



# A Consideration of Effects of Different Numbers of Seconds in Spontaneous Time Production with fMRI Analysis

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**Abstract.** Time is a fundamental property of human perception and action. Previous studies on how time perception is related to the brain have been refined over the years. Cerebral activity areas relating to time are a basal ganglia, a cerebellum, an insula, a right inferior frontal gyrus (IFG) and a right inferior parietal lobule (IPL). In our previous study, a spontaneous time production task was conducted using the fMRI measurement. As the experimental conditions, the different number of seconds (5 s and 10 s) and the different situations were set. In brain analysis results by situation conditions, significant activities were obtained in the right IPL and the right IFG. Therefore, analysis results were considered to be brain activity related to time perception. In this paper, we describe analysis results by the difference in the number of seconds.

**Keywords:** Time perception · Time production · fMRI · BCI

## 1 Introduction

In recent years, numerous brain-computer interface (BCI) studies have been conducted. BCI is the external control system which interprets a subject's intentions by measuring brain activity. For example, it can be used for wheelchairs control [1] and character input support [2]. BCI is expected to support communication and comfort-able environment for quadriplegic patients, such as patients with Amyotrophic Lateral Sclerosis (ALS) or spinal cord injury. In previous BCI, there are many researches using motor area [3], visual cortex [4] or auditory cortex [5] located on the brain surface. And many of them use only one area. For the future development of BCI, it is expected to use the brain region which has not been used so far and to improve BCI function by combining many areas. In this research, we focus on using new brain regions.

In our lives, time is involved in every action, for example, when exercising, planning or sleeping. Time is a fundamental property of human perception and action. Research on time theory has started many years ago (as far back as 400) and research has been conducted in several fields such as psychology and medicine, physics, and engineering. Research on how time is related to the brain has been refined over the

years [6–8]. Patients with Parkinson’s disease, schizophrenia, attention-deficit/hyperactivity disorder, and autism were reported to have temporal perception modulation in the frontal cortex, basal ganglia, cerebellum, hippocampus, and parietal cortex [9]. In addition, it is revealed by magnetoencephalography using temporal shrinking illusion that temporal perception is controlled by the right hemisphere temporo-parietal junction and time judgment by the right hemispheric inferior frontal gyrus (IFG) [10]. It was reported that when the visual stimulus at the same time interval was repeatedly presented, the activation intensity of the right inferior parietal lobule (IPL) decreased as compared with the case where the time intervals of stimulation were different [11].

As a preliminary experiment for use in BCI, time guessing game was performed using fMRI measurement. Right Inferior Parietal Lobule (IPL) was obtained as a common area due to the difference in situations of the time guessing game [12]. Since it is reported that the right IPL is related to the time length [11], we consider that time-based brain activity was obtained from the time guessing game. In this paper, we analyze specific brain activity about the difference of situation by time guessing game.

## 2 Materials and Methods

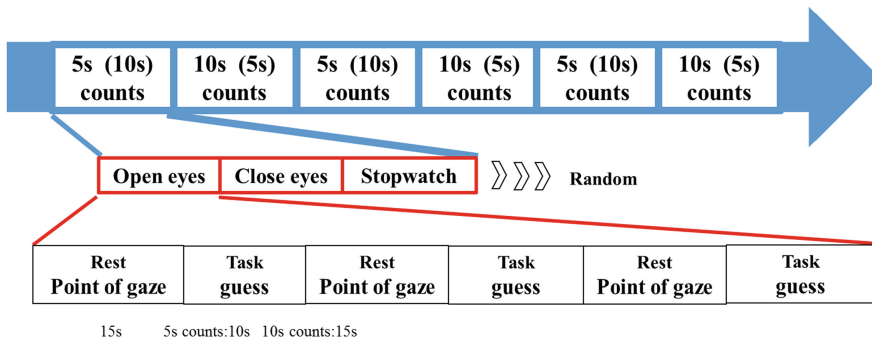
This experiment was conducted on 21 participants. Fourteen participants had corrected eyesight, and seven people had no eyesight correction. The participants with eyesight corrections were asked to use nonmetallic eyeglasses. Two of the participants were left-handed and the rest were right-handed. The average age of the participants was 21.42 years, and the standard deviation was 1.99. We asked the examinees whether they had stopped the determined time like a time guessing task with a stopwatch, and as a result, all 21 participants that they had done so.

Two types of evaluation method are often used for the time perception experiment. One is the time production method. In the method, a participant performs to measure a predetermined period of time. At this time, he/she measures the time by the mind without measurement clues. The other one is the time re-production method. Firstly, a participant receives a certain time width stimulus such as a sound or a visual image. Then, he/she is asked to measure this period of certain time in the mind [13]. This experiment was conducted by using a time guessing game based on the time production method. In the time guessing game, participants are required to stop a watch by pressing a button after a specified number of seconds. In this experiment, two kinds of conditions were set, one condition used the 2 measurement times, and the other condition used the 3 situations. Conditions are as follows.

- Measurement times
  - 5 s counts
  - 10 s counts
- Situations
  - No animation + open eyes (a Open eyes)
  - No animation + close eyes (a Close eyes)
  - Animation stopwatch + open eyes (a Stopwatch)

As the first condition, the 2 measurement times were set for a section to measure five seconds (a 5 s counts) and another section to measure ten seconds (a 10 s counts). The 2 measurement times were set to verify whether there is an effect on cerebral activation with the difference in the number of seconds. The second condition consisted of the 3 situations. In the Open eye measurement, participants were asked to count the number of seconds without displaying the screen with their eyes open. In the Close eye measurement, participants were asked to count the number of seconds without the screen display with their eyes closed. In the Stopwatch measurement, participants were asked to count the number of seconds using a stopwatch displayed on the screen with their eyes open. The 3 situations were set to verify the difference in cerebral activation depending on the opening and closing of the eyes, the presence or absence of a display on the screen. This experiment was carried out in a total of six ways with conditions being two (the 2 measurement times) times three (the 3 situations).

A block design was adopted for experimental design. A run is included in the 2 measurement times. The 2 measurement times were included in the 3 situations. The 3 situations were included in a task block and a rest block. In the task block, participants performed the time guessing game. In the case of the Open eyes measurement and 5 s counts, there are probably individual differences. We considered whether the button would be pressed in seven or eight seconds, thus we set it for ten seconds in one task block. Likewise, the 10 s counts were set for one task block in fifteen seconds. The rest block was set at fifteen seconds. The rest block was placed in the participant’s gaze point and participants were instructed to look at it. In the rest block, participants were asked to look at a gaze point without any thinking. A task sequence example is shown in Fig. 1.



**Fig. 1.** Task sequence

The order of measurement times and situations was counterbalanced cross participants. The counterbalance is to counteract the effect of allowing the independent variable of the general linear model to equally influence the potential confounding factors. In this experiment, the counterbalance between participants became necessary because the grading improves gradually according to the order of experiments and the degree of concentration changes depending on fatigue and record. In order to the

counterbalance between the conditions, we divided participants starting from the 5 s counts and participants starting from the 10 s counts. The task block of each section was also randomized in the 3 situations for each participant.

The flow of each section is shown in Fig. 2. First of all, the next task was introduced by the information screen. In the case of the Close eyed measurement, we instructed in advance to close their eyes when they saw the information screen. After the information screen disappeared, a start tone was played and the participants instructed to start counting numbers for Open eyes measurement and Close eyed measurement. The Stopwatch measurement was also used to check the 3 situations difference between tasks by playing the start sound. We instructed participants to push the button when they thought that the instructed time was reached. In Close eyed task, participants were taught to open their closed eyes when the last tone was heard. As a precaution to the examinees, we instructed them not to keep a timing with their body, such as with their hands or feet and not to count using their voice.

In this experiment, we tried to analyze the brain function map when fulfilling the time guessing task using the fMRI measurement. The fMRI captured the image using a MAGNETOM Verio 3T manufactured by SIEMENS. The imaging parameters were set with TR/TE = 2500/30 ms, FoV = 192 mm<sup>2</sup>, Voxel size = 3.0 × 3.0 × 3.0 mm, a slice thickness = 3.0 mm. the 5 s counts of the 2 measurement times were captured in 105 scans for one section and the 10 s counts of the 2 measurement times were captured in 123 scans for one section. Two scans from the start of the imaging process were excluded from the analysis because the longitudinal magnetization of the tissue was unsteady. Furthermore, in order to obtain the position information, an anatomical image with a resolution of 1.0 × 1.0 × 1.0 mm was captured as a T1 weighted sequence. A presentation of the experimental tasks and the reaction acquisition were conducted by creating, executing and controlling the experimental programs using Matlab R2014a software manufactured by Math Works. Logs concerning time during the experiment were also recorded in Matlab.

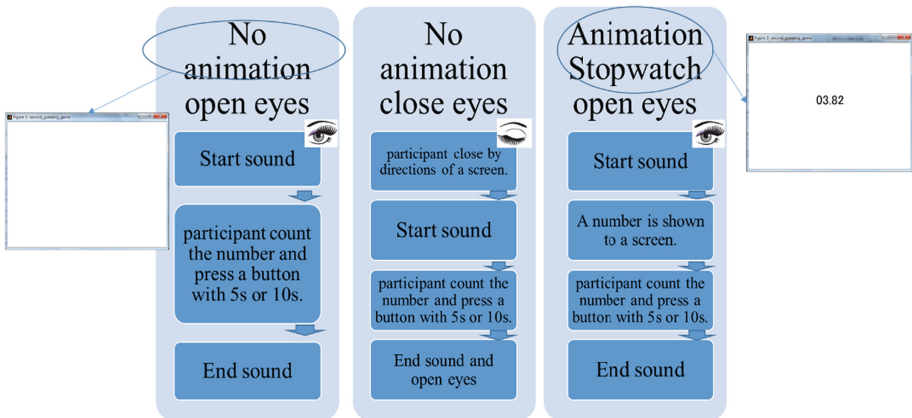


Fig. 2. Task blocks of 3 situations

### 3 Result and Discussion

Participant's experimental logs are used to confirm the difficulty level of the task. The purpose of this experiment was to compare the brain activities in the condition that the difficulty of the task condition is not different and to consider using the BCI. First, the number of samples of logs by each situation of 21 participants was 189 in total. Logs of the total participants were checked and there were participants who were not able to carry out the task or participants who made a mistake in the count time. In the fMRI analysis, it is necessary to make the number of data in the participant uniform, so the number of data was set for each participant in 3 situations. Six samples were excluded at 5 s counts and 30 samples were excluded at 10 s counts.

In this experiment, we consider brain areas related to time measurement. FMRI images were analyzed for SPM12 and the fMRI image data was been preprocessing. For example, standard time, spatial. To define specifically of 2 measurement times at the group level, one-sample t-test was conducted on the contrast images of specifically of 2 measurement times. The resulting set of voxel values for each contrast constituted the SPM{t}. The statistical height threshold was set at  $p < 0.05$  corrected for multiple comparisons at the peak level over the whole brain (Family-Wise Error: FWE). Anatomic and Brodmann area labeling of activity clusters was performed using the Anatomy Toolbox [14]. In this paper, the analysis of 3 situations combined data are reported.

The analysis results of 2 measurement times are shown in Fig. 3. Both 5 s counts and 10 s counts showed the significant difference in brain activity in right inferior parietal lobule, right insula and right middle frontal gyrus. However, comparing these activities did not give a big difference. In this experiment, only two ways of difference in the number of seconds are done so it cannot be suggested accurately. Since the brain activity of the right insula has a larger brain activity amount compared with others, we considered that there is a possibility of seeing a difference when conducting an

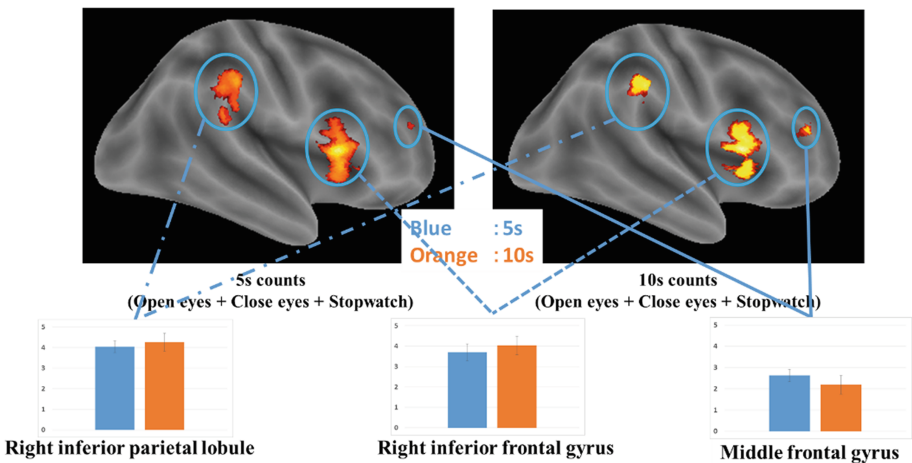


Fig. 3. The brain activity of 2 measurement times

experiment by adding a second number of seconds. If the change in brain activity appears in a specific area of the brain due to the difference in seconds, this feature is considered to be usable for brain-computer interface. In the future, we are planning to investigate the change in the amount of cerebral activity due to the difference in the number of seconds.

## 4 Conclusion

The time is a fundamental property of human perception and action. In this paper, we analyzed specific brain activity about the difference of situation by time guessing game. In this experimental result, there was no big difference in the number of seconds. From now on, we are going to experiment with increasing the number of seconds and we plan to make BCI using the time production.

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