# USER MANUAL

# Home appliance control BCI system using ERP

BCILAB,
Ulsan National Institute of Science and Technology (UNIST)

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# INTRODUCTION

## 1.    What is our program?

The Brain-Computer Interface (BCI) system allows direct interaction with the external world by interpreting users' intentions from brain signals. Our "*Home Appliance Control BCI System (IoTHomeERP)*" is a program made as a part of the "*Integrated BCI |* https://github.com/NIBCI/IntegrationBCI)*."*
We designed it to enable real-time control of IoT home appliances through noninvasive electroencephalography (EEG). Specifically, this program is an event-related potential (ERP)-based BCI system that uses ERPs generated by an oddball paradigm. Our program is featured to facilitate the operation of IoT devices without requiring a detailed understanding of BCI. The *IoTHomeERP* was primarily developed using *MATLAB*. Additionally, the program is compatible with various EEG devices through the use of the open-source *Lab Streaming Layer (LSL)* software (Lab Streaming Layer|(https://labstreaminglayer.org/#/).

## 2.    Main Features

The program has three key features:

### Real-time ERP processing & home appliance control
You can control IoT home devices in real time using brain signals. Simply wear your EEG device and follow the several steps on our program interface.

### User customizable stimulus
You enable us to customize the settings for stimuli in our BCI. This involves the option to customize the speed of transmitting commands to home appliances, the amount of data, including ERPs from responses to stimuli, used for training, and the visual icon utilized in the stimuli.

### Save ERP dataset and options
You can store your raw ERP dataset, which is utilized to control home appliances, in a location of your choice on your computer. Later, you can access and use these ERP datasets to control the home appliances. It is advisable to update your ERP dataset regularly, as using an outdated version may impact your BCI performance due to inconsistent brain signals. Additionally, if you want, you can analyze these ERP datasets in your own way, which are saved in the ". mat" format compatible with MATLAB.

# TUTORIAL

## 1.   Installation

### System requirements

Under normal conditions, This Program does not impact on any programs already installed. However, only guarantees that programs would interact without problems if the programs concerned have been tested for compatibility. This applies to systems with the Microsoft operating system Windows® 10 or later, provided no modifications have been made to the provided operating system configuration (including official service packs and updates).

The following hardware and software requirements must be fulfilled:

- ✓ Operating system: Windows® 10 or later (It may work in lower versions, but we are not sure about that)
- ✓ Minimum configuration: Intel Core i5 or higher, 512 MB of RAM, 8 GB hard disk, graphics adapter with 64 MB of RAM
- ✓ You must have equipment to acquire brain waves. We provide *LSL* programs for Biosemi, BrainProduct(actiCHamp), Cognionix, and G.tec (gNeedaccess) equipment. If you use other equipment, please install and use a separate *LSL* link program required for that equipment.
- ✓ Since all devices acquire data through *LSL*, *LSL* must be available. For more information about *LSL*, see Lab Streaming Layer (https://labstreaminglayer.org/#/)
- ✓ When installing for the first time, an internet connection is required.
- ✓ Depending on the selected mode, an internet connection is required.

## How to find our program

Proceed as follows to install Analyzer under Windows

1    Start Windows.

2    Download the program from the link here - BCI/IoTHomeERP (github.com)
     (https://github.com/Heodojin/IoTHomeERP).

3    You have two choices for obtaining our program. The first option is to use *MATLAB*
     Runtime by accessing the "*current_forDownload*" folder, which is the recommended
     way. Alternatively, you can download the program directly from the "*exe*" folder on
     *GitHub*. See the details in the following instructions.
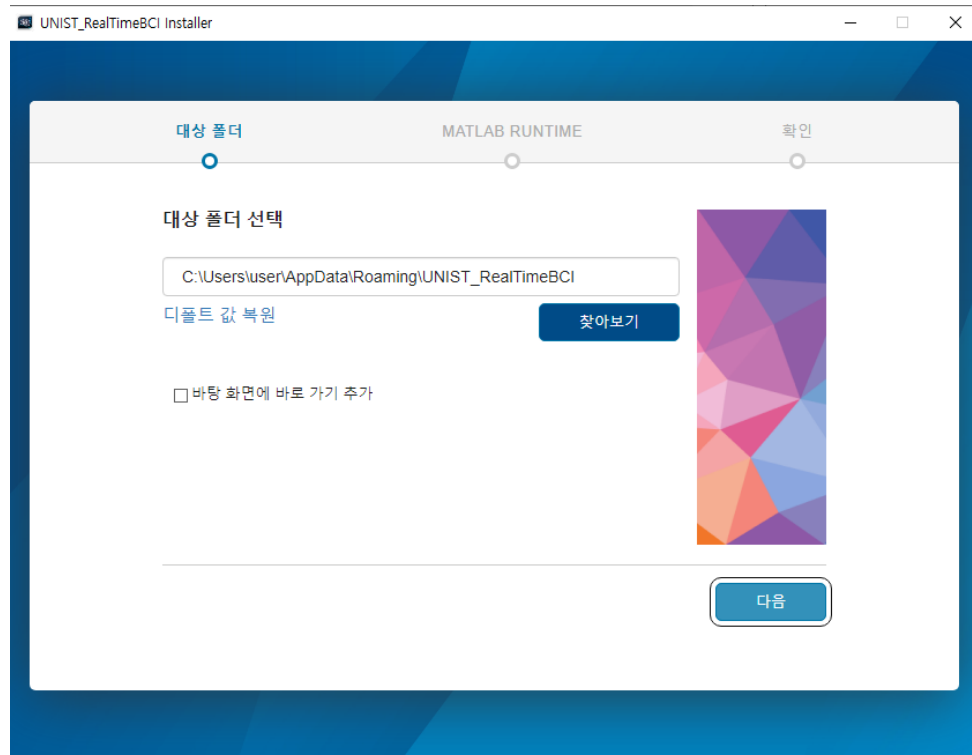
## Download from the MATLAB Runtime

1    Locate and download the "*UNIST_BCISystem.exe*" file from the "*current_forDownload*"
     directory on GitHub.
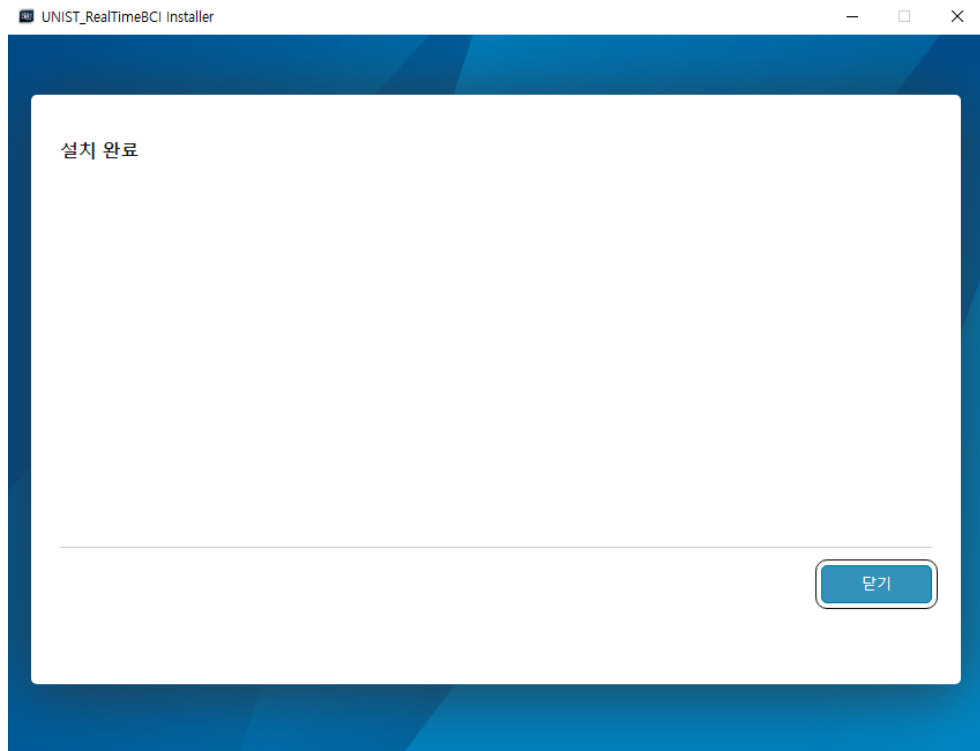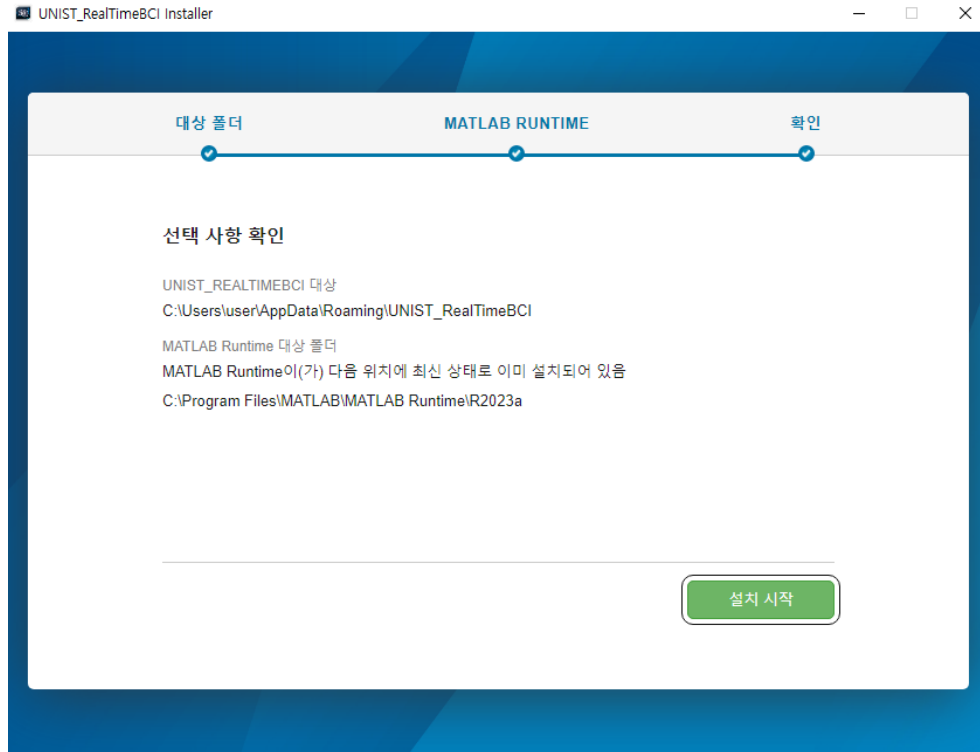
2    Run the "*UNIST_BCISystem.exe*" program.
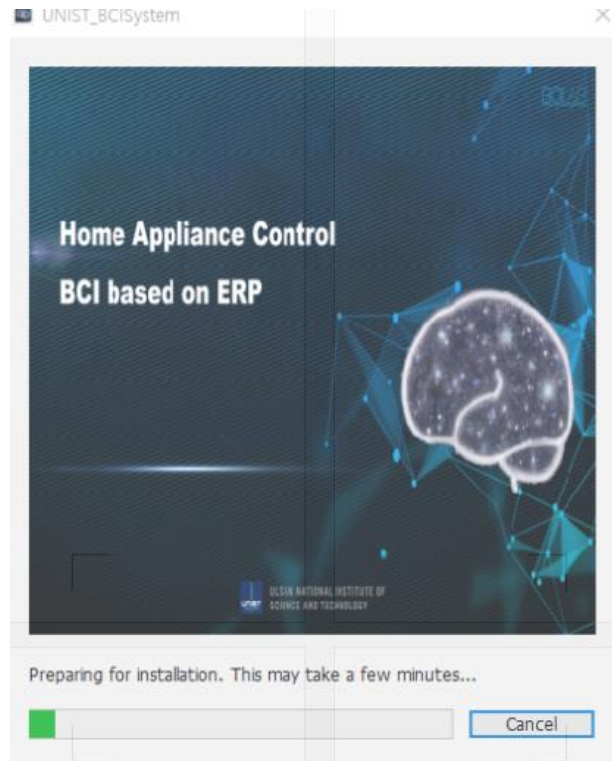
3   Start the installer and click the "**Next**".
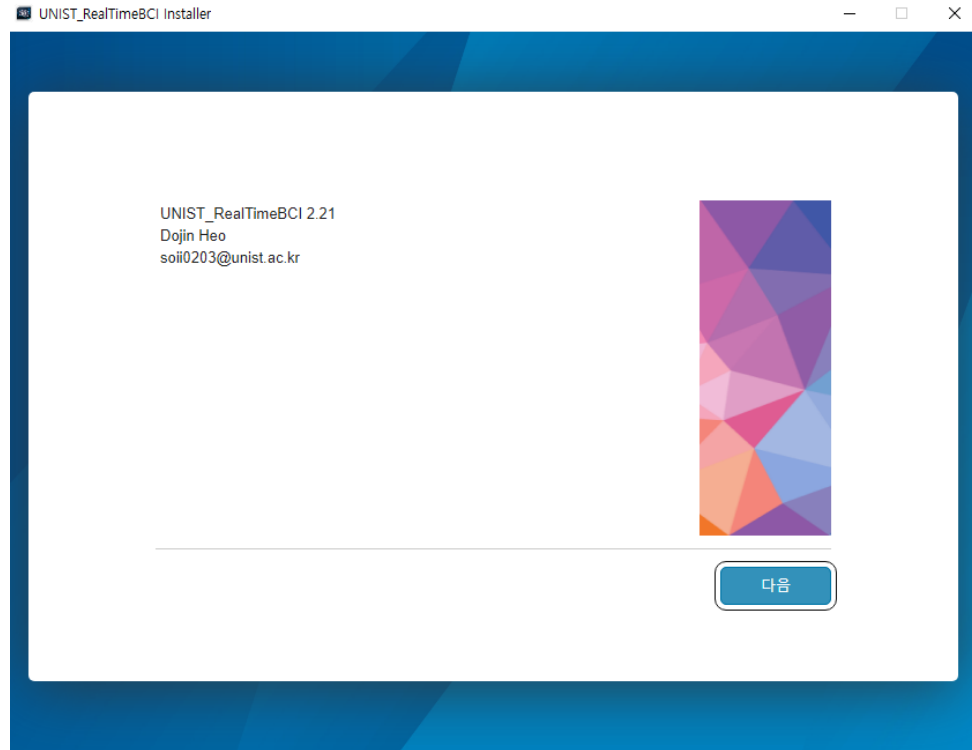


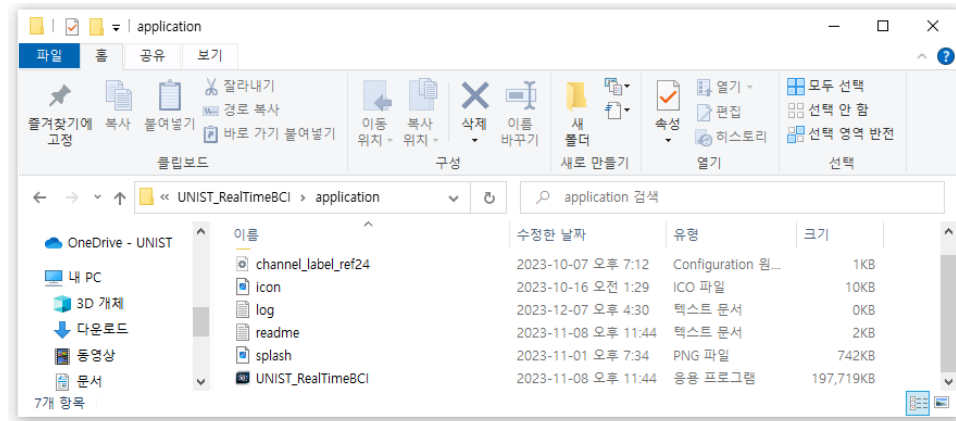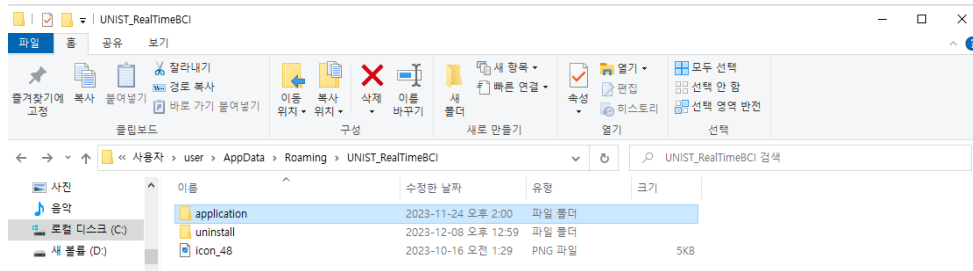4   Select the folder location you prefer (It is recommended to use the default path).

5    Click the **"Start"** button to initiate the installation and wait for it to finish.

6    After the download is complete, go to the program's location. Locate and click "*UNIST_RealTimeBCI.exe*" within the "*application*" folder.





## Directly download the program

1    Get the "*exe*" folder from GitHub and also obtain the "*video*" and "*stimulus*" folders.

2    Make sure to place all the "*video*" and "*stimulus*" folders, along with the "*UNIST_RealTimeBCI.exe*" from the "*exe*" folder, in the same location.
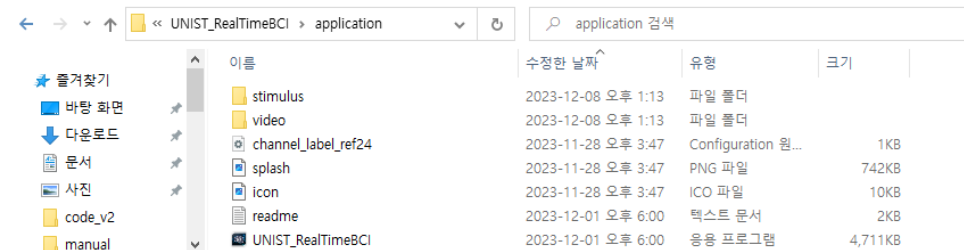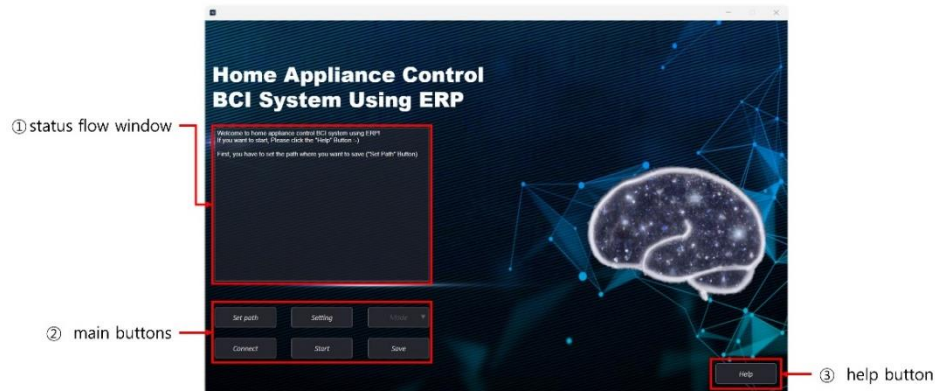


3    Run the "*UNIST_BCISystem.exe*" program.

## 2.     How to Use

### Description of the program layout

The program layout has three primary factors.



①   <u>Status Flow Window</u>: shows the program's current settings that you have entered and provides information about the upcoming actions.

②   <u>Main Buttons</u>: contains six main buttons.

    (a)   **Set Path**: selecting the path for saving data.

    (b)   **Setting**: establishing the username, reference channel information, and options for stimuli.

    (c)   **Mode**: selecting the mode for controlling the home appliances.

    (d)   **Connect**: confirming the user's EEG device details and connection and choosing which home appliance to control.

    (e)   **Start**: initiating presenting a stimulus and beginning real-time appliance control

    (f)   **Save**: saving your options and your dataset obtained during BCI control

③   <u>Help Button</u>: provides instructions for using the program.

## Summary of each step for using the interface

There are a total of seven steps for utilizing our program, with each step containing the following information:

Step 0. Basic network configuration

Step 1. Set the path for saving dataset

Step 2. Set options

Step 3. Select mode

Step 4. Connect to the EEG device and select the home appliance to control

Step 5. Start to represent stimulus and control home appliances

Step 6. Save the dataset


## Step 0. Basic network configuration

In order to utilize the program, it is essential to set up the network configuration. Failure to do so may result in errors when running the stimulus. The program will guide for setting up the network configuration upon launch.

1  Go to "*Control Panel > Network and Internet*".

2  Click on "*Ethernet Properties*".

3  Uncheck "*Internet Protocol Version 6 (TCP/IPv6)*".
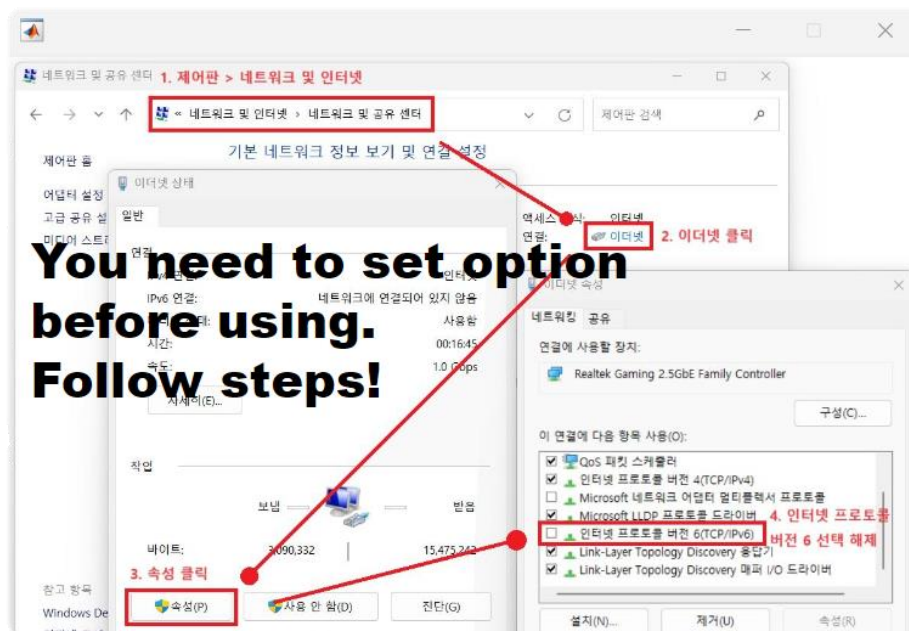
## Step 1. Set the path for saving dataset

1    Click the "**Set path**" button from the ② <u>main buttons.</u>

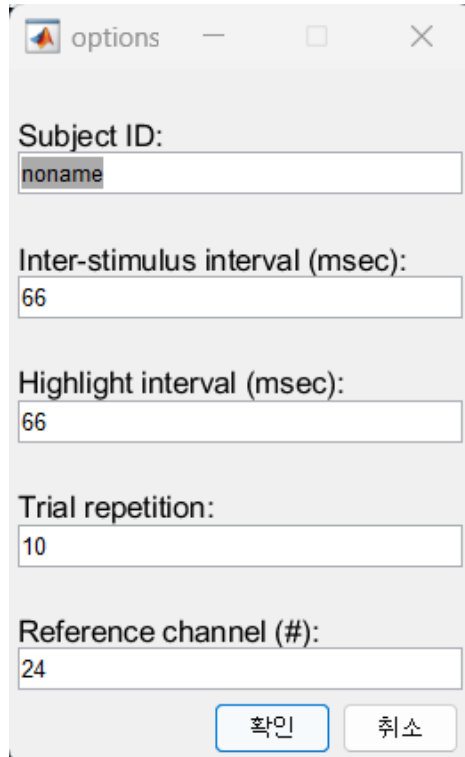2    A window will appear; choose a folder location where you desired.
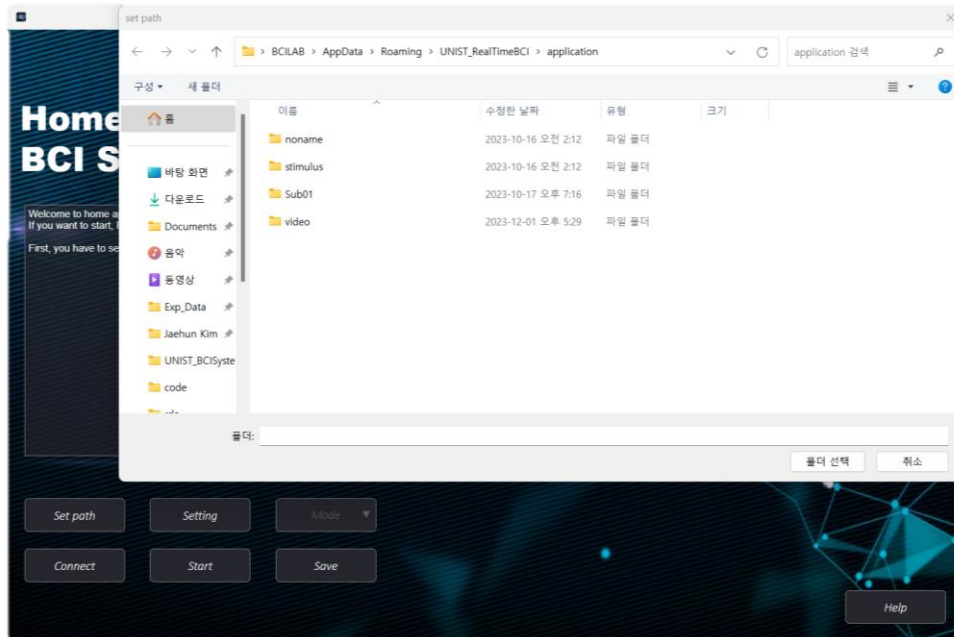


3    The selected location can be verified in the ① <u>status flow window</u>

## Step 2. Set options

1  Click the "**Setting**" button among the main buttons.

2  Set the subject ID, three stimulus options and the reference channel.



(a)  Options for stimuli in a BCI system include the inter-stimulus interval (ISI) length, the Highlight interval length, and the number of trial repetitions.

(b)  These choices affect the total time for representing stimuli, with ISI representing the duration the stimulus is off and the Highlight interval representing the duration it's on (default: 66 msec).

(c)  Trial repetition refers to the number of times the stimulus turns off and on (default: 10).

(d)  If these options are set too short, it may reduce the time for controlling the home appliance but could also lower BCI performance.

(e)  The user should enter the desired channel number for the Reference channel (default: 24th channel for the Brain Products actiCHamp/actiCHamp Plus).

3    Select whether to **"LOAD"** existing EEG data or to collect **"NEW"** data, for training the computer.
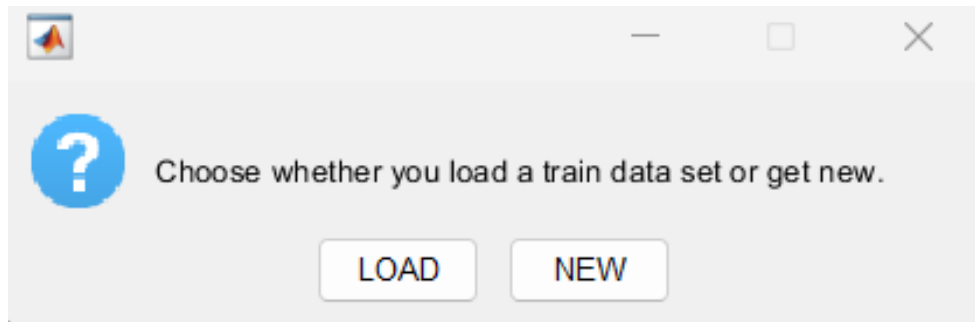


4    (1) If you opt to **"LOAD"**, choose the folder that contains the necessary data (which must include *cal_sig.mat*, *param.mat*, and the training dataset). Wait for the Processing popup to finish.
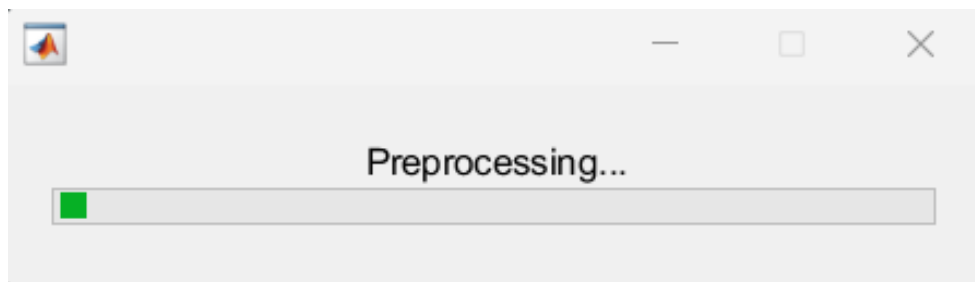


(2) If you choose to correct **"NEW"** dataset, enter the number of blocks to the following message box (default: 40). Using too many blocks may lead to fatigue.
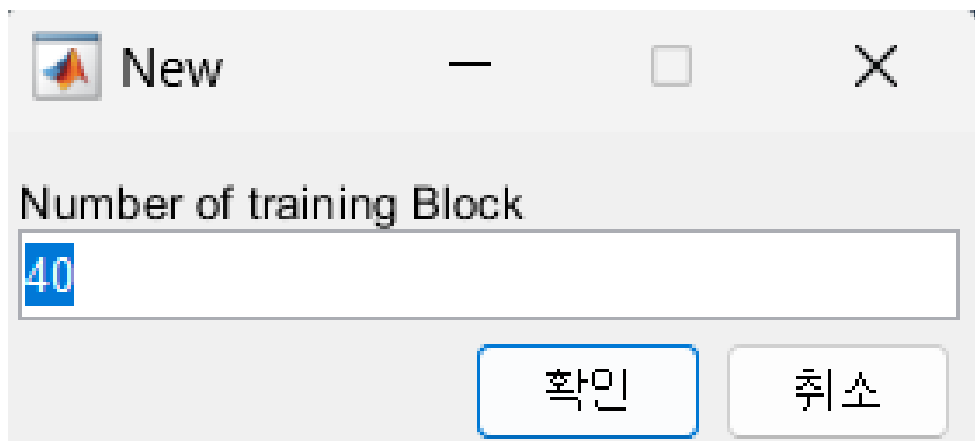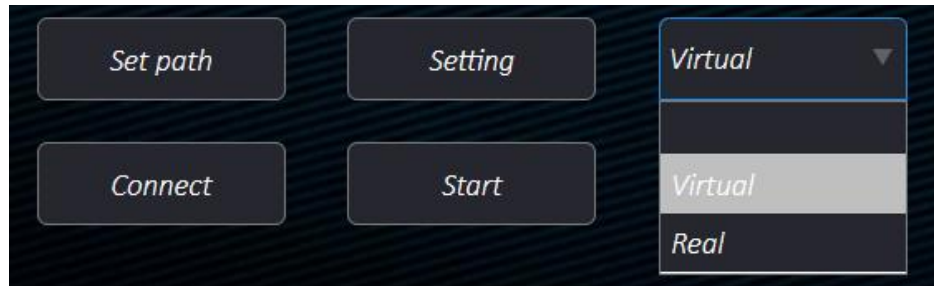
5   The ① <u>status flow window</u> shows the configured values and indicates the current program status as either "training" or "testing". When "**LOAD**" is selected, it appears as "testing", and when "**NEW**" is selected, it appears as "training".
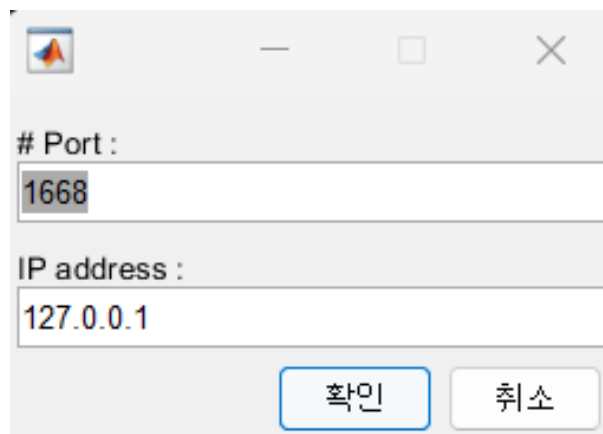
## Step 3. Select mode

1   Click the "**Mode**" button among the ② <u>main buttons</u>.

2   Select either "**Virtual**" or "**Real**" from the list that appears.



(a)   "**Real**" mode is the setting that links to IoT home appliances and displays real-time results by controlling the appliances.

(b)   "**Virtual**" mode is the setting that demonstrates results through a sample video without being connected to the IoT home appliances.

3   If you choose "Real" mode, proceed with the following 4-6 instructions. If not (choose "Virtual"), then skip 4-6 instructions.

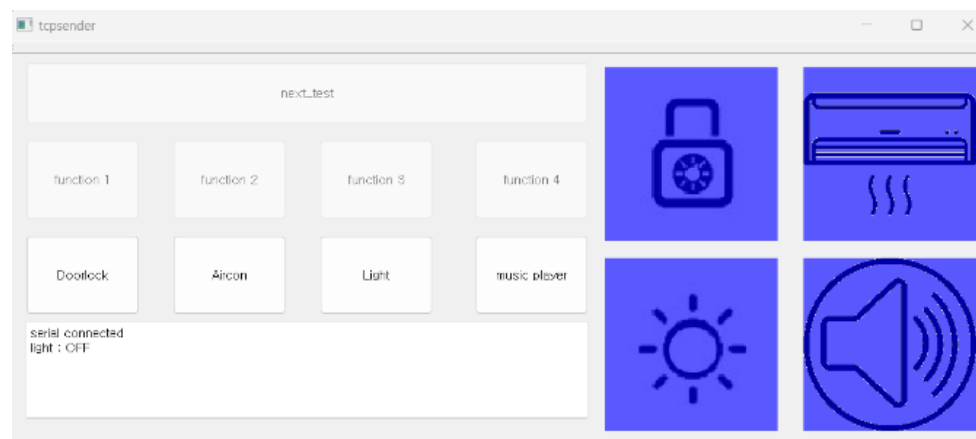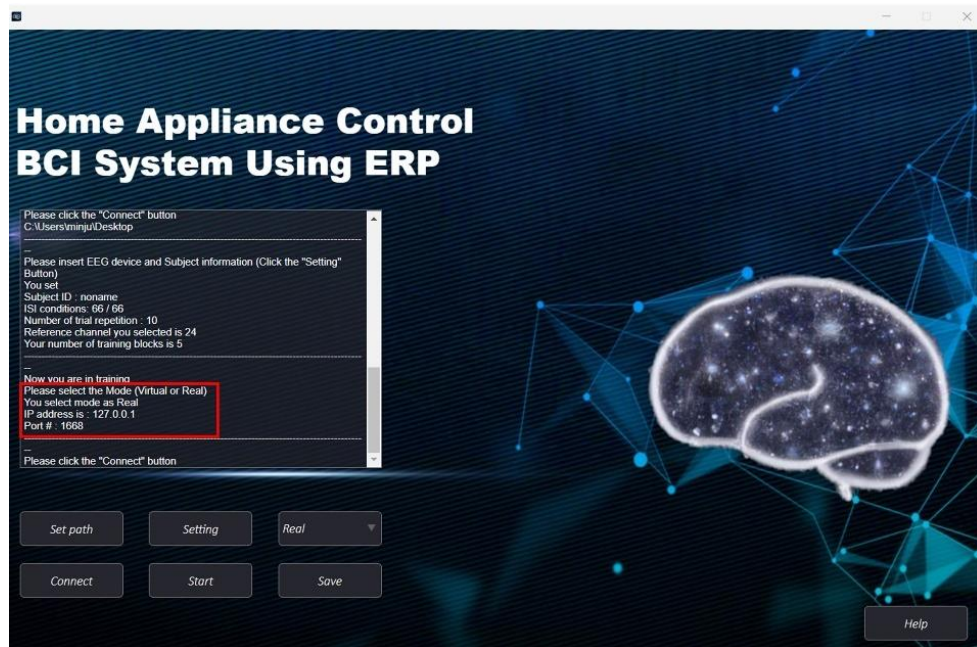4   Set the "*Port number*" and "*IP address*" for the IoT home appliance.

5    The "*tcpsender*" program is launched automatically. Select the "**liblsl**" checkbox and
     then click on "**start**".
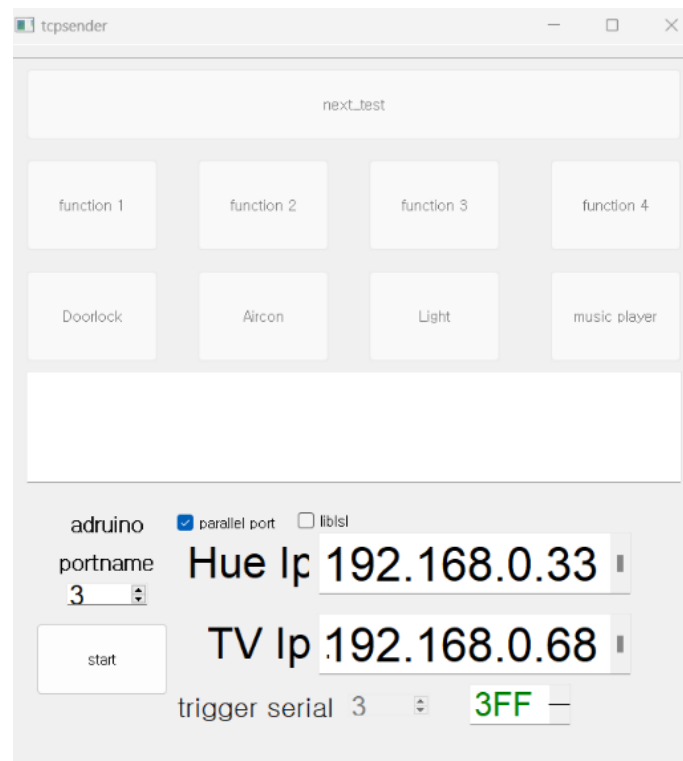


6    Choose the home appliance you want to operate. Next, return to the screen for
     *IoTHomeERP* program.

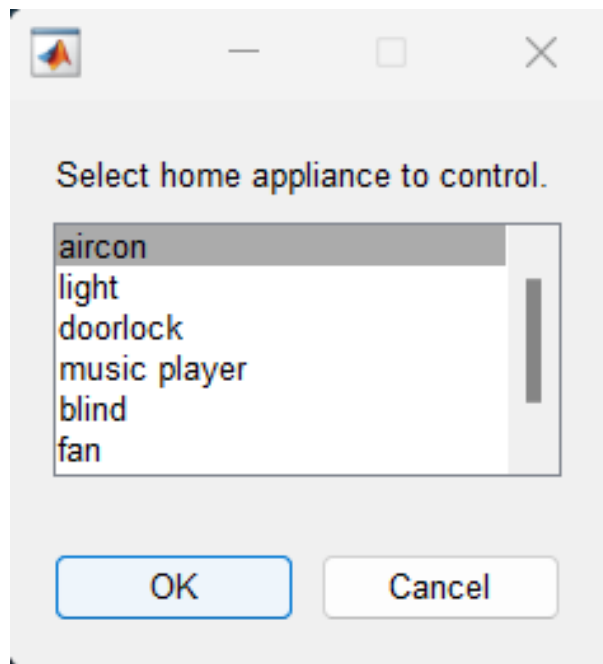7   Verify the settings in the ① <u>status flow window</u> to confirm the selection mode step has been finished.

## Step 4. Connect to the EEG device and select the home appliance to control

1    Click the "**Connect**" button among the ② <u>main buttons</u>.

2    After the EEG device is connected successfully, a confirmation window will pop up. If a message indicating an indefinite wait appears, click "**Cancel**" and verify the connection between the LSL and your EEG device.
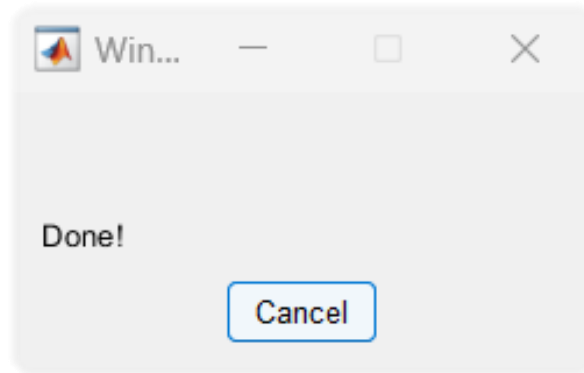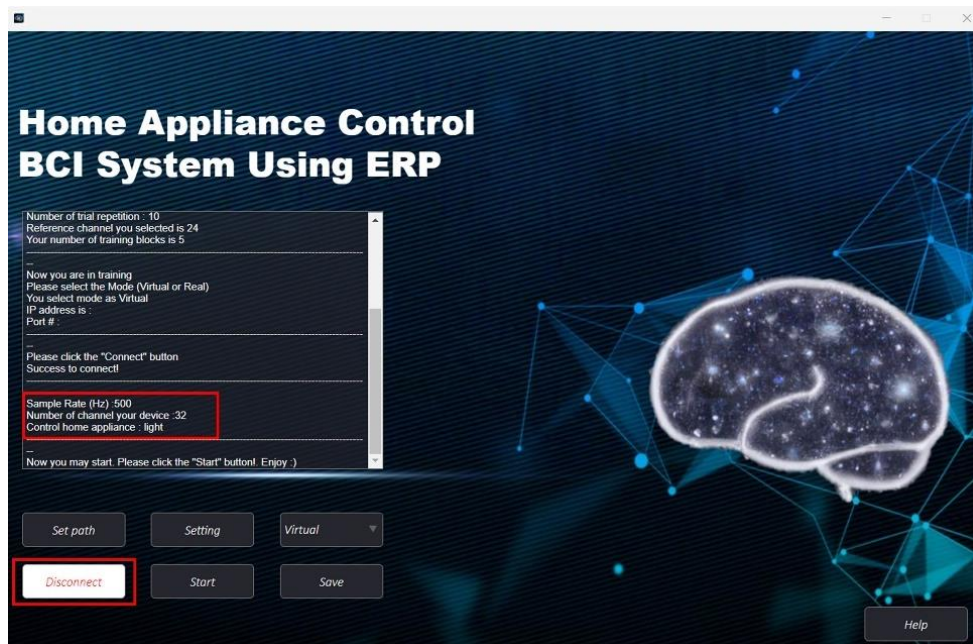


3    Choose the home appliance you want to control.

4    Enter the *"Sampling Rate"* and *"the total number of channels"* of your EEG device as set in LSL.
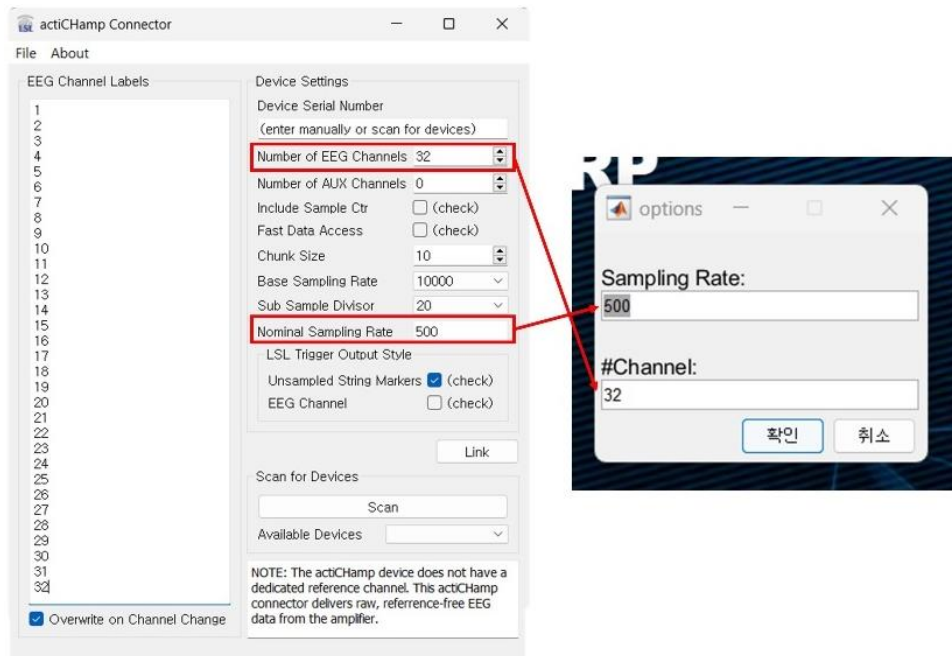


5    Verify your settings in the ① status flow window. Additionally, the "**Connect**" button will switch to "**Disconnect**" to show that the connection between LSL and your EEG device has been established.

## Step 5. Start to represent stimulus and control home appliances

1. Begin the stimulus presentation by clicking the "**Start**" button from the ② main buttons.

2. If you are in the "training" status, proceed with the following 3-9 instructions. If you are in "testing" status, skip the following 3-9 instructions.

3. Upon starting the first block, it is necessary to record your EEG for a resting state for 60 seconds. This will be directed by a pop-up window with instructions. It is important to stay still during this period.
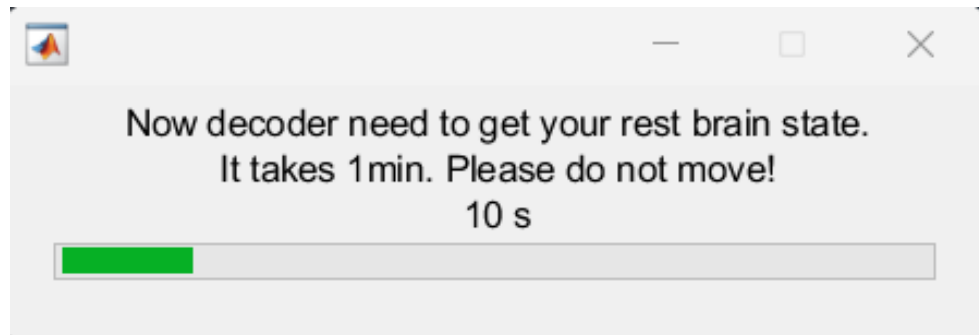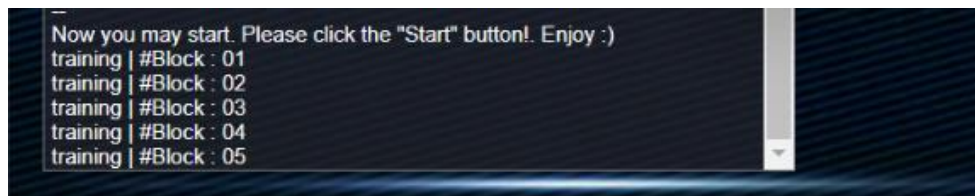


4. After waiting, remember the specific location you need to focus on as per the instructions.
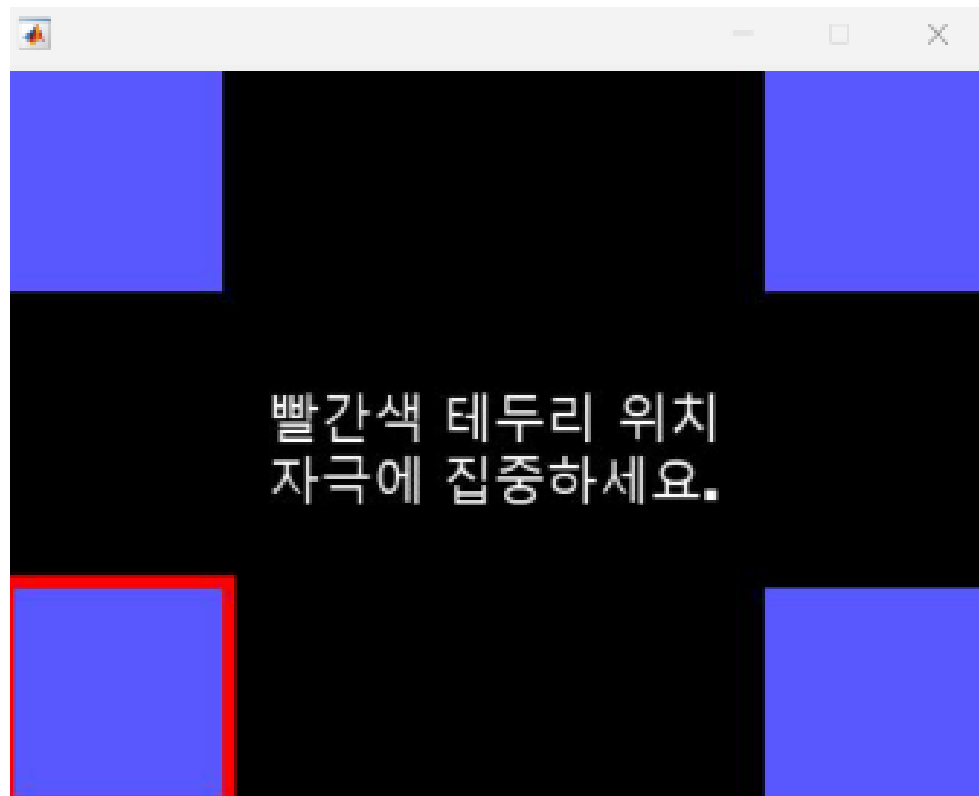
5     The screen will display stimuli and the four corner icons will be randomly highlighted. Focus on whether the specified icon guided in the instruction before is highlighted.
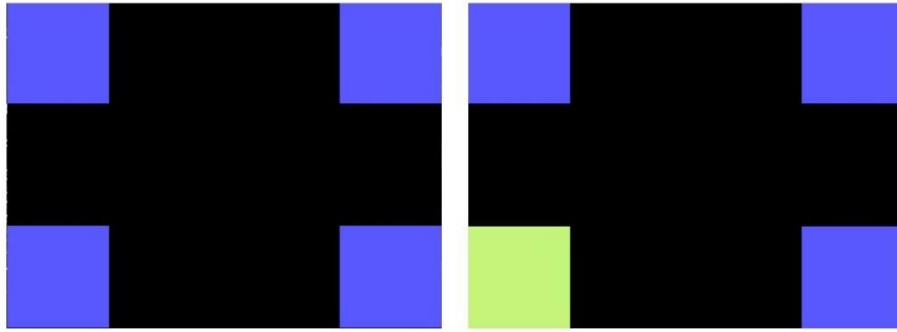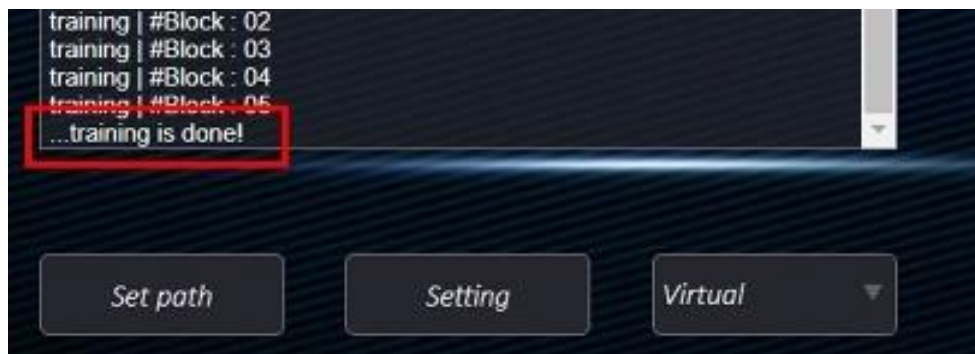


6     The ① status flow window shows the current program status and keeps track of the number of blocks you have completed.



Now you may start. Please click the "Start" button!. Enjoy :)
training | #Block : 01
training | #Block : 02
training | #Block : 03
training | #Block : 04
training | #Block : 05

7     Continue to follow steps 1-4 until you reach the specified number of blocks set during the 4(2) instruction in step 2.

8     After finishing, please wait for the confirmation message on the pop-up window.
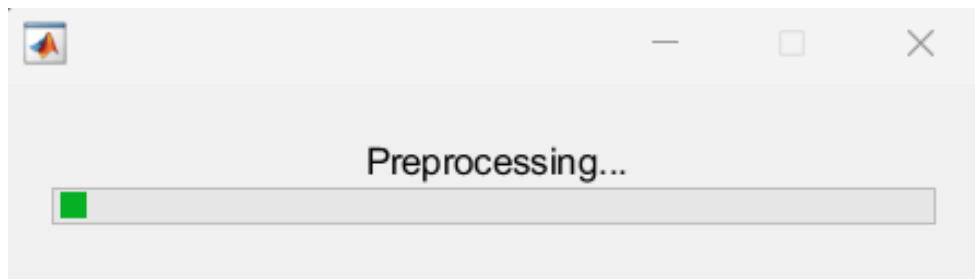


Preprocessing...

9     Verify the indication that the training process is done on the ① status flow window. The program will automatically change the status from "training" to "testing".



training | #Block : 02
training | #Block : 03
training | #Block : 04
training | #Block : 05
...training is done!

Set path       Setting       Virtual

10  To operate the selected home appliance, simply click the "**Start**" button.

11  Focus on the desired icon. The command choices are shown as icons (refer to the example below, which illustrates controlling an air conditioner with options for turning it on, off, decreasing temperature, and increasing temperature).
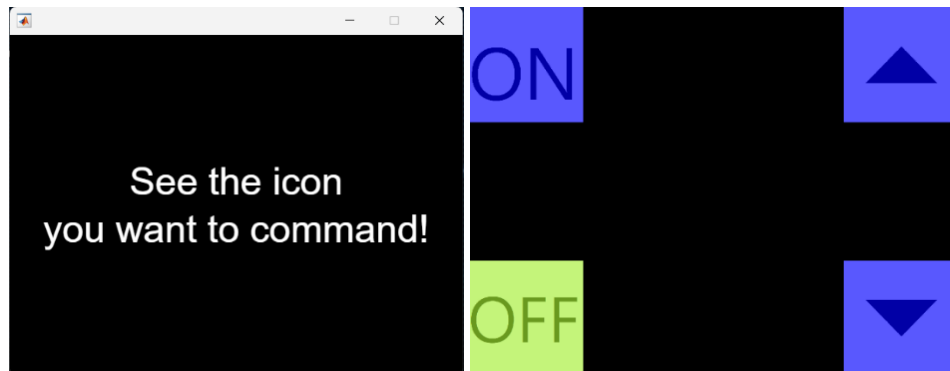


12  Check the selected command in the ① status flow window. Additionally, the "**Virtual**" mode displays the results using a video, while the "**Real**" mode shows the results by controlling the connected home appliance.
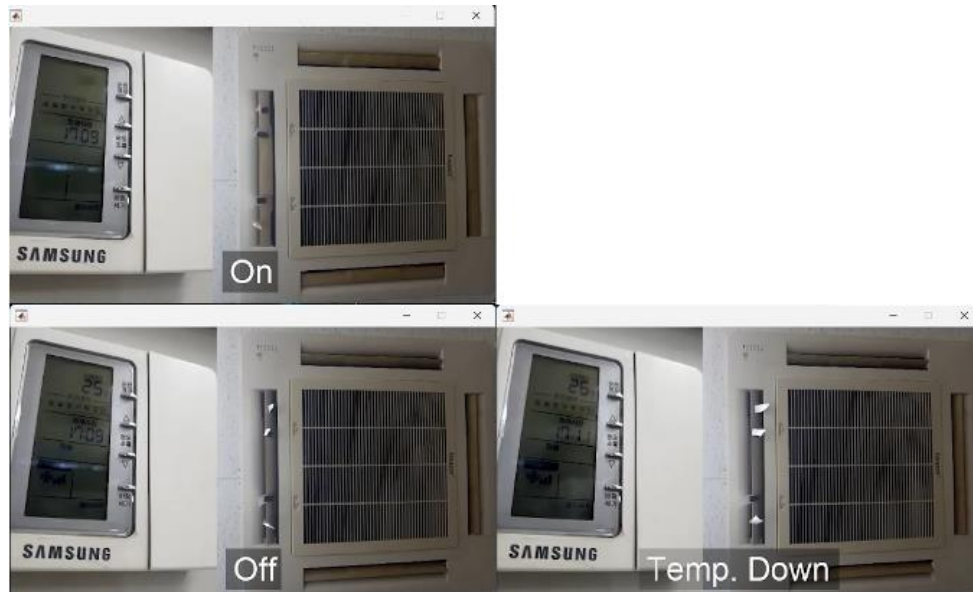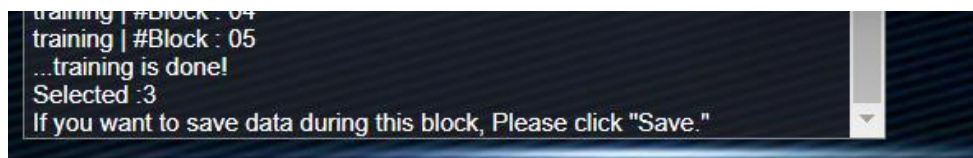




13  Repeat 10-12 instructions until you decide to stop controlling.

14  If you wish to switch the home appliance being controlled, simply click the "**Disconnect**" button and go back to step 4.

## Step 6. Save the Dataset

1   To save the latest block data along with your chosen options, simply click the "**Save**" button located among the ② <u>main buttons</u>. Note that during the "training" status, blocks are automatically saved.

2   Verify the message displayed on the ① <u>status flow window</u> to ensure that your data has been successfully saved.

3   To move on to the next block, click the "**Start**" button. Keep in mind that if you proceed without saving, the recent data will not be retained and cannot be recovered later.
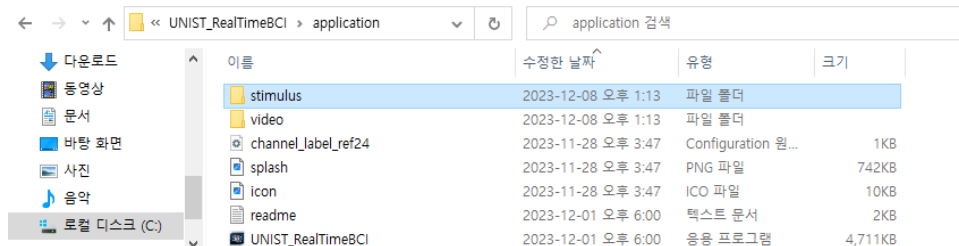
# ADVANCED TIPS

## 1. Customizing Stimulus Icons and Videos for Virtual Mode

You have the option to modify the stimulus icons, and you can also change the videos displayed as a result while in virtual mode.

## Customizing stimulus icons

1  Go to the "*stimulus>singleshot_stimulus>img*" folder within the program folder that you have downloaded.



2  Modify the icon image while retaining the original image name.
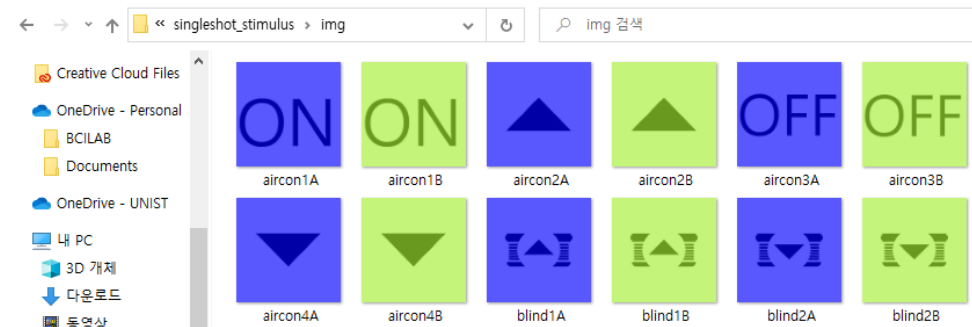


3  You can adjust advanced settings for stimuli in the "*settings > setting.txt*" or "*testlist > example.txt*". It's important to have a thorough understanding of the .txt file to prevent errors.
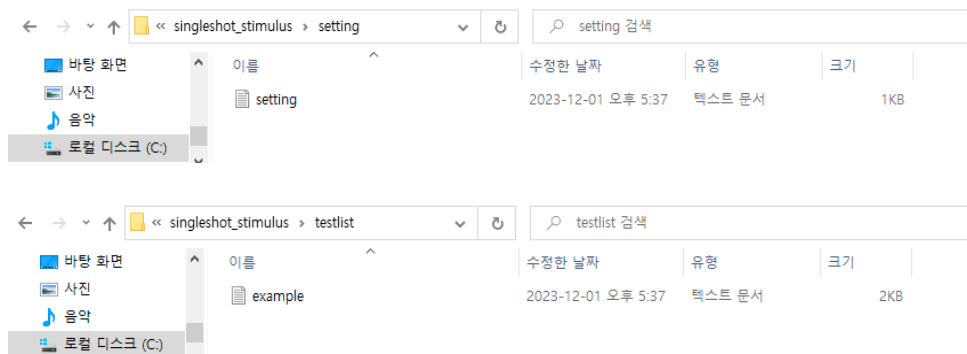
## Customizing Videos for Virtual Mode

1  Go to the "*video*" folder within the program folder where you have installed the program.
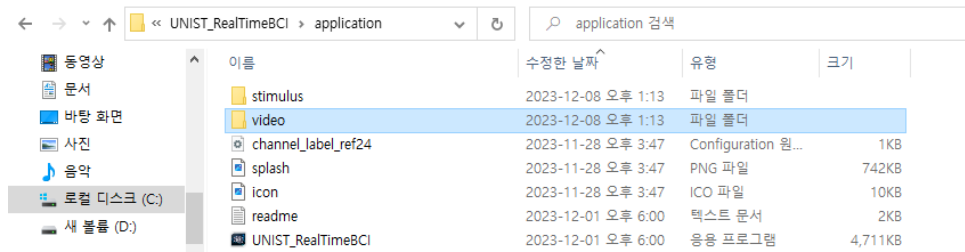


2  Replace the video with a new one, making sure that the new video has the same name as the original.

## 2.    Description of the dataset

1    The dataset is stored in a folder named subject ID in the selected path you entered. The data is saved in ".mat" format.

2    The data files are labeled as "*subjectID_state#block.mat*." Data of EEG during Rest state (during 2th instruction in step 5) is saved as "*cal_sig.mat*," and the list of settings is saved as "*param.mat*."

| 이름 | 상태 | 수정한 날짜 | 유형 | 크기 |
|---|---|---|---|---|
| cal_sig | ⊘ | 2023-09-28 오후 4:30 | MATLAB Data | 2,254KB |
| noname_testing00 | ⊘ | 2023-09-28 오후 5:06 | MATLAB Data | 579KB |
| noname_testing01 | ⊘ | 2023-09-28 오전 1:13 | MATLAB Data | 721KB |
| noname_testing02 | ⊘ | 2023-09-28 오전 1:25 | MATLAB Data | 723KB |
| noname_training01 | ⊘ | 2023-09-28 오후 4:30 | MATLAB Data | 497KB |
| noname_training02 | ⊘ | 2023-09-28 오후 4:35 | MATLAB Data | 492KB |
| param | ⊘ | 2023-10-07 오전 12:56 | MATLAB Data | 2KB |

3    Each piece of data is structured as follows:

   (a)   *cal_sig*: This is saved as a matrix with dimensions channel X time, and it contains 60 seconds of EEG data during a resting state.

   (b)   *sig_vec*: This is also in the format of channel X time and contains raw ERP data responded to the specific block stimuli.

   (c)   *trigger*: This is a vector with dimensions 1X time, and it records the latency when stimulus icons are highlighted. It uses floor numbers with values of 0, 1, 2, 3, or 4, where 0 indicates no stimulus and 1-4 represents the highlighted moments of icons as depicted in the accompanying figure.
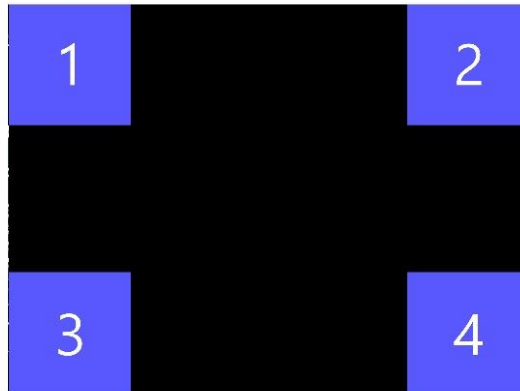


   (d)   *param*: It has struct format. The data includes the stimulus set by the user, the true label data for training, and default brainwave processing parameters.

## 3.    Finding Source Code

All the functions used in this program are available for download from the "*function*" folder on GitHub "BCI/IoTHomeERP (https://github.com/Heodojin/IoTHomeERP)"