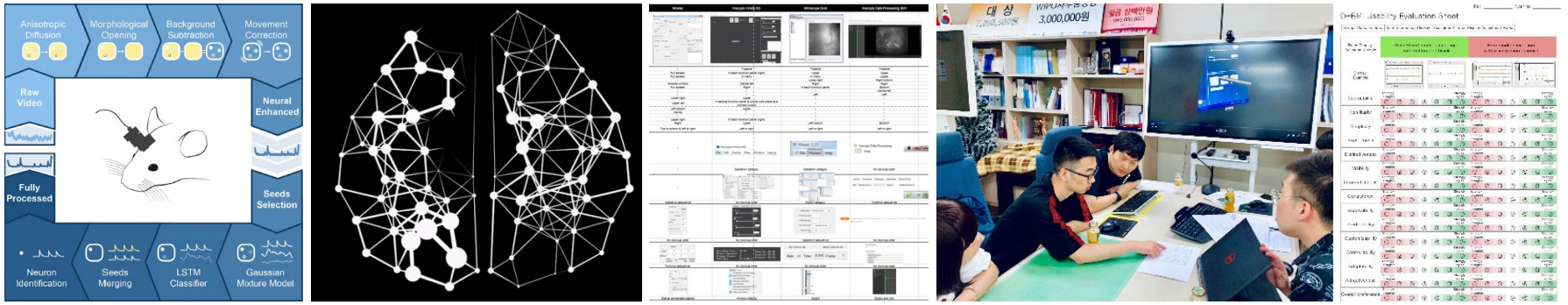
INDUSTRIAL AND MANAGEMENT ENGINEERING, POSTECH

Ergonomic Design Technology Lab

Benchmarking and User Needs Analysis for the UI Design of Optical Brain-Machine Interface System

뇌-기계 인터페이스 시스템 UI 설계를 위한 벤치마킹 및 사용자 요구사항 분석



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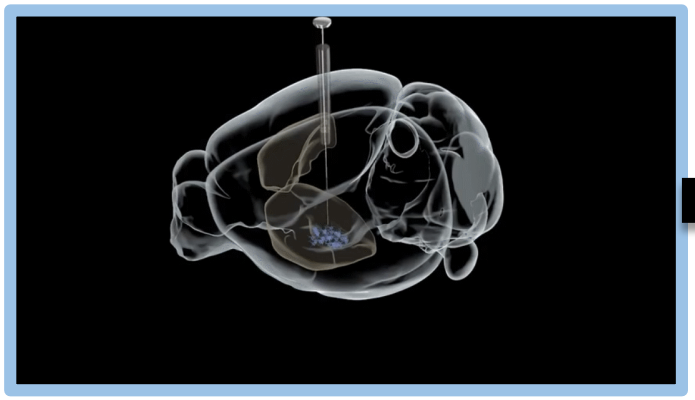
본 연구는 한국연구재단의 "한중 협력 연구 사업"의 지원을 받아 수행된 연구결과임(NRF-2018K1A3A1A20026539)

Contents

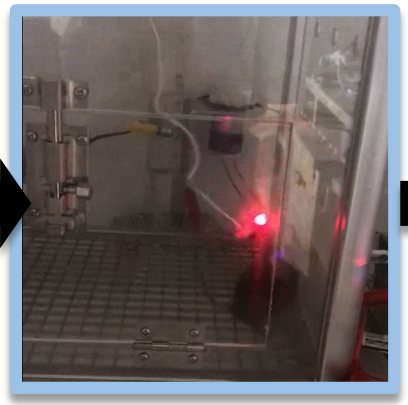
Background: Brain Machine Interface

- A **brain-machine interface (BMI)** is a device that translates neuronal information into commands capable of controlling an external device.
  - Ex. a computer or a robotic arm

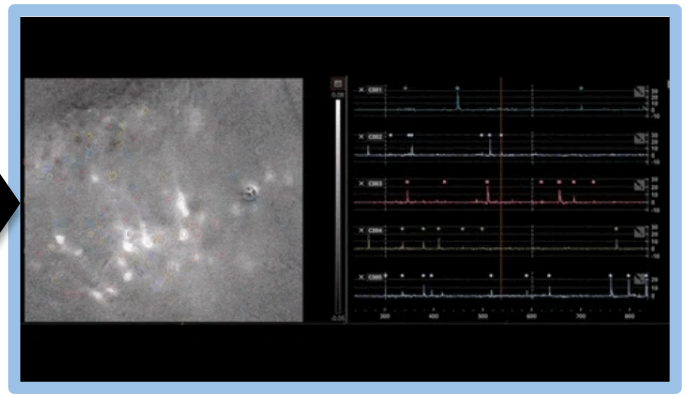
- **Optical vivo calcium imaging technology** is used to observe brain activity in **optical brain-machine interface (O-BMI) systems.**



Operation on a mouse



Behavior training and recording

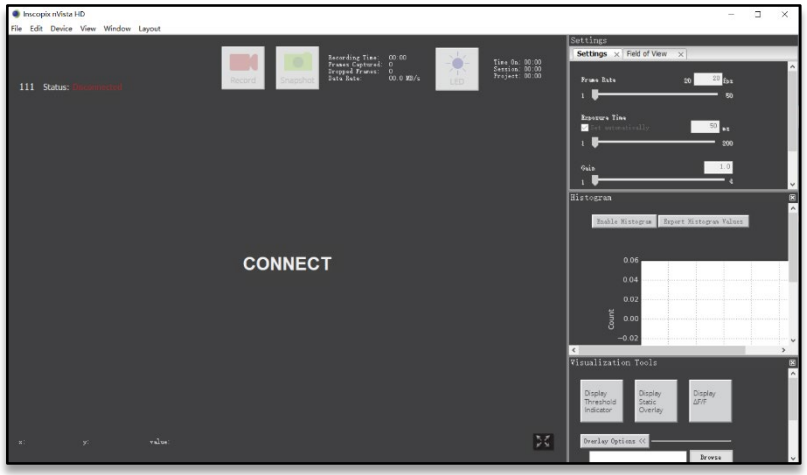


Researching with O-BMIs

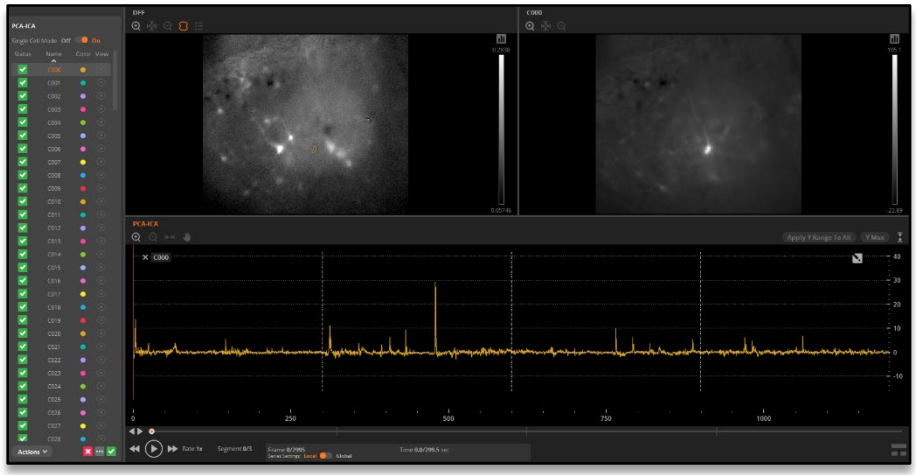
Background: Applied O-BMI System UI

- **O-BMI system** is used to acquire, analyze brain signals, and control external devices.
- **Current O-BMI system UI** consists of signal acquisition, signal processing, neuron extraction, and signal visualization module.

Examples of O-BMI system UI



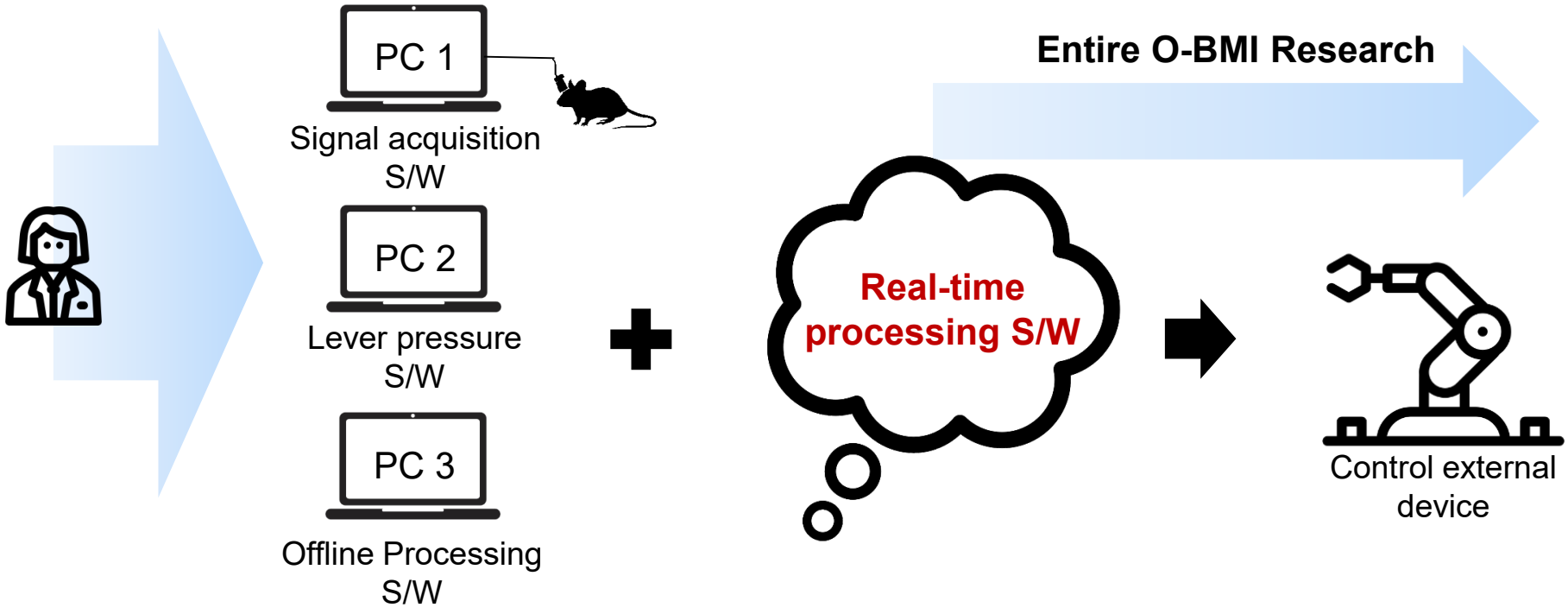
Signal acquisition module
(Inscopix nVisata HD)



Signal visualization module
(Inscopix Data Processing Software)

Background: Limitation of Current O-BMI System UI

- **Better** usability and functionality of **current O-BMI systems UI** is needed.
  - Many usage problems are identified by researchers.
  - Several independent S/W is used for carrying out necessary functions.
  - Desired function cannot be carried out by current O-BMI systems.

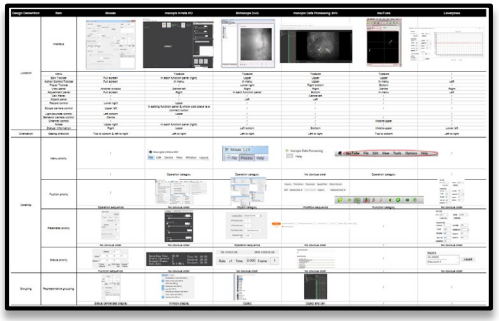


Objectives of the Study

Benchmarking and **User Needs Analysis**
for **Ergonomic Design** of **O-BMI System UI**

1. O-BMI System Benchmarking

- O-BMI task flow with related functions and parameters
- O-BMI design features and concepts



2. User Needs Analysis

- Unmet user needs
- Ergonomic design principles for O-BMI system UI
- User preference designs

Overall Research Process

S1. Literature Review

S2. Benchmarking of the O-BMI System

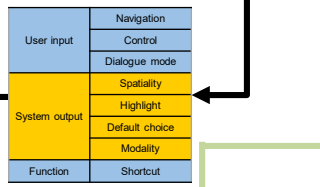
S3. User Survey

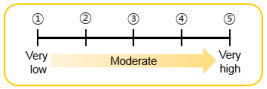
S3.1 Importance and Frequency Evaluation

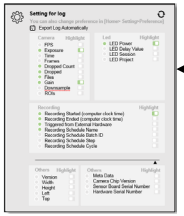
S3.2 Focus Group Interview

S3.3 Usability Testing of Design Feature

S4. Identification of UI system requirement







- Desk research for O-BMI system
- System UI benchmarking **framework**
- UI design evaluation **criteria**
- **Design features** and concepts
- BMI tasks with functions and parameters
- **Use scenario**
- Frequency and importance of factors
- Feedback and user needs
- User preferred designs and concepts
- Ergonomic design principles
- Proposals of novel functions and features

S1. Literature Review: Method

❑ Source

- ➢ http://www.sciencedirect.com/
- ➢ https://www.google.co.kr/

❑ Scope

- ➢ Search title, abstract, or auto-specified keywords

❑ Keywords

- ➢ **O-BMI related:** “calcium” AND (“signal” or “image”) AND “miniscope”
- ➢ **Benchmark related:** (“benchmark method” OR “benchmark framework”) AND (“software” or “application”)
- ➢ **Usability evaluation related:** Kim (2015)

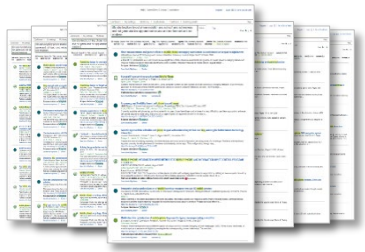
❑ Process

① Search papers using keywords

② 1st screening: Title

③ 2nd screening: Abstract

④ Finalize the list of papers to review



S1. Literature Review: Paper List

- Seventeen highly relevant papers in three field have been reviewed.

No.	Author(s)	Year	Title	Source	Relevancy
1	Lu et al.	2018	MIN1PIPE: A Miniscope 1-Photon-Based Calcium Imaging Signal Extraction Pipeline	Cell Reports	High
2	Gage et al.	2005	Na¨ıve coadaptive cortical control	Journal of neural engineering	High
3	Koralet et al.	2012	Corticostriatal plasticity is necessary for learning intentional neuroprosthetic skills	Nature (International journal of science)	High
4	DiGiovanna et al.	2007	Co-adaptive Brain-Machine Interface via Reinforcement Learning	IEEE Transactions on Biomedical Engineering	High
5	Chapin et al.	1999	Real-time control of a robot arm using simultaneously recorded neurons in the motor cortex	Nature America Inc.	High
6	Koralet et al.	2013	Temporally Precise Cell-Specific Coherence Develops in Corticostriatal Networks during Learning	Neuron	High
7	Clancy et al.	2014	Volitional modulation of optically recorded calcium signals during neuroprosthetic learning	Nature neuroscience	High
8	L. Ibáñez et al.	2019	Non-uniform HYSCORE: Measurement, processing and analysis with Hyscorean	Magnetic Resonance	High
9	R. Veral et al.	2019	Supporting user-perceived usability benchmarking through a developed quantitative metric	International Journal of Human-Computer Studies	High
10	R.Ramakrishnan et al.	2019	Little's law based validation framework for load testing	Information and Software Technology	High
11	P. Goel et al.	2019	A data-driven alarm and event management framework	Loss Prevention in the Process Industries	High
12	J. Martinez1 et al.	2018	Feature location benchmark for extractive software product line adoption research using realistic and synthetic Eclipse variants	Information and Software Technology	High
13	P.C. Vérasa et al.	2015	A benchmarking process to assess software requirementsdocumentation for space applications	Systems and Software	High
14	A.H. Yousef et al.	2013	Benchmarking and performance enhancement framework for multi-staging object-oriented languages	Ain Shams Engineering	High
15	C. Wagels et al.	2012	Benchmarking of Methods and Instruments for Self-Optimization in Future Production Systems	Procedia CIRP	High
16	R. Cornubert et al.	1995	Benchmark of application software kernels on the SUPERNODE SN1000 using the 3P PARLI	Elsevier Science	High
17	S. Kim	2015	Development of a Graphic User Interface Usability Evaluation Framework for Computer-Based Training System	Master's Thesis of POSTECH	High

S1. Literature Review Result: Benchmarking Framework

- Benchmarking framework was obtained by the previous research of Kim (2015).
- Both GUI design style (static) and interaction of system use (dynamic) were included in benchmarking framework.

Benchmark framework for Static GUI design

Style	Color
Layout	Location
	Orientation
	Ordering
	Grouping
Structure	Depth
	Breadth
Terminology	Abbreviation
	Naming
Representation	Coding
	Metaphor

Benchmark framework for dynamic interaction

User input	Navigation
	Control
	Dialogue mode
System output	Spatiality
	Highlight
	Default choice
	Modality
Function	Shortcut

S1. Literature Review Result: UI Design Evaluation Criteria

- Eighteen criteria for usability evaluation was selected by the literature review.

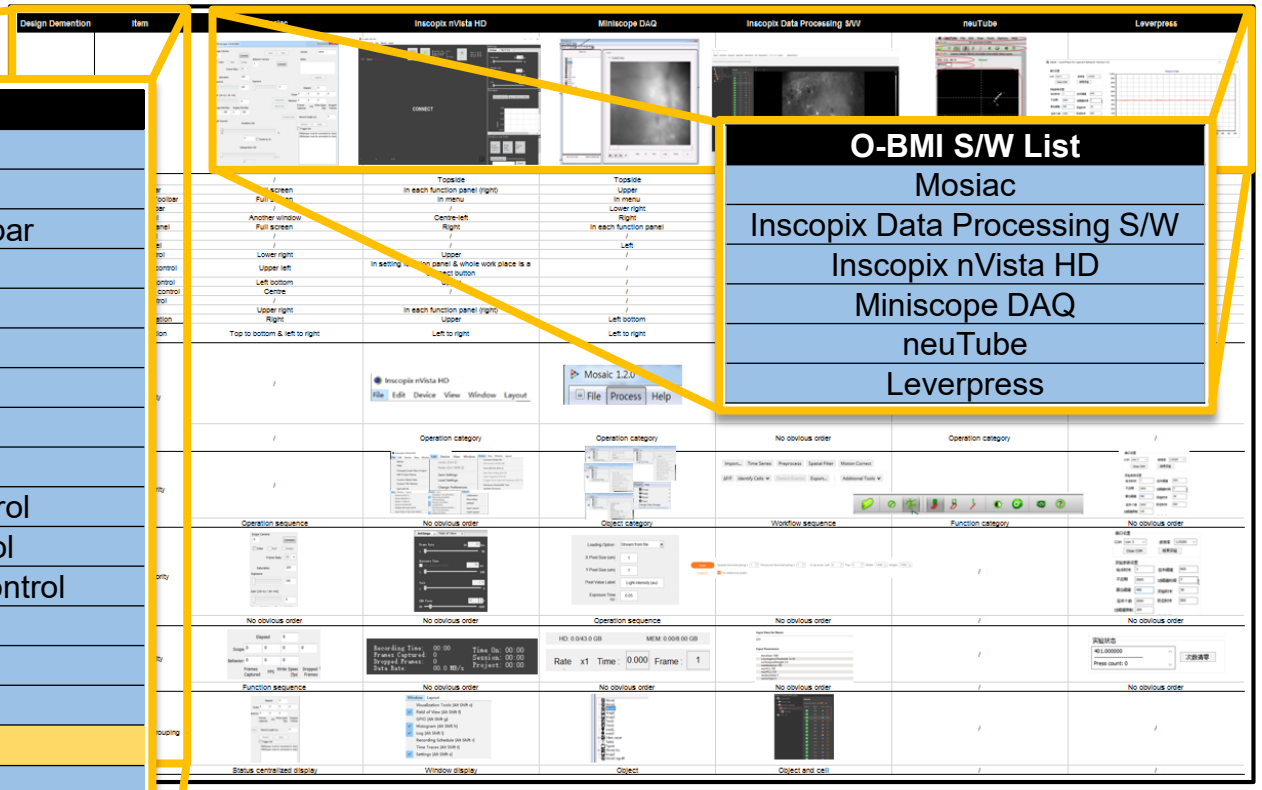
Category	Evaluation Attributes	Definition
Learnability	Learnability	The degree to which the information and interfaces are easy to learn
	Familiarity	The degree to which the information and interfaces are familiar with user
	Simplicity	The degree to which the information and interfaces are simple
Helpfulness	Explicitness	The degree to which the information provided is clearly expressed
	Distinctiveness	The degree to which the information provided is distinguished from the surrounding information
	Visibility	The degree to which the information is clearly visible
	Informativeness	The degree to which the information is meaningful
Efficiency	Responsiveness	The degree to which rapid feedback is provided for interface operations
	Consistency	The degree to which the information display and interfaces are consistent
	Accessibility	The degree to which the interface is easy to access for operation
Controllability	Predictability	The degree to which the interface operation results match the user's expectations
	Customizability	The degree to which the information and interfaces are customized based on user preferences or intent
	Controllability	The degree to which the interface can be easily operated
	Adaptability	The degree to which the interface changes depending on the usage environment and situation
	Error prevention	The degree to prevent usage errors in advance
	Forgiveness	The degree to easily return to the previous state when an error occurs
Attractiveness	Attractiveness	Aesthetics of the Information and Interfaces provided
	Overall preference	The degree of overall preference

S2. Benchmarking of O-BMI System

- Six S/W was benchmarked according to the benchmarking framework

Design Dimension	Item
Location	Menu
	Edit Toolbar
	Action Control/Toolbar
	Player Toolbar
	View panel
	Adjustment panel
	Cell Panel
	Object panel
	Record control
	Scope camera control
	Light sources control
	Behavior camera control
	Channel control
	Notes
	Status/ Information
Orientation	Gazing direction
Ordering	Menu priority
	Function priority
	Parameter priority
	Status priority
Grouping	Representative grouping

Benchmarking framework (Ex. Layout)



Benchmarking table (Ex. Layout)

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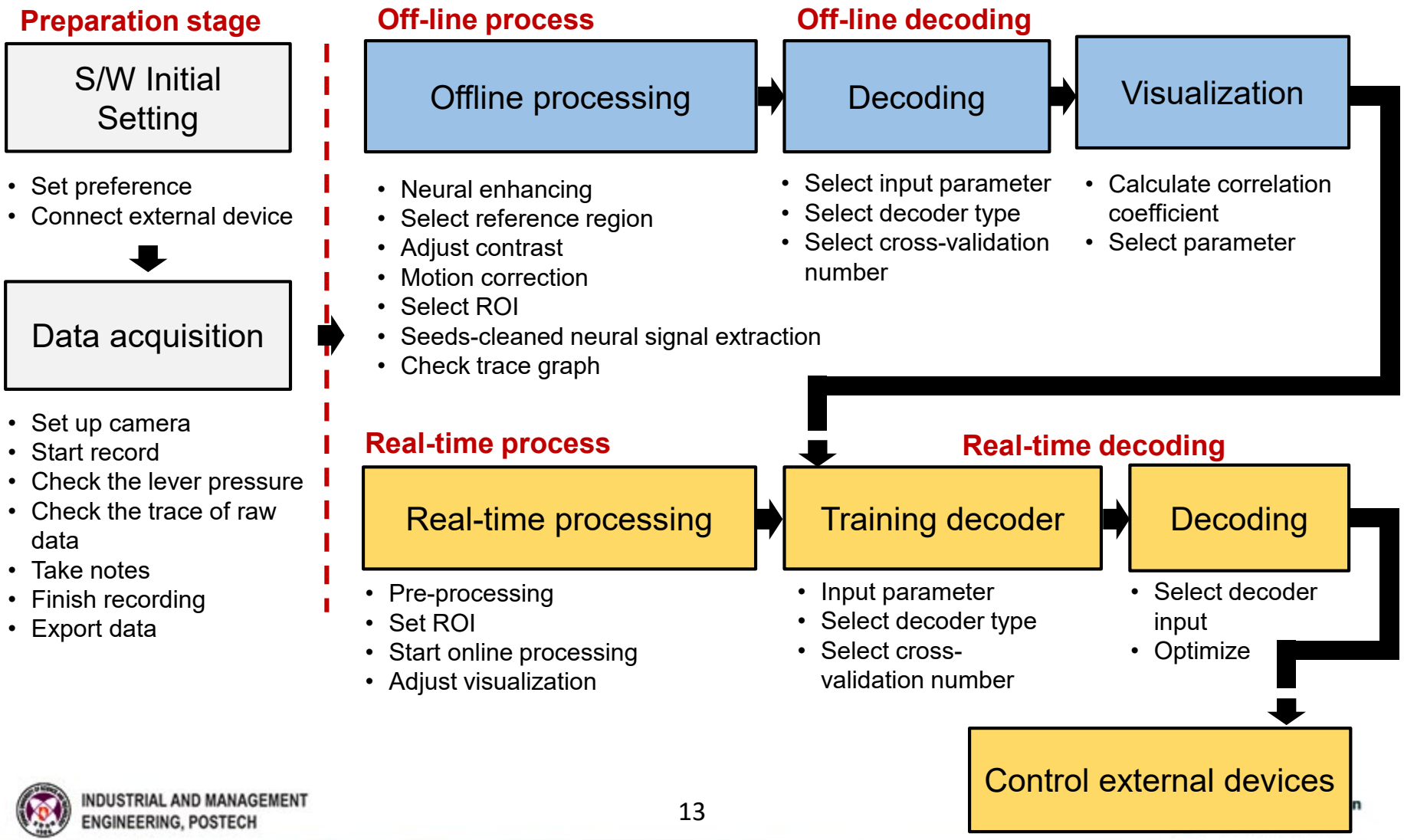
S2. Benchmarking Result: O-BMI Task Flow (1/3)

- Entire O-BMI task flow was organized.



S2. Benchmarking Result: Use Scenario (2/3)

- Use scenario was developed according to O-BMI task flow.

Ex. Use scenario of data acquisition task

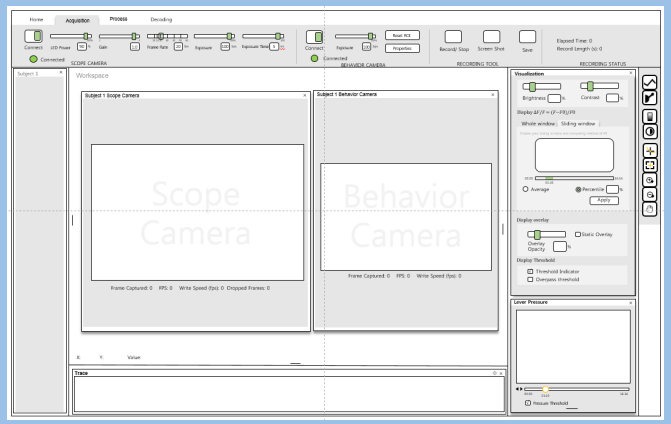
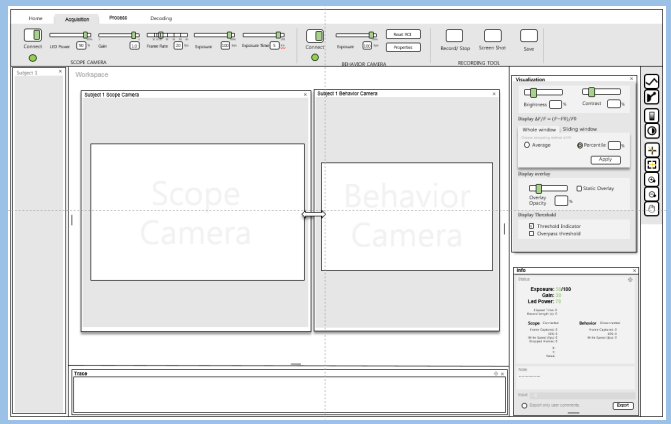
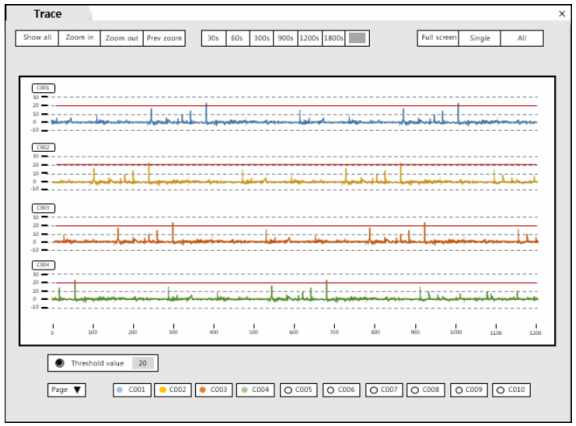
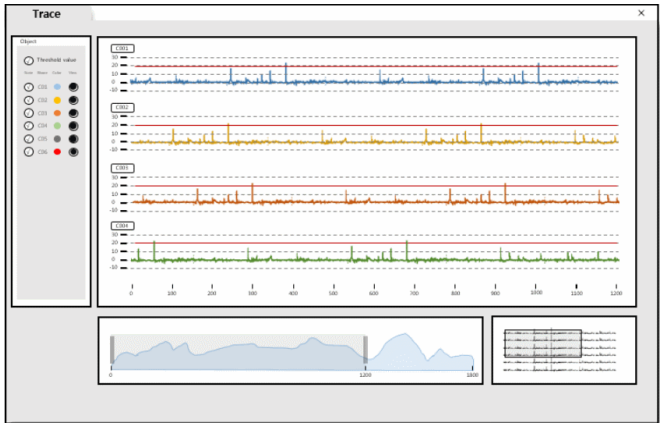
S2. Benchmarking Result: O-BMI Design Features (3/3)

❑ Seven design features of various types were identified through benchmarking.

Category	Attribute	Design Feature	Design Type
GUI Design Style (Static)	Layout	Overall Layout	① Full freestyle ② Semi-freestyle ③ Fixed design
	Display	**Status Info. Location**	**① Separate ② Combined**
Interaction Design Style (Dynamic)	Navigation	Function Navigation	① Workflow-based ② Category-based ③ Tiled navigation
	Output	Window Appearance Mode	① Attached panel ② Independent window ③ Re-planned area ④ Folded tag
	Input	Parameters Input Mode	① Standardized mode ② Customized mode
	Controllability	Trace Adjustment Mode	① Button type ② Slider type
		Parameter Adjustment Mode	① Property-based ② Alphabet-based ③ Frequency-based

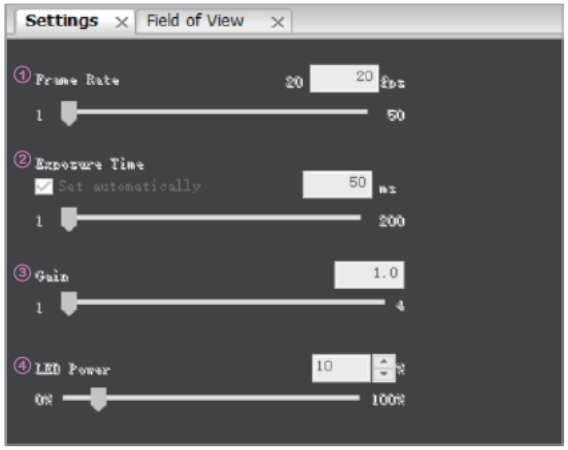
S2. Benchmarking Result: Various Designs (3/3)

❑ **Various designs** were developed according to design features.

Design Feature	Design Type	
	Type A	Type B
Status Info. Location	① Separate	② Combined
		
Trace Adjustment Mode	① Button type	② Slider type
		

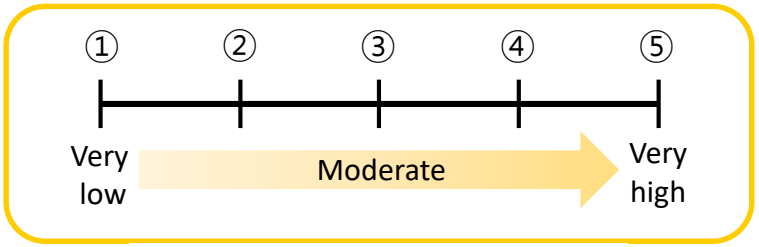
S3.1 User Survey: Importance & Frequency Evaluation

- **Purpose:** to identify importance and frequency of tasks, functions, and parameters
- **Participant:** experts (≥1 year) in the O-BMI field (*n* = 5)
- **Method:** using 5-point degree scale (1: very low, 3: moderate, 5: very high) to evaluate importance and frequency of subjects



Functions	Frequency					Importance				
	Very low	Low	Mod erate	High	Very high	Very low	Low	Mod erate	High	Very high
① Frame Rate	①	②	③	④	⑤	①	②	③	④	⑤
② Exposure Time	①	②	③	④	⑤	①	②	③	④	⑤
③ Gain	①	②	③	④	⑤	①	②	③	④	⑤
④ LED Power	①	②	③	④	⑤	①	②	③	④	⑤

Ex. Evaluation sheet



5-point degree scale

S3.1 Importance & Frequency Evaluation Results

- Ranking of frequency and importance of tasks, functions, and parameters was obtained (ex. status displayed in log).

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

Ex. Frequency and importance List of displayed statuses in the log

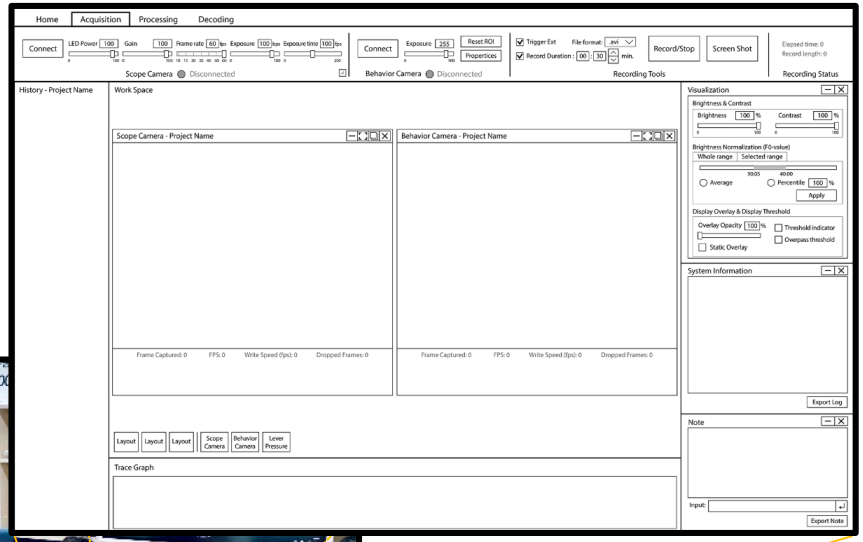
Category	Function
Preference → Log	**FPS**
	Exposure
	Frames
	Gain
	LED Power
	ROIs
	Time
	Dropped Count
	Dropped

Important and frequently used functions

S3.2 User Survey: Focus Group Interview

- **Purpose:** to identify unmet user needs and get feedback on **previous work** (task flow & use scenario)
- **Participant:** experts (≥1 year) in the O-BMI field (*n* = 3)
- **Method:** qualitative interview

Ex. Data acquisition user scenario



Focus Group Interview Questionnaire

- **Probe Questions**
  - What usage problem do you meet during simulation on scenario?
  - What S/W usage problem do you meet during your current work?
  - What features do you want to use in future software?
- **Follow-up questions**
  - Does the diagram match your use order?
  - When do you want to the visualization tool?
  - Can the record parameters be changed during recording process?
  - What kind of content do you want to save?
  - Do you want to select ROI during real-time processing?
- **Exit question**
  - How do you feel about the current UI?
  - Do you have any other suggestions?

FGI question list

FGI environment

S3.2 Focus Group Interview Results

- Unmet user needs and feedback lists were obtained by FGI

No.	Unmet needs
1	I want to check lever pressure when record.
2	I want to display important status in the log window.
3	I need a function showed the time of success with the visualization tool.
4	I need to calculate select $F0$ in 5 different ways.
5	I want to select ROI manually in real-time process.
6	I hope I can select ROIs while the frames are playing or pausing and the mark can be preserved on the screen.
7	Real-time decoding module is needed.
8	I hope that the last data can be called directly.
9	For real-time decoding, checking the runtime environment is important.

User requirement list

No.	Feedback
1	Preference setting is useful.
2	The parameters here should not be changed during the recording.
3	Functions of real-time and offline process are significantly different.
4	In the real-time processing, ROI should be selected before preprocessing.
5	The location of Default, Cancel, Apply is different in different panel.
6	Visualization function should also be realized in acquisition process.
7	Real-time recording time is expected to be 20-25 minutes.
8	I think it is convenient to change the layout with different module.
9	Trace should be possible save if wanted.
10	In the recording process, parameters should not be changed.
11	Further discussion is needed on the outline shape of the ROIs.

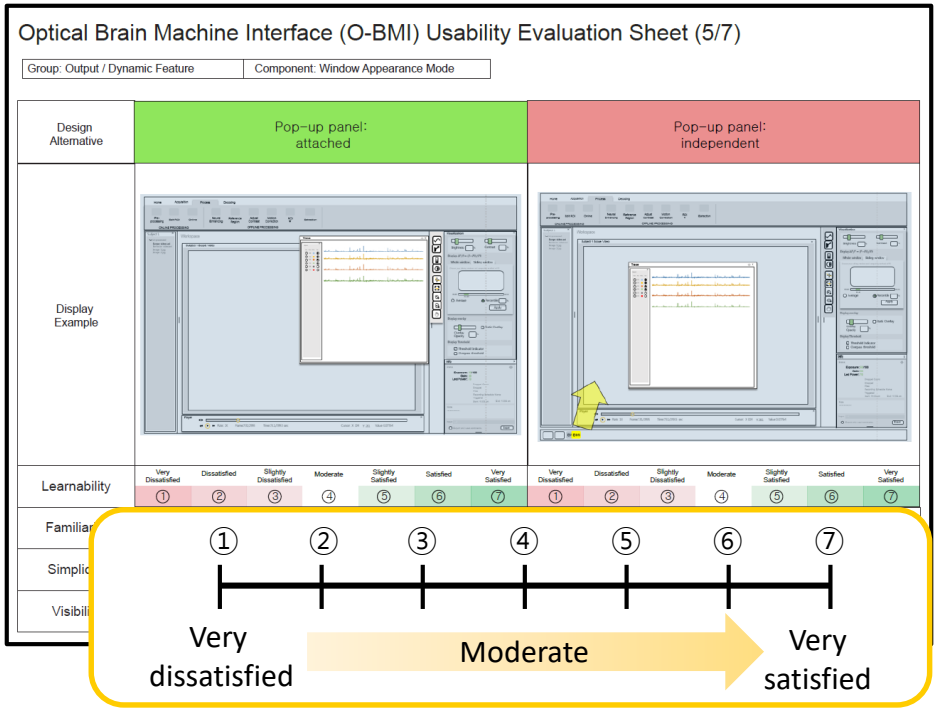
Feedback list

S3.3 User Survey: Usability Evaluation of Design Features

- **Purpose:** to identify user preference designs and concepts
- **Participant:** researchers in the ergonomic field (n = 5)
- **Method:** using a 7-point satisfaction scale (1: very dissatisfied, 4: moderate, 7: very satisfied) to evaluate seven design features according to the evaluation criteria

Evaluation environment

7-point satisfaction scale evaluation sheet

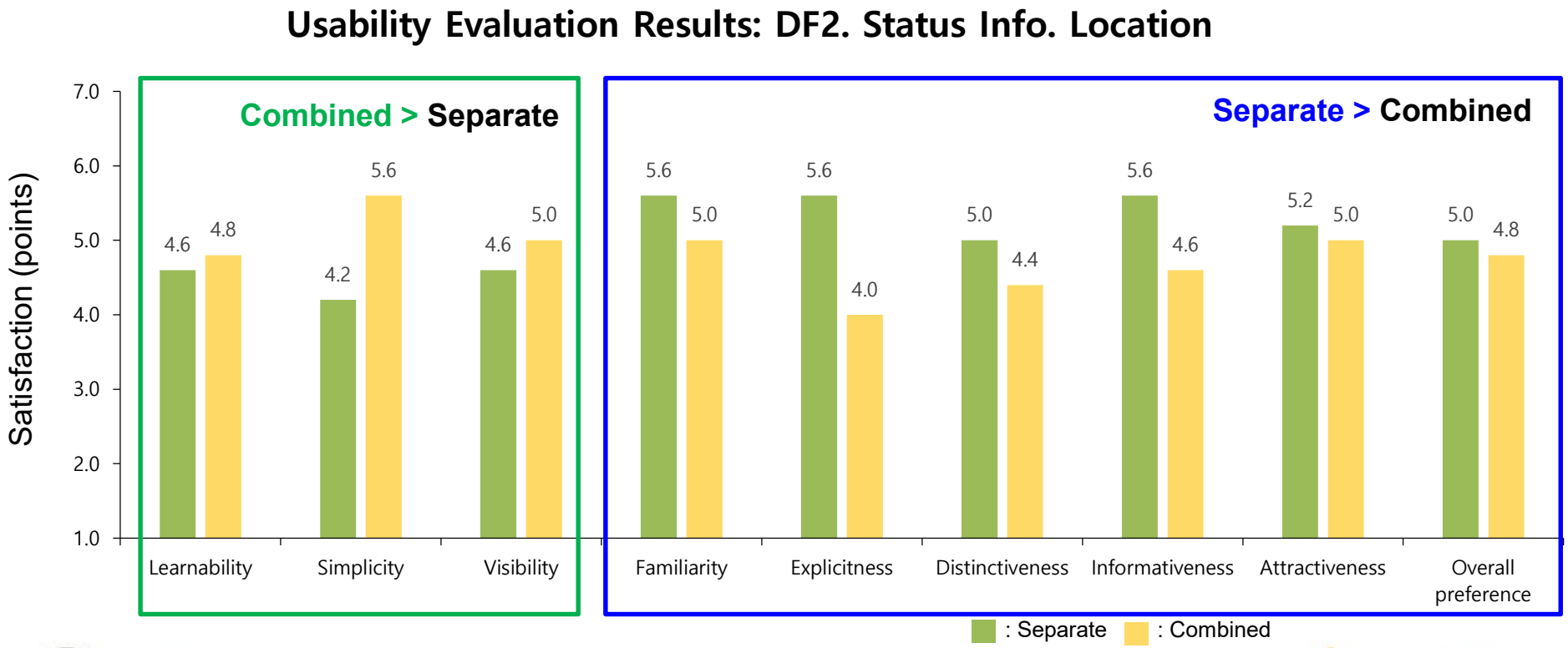


S3.3 Usability Evaluation Results: Summary

No.	Design Feature	Preference	Types (Mean Satisfaction)			
			Type A	Type B	Type C	Type D
DF1	Overall Layout	Fixed = Semi	Full freestyle (4.0)	Semi-freestyle (5.4)	Fixed design (5.4)	-
DF2	**Status Info. Location**	Separate ≈ Combined	Separate (5.0)	Combined (4.8)	-	-
DF3	Function Navigation	Tiled navigation	Workflow-based (4.9)	Category-based (3.7)	Tiled navigation (5.3)	
DF4	Window Appearance Mode	Attached panel	Attached panel (6.0)	Independent window (5.3)	Re-planned area (3.9)	Folded tag (4.9)
DF5	Parameters Input Mode	Customized mode	Standardized mode (5.5)	Customized mode (6.0)	-	-
DF6	**Trace Adjustment Mode**	Slider type	Button type (4.7)	Slider type (5.9)	-	-
DF7	Parameter Adjustment Mode	Property-based	Property-based (5.7)	Alphabet-based (3.9)	Frequency-based (3.7)	-

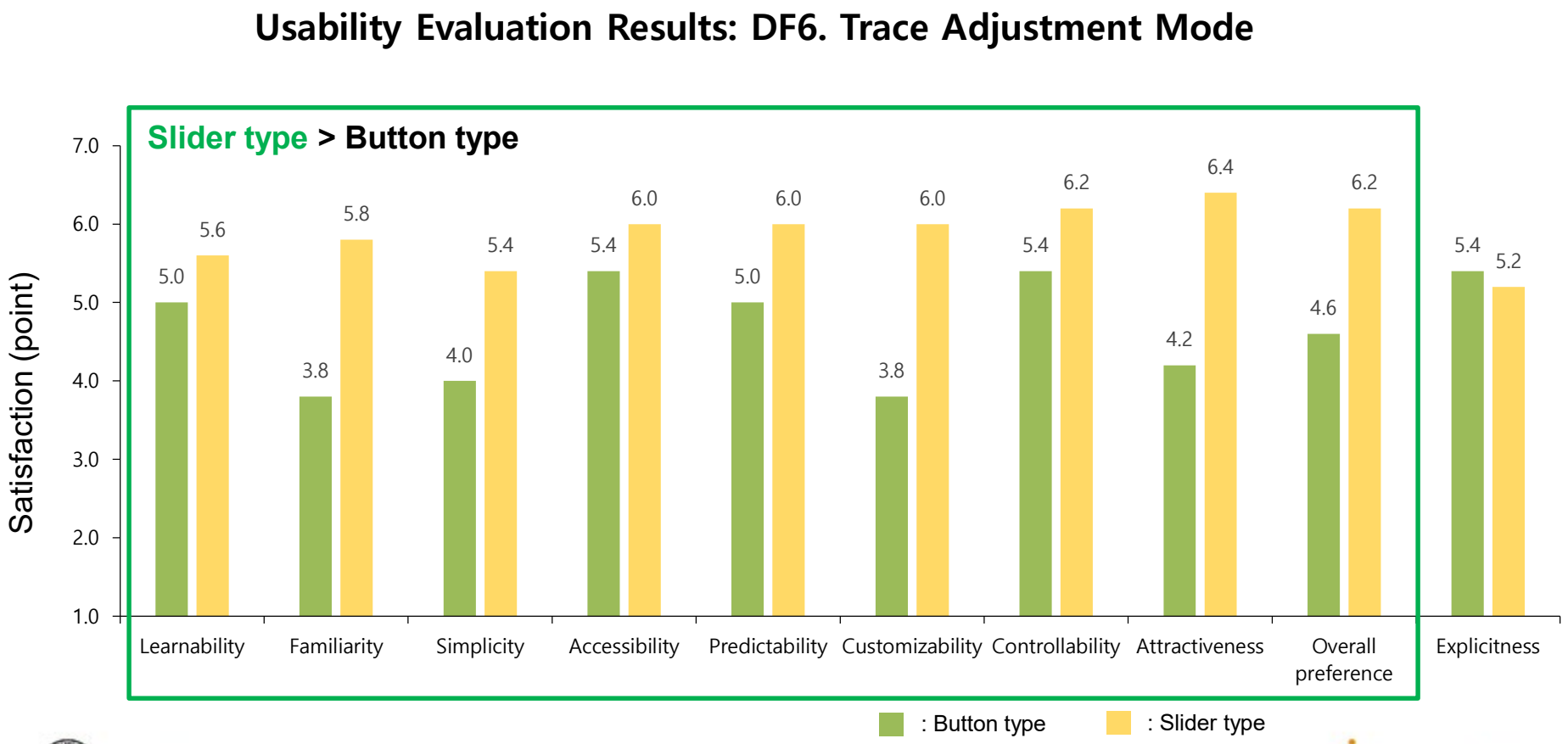
S3.3 Usability Evaluation Results: Status Info. Location

- Mean of separate type (5.0) ≈ Mean of combined type (4.8)
- Combined type is more preferred for learnability, simplicity and visibility.
- Separate type is more preferred for familiarity, explicitness, distinctiveness, informativeness, and attractiveness.



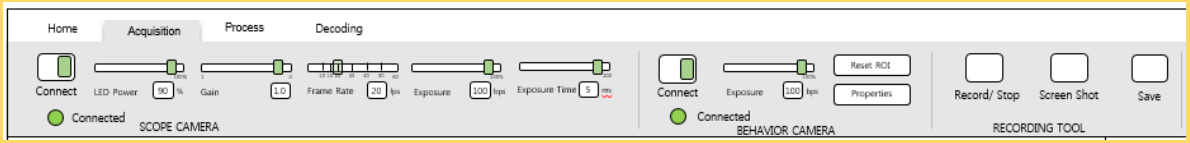
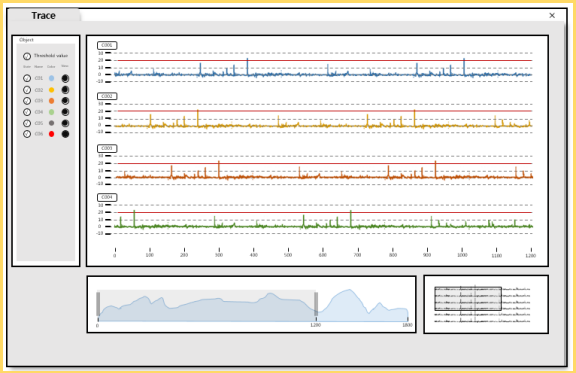
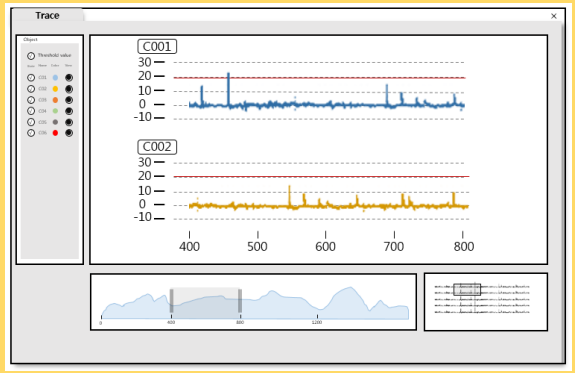
S3.3 Usability Evaluation Results: Trace Adjustment Mode

- Trace adjustment mode with sliders (Mean: 5.9) is preferred more than using buttons (Mean: 4.7) for most aspects except explicitness



S4. Identification of System Requirements: Design Principle

- **Design principles** of O-BMI system were developed.

Design Principle	Description	Image
Accessibility	It should be designed to make it easier to access target objects.	Ex. Tiled navigation  Ex. Visualized slider type of trace adjustment  

S4. Identification of System Requirements: Design Proposal

- New UI design with novel functions and preferred design features were proposed.

Design Attribute	Proposal (Novel Function)
Input	Customized parameter input function
	Value calculation function using video slider
	A simulation function in decoding module (using input parameters to test run)
Control	Manual ROI select function
Display	Lever pressure visualization function

Design Attribute	Proposal (Design Feature)
Overall Layout	Both fixed layout and semi-layout are suggested.
	Layout of real-time and offline process should be designed with different features.
Output	For window appearance, both attached panel and independent window are suggested.
Parameters	Unimportant and less used functions and parameters are suggested to be hidden.

Discussion: Contribution

O-BMI System

1 Benchmarking Framework

2 User Scenario

3 Components & Task Flow

4 Important and frequently used functions &parameters

5 Users' needs

6 Evaluation criteria

7 Preferred design features

No.	Design Feature	Preference	Types (Mean Satisfaction)			
			Type A	Type B	Type C	Type D
DF1	Overall Layout	Fixed = Semi	Full freestyle (4.0)	Semi-freestyle (5.4)	Fixed design (5.4)	-
DF2	**Status Info. Location**	Separate ≈ Combined	Separate (5.0)	Combined (4.8)	-	-
DF3	Function Navigation	Tiled navigation	Workflow-based (4.9)	Category-based (3.7)	Tiled navigation (5.3)	
DF4	Window Appearance Mode	Attached panel	Attached panel (6.0)	Independent window (5.3)	Re-planned area (3.9)	Folded tag (4.9)
DF5	Parameters Input Mode	Customized mode	Standardized mode (5.5)	Customized mode (6.0)	-	-
DF6	**Trace Adjustment Mode**	Slider type	Button type (4.7)	Slider type (5.9)	-	-
DF7	Parameter Adjustment Mode	Property-based	Property-based (5.7)	Alphabet-based (3.9)	Frequency-based (3.7)	-

Discussion: Analysis of User's Needs - Information

- Important information is hidden or scattered in the current O-BMI system UI.
  ⇒ Improve **visibility**, **accessibility** and give **hierarchy** to the important information.

From FGI results

No.	Unmet needs
1	I want to check lever pressure when record.
2	I want to display important status in the log window.
3	I need a function showed the time of success with the visualization tool.
6	I hope I can select ROIs while the frames are playing or pausing and the mark can be preserved on the screen.
9	For real-time decoding, checking the runtime environment is important.

No.	Feedback
6	Visualization function should also be realized in acquisition process.

From Function evaluation

Category	Function
Preference → Log	FPS
	Exposure
	Frames
	Gain
	LED Power
	ROIs
	Time
	Dropped Count
	Dropped

Important and frequently used functions

Discussion: Analysis of User's Needs - Controls

- Controlling parameters in detail, efficient managing, and convenient selecting ROI is critical in BMI research to get the good quality of results.
  ⇒ Provide **easier way** to control, manage parameters with **customization**
  ⇒ Provide **intuitive selection** method to ROI region

From the FGI results

No.	Unmet needs
4	I need to calculate select $F0$ in 5 different ways.
5	I want to select ROI manually in real-time process.
7	Real-time decoding module is needed.
8	I hope that the last (recent) data can be called directly.

No.	Feedback
1	Preference setting is useful.
2	The parameters here should not be changed during the recording.
4	In the real-time processing, ROI should be selected before pre-processing.
9	Trace should be possible save if wanted.
10	In the recording process, parameters should not be changed.

Discussion: Analysis of User's Needs - Layout

- Layout of system UI need to be changed by the context (used module, task types)
  ⇒ Provide **different optimal layout** with adequate **functions** correspond to the module and the tasks (real-time, off-line)

From FGI results

No.	Feedback
3	Functions of real-time and offline process are significantly different.
8	I think it is convenient to change the layout with different module.

No.	Unmet needs
1	I want to check lever pressure when record.
2	I want to display important status in the log window.
9	For real-time decoding, checking the runtime environment is important.

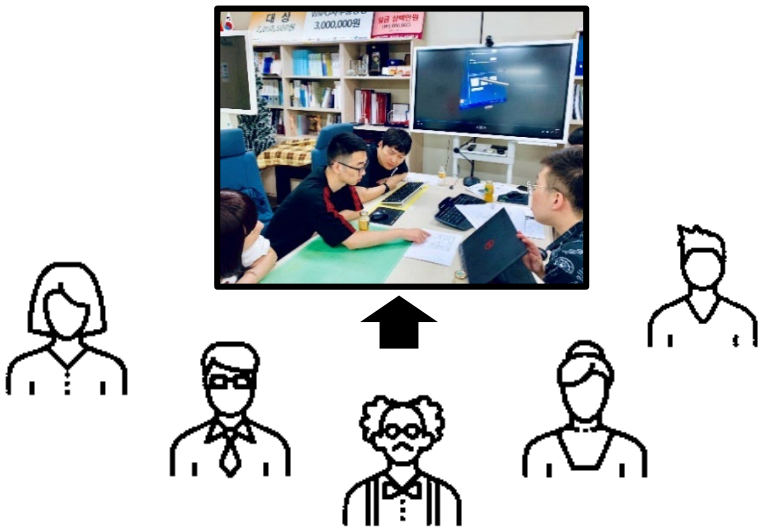
Discussion: Limitation and Further Research

- Number of expert participants (*n*=5, experience ≥ 1 year) were limited.

  → Let more qualified researchers participate in design and evaluation.

- Benchmarking mainly focuses on offline processing O-BMI system.

  → Benchmark on real-time systems.



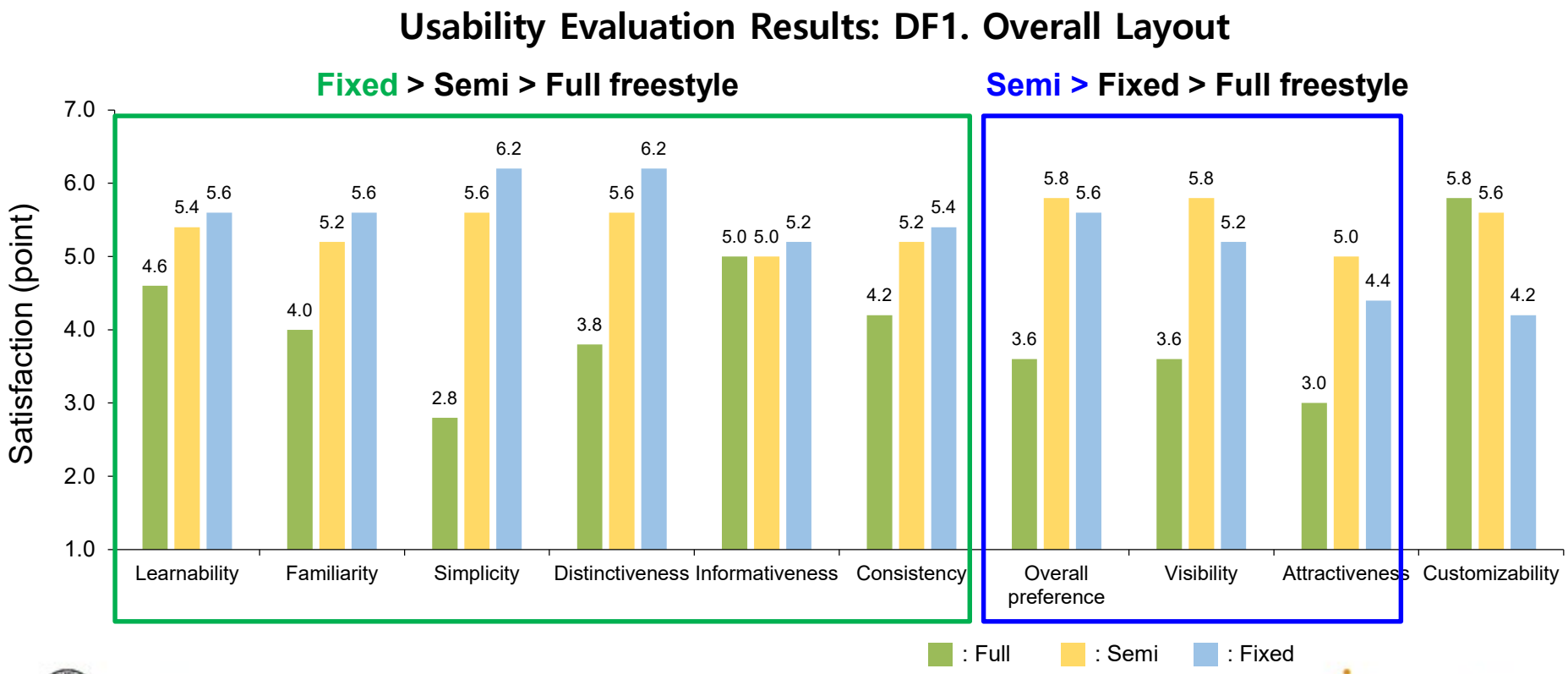
Thank you for your attention!

Q & A

Appendix

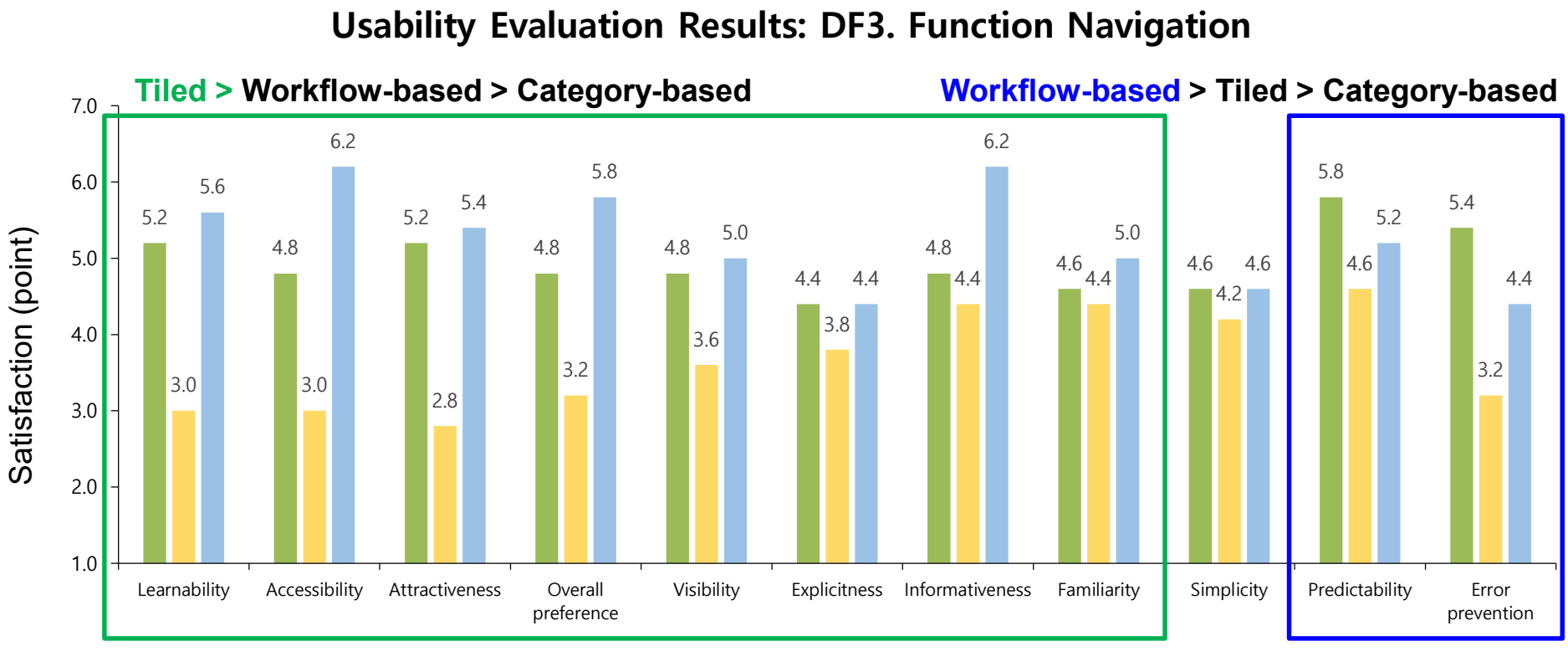
S3. Usability Evaluation Results: Overall Layout

- Fixed type of layout design is more preferred than other types in terms of overall usability
  - learnability, familiarity, simplicity, distinctiveness, informativeness, and consistency
- Semi type is preferred for overall satisfaction, attractiveness and visibility



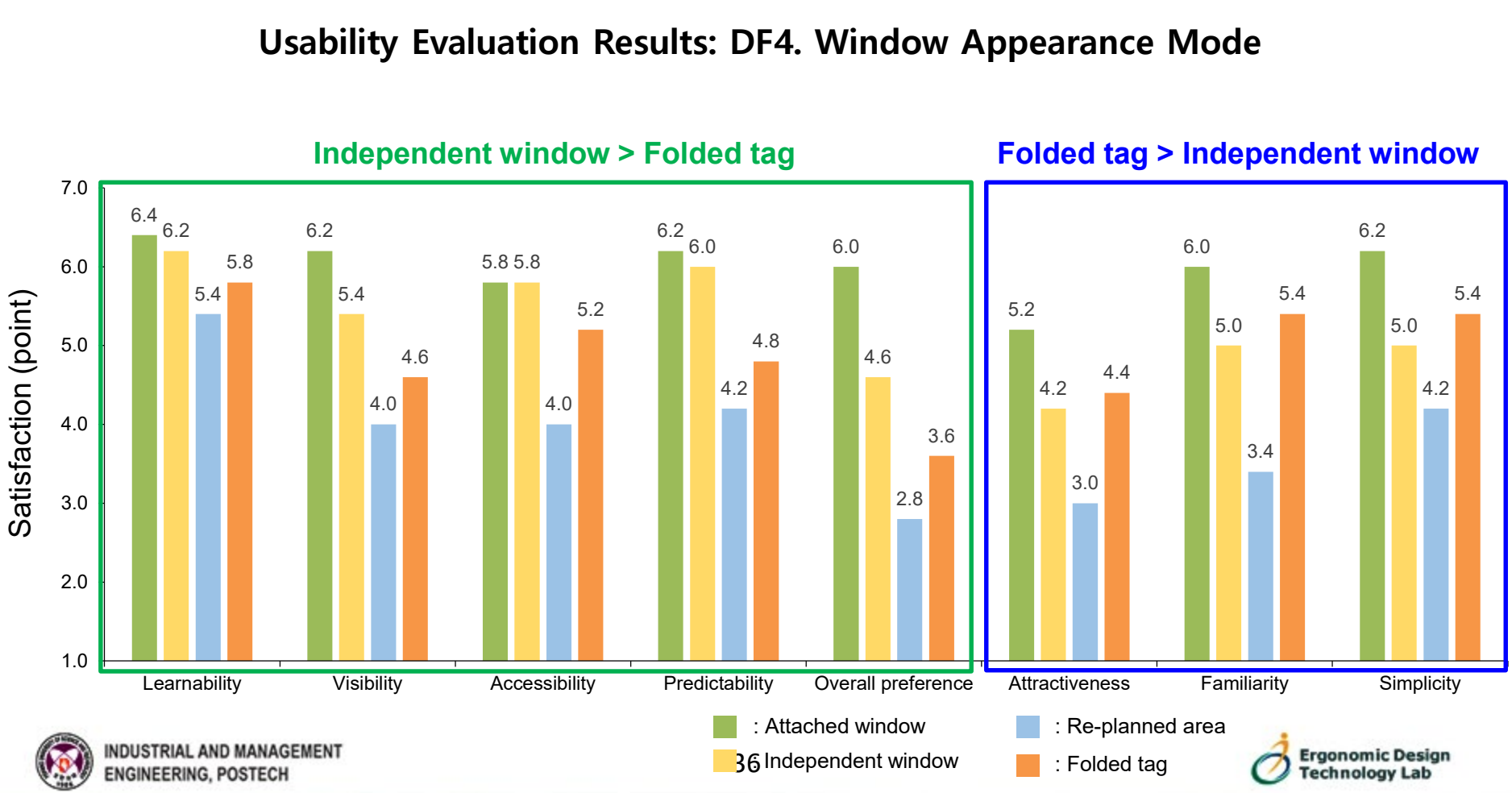
S3. Usability Evaluation Results: Function Navigation

- Tiled function navigation is preferred in terms of overall usability
  - Learnability, accessibility, attractiveness, overall preference, visibility, explicitness, informativeness, familiarity
- Workflow-based navigation is preferred in predictability and error prevention



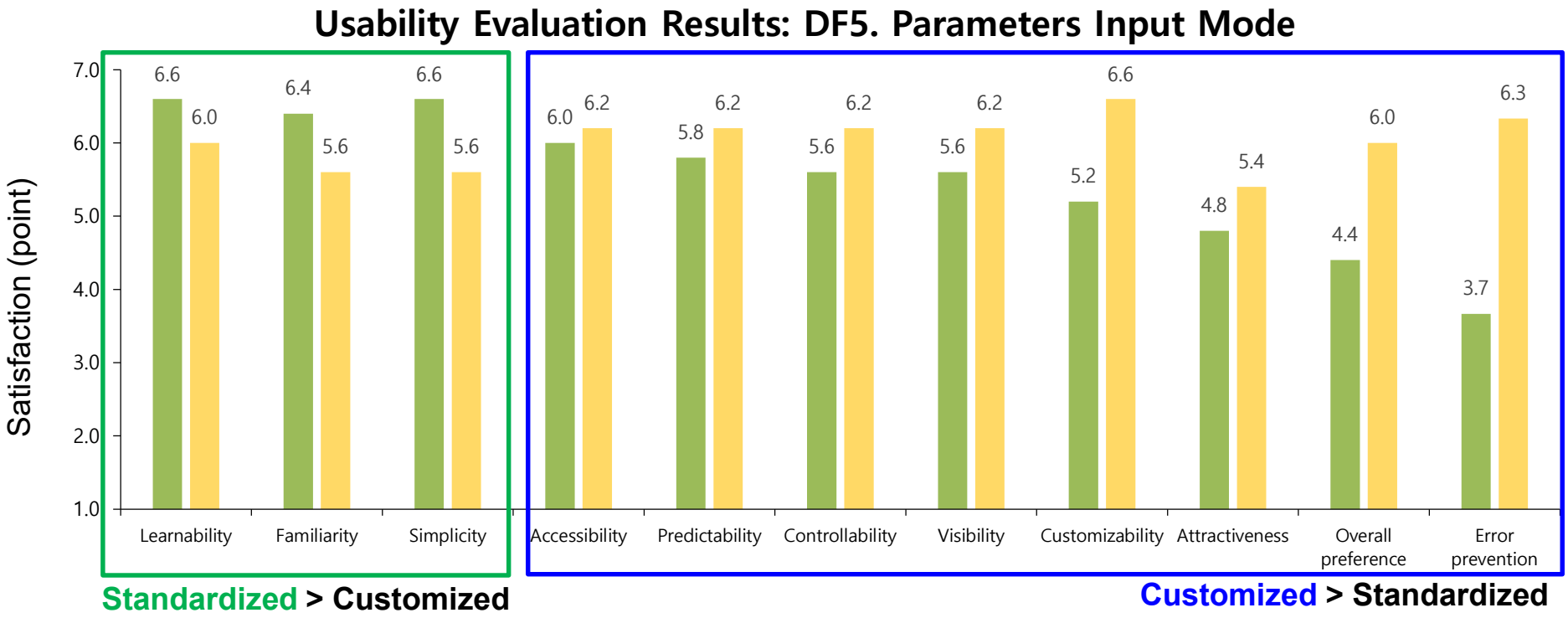
S3. Usability Evaluation Results: Window Appearance Mode

- Attached style is the most preferred window appearance mode in all aspects
- Re-planned area is the most dissatisfied in overall evaluation



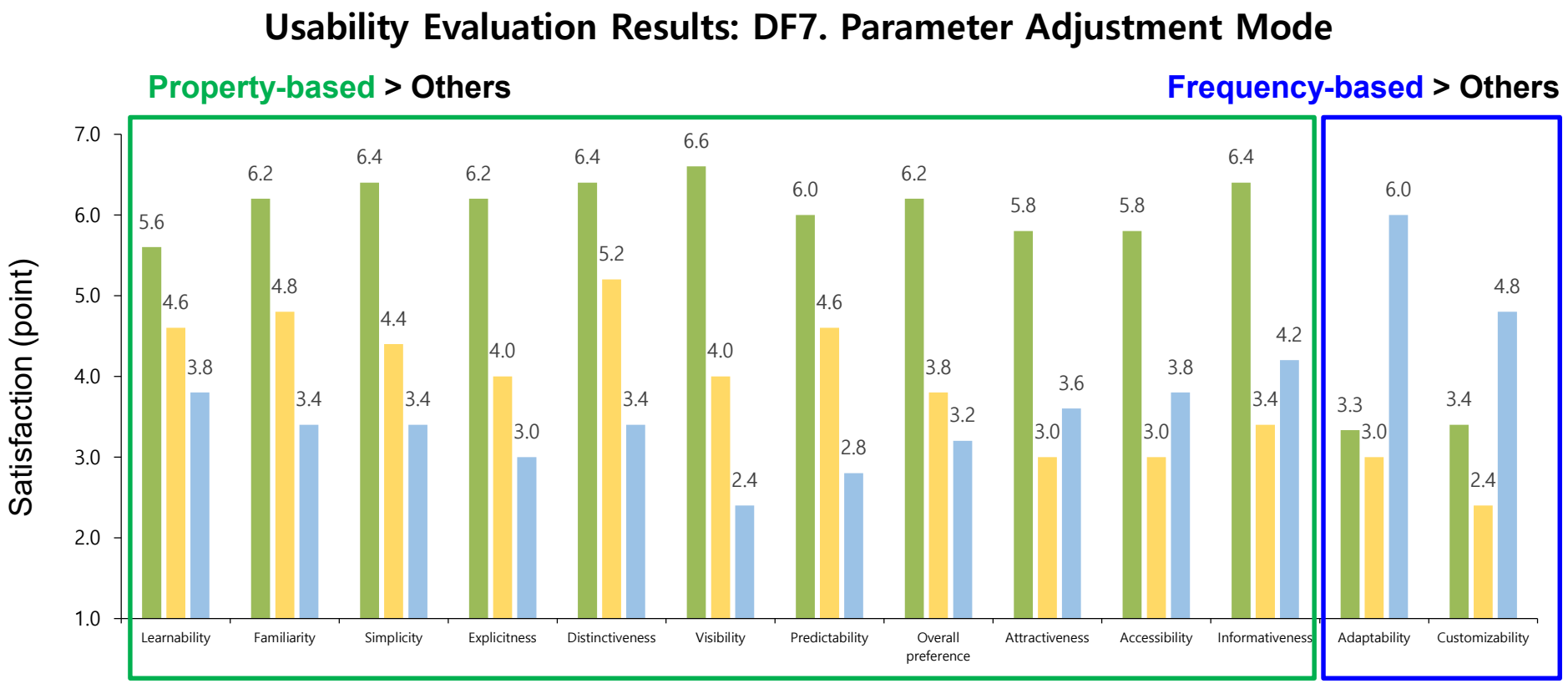
S3. Usability Evaluation Results: Parameters Input Mode

- Standardized input mode of parameters is preferred in learnability, familiarity, simplicity
- Customized input mode of parameters is preferred in overall preference
  - Accessibility, predictability, controllability, visibility, customizability, attractiveness, error prevention and overall preference



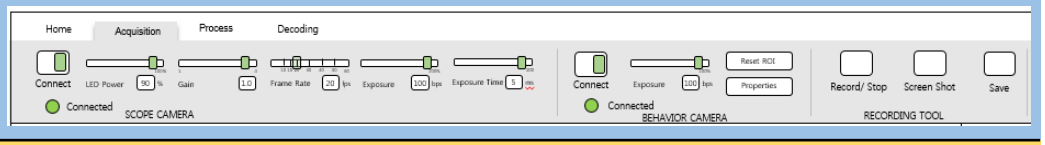
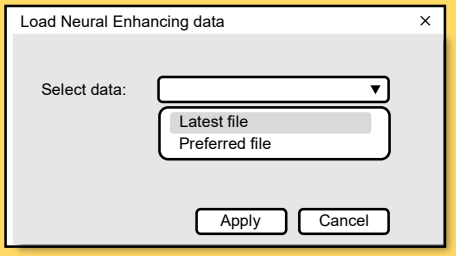
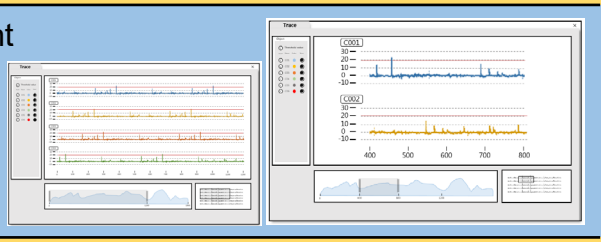
S3. Usability Evaluation Results: Ex. Parameter Adjustment Mode

- **Property-based** mode is most preferred in most aspects
- **Frequency-based** mode is most preferred in adaptability and customizability



S4. Identification of System Requirements: Design Principle

- **Design principles** of O-BMI system were developed.

Design Principle	Description	Image
Accessibility	Function and parameter should be easy to access for operation.	Ex. Tiled navigation 
Customizability	Interface and information should be designed based on users' preference.	Ex. Customized parameter input mode 
Intuition	Interface and interaction should be visualized as much as possible.	Ex. Slider type of trace adjustment 
Distinguishing	Multiple objects should be distinguished by basis.	Ex. Property-based parameter adjustment