

Introduction to Brain Science and fMRI (1)

fMRI basics and
Stimulus

Presentation: EPrime2.0

Tentative: 20110915

Introduction to Brain Science and fMRI (1-0-0)

Outline of lecture

As a new functional magnetic resonance imaging (fMRI) environment will be opened to the public in October, 2011 for the Tokyo Tech people, this subject provides practical skills of a basic neuro-imaging technology using our fMRI scanner.

Purpose of lecture

The aim of this course is to bring to the potential users of the fMRI scanner at Tokyo Tech the most practical information about the software applications indispensable through the workflow of the fMRI experiments.

Plan of lecture

No.1:November 4th, No.2:November 11th, No.3:November 18th, No.4:November 25th, No.5:December 2nd, No.6: December 9th, No.7:December 16th. Time slots: 5-6 (13:20~14:50) at the 2nd Practice room of Global Scientific Information and Computing Center (GSIC).

No.1~No.3:fMRI basics and Stimulus Presentation: E-Prime2.0

First, students will learn the programming skill of E-Prime 2.0 for providing stimuli to be given to fMRI participants and recording their behavioural responses during the task. The information given here will be directly useful for running fMRI experiments at Tokyo Tech.

- 1)Making a program for trigger synchronization
- 2)Recording responses made by the fMRI-safe response pad
- 3)Visual stimuli through the projector
- 4)Auditory stimuli through the fMRI-safe headset
- 5)Multimodal stimuli using a slide object
- 6)Jittering (how to randomize duration times)
- 7)Running the E-run programs for fMRI experiments
(how to collaborate with the operator)

No.4~No.6: Data Analysis: SPM8 (enhanced with Python2.5)

Second, there will be a practice of SPM8 using the educational computer system at GSIC from the preprocessing of the brain images through the statistical analyses applied to the treated data.

- 1)File formats of brain images (DICOM, Analyze, NIFTI)
- 2)Concept of dependency in SPM8
- 3)Preprocessing from realignment through smoothing
- 4)ROI analysis using masks by wfu_pickatlas
- 5)First-level analysis using GLM
- 6)Second-level analysis (Fixed effect and random effect)
- 7)2-sample t-test and factorial design

No.7: Miscellaneous: FSL, MRICron, or Matlab

Third, various techniques using MRICron (run on the platform of the Educational Computer System), FSL-View or Matlab will be introduced for manipulating the voxel-based information for the extended approaches in brain science.

- 1)Voxel coordinate system
- 2)MNI, Talairach and coordinate conversion
- 3)How to extract the voxel values from image files
- 4)Advanced topics: ICA, MVPA, fMRI, etc.

Textbook and reference

Lecture note will be downloadable from OCW-i.

Related and/or prerequisite courses

Students wishing to attend the course are requested to watch the program of this course held last year by Prof. Jorge Jovicich (University of Trento, Italy) to gain knowledge about the fMRI basics.

<http://www.ocw.titech.ac.jp/index.php?module=General&action=T0300&GakubuCD=227&GakkaCD=227615&KougiCD=65061&Nendo=2010&Gakki=2&lang=JA&vid=03>

Evaluation

Full attendance is required.

Office hours

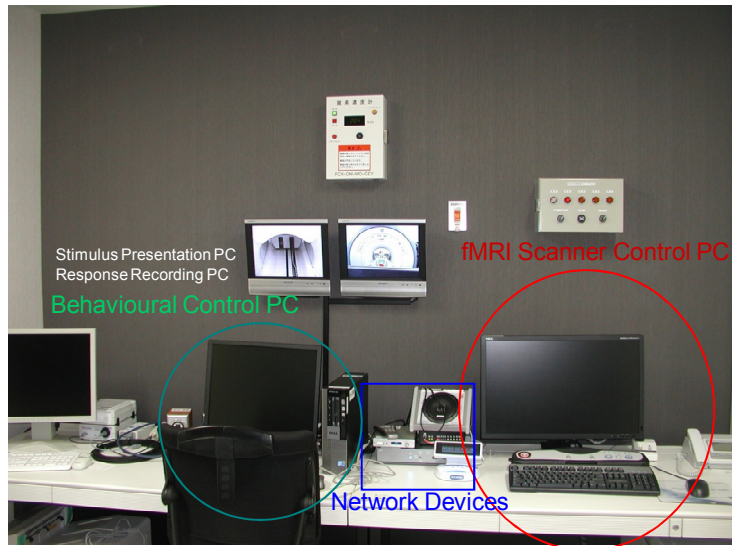
The lecturer is available after each session in the same Practice room.

Comments from lecturers

For the more detailed information on the course, please feel free to send an email to akama@dp.hum.titech.ac.jp.

fMRI BASICS

Our fMRI scanner —Control room

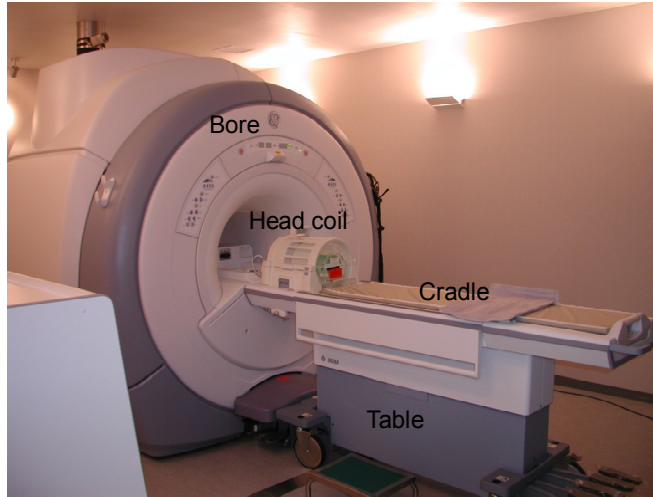


Our fMRI scanner —Machine room



Only the authorized operators are permitted to enter this room.

Our fMRI scanner —Magnet room



Don't bring any
ferromagnetic item
in the room

It is TOO
DANGEROUS!

People with
-A pacemaker
-An aneurysm clip
-Metal implants
are
prohibited to enter

Only the authorized operators and participants are permitted to enter this room.

What is MRI?

- MRI: magnetic resonance imaging (磁気共鳴画像法)
- *Structural and anatomical scans* (構造的、解剖学的スキャン): patients or participants are required to refrain from making any reaction but simply keep still.
- Not necessarily functional (機能的)
- *Functional* signifies detecting traces of hemodynamic activation (increase of blood in certain anatomical regions) considered as responses to stimuli or tasks

What is fMRI?

- fMRI (functional magnetic resonance imaging)(機能的磁気共鳴画像法)
- BOLD (Blood-Oxygen-Level-Dependent)
 - Indirect index of neural activation: hemodynamic response(血流動態反応)
 - **the increase of blood** in some of brain regions can be detected as effect of consuming oxygen needed for making activities related and bound to these regions.
 - Oxyhemoglobin(酸素化ヘモグロビン) remain > deoxyhemoglobin (脱酸素化ヘモグロビン)
 - Magnetic susceptibility becomes lower by the increase of oxy-hb, so **the MR signal becomes much intense**.

RF (Radio Frequencies)(高周波)

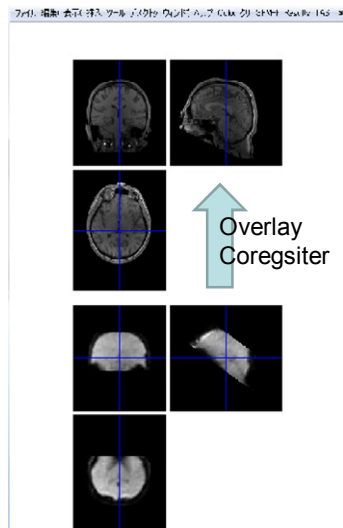
- Used to **create images** sensitive to a particular property of the body (RF have both electric and magnetic aspects)
- In our fMRI scanner, there is an RF Amplifier of 35kW → Power of a small radio broadcasting center!
- This electric wave is received by a **head coil** (Receiver coil) in which the brain of a subject is inserted.
- Excitation (励起) and Relaxation (緩和):
 - The RF pulses lay down (spin) the magnetization vectors and we can catch the information of how these vectors will get up and recover after that
 - →produces MR signals (磁気共鳴信号)
 - The recovery times vary according to body tissues
 - White matter, Grey matter, Cerebro-spinal fluid etc.



Gradient Fields (傾斜磁場)

- Used to *change the strength of the magnetic field over space* to detect the difference in location (necessary for position information).
- There are 3 independent gradients
- **X gradient** : A direction in the transverse plane where magnetization vectors become downed and flat.
- **Y gradient** : Another direction in this plan.
- **Z gradient** : longitudinal direction, slice direction, which is parallel with the scanner bore.

Structural versus Functional



Upper images: **Structural**

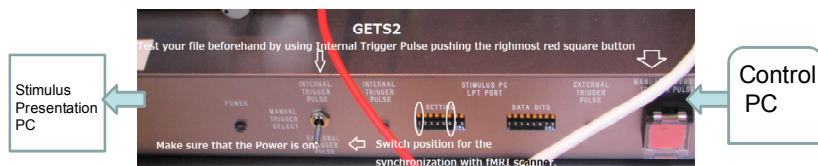
- Whole brain (needs long time)
- Anatomical scan (needs accuracy)
- High spatial resolution

Lower images: **Functional**

- Part of a brain or ROI
(region of interest) (switched in short times)
- Activation as a result of making tasks (information cut off)
- Low spatial resolution

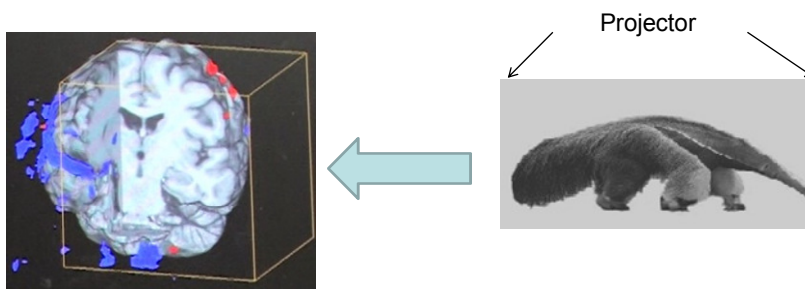
Providing stimuli to a subject

- A subject in the fMRI scanner sees and/or hears something transmitted by the stimulus provision system.
- A trigger synchronization (トリガー同期) device is necessary to **set the temporal progress** between the control PC of fMRI and the stimulus presentation PC.



Rough Sketch of an experiment

Time point: Stimulus onset ← Time point: Stimulus onset



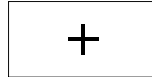
Simultaneously, the activation is recorded ← When seeing a picture

Think about
A typical
Property of
The object...



Experiment Design

Take a rest



- 3 seconds for stimulus → 7 seconds for rest
- Quick Event-related Design
- 20 mammals, 20 tools
 - Randomly presented
 - Order of appearance must be recorded in E-Run log files.
- 400 seconds in total
- TR=1000 milliseconds
 - 400 volumes (400 samples according to the terminology of GE.)

Imaging Recordings

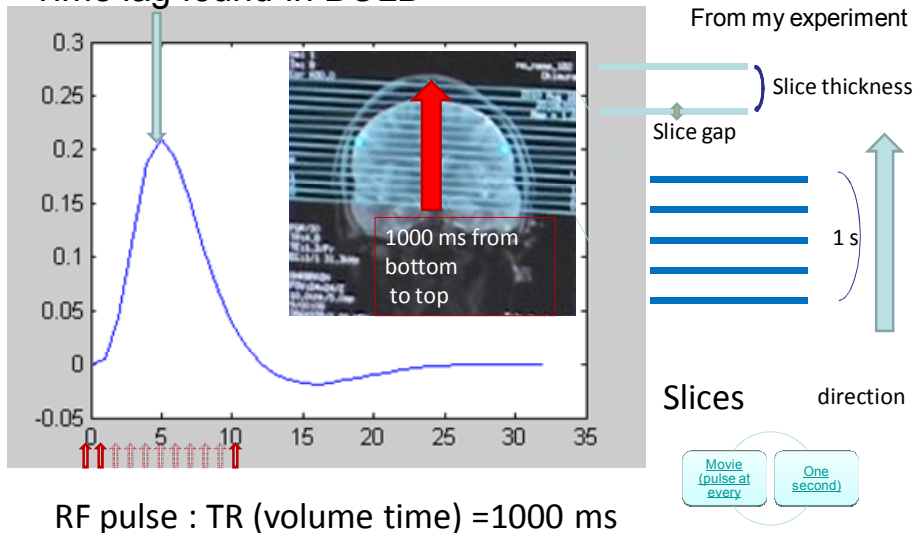
- Protocol
 - Series
- **3 Plane Localizer**
 - Rough Positioning
 - 3 pictures for each plane
- **3D T1 SPGR**
 - Anatomical (Structural) scan, needs about 5 minutes, MPRAGE for a Siemens scanner
- **fMRI BrainWave**
 - Functional Imaging, needs trigger synchronization

fMRI BrainWave

- Parameter values dependent on the experiment design of a user group
- Axial slices or oblique slices?
- Cover the whole brain or focus on ROI?
- 4 initial volumes will be automatically abandoned by the scanner as dummy scans
- The first trigger pulse will be transmitted just after the dummy scans

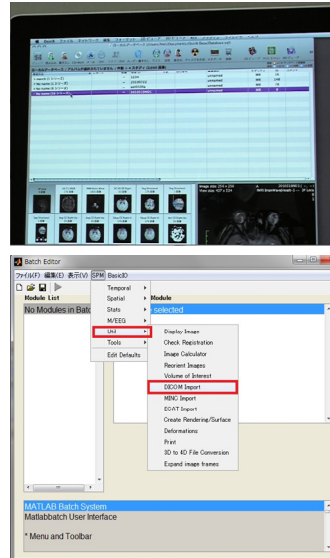
Recording brain images

Time lag found in BOLD



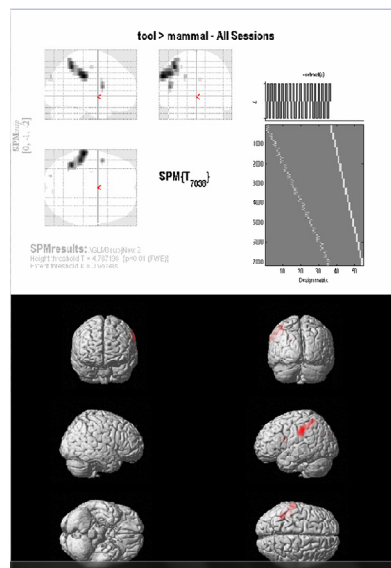
Captured Images

- After the experiment, you will see all the images are automatically saved in the GE Control PC.
- But they must be transferred via Dicom Network to the dicom software “**OsiriX**” installed in the work station (Macintosh) of the fMRI laboratory for saving them as dcm files in a DVD disk.
- **Dcm files**: 1 slice for 1 file, so immense number of images, and no metadata in the file name.
- Using the utility of “Dicom Import” in SPM, these files must be converted into Analyze ([hdr/img](#)) for the research.

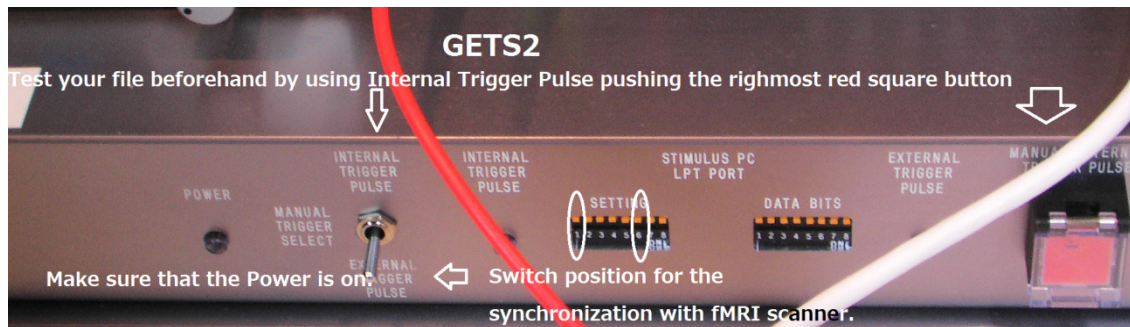


Brain Images

- GE Control PC
 - Real time checks of activation intensity is roughly possible, but we can't do any detailed analysis then and there.
- Parametric Images
 - Rendered images like these become available by using SPM8 and furthermore, they are “parametric” so directly readable as a 3-D array of activation values.
- ROI or VOI can be identified and manipulated as “masks” for further analysis.
- Refer to various brain atlases!



TRIGGER SYNCHRONIZATION



Front face of GETS2

We use the machine called GETS2" for trigger synchronization. You **MUST** NOT detach any cable from GETS2. However, the experimenters may use either the stimulus provider PC (DELL machine) settled on the console desk or a Laptop PC you will bring in the control room. Your Laptop PC must have either a printer port (Parallel Port, LPT port) or a digital I/O board to be connected with a BNC port of GETS2 (nowadays these ports became obsolete so we strongly recommend to use the regulation equipment).

There are many applications used in the purpose of providing stimuli to the participants and collecting their behavioural reactions: E-Prime, Matlab (Psychtoolbox, Cogent), Presentation, Superlab, your hand-made C or C++ program, etc. In this section we treat solely E-Prime (E-Studio) for an fMRI experiment, which would be also helpful for the other kinds of stimulus programming.

1) E-Prime

Some "es2" files found in ¥MyDocuments¥MyExperiments¥... will give you some hints of programming.

a) Parallel port setting

You must program E-studio file in your laboratory and bring it by a USB memory to the equipped DELL PC. But it is better to know the port setting for your own PC before copying the E-studio file to the machine in the fMRI laboratory.

Check the I/O range of the parallel port of your PC proceeding Control

Panel-> System-> Hardware-> Device Manager-> Port-> Printer Port(LPT1)-> Resource-> I/O range. That of the stimulus presentation PC in our fMRI control room is **0378-037F in hex, 888-895 decimally** (you have only to use "function calculator" implemented in the "Calculator" found in "Accessories" of Windows OS for changing numeration system). This data must be entered in E-Studio (E-Prime) as the port number, but please do not forget to add +1 to the minimum value of I/O range, in the case of our shared desktop, it is 889 (=888+1) decimally, and to add "&H" if you use hex at the head of the number.

Start your E-Studio (in E-Prime), select Edit from the tool bar, click Experiment from the pull down menu, choose Device tab and click Add for adding "Port" from the available devices. "Edit" the port data as follows.

Collection mode: Presses and Releases

Address: the first value of I/O range +1. It depends on "your" computer if you want to try to run the file in your environment.

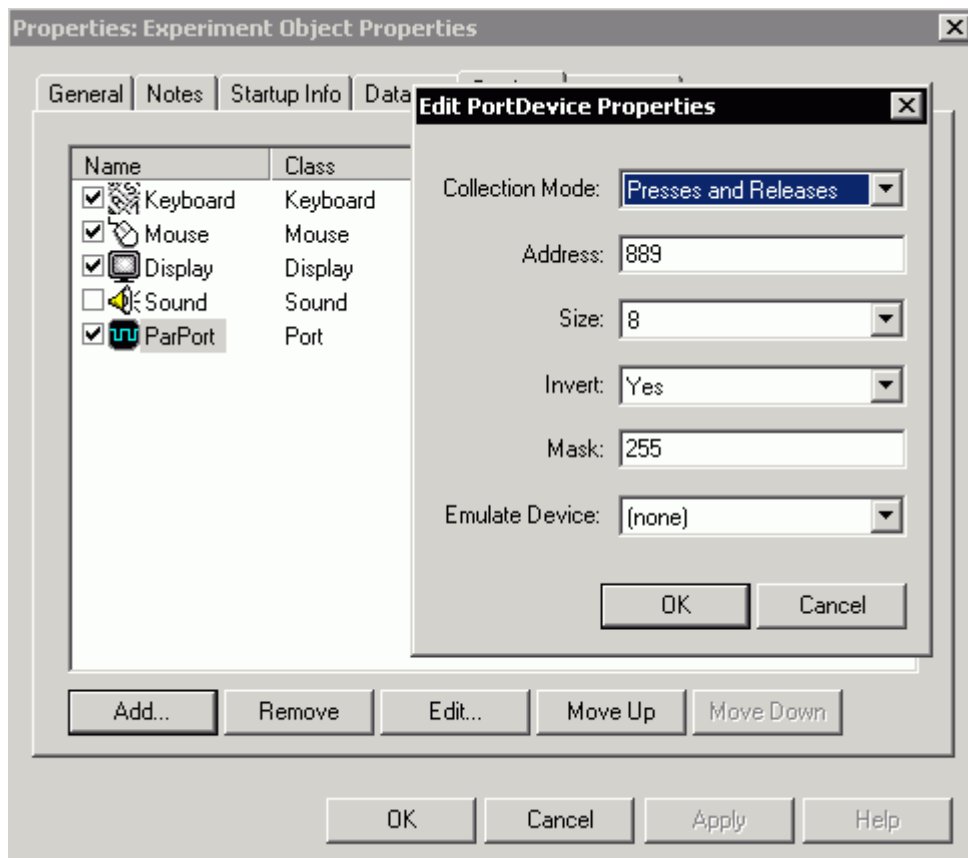
Size:8

Invert: Yes

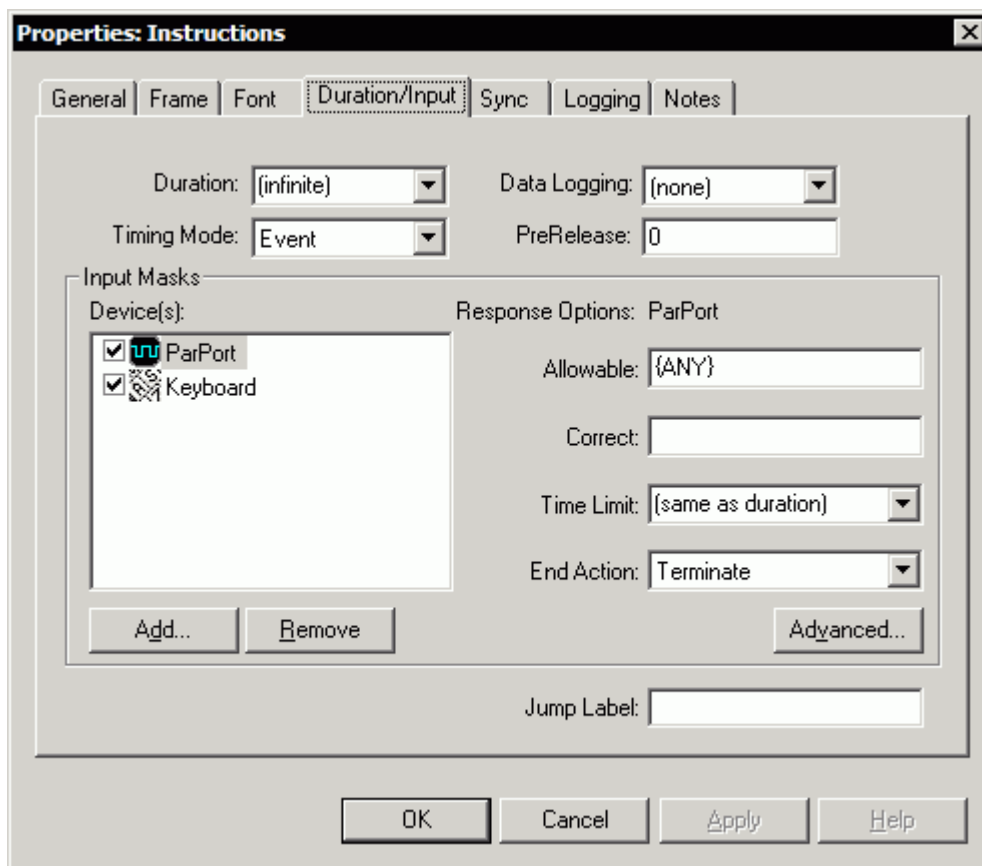
Mask:255

Emulation Device:(none)

The fMRI scanner sends TTL triggers at the onset of each volume discarding the initial dummy pulses. So in the case of "Mitchell.es", the very beginning of the first task period strictly corresponds to that of the presentation of the first drawing, which means the synchronization is assured at the first stimulus onset once for all.



Example of the parameter setting for the Experiment Object Properties



Example of Duration/Input setting

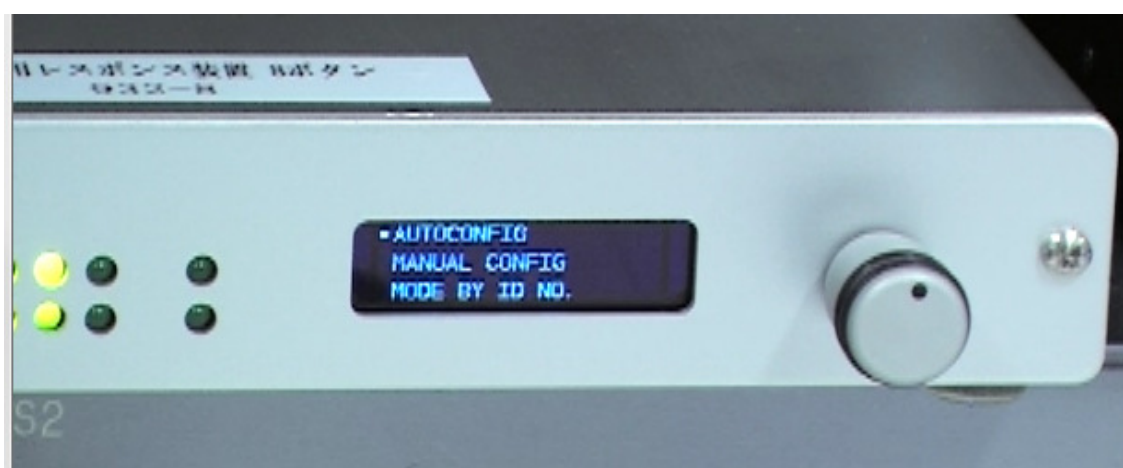
For auditory stimuli, an fMRI-safe headphone is prepared in the magnet room. It is necessary to supply power to the sound system by switching on the Transducer whose core part is located in the machine room just in front of the gradient chiller. Remember that for the sound stimuli, turning the power on and off is possible neither in the control room nor in the magnet room. So it is the operator that turns on the switch of the audio system.

RESPONSE RECORDING

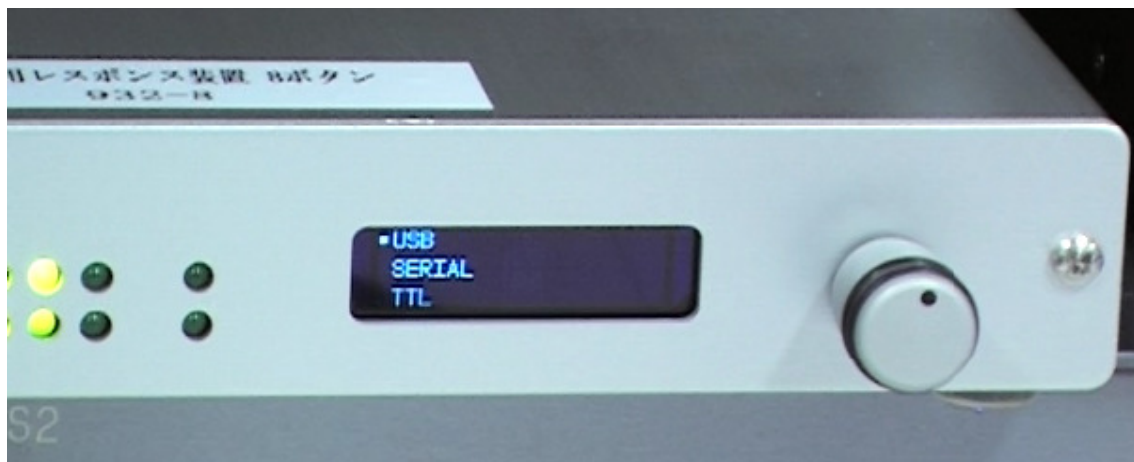
The fORP -- Fiber Optic Response Pad -- is a light based subject response device. All response pads and fiber optic bundles are completely non-metallic and non-electronic. The response pad we use is a set of two rectangular boxes (8 buttons) with 36-inch span. The electronic interface (Current Design Inc. 932-fORP) which is located on the console desk is connected to the stimulus provider PC (DELL machine) through the USB and the serial connection. Naturally, you will be able to connect your own Laptop to the electronic interface of the fORP, but you need a screw driver to remove the Serial cable from the DELL machine.



First of all, it is the operator that will enter the magnet room for connecting the response pads with the black fiber optic cable found near the bore. The operator must pay attention to the positions of the cable and the arms of a participant so that there is no crossing which would pose a risk to a burn by a current circuit of RF on the body. After this setup, the electronic interface of fORP will easily make the device recognition.



This interface has both AUTOCONFIG mode and MANUAL mode. The operator will select AUTOCONFIG and press the button.



And the operator will select USB in usual cases.

When using E-Prime as software for receiving signals from the fORP, you will be able to choose "keyboard" as a device to be added (in the window of the "Duration/Input" tab of the object's "Properties") so that the PC recognizes the response pad as the second keyboard connected by USB.

This will allow you to perfectly distinguish these 8 buttons as 8 different ASCII characters. Select either Mode 000 or Mode 001 from the "Mode by ID NO." on the fORP.



Mode000 HID KEY BYGRT (USB)

left red, green, yellow, blue and right red, green, yellow, blue correspond to

d, n, w, e, r, g, y, b

respectively.

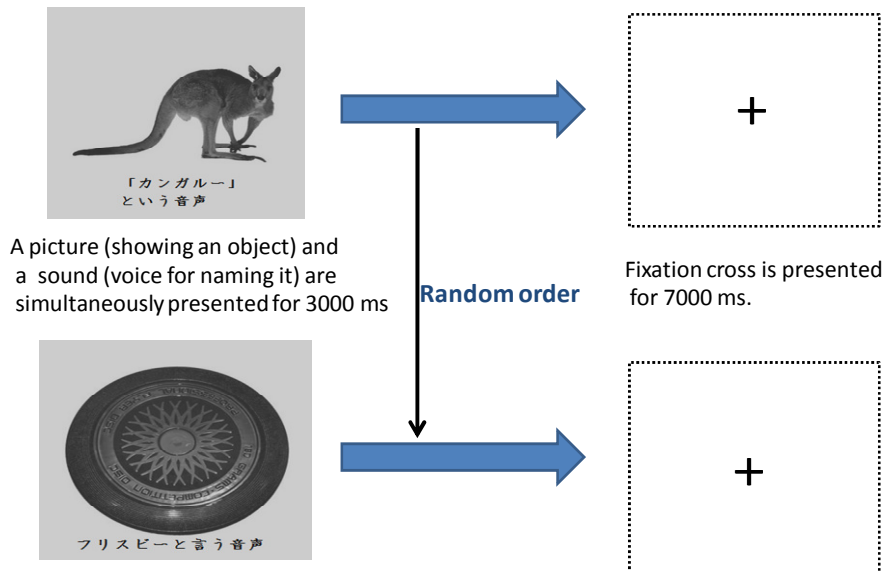
Mode001 HID KEY 12345 (USB)

left red, green, yellow, blue and right red, green, yellow, blue

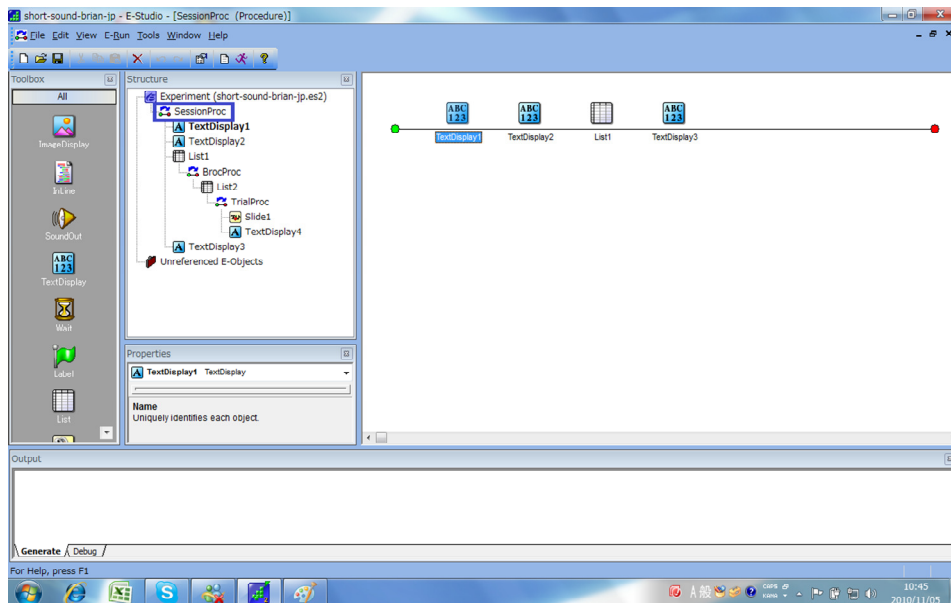
correspond to
9,8,7,6,4,3,2,1
respectively.

E-Prime for fMRI BASICS

Example of Experiment Design

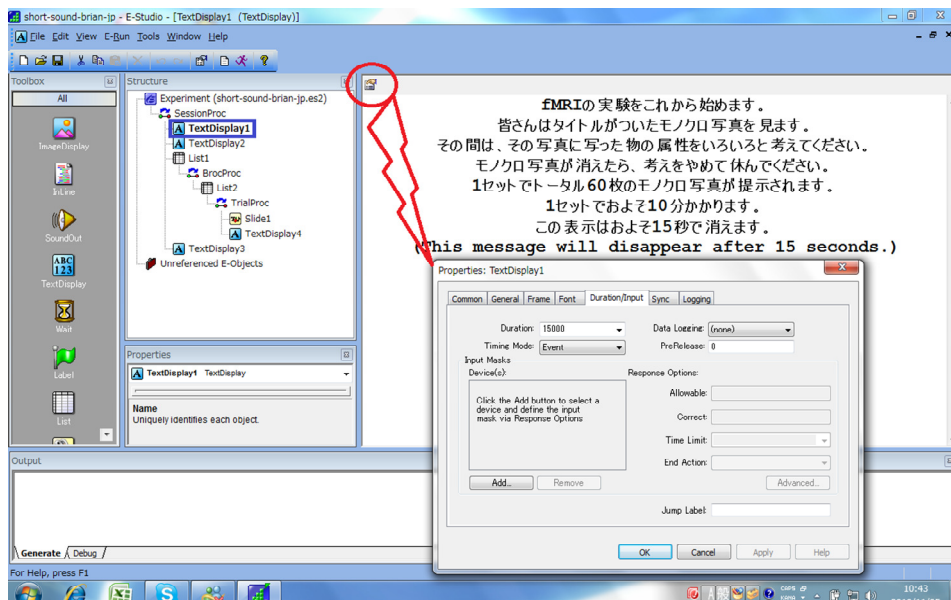


1. RootにSessionProcを配置する。



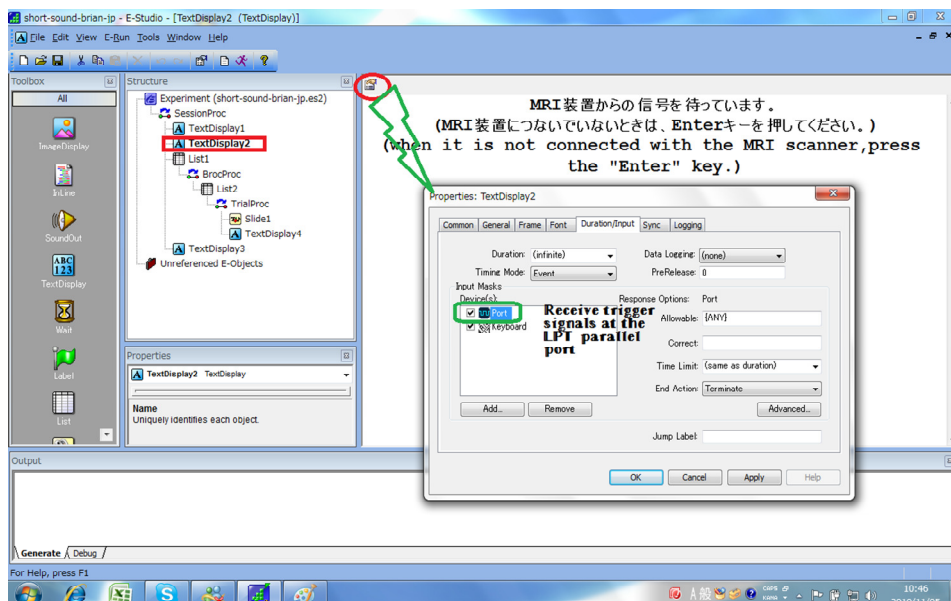
1. Set “SessionProc” at the level of Root.

2. TextDisplayを配置する。最初のメッセージ



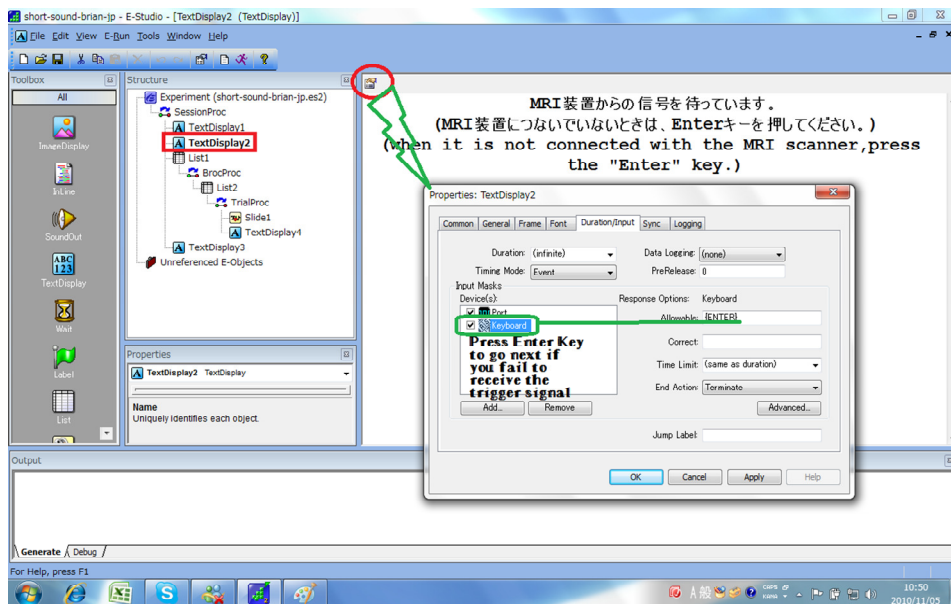
2. Place "TextDisplay" for the first message (explaining the outline of an experiment).

3.fMRIからのトリガー同期信号を受け取って次に移る。失敗したらEnterキーで抜ける



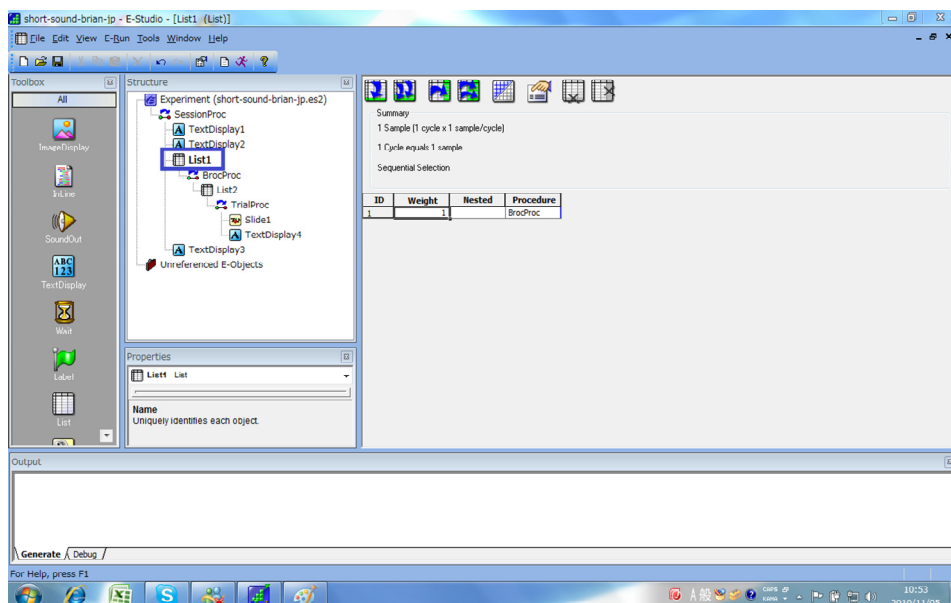
3. 1. Receiving a trigger signal at the (LPT) "Port" from the fMRI control PC, the program proceeds to the next object. In case of failure "escape" is possible by pressing the Enter key.

3.fMRIからのトリガー同期信号を受け取って次に移る。失敗したらEnterキーで抜ける



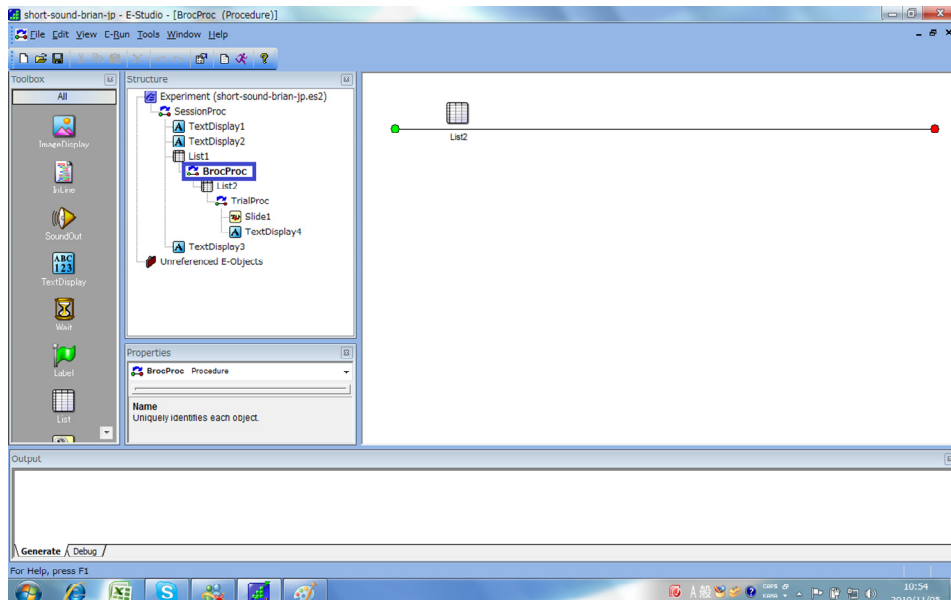
3.2. This TEXT object plays the role of “standby display” for the trigger signal. If the operator presses the “SCAN” button just after the onset of this TEXT object, the program will be in time without fail. **So you must let the operator know the timing of this object with the precise message of “now waiting for the signal from fMRI scanner”.**

4. Listの設定



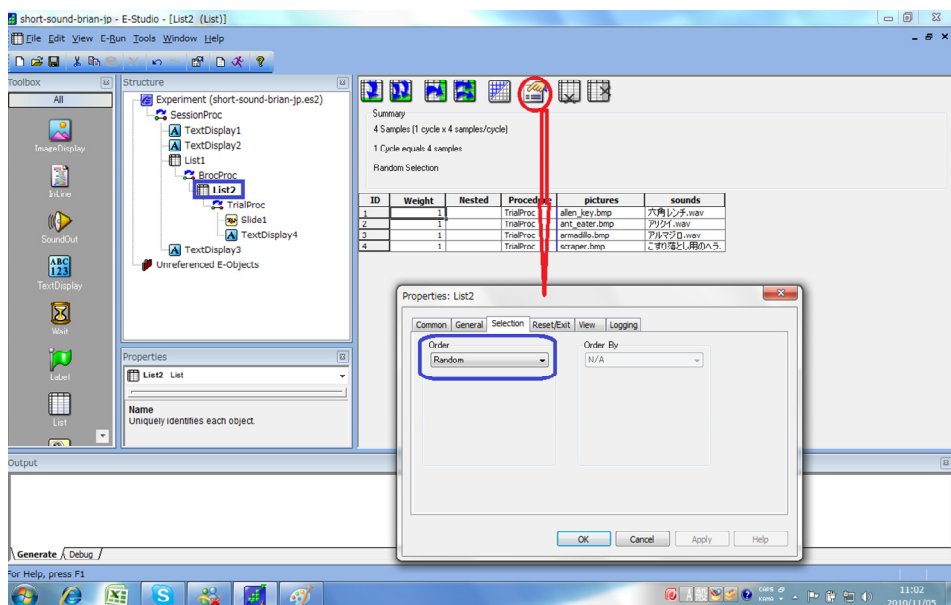
4. Setup of a “List”

5. BrocProcの設定



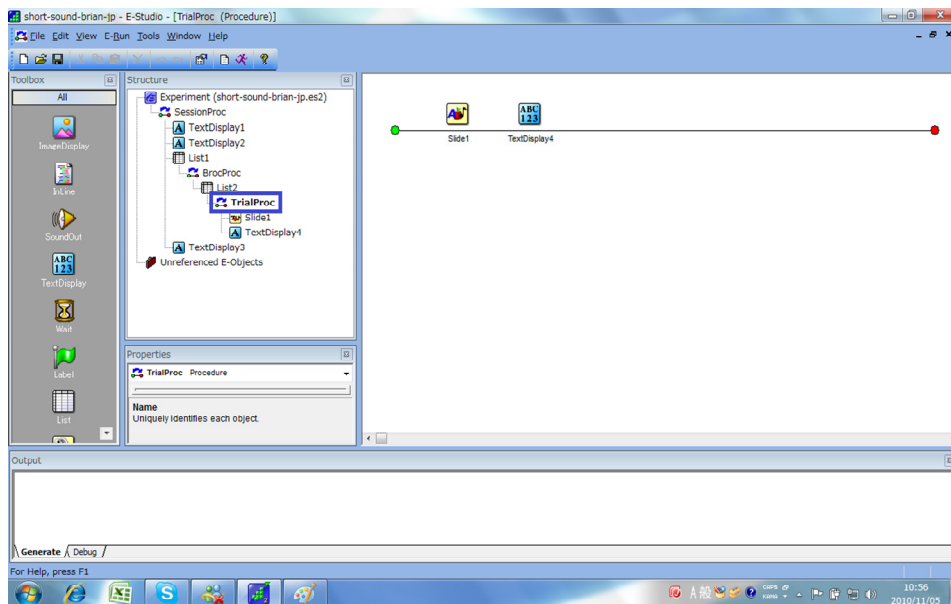
5. Setup of “ BrocProc”

6. 刺激アイテムの設定。pictures soundsは変数名で、同期する画像刺激、音声刺激になる。対応関係とランダム順序に注意。



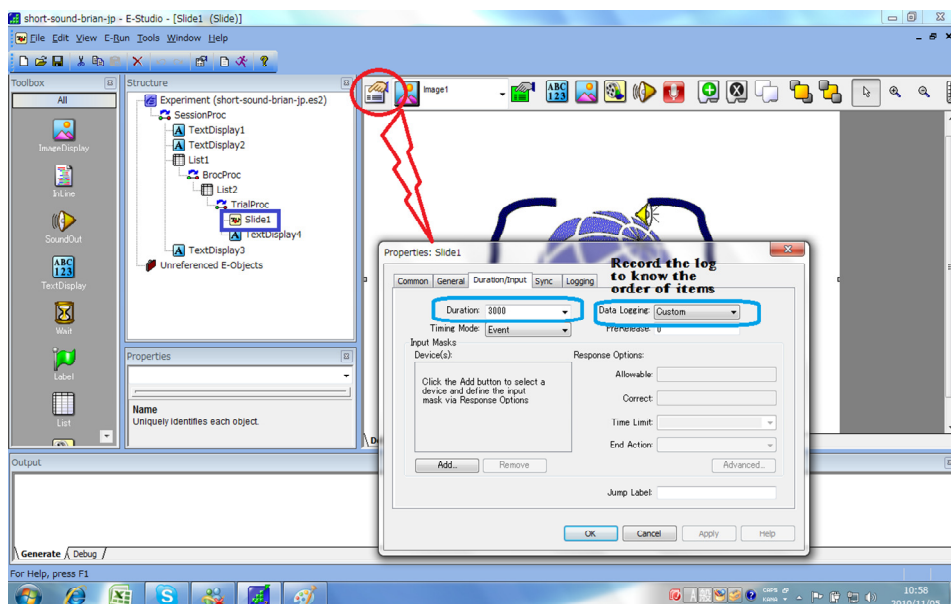
6. Setup of stimulus items. Here “pictures” and “sounds” are variable names of visual and auditory stimuli. Please pay attention to the correspondence (between the two modes) and the random order of presentation.

7. TrialProcの設定 画像音声同期刺激の後、fixation cross+が表示されるようにする。



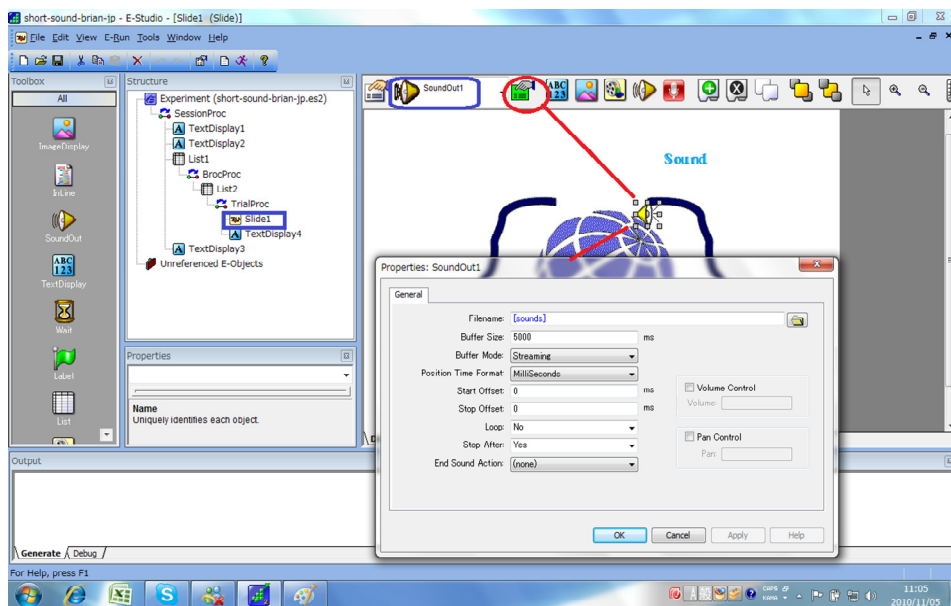
7. Setup of “TrialProc.” A fixation cross “+” will be displayed just after the synchronization of visual and auditory stimulus items.

8. Slide: 視覚刺激と音声刺激の同期 ログを取るのを忘れない



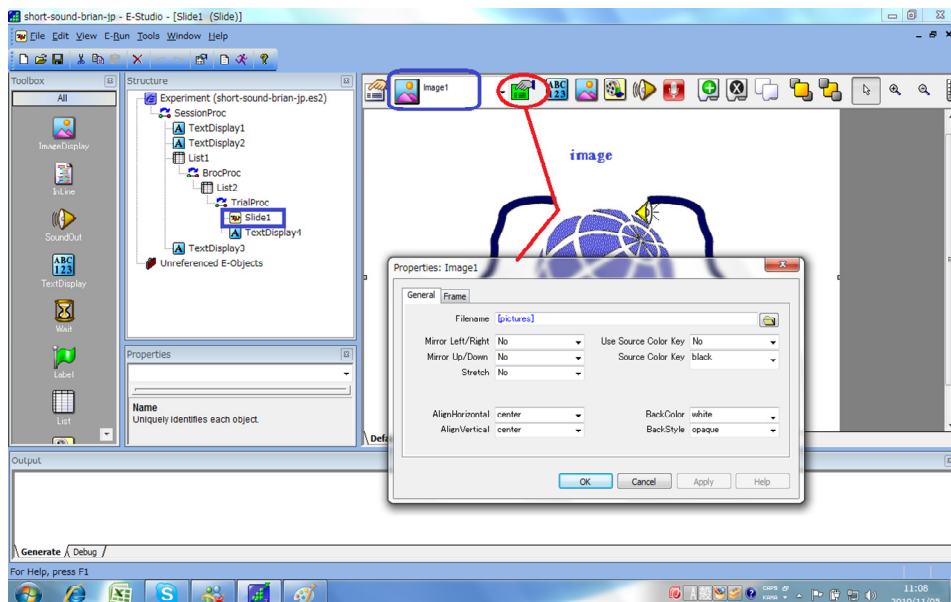
8. 1. Synchronization setup of visual and auditory stimulus items. Please never fail to record the log.

8. Slide: 視覚刺激と音声刺激の同期 音声側の設定



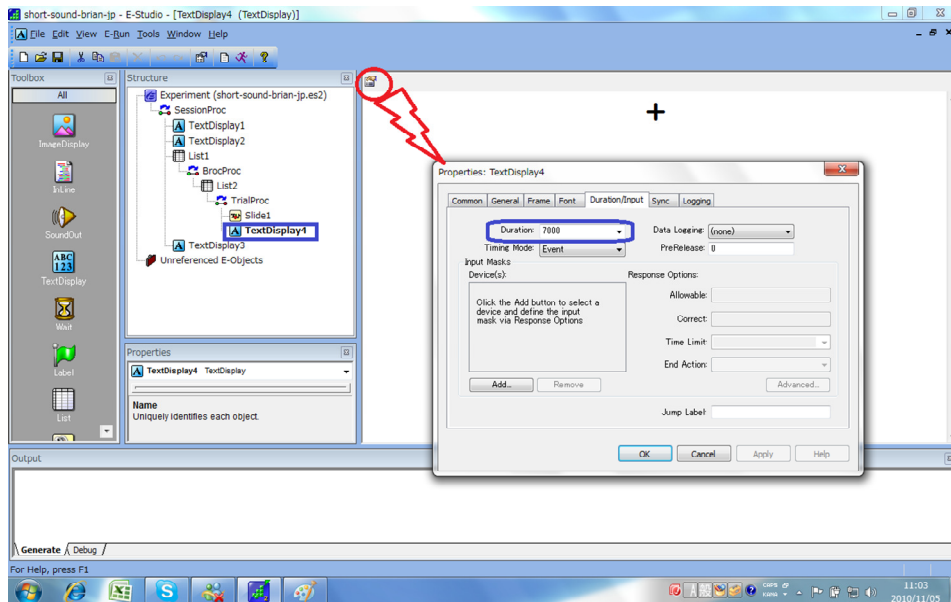
8. 2. Synchronization setup of visual and auditory stimulus items: setting the side of auditory stimuli.

8. Slide: 視覚刺激と音声刺激の同期 画像の設定



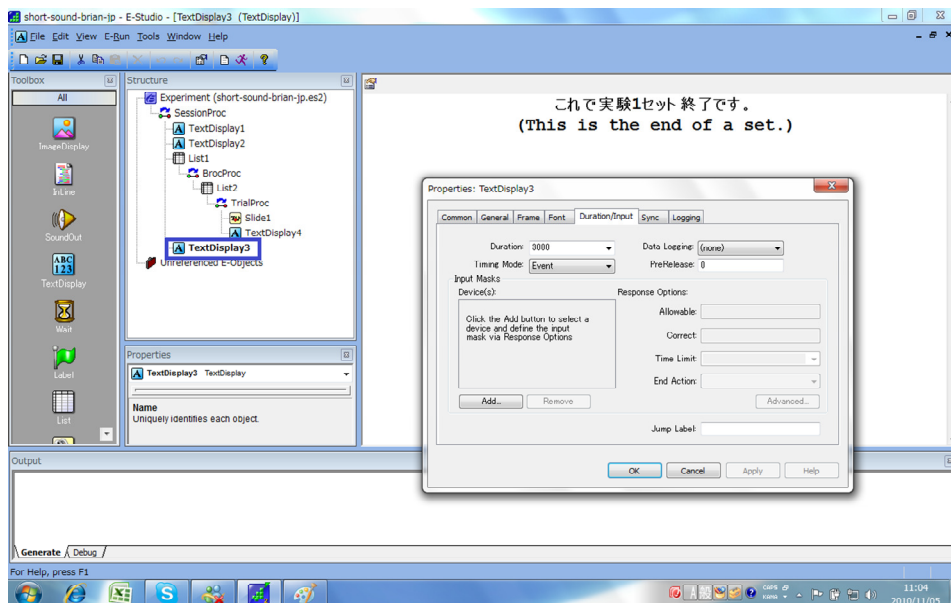
8. 3. Synchronization setup of visual and auditory stimulus items: setting the side of visual stimuli.

9. Fixation Cross: 実験参加者がこの間7秒休む



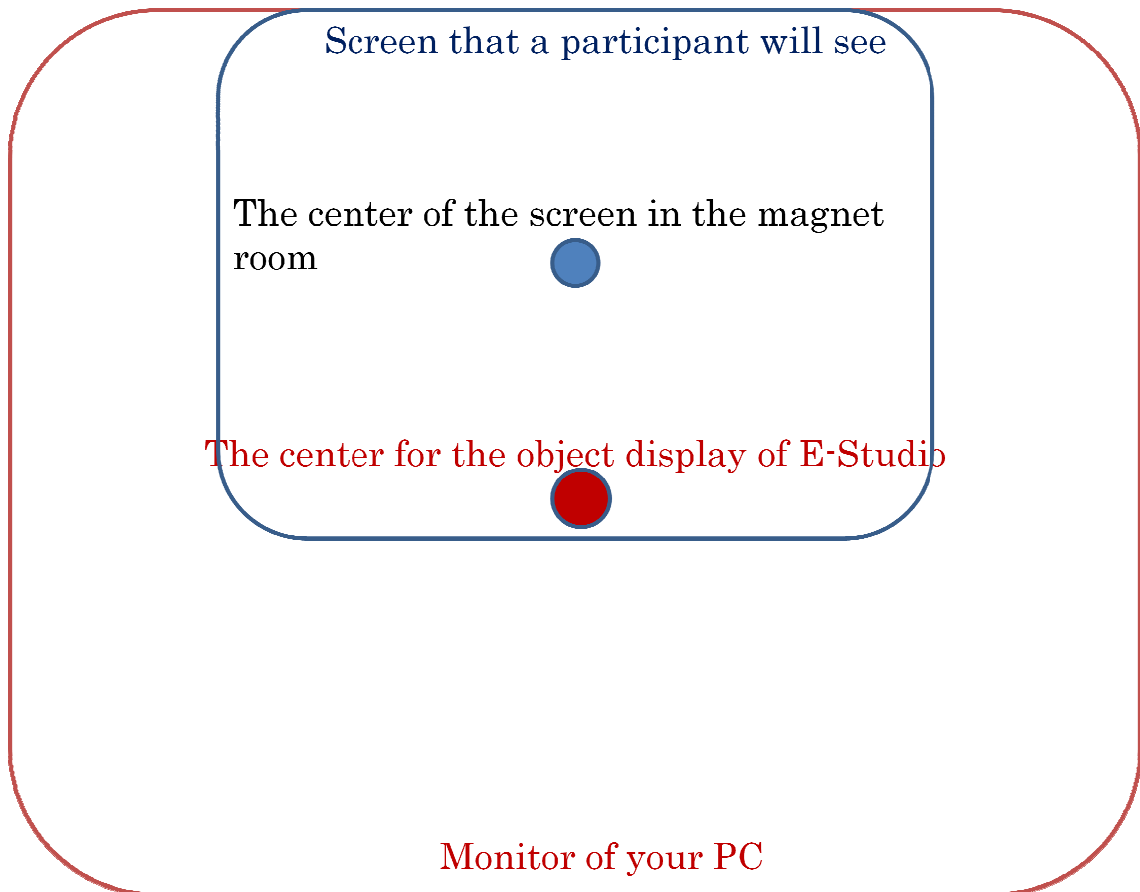
9. Setup of a fixation cross: a participant takes a rest for 7 seconds

10. 実験終了



10. End of an experiment

Important! The center for the object display of E-Studio program DOES NOT coincide with the center of the screen in the magnet room that a participant will watch from inside the bore of the fMRI scanner!

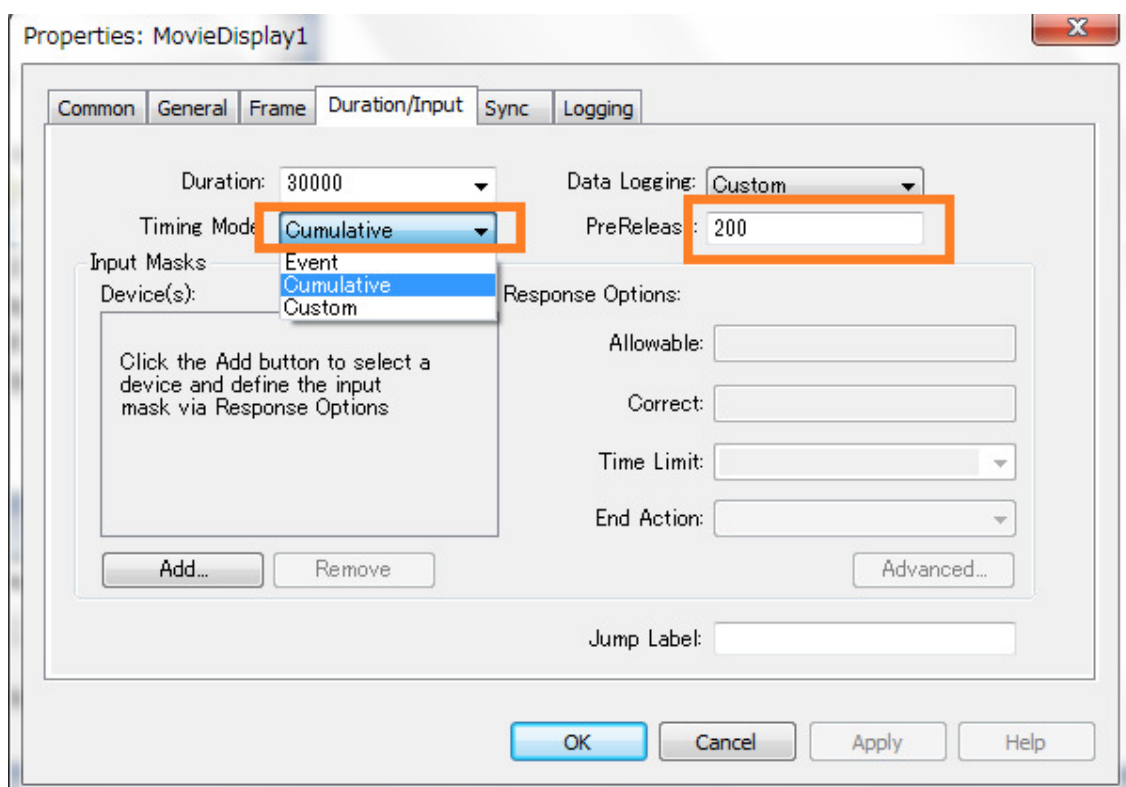


SOUND OBJECT

If you want use the "SoundOut" function of E-Prime, you must always take into account the latency depending on the quality of the sound card, that is, time lag between when an audio signal enters and when it emerges from a system regardless of the time length (size) of each sound (file—"wma" file recommended).

In the case of E-studio installed in the DELL PC, you have to reduce the duration time from 3000 milliseconds to 2921 for each "SoundOut" object to be set through one of the tabs of the property. But it is NOT an elegant way.

You might want to select "Cumulative" (not "Event") as the value of "Timing Mode" in the tab of "Duration/Input" of "Properties" to strictly regulate the length of time for a sound object.



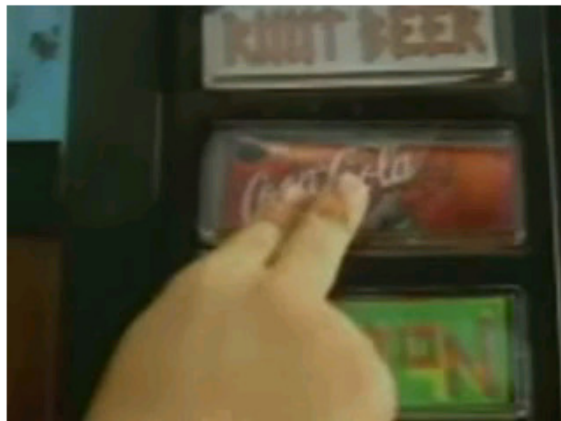
Anyway it is better to record all the sounds at the same time to homogenize the conditions (especially of the noises) and equalize the lengths of all the sound files by using the free software such as SoundEngine. <http://www.cycleof5th.com/products/soundengine/>

MOVIE

The video clip of “**avi**” is available for E-Prime. However you must connect your PC to the internet when editing the movies for E-Prime as stimuli, otherwise as the CODEC cannot be downloaded and there is no LAN in the fMRI laboratory, it would be impossible to show the movie to anyone by using the stand alone DELL PC. You might want to borrow a laptop with a Parallel port from the operator for the movie presentation.

The way of making movie objects is quite simple. You choose the object icon of MovieDisplay. If you use a Laptop PC for a stimulus provider, you will connect to it the RGB cable you see on the table. It is attached to the analog RGB switcher IMAGENICS. You will push the button 2 from Input Select. The default setting is the button 1 to display the monitor of the stimulus provider PC (DELL machine).

A concrete stimulus program using movie objects is available for ease of reference: **EPrimeMovieProgram.zip**



JITTERING

Randomization of the duration times of ISI (Inter stimulus interval)—random modulation for the time lengths of a fixation mark.

This use of different delays between the starting times of BOLD recording has several merits.

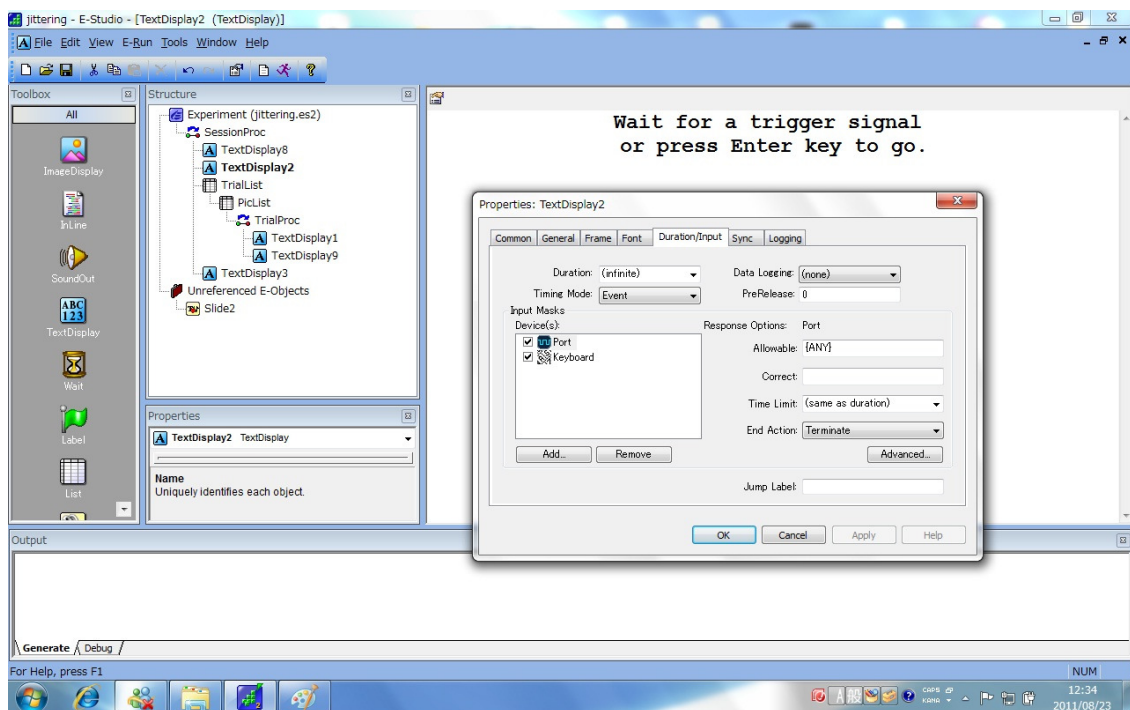
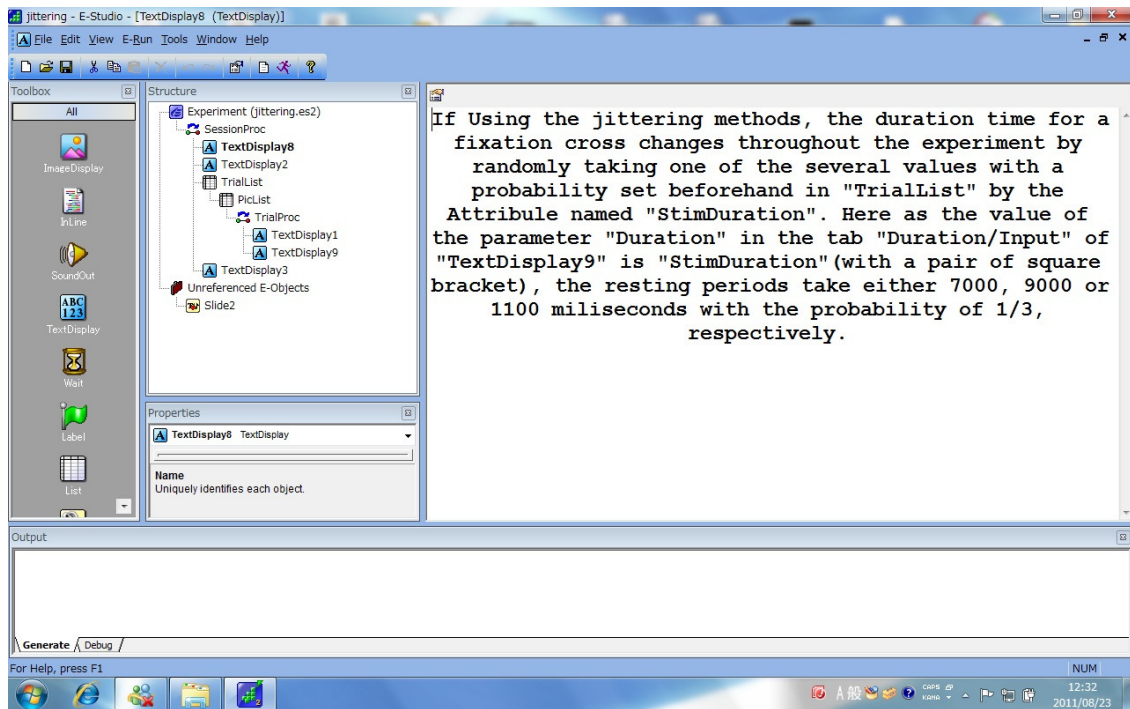
Merit:

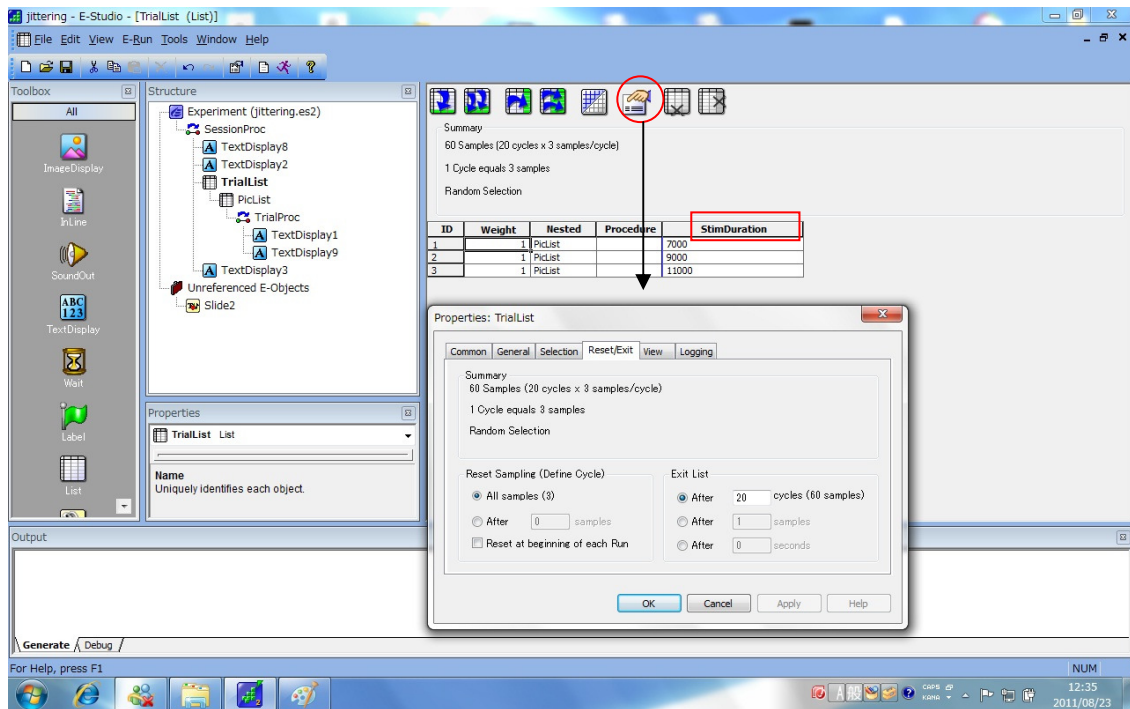
Different time points can be sampled at each stimulus presentation by jittering.

Jittering prevent the subject behavior from using a task strategy brought by a learning effect: predicting the pattern of appearance timing for every stimulus.

Example

If using the jittering methods, the duration time for a fixation cross changes throughout the experiment by randomly taking one of the several values with a probability set beforehand in "TrialList" by the Attribute named "StimDuration". Here as the value of the parameter "Duration" in the tab "Duration/Input" of "TextDisplay9" is "StimDuration"(with a pair of square bracket), the resting periods take either 7000, 9000 or 1100 milliseconds with the probability of 1/3, respectively.

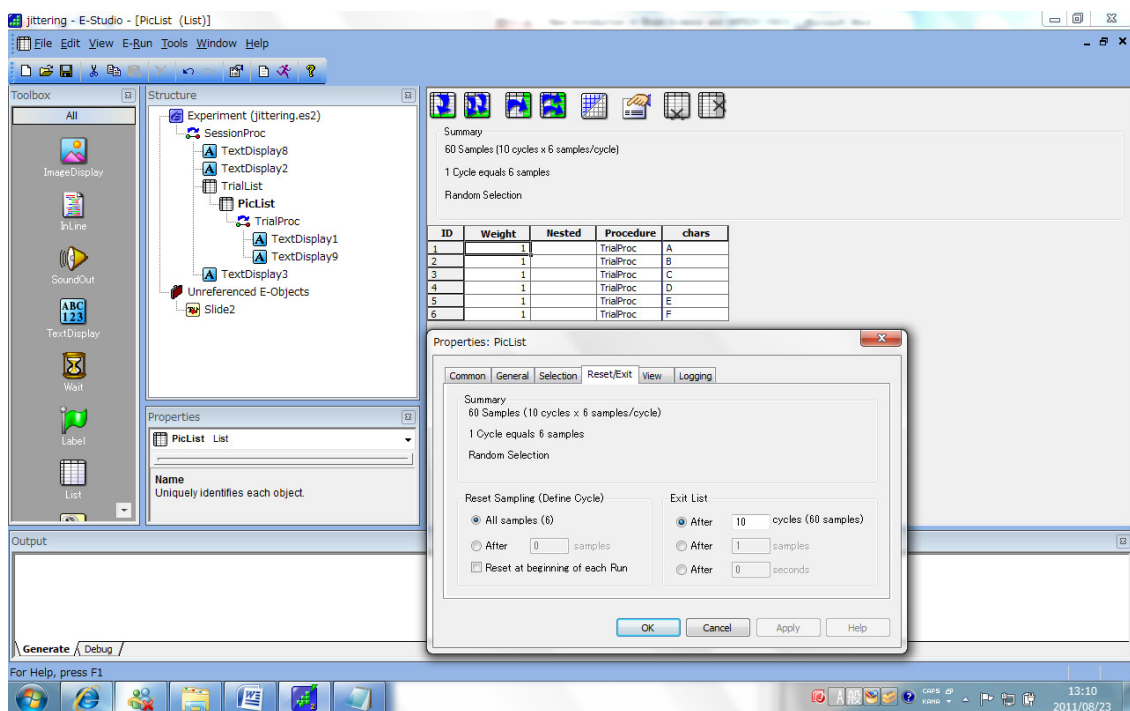


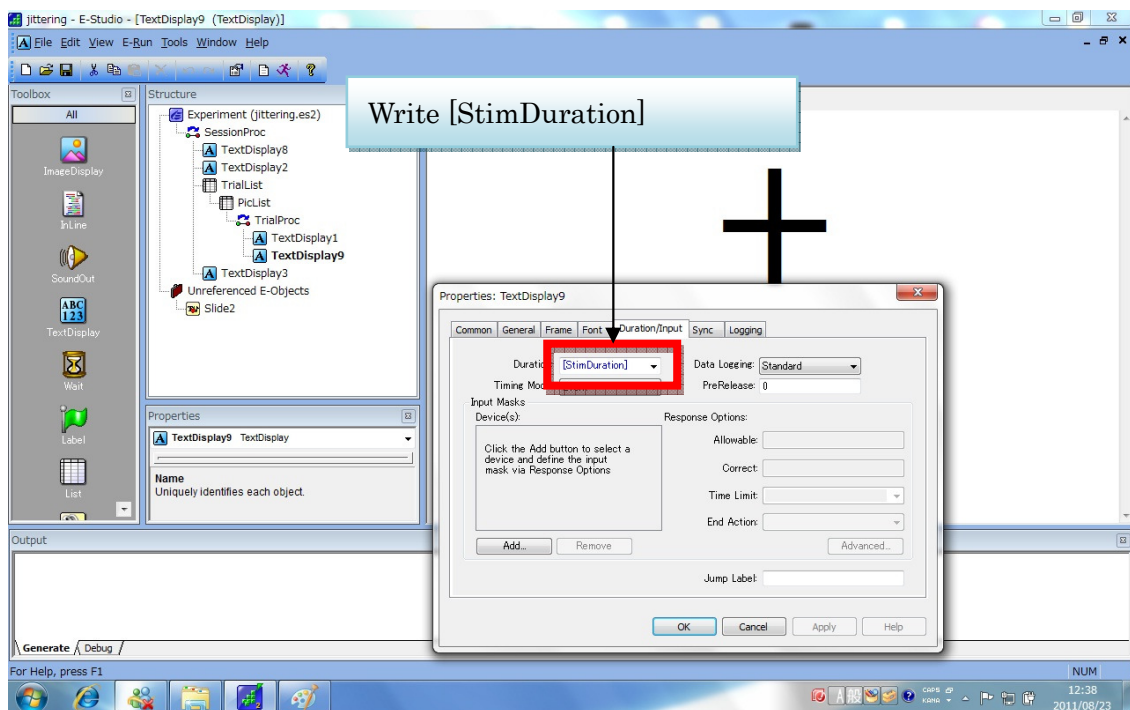
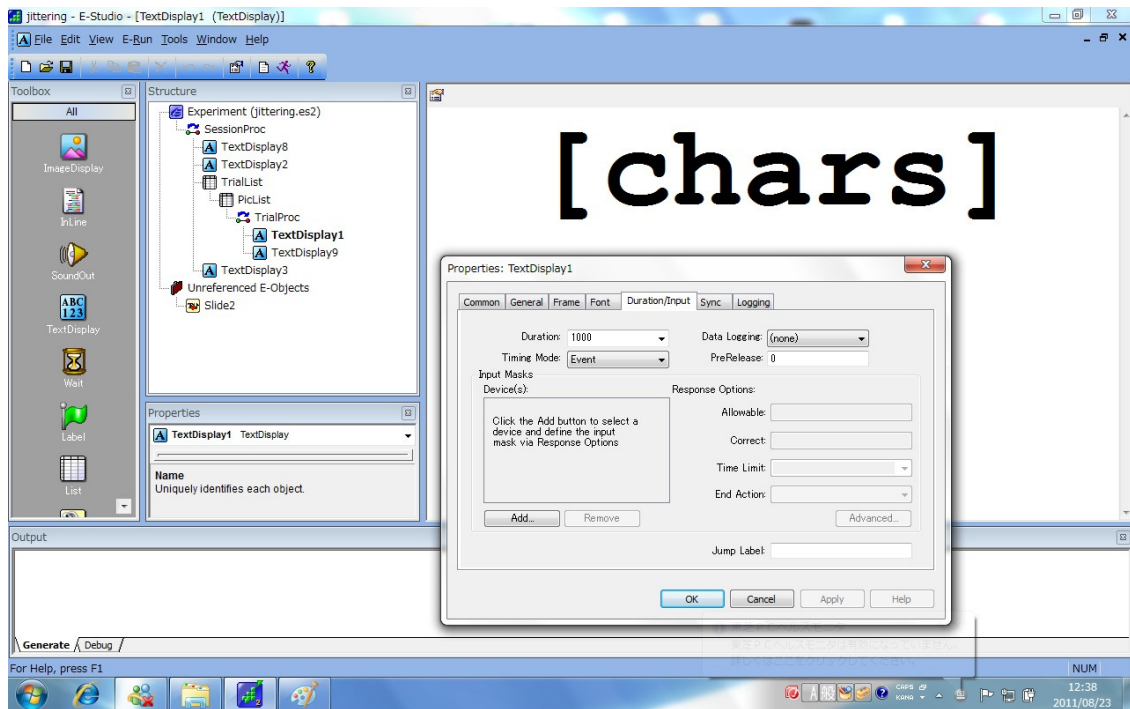


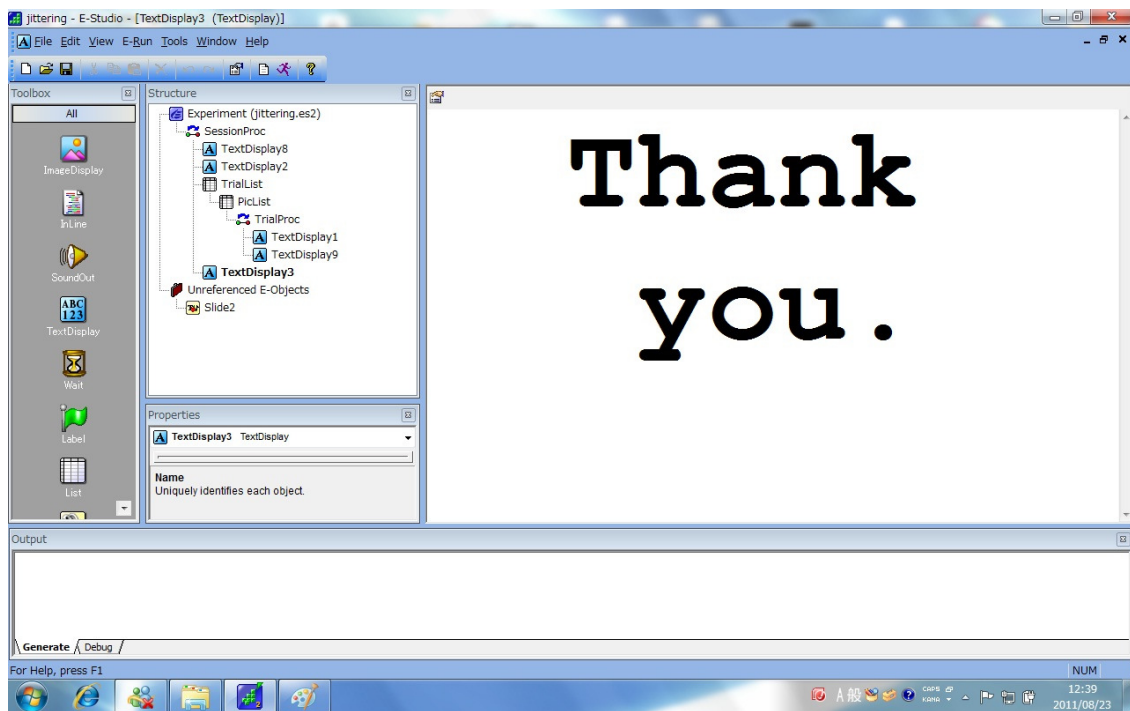
in Duration (Duration/Input) of the Properties for the textDisplay of a fixation mark

Click the icon of Properties and input "20" cycles to make 60 samples.

This variable "StimDuration" taking 3 values for the ISI lengths will be set as [StimDuration] (with square brackets) in Duration (Duration/Input) of the Properties for the textDisplay of a fixation mark







Check **EPrimeJitteringProgram.zip**

*** Header Start ***

VersionPersist: 1

Level: 2

*** LogFrame Start ***

TrialList: 2

Procedure: TrialProc

StimDuration: 9000

PicList: 1

chars: A

TrialList.Cycle: 1

TrialList.Sample: 1

Running: TrialList

TextDisplay9.OnsetDelay: 15

TextDisplay9.OnsetTime: 17771

TextDisplay9.DurationError: 0

TextDisplay9.RTTime: 0

TextDisplay9.ACC: 0
TextDisplay9.RT: 0
TextDisplay9.RESP:
TextDisplay9.CRESP:
*** LogFrame End ***
Level: 2
*** LogFrame Start ***
TrialList: 3
Procedure: TrialProc
StimDuration: 11000
PicList: 5
chars: E
TrialList.Cycle: 1
TrialList.Sample: 2
Running: TrialList
TextDisplay9.OnsetDelay: 15
TextDisplay9.OnsetTime: 27805
TextDisplay9.DurationError: 0
TextDisplay9.RTTime: 0
TextDisplay9.ACC: 0
TextDisplay9.RT: 0
TextDisplay9.RESP:
TextDisplay9.CRESP:
*** LogFrame End ***

Be careful!

You must not forget to make sure that

- the subject number and the session number are correct; otherwise you will run the risk of overwriting the data you have obtained by now.
- the E-studio has been set to record the log files in which the order of the stimuli and the duration times (in the case of jittering) will be surely saved.
- the textDisplay playing the role of standby for the first trigger is displayed before the operator presses the scan button.

If you are a user of E-Prime Professional, you must know how to convert your E-Studio file so that you will be able to use it on the DELL PC in the fMRI laboratory.

Here is how you can achieve

The effect of having an instance of Professional and an instance of Standard:

First, open your experiment in E-Prime. Then, open a new instance of E-Prime 2.0 Professional. You should see a prompt titled 'New E-Prime 2.0 Experiment'. If you do not, go to Tools - Options - Templates and check the box for 'Show the Choose Template Dialog when E-Studio Opens'. Then, open E-Prime again.

You should have four choices. Select 'Blank' (not 'Blank (Professional)'). Anything saved in this format will be able to be opened by an E-Prime 2.0 Standard user. Now you can copy the E-Objects from your original experiment into the new Standard-compatible experiment.

In the future, encourage your experiment designers to use the 'Blank' option when designing a new experiment.