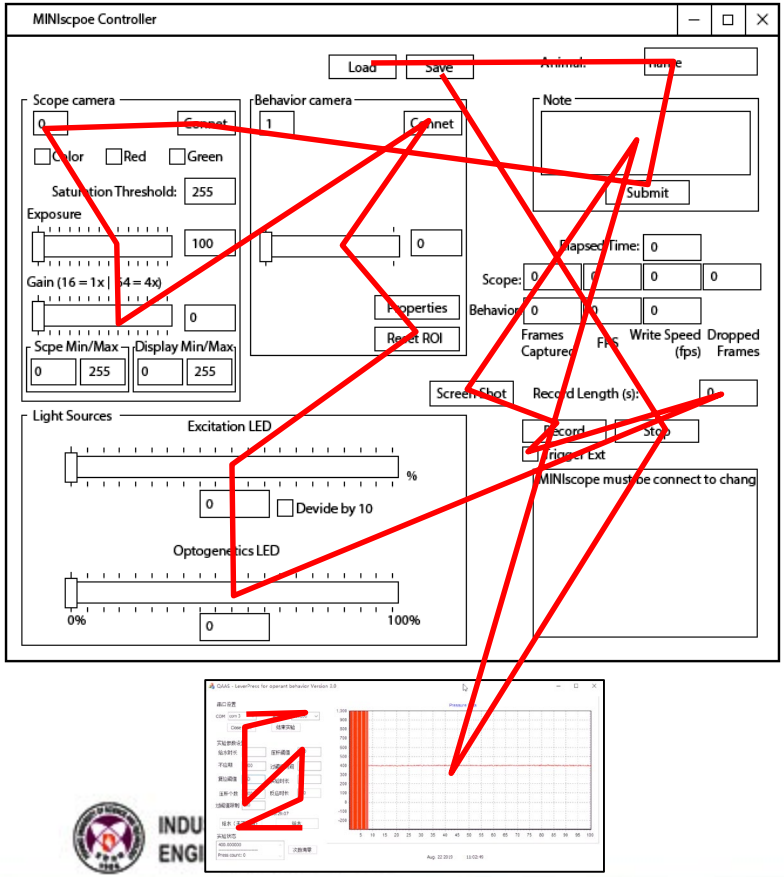




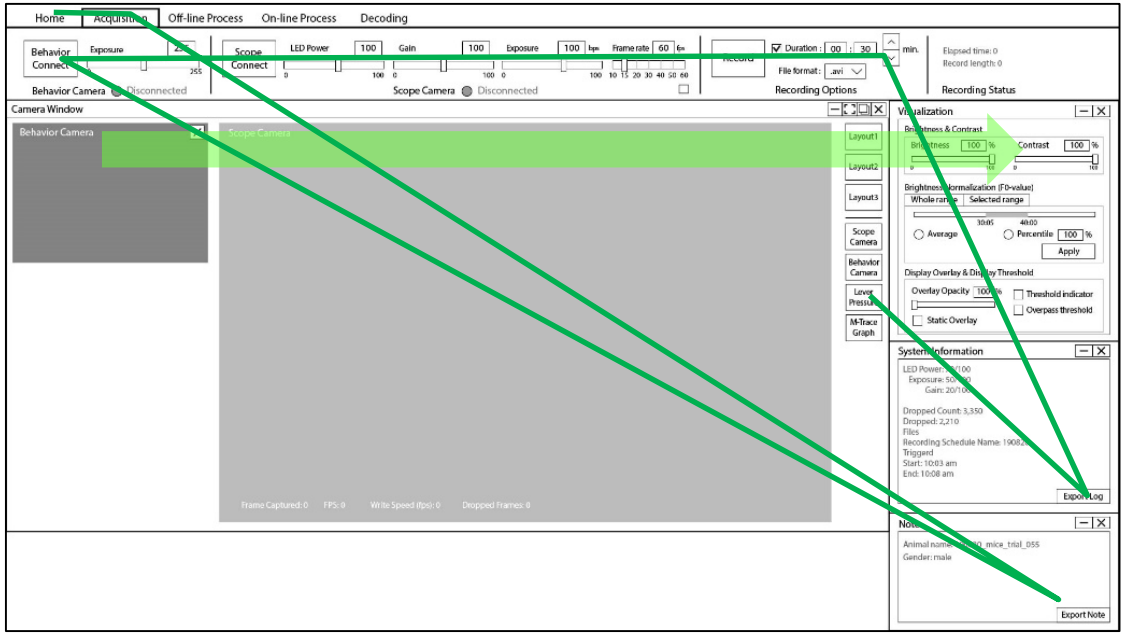
S3. Wireframe Design:
Improved Usability and Functionality (1/3)

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

Existing S/W (Miniscope)



Proposed OBMI system



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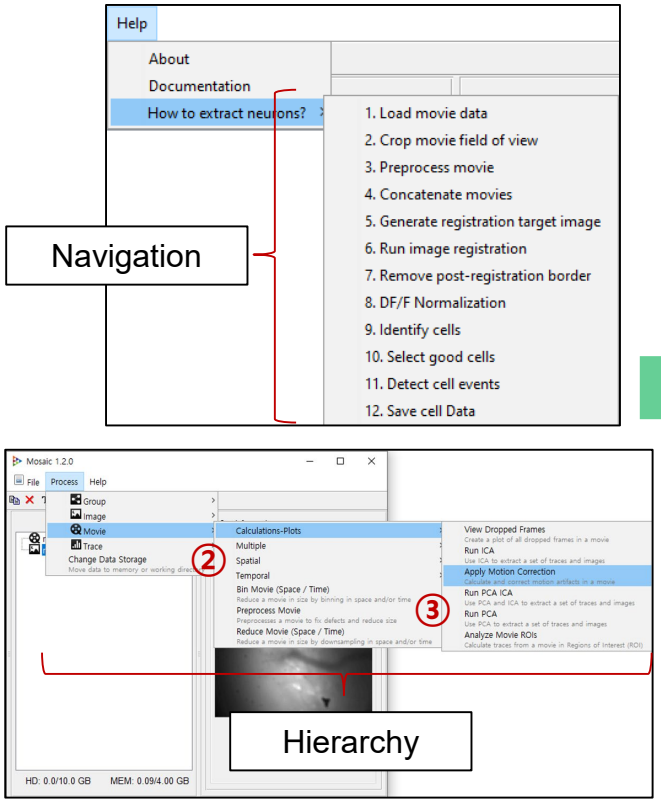
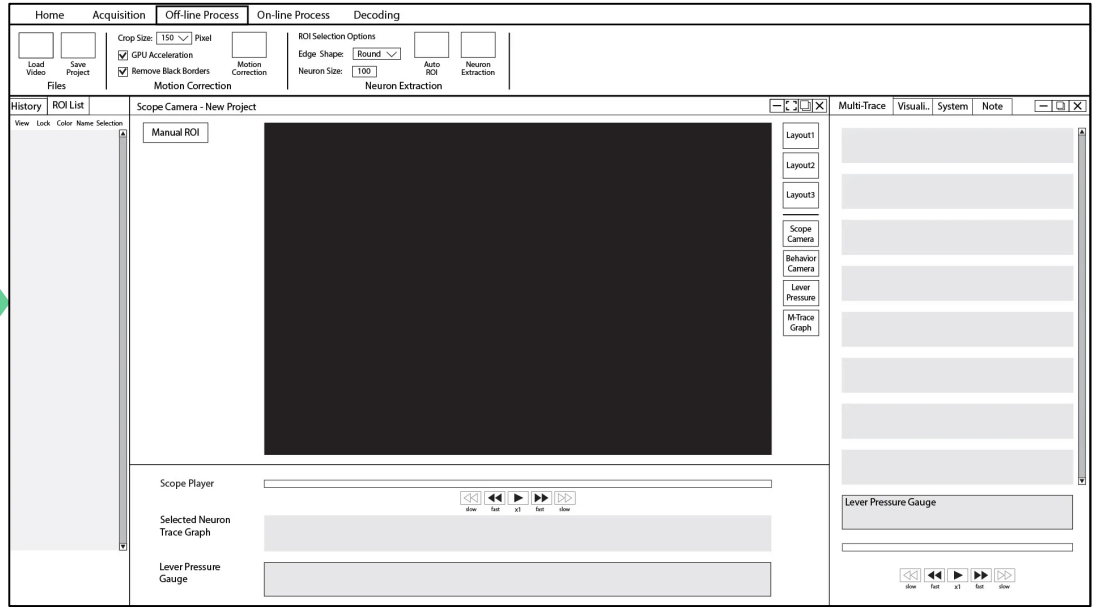
S3. Wireframe Design:
Improved Usability and Functionality (2/3)

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

UI/UX of existing S/W (Mosaic)



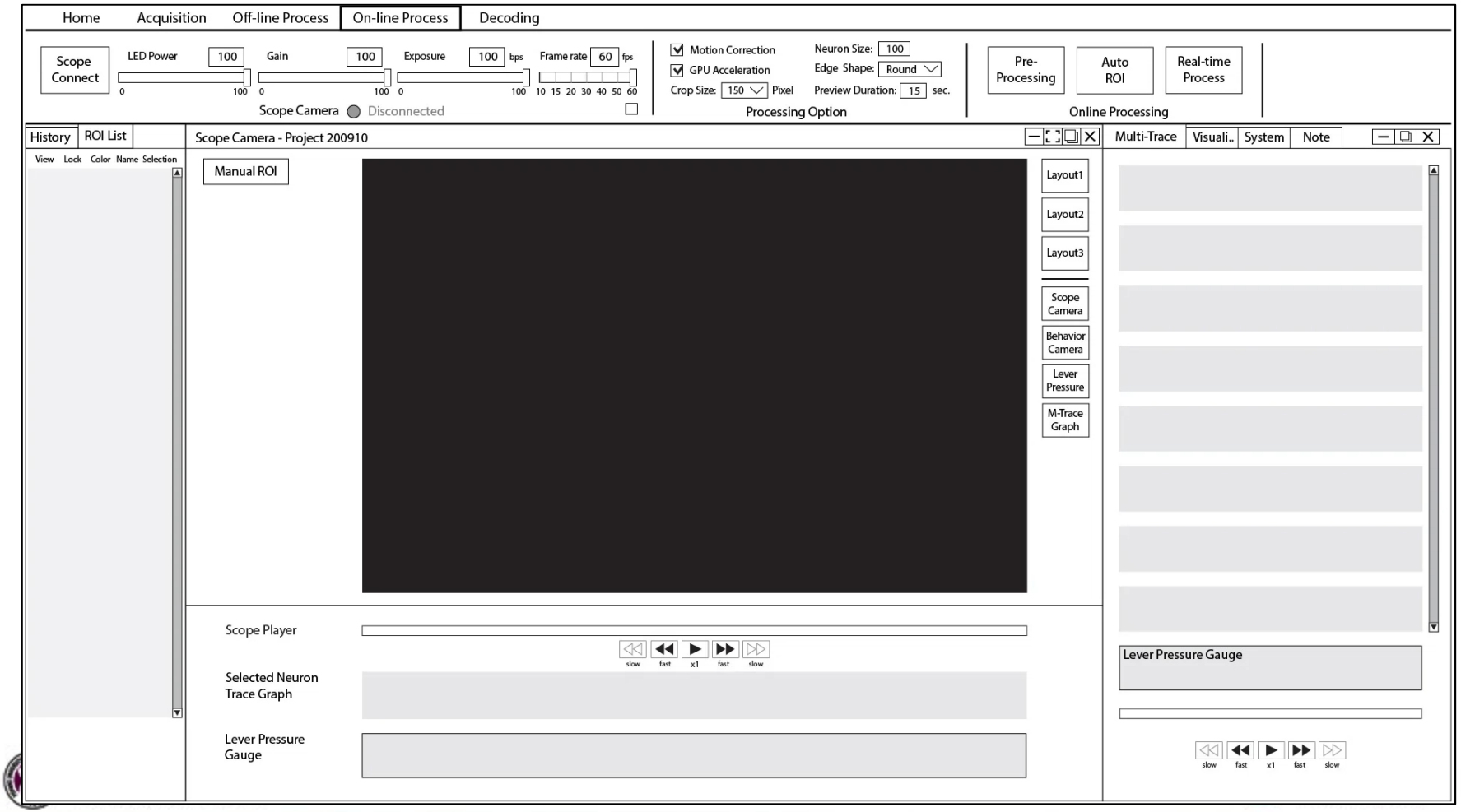
UI/UX of proposed OBMI system



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

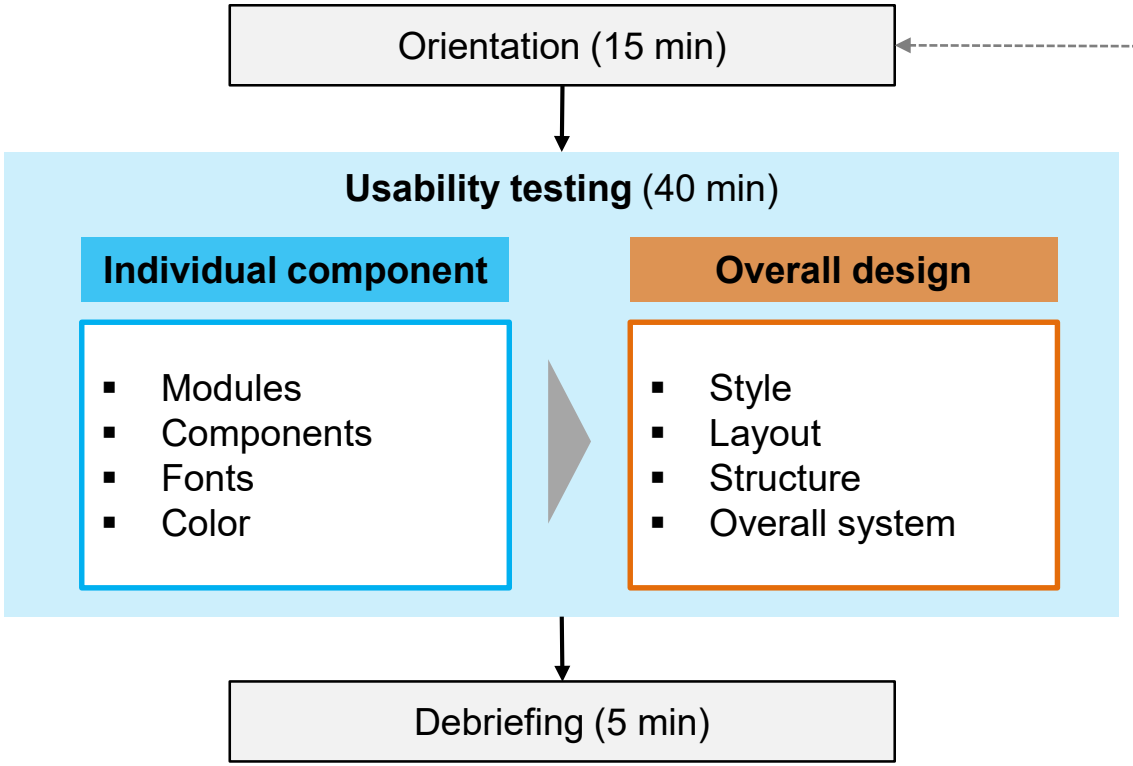
- On-line module with real-time recoding and processing functions was proposed.

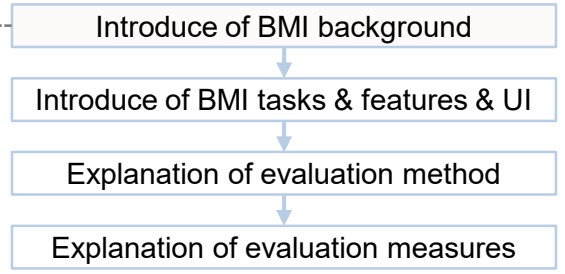
On-line module of proposed OBMI system



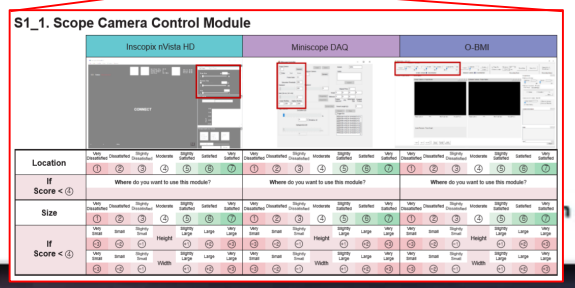
S4. Evaluation on Wireframe Design

- 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





Evaluation environment

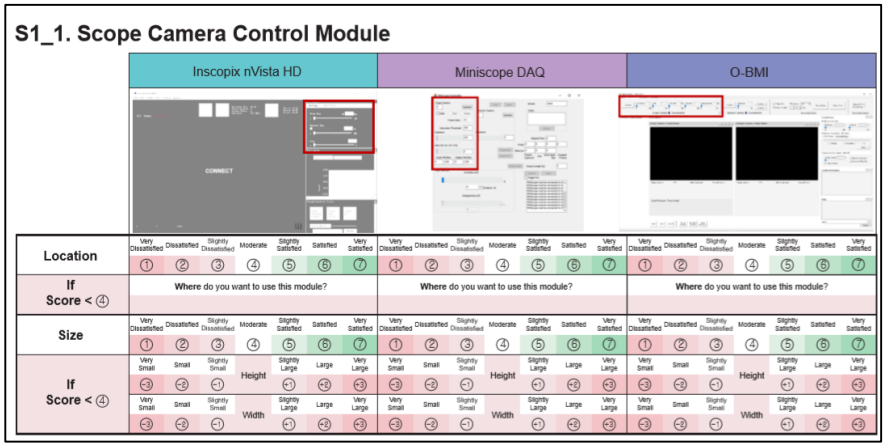


Overall duration: 1h/person

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



Evaluation on overall design

Category		Evaluation Dimensions	Descriptions
1	Style	Text style	▪ Typeface, size, color
2		Color style	▪ Colors of UI components
3		Overall style	▪ Appearance and atmosphere of the UI which is reflected by the visual elements
4	Layout	Distribution	▪ Orientation (horizontal/vertical) ▪ and arrangement way of the UI components
5		Spacing	▪ Free space between modules
6		Design concept	▪ The design concept about how to execute a function
7	Structure	Navigation system	▪ 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: $\text{Mean} < 5.0$ / $\text{MD} \geq 0.3$

Result of evaluation on individual components

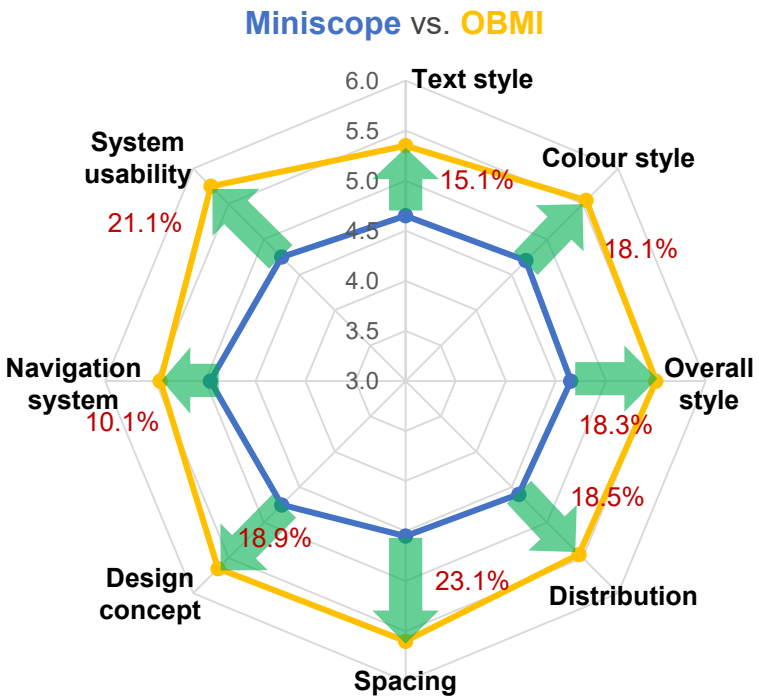
No.	Category	Design Variable	Satisfaction (Mean)			MD
			A	B	C	
1	Location of module	Scope Camera Control Module	5.4	5.1	5.2	0.3
2		Behavior Camera Control Module	-	4.8	5.4	-
3		Record Control Module	5.7	4.6	5.2	0.5
4		Information Record Module	5.4	5.6	5.6	-
5		System Information Display Module	5.4	5.4	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	-

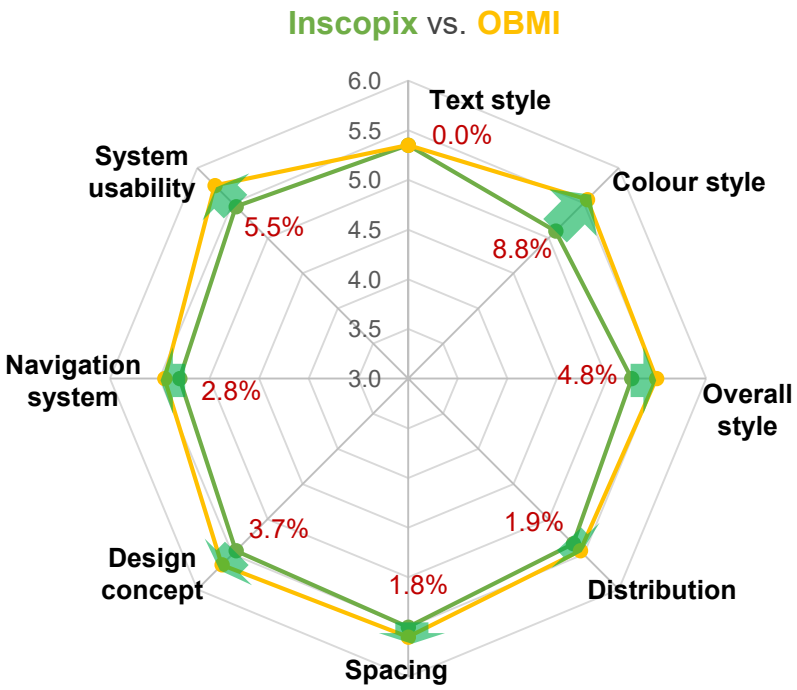
No.	Category	Design Variable	A	B	C	MD
15	Size of components	Connect Button	5.6	4.7	5.2	0.4
16		Record Button	5.5	4.8	5.3	0.2
17		Slider	5.7	5.3	5.3	0.4
18		Slider Control Widget	5.6	5.1	4.9	0.7
19		Selector	5.1	5.0	5.3	-
20		Spin Box	4.9	-	5.2	-
21		Plus/Minus Controller	4.8	-	-	-
22		Check Box	4.5	5.1	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

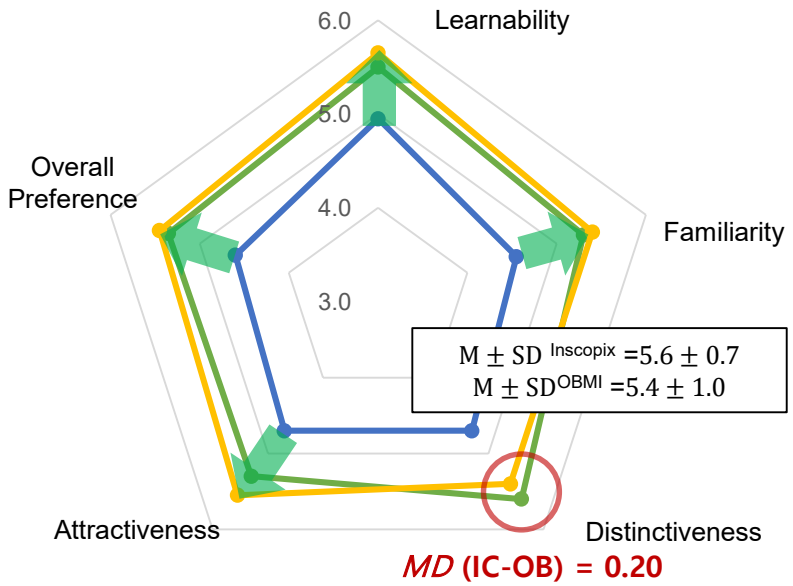




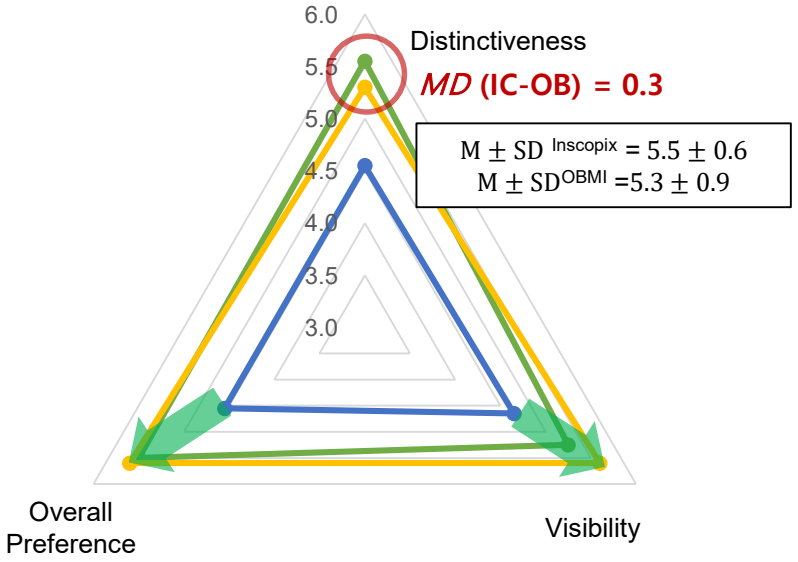
S4. Results: Overall System Usability (1/2)

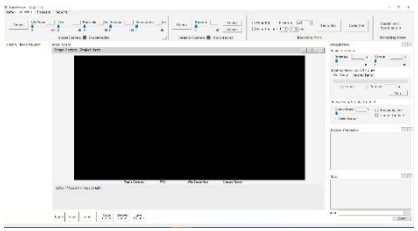
- The distribution and spacing of UI may need improvement in terms of distinctiveness ($MD \geq 0.2$).

Satisfaction of distribution



Satisfaction of spacing

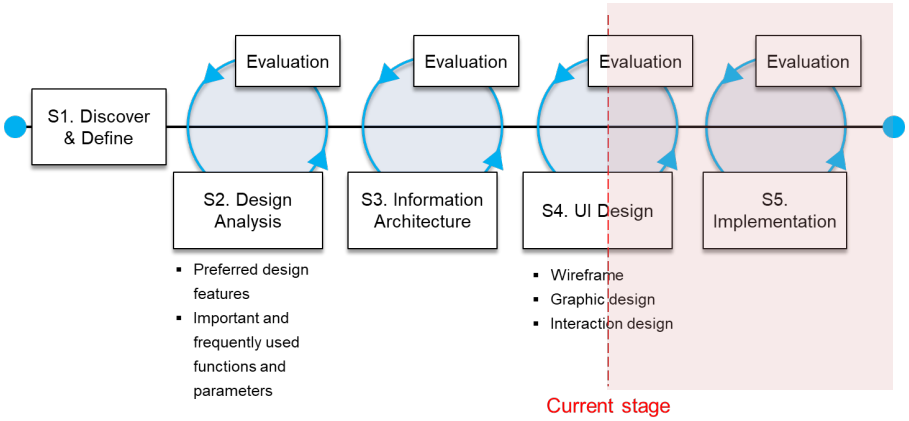


Evaluation Object	Description	OBMI	Inscopix
Distribution	Orientation and arrangement way of the UI components		
Spacing	Free space between modules		

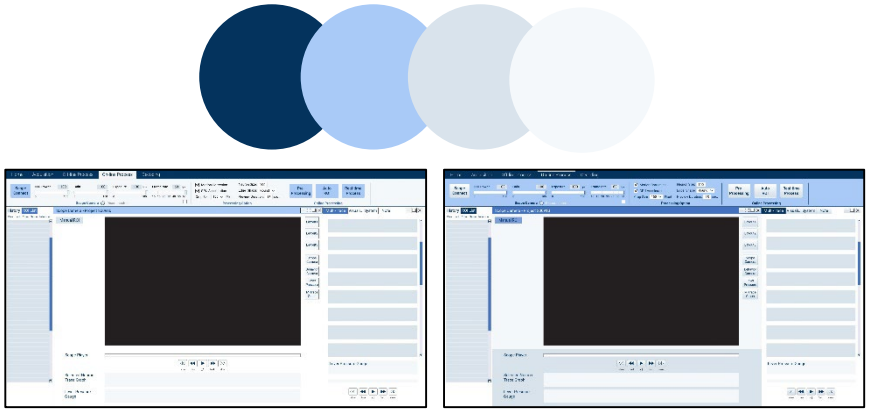
Discussion (1/2)

- 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



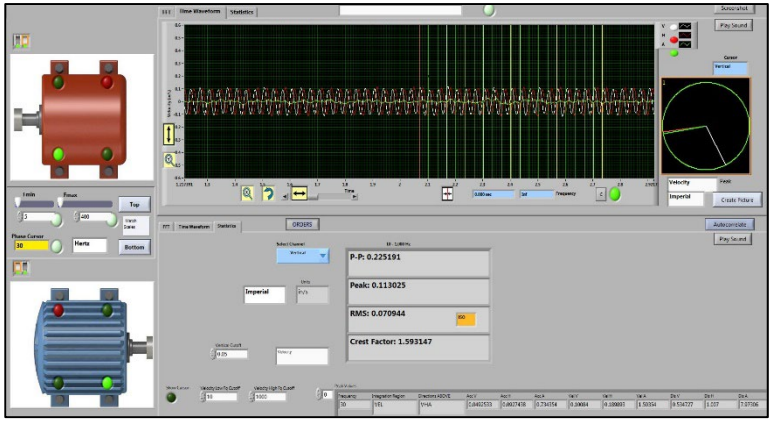
Color schemes of OBMI UI design



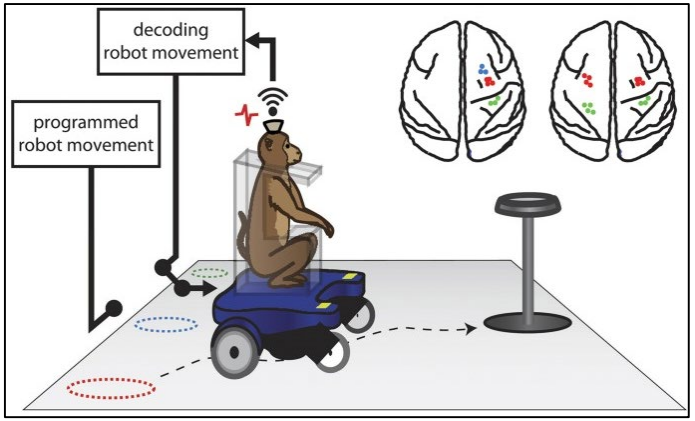
Discussion (2/2)

- 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



Q & A

경청해 주셔서 감사합니다.

본 연구는 한국연구재단의 "한중 협력 연구 사업"의 지원을 받아
수행된 연구결과임(NRF-2018K1A3A1A20026539)

Appendix

Simulation S/W: On-line Module