Evaluation of the Exact Moment of Random-dot Stereogram Cognition by EOG and its Process by EEG

Shusaku Nomura
Interdisciplinary Faculty of Science and Engineering
Shimane University, 1060 Nishikawatsu, Matsue, Japan
nomura@cis.shimane-u.ac.jp

Kentaro Nakagawa
Interdisciplinary Graduate School of Science and Engineering
Shimane University, 1060 Nishikawatsu, Matsue, Japan
s049309@cis.shimane-u.ac.jp

Tomomasa Nagashima
Satellite Venture Business Laboratory
Muroran Institute of Technology, 27-1 Mizumoto, Muroran, Japan
nagasima@epsilon2.csse.muroran-it.ac.jp

Abstract
Random-dot Stereogram (RDS) has been used for the research on neurophysiological mechanism of binocular vision and characteristic brain waves (VEP) evoked by three-dimensional perception were reported. However, in previous studies, because the RDS was presented to a subject rather passively with the aid of supportive devices, the VEP has been recorded at a short period by which the subject's perception of RDS and cognition of the embedded figure was not distinguishable. By contrast, we designed an experiment in which a subject was required to find out the embedded figure so that the moment of the perception of RDS appearance and the cognition of the embedded figure is distinguishable. We then estimated the moment of the cognition by EOG profiles and observed characteristic brain potentials by referring to that estimated moment.
Keywords: Visual evoked potential; Stereopsis; Random-dot Stereogram; EEG; EOG

1 Introduction

Random-dot Stereogram (RDS) is a pair of the identical images consists of randomly distributed black and white dots as shown in Figure 1(a). RDS is just a tow random-dot images in appearance, but because some area within it, i.e. the corresponding dots in the two images, is shifted horizontally several dots, a particular figure with a certain depth emerges when the subjects correctly adjust the convergence with an appropriate focal depth.

RDS has been widely used for the researches on neurophysiological mechanism of binocular vision because of the simple fact that the RDS has no monocular cues to find out a three-dimensional target figure embedded in it. In those previous studies, visually evoked potentials (VEP) were frequently recorded from the occipital cortices of subjects as a physiological index. Most of those RDS studies suggested that the VEP consisted of a negative peak in the latency of 200-400 ms time window was evoked by the perception of the embedded figures of RDS, while other studies reported various VEPs composed of several negative and positive peaks in the latency of 100-600 ms time window [1-8]. Those brain potentials thus were considered to relate to the perception of three-dimension and/or stereopsis. Actually, there are much studies reporting such potentials were evoked by various illusory visual stimuli other than RDS (e.g., [9,10]).

However, as a common experimental procedure of previous RDS studies, the RDS was frequently presented to a subject with supportive devices such as a stereoscope. In such a case, since convergence was to be fixed, it would be assumed that a subject perceives the embedded figure of RDS at almost the same moment when the RDS is presented. In other words, the subject is not required to search and find out the embedded figure of RDS but perceives one passively just as a self-apparent figure placed above random-dot background. Therefore, it also could be said that VEP has been recorded at a short period by which the subject's perception of RDS and one's cognition of the embedded figure was not distinguishable.

On the other hand, in order to investigate VEP evoked solely by subject's cognition of the embedded figure of RDS, we designed an experiment in which subjects have to search and find out a target figure without any supportive device. Although subject's cognition of embedded figure is subjective and the exact moment of the cognition cannot directly be determined for an observer, we attempted to estimate that moment of the cognition by analysing characteristics of subjects' eye movement with referring to electrooculogram (EOG) and investigated evoked potentials by referring to the estimated moment of subject's cognition of the embedded figures, thus the moment when subject's stereopsis is realized.

2 Methods

2.1 Subjects

Four right-handed male subjects voluntary participate in this study. The mean age was 24.5 ± 3.3 years old. Their vision was normal or corrected to normal. Because finding out the embedded figures in the RDS is difficult for the first experience, all subjects are well trained to familiarize the RDS before experiments.

2.2 Stimulus

In our experiments, forty types of static RDSs were presented to subjects recording various physiological indices. Each of the RDSs consists of a pair of 150×150 dots random-dot images presented on the laptop monitor with the distance of 10 dots as shown in Figure 1(a). Twenty types consists of each two of different mere random-dot images, which is not a correlogram and named "Random-dot Image (RDI)" in this paper, were also prepared for controls, which paired images was not able to be fused, and thus no image was embedded (example is as shown in Figure 1(b)). The numbers of white and black dots in both RDS and RDI were the same, thus the density of black dots was 50%. The embedded figures of each forty types of RDSs were a simple sign, symbol, and character, as shown in Figure 2. Totally 40 types of RDS and 20 types of RDI were presented to subjects at random order.

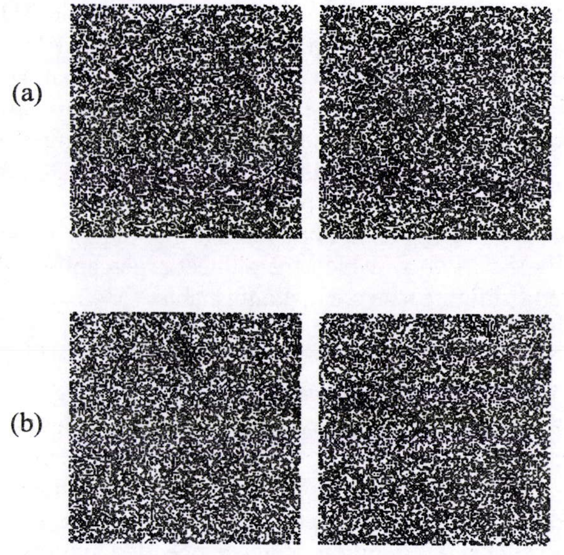


Figure 1: (a) An example of RDS. The embedded figure of "circle" is perceived as located in front of (by the parallel method) or behind (by the cross method) the background. (b) An example of a mere random-dot image (RDI). It cannot be fused, thus no image is embedded.

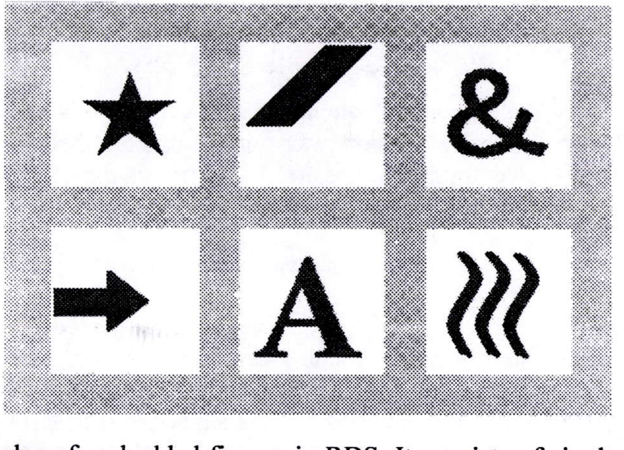
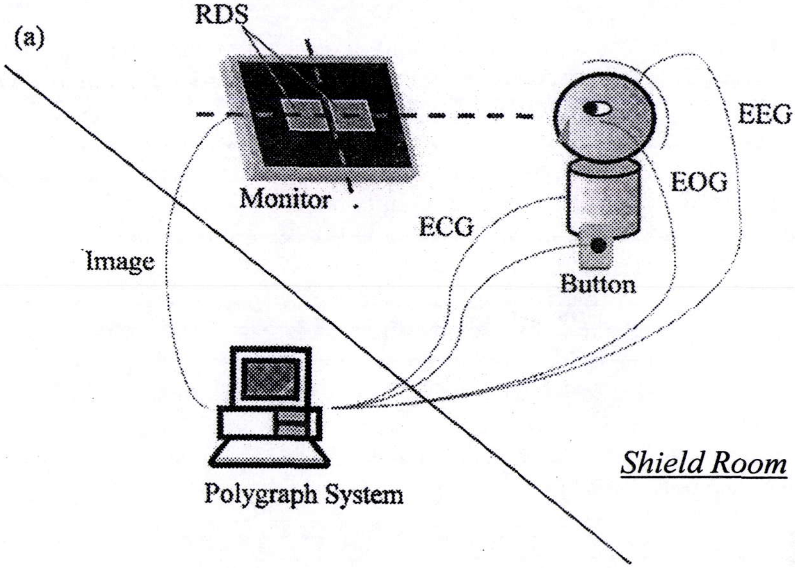


Figure 2: Examples of embedded figures in RDS. It consists of single signs, symbols, and characters.

(a)



(b)

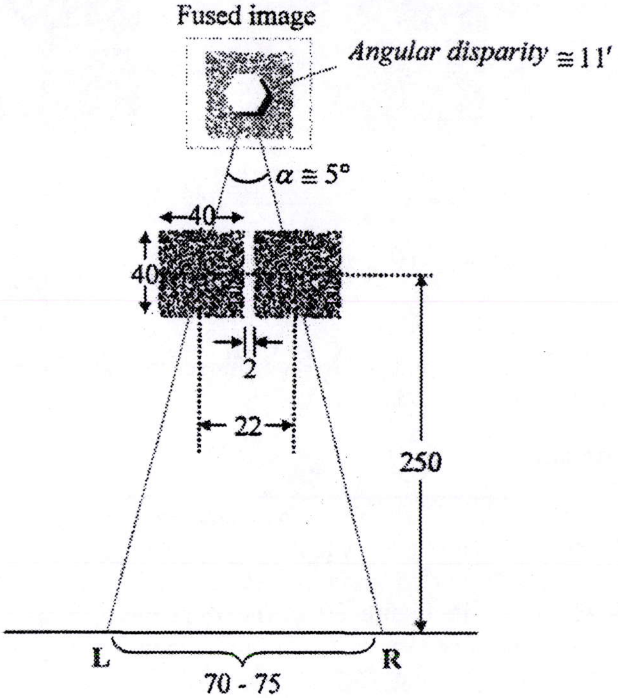


Figure 3: (a) Schematic diagram of our experiments. (b) Physical position in appearance of presented RDS. The unit of denoted number is mm.

2.3 Recording

Figure 3(a) shows the schematic diagram of our experiments. We recorded subjects' bioelectricities, such as electroencephalogram (EEG), electrooculogram (EOG), electrocardiogram (ECG) by the polygraph system (*SYNAFIT*, NEC Medical Systems Co., Japan), which consists of the pre- and main-amplifier with A-D converter. Sampling rate of the system was 1000 Hz. Ag-AgCl electrodes were used to record the bioelectricities keeping low impedances up to 5 $k\Omega$. For EEG, active electrodes were placed at Fz, Cz, Pz, P3, P4, T5, T6, O1 and O2 according to the International 10-20 System, and the reference electrodes were placed at both ear lobes. EEG signals were 0.15-100 Hz band-pass filtered. For EOG, active electrodes were placed at the right and left outer canthi of the eyes to monitor horizontal eye movement (horizontal electrooculogram). For ECG, three electrodes were attached to the wrists and the left ankle. ECG was introduced for checking the body movement and other possible artefacts on ECG and EOG data. An accelerometer was attached to the right arms for tracing respirations, body movements, and artefacts. Signal of accelerometer was also recorded by the polygraph system.

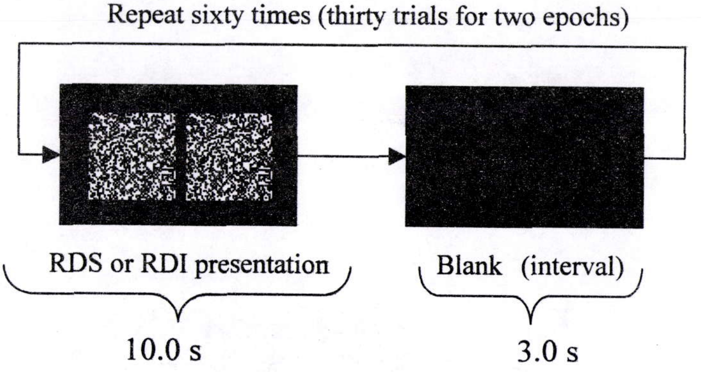


Figure 4: Procedure of the experiments.

2.4 Experiments

In the experiments, each subject was seated on a chair and required to fuse the RDS /RDI presented on the laptop monitor (14.1-inch thin film transistor-liquid crystal display, *Inspiron8000*, Dell Inc.) placed at approximately 25 cm away from their foreheads as shown in Figure 3(b). The right and left part of RDS/RDI appeared 40×40 mm with the distance of 2 mm on the monitor. The embedded figures of RDS were made by shifting the corresponding area of the right and left part of RSD horizontally three dots, i.e. 0.8 mm in appearance. Subjects were required to fuse RDS/RDI by the parallel method; focusing the right part by the right eye, the left part by the left eye, respectively. Thus the retinal angular disparity of the RDS in our experiment was approximately $11'$.

Figure 4 shows the procedure of the experiments. Forty types of RDS and twenty types of RDI were repeatedly presented for subjects at random order. Each RDSs/RDIs was presented for 10.0 s with 3.0 s of black background as an interval. Accounting for keeping subjects' concentration, the number of trials in an epoch was set to 30, and the experiment was conducted for two epochs in two succeeding days.

In addition, subjects were required push the button right after they correctly adjusted convergence and cognised the embedded figure to see if they could subjectively perceive the embedded figure. The signals of the button and RDSs/RDIs appearance were also recoded by the polygraph system.

All experiments were conducted in sound proofed shield room.

3 Results

For analysis of the EEG and EOG data mentioned below, ECG and accelerometer profiles were referred to exclude such bioelectricities possibly contaminated by the artefacts, especially caused by body movements.

3.1 Evaluation of the Moment RDS Cognition by EOG

According to the button press records of our experiment, subjects successfully cognised all embedded figures in RDS during each 10.0 s of presentation with exception of two times out of 160, i.e. four subjects $\times$ forty RDS types. The mean (standard deviation) duration from RDS presentation to the button press was 4176.04 ms (1799.25). A two-way analysis of variance (ANOVA) on individuals $\times$ RDS types indicates the significant main effects of individuals ($p<.005$) and RDS types ($p<.05$). It means there are time differences between subjects' button press and cognition of each embedded figures.

Subjectively, subjects are assumed to cognise the embedded figures of RDS mentioned above, but, practically, the exact moment of their figure cognition must be prior to the moment of the button press with regards to millisecond order. Because the regulation of subjects' convergence was recorded as the fluctuations of EOG, we expected that the fluctuations of EOG indicated the subjects' cognition processes. Therefore we analysed EOG profiles just before the subjects' button press to detect the exact moment of the cognition of the embedded figures. Figure 5 shows the typical profile of EOG (upper line) for 2000 ms prior to the button press. It shows the rapid and discontinuous fluctuation (denoted as 'α' in the figure) and succeeding stable phase (denoted as 'β'). One could assume these two characteristic movements of EOG as the two succeeding processes concerning with cognition of RDS. We then simply hypothesized that those characteristic EOG profiles, discontinuous fluctuation and stable phase, indicated the moment that the subjects successfully fused on the embedded figure with appropriate focal depth, i.e. cognition of the embedded figure, and the duration that the subjects were deciding the meaning of the embedded figure, i.e.

understanding of the embedded figure, respectively. We then introduced the moving variance of EOGs to estimate the exact moment of subjects' cognition and the beginning of the understanding of the embedded figures according to our previous study [11].

We calculated the moving variance of EOG at hundred points (100 ms) for each point for 2000 ms before the button press. As Figure 5 shows, the moving variance of EOG (lower line) effectively detects the fluctuation property of the EOG raw profile. In this study, we estimated two of the exact moments as following method. First, we assumed the "first reference time (FRT)" as the moment immediately after the biggest fluctuation of the EOG variance for 2000 ms before the button press as shown in Figure 5. The Next, we assumed the "second reference time (SRT)" as the starting point of relatively low and stable profiles of the EOG variance after FRT as shown in Figure 5 either. Note that such a low and stable profile was not observed in the case of the RDI stimuli suggesting that subjects keep adjusting convergence despite no embedded figure exits.

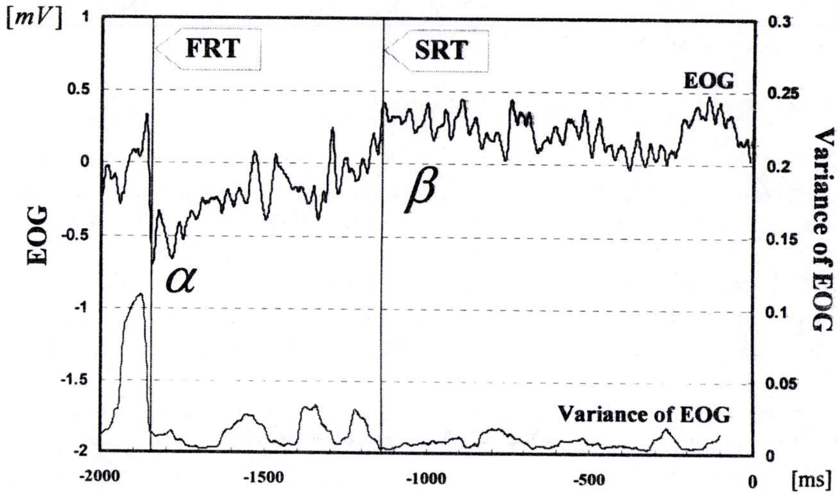


Figure 5: Typical profile of EOG (upper line) and the moving variance of EOG (lower line) 2000ms before the button press. EOG shows the rapid and discontinuous fluctuation 'α' and succeeding stable phase 'β'. Two reference times, "FRT" and "SRT", were defined as described in the text.

Table 1: Average durations and standard deviations (*SD*) of the RDS presentation to FRT, FRT to SRT, and SRT to the button press.

(n=111)	**RDS-FRT**	**FRT-SRT**	**SRT-Button**	**RDS-Button**
Average [ms]	2801.6	522.6	851.8	4176.0
SD	1879.9	250.8	325.3	1799.3

Table 1 shows the average duration of the RDS presentation to FRT, FRT to SRT, and SRT to the button press, and Figure 6 shows the time course of the averages within the experimental procedure. Note that 49 EOG profiles out of 160 were excluded for the analysis because of possible contamination of artefacts, no remark profiles of the variance of EOGs. A two-way analysis of variance (ANOVA) on individuals × RDS types with regard to the duration of the RDS presentation to FRT indicates the significant main effect of individuals ($p<.05$), but no effect of RDS types. Correspondingly, ANOVAs with the duration of FRT to SRT and SRT to the button press indicates no main effect, respectively. On the other hand, high positive correlation is found between the duration of the RDS presentation to FRT and the RDS presentation to button press (the correlation coefficient is 0.97), while no correlation is found between FRT to SRT and the RDS presentation to button press (the correlation coefficient is 0.07).

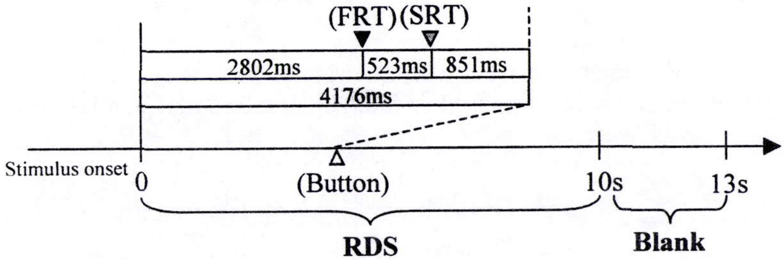


Figure 6: Time course of the average durations of the RDS presentation to FRT, FRT to SRT, and SRT to button press within the experimental procedure.

3.2 EEG Analysis

3.2.1 EEG Analysis at FRT

We performed averaging of brain waves with referring to FRT for all subjects and RDSs. Because no reference time has been defined on the profiles of the EOG as mentioned above, 49 EEG profiles out of 160 were excluded for the analysis. As the result, remarkable brain potentials are obtained at Fz, Cz and Pz positions as shown in Figure 7. Note that baseline of each profiles are adjusted by referring each averages of 200 ms prior to FRT. The Cz profile in Figure 7 seems to be composed of four negative peaks around 30 ms, 150 ms, 250 ms, and 320 ms, and a positive peak around 190 ms. Those peaks are also observed in Fz and Pz profiles while the amplitude are relatively lower. In this paper, we named those EEG peaks as F_N0, F_N1, F_N2, F_N3, and F_P1 as denoted in the figure.

On the other hand, no such a remarkable brain potential is observed in EEG profiles recorded from P3, P4, T5, T6, O1, and O2 as shown in Figure 8, while those profiles, especially O1 and O2, seem to have rather unclear but similar peaks with Cz. In addition, no remarkable difference is found in the phase shifting and amplitude between each corresponding EEG profiles of right (P4, T6, and O2) and left (P3, T5, and O1) hemisphere of the brain.

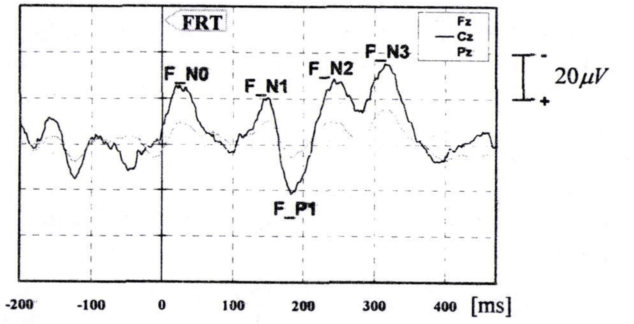


Figure 7: Grand averages of EEG with referring to FRT at Fz, Cz, and Pz position. A remarkable brain potential composed of four negative and one positive peak is observed.

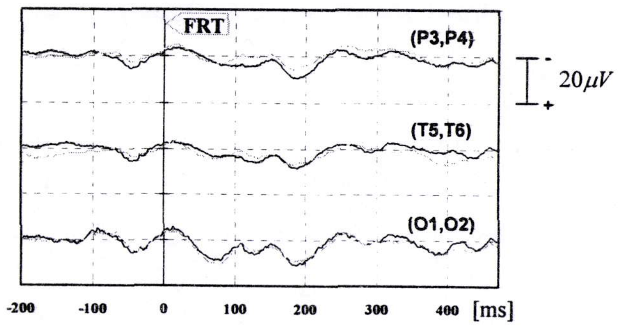


Figure 8: Grand averages of EEG with referring to FRT at each corresponding brain potential of right (P4, T2, and O2, denoted as black line) and left (P3, T1, and O1 denoted as grey line) hemisphere of the brain.

3.2.2 EEG Analysis at SRT

The same analysis procedures were applied with referring to SRT. As shown in Figure 9, remarkable brain potentials are obtained at Cz, which is seems to be composed two negative peaks around 240 ms and 390 ms, and a positive peak around 120 ms. In this paper, we named those EEG peaks as S_N1, S_N2, and S_P1. The Pz and Fz profiles seem to have the similar peak at the same latencies, but the amplitudes are relatively very small. From records of other positions, P3, P4, T5, T6, O1, and O2, no such a remarkable brain potential is observed while those profiles seem to have rather unclear but similar peaks with Cz as shown in Figure 10.

On the other hand, comparing with corresponding each EEG profiles of right and left hemisphere of the brain, only T5 and T6 has a difference in phase shifting around 100-300 ms, as denoted 'γ' in Figure 10.

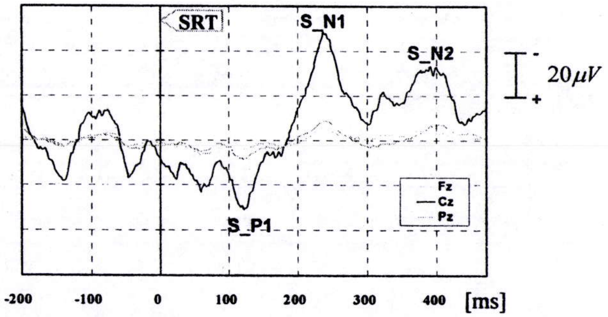


Figure 9: Grand averages of EEG with referring to SRT at Fz, Cz, and Pz position. A Remarkable brain potential composed of two negative and one positive peak is observed.

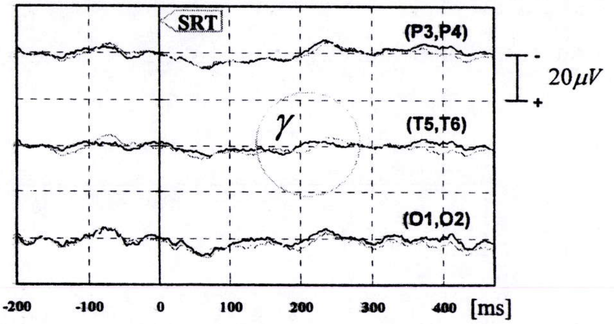


Figure 10: Grand averages of EEG with referring to SRT at each corresponding brain potential of right (P4, T2, and O2, denoted as black line) and left (P3, T1, and O1, denoted as grey line) hemisphere of the brain. Phase difference 'γ' is observed between T5 and T6.

3.3 Event-Related Potential (ERP) at Stimuli Onset

To compare our study with the previous VEP studies using RDS, we focused on event-related potential (ERP) with referring to the moment of the stimulus onset. The ERP is the category of the brain potentials evoked by various identifiable events as the name shows, and VEP is a kind of ERP evoked by visual stimuli. There are other kinds of ERP, such as auditory EP (AEP) and somato-sensory EP (SEP). Because the ERP is evoked by any sporadic and identifiable stimuli in time series (e.g., [12,13]), and thus the stimulus is not necessary to be the RDS, we expected to make a clear distinction between the evoked brain potential derived by the presentation (emergence) of RDSs and one by the subjects' cognition of the embedded figures of RDS.

We then performed averaging of brain waves with referring to stimuli onset for all subjects and RDSs/RDIs. As the result, a positive brain potential, commonly called as "P300" or merely "P3", is observed as shown in Figure 11. Note that about a half out of 240 data, i.e. four subjects × sixty RDS/RDI types, was excluded for the analysis because of possible contamination of large EOG fluctuations coursed by eye movements during a target time windows.

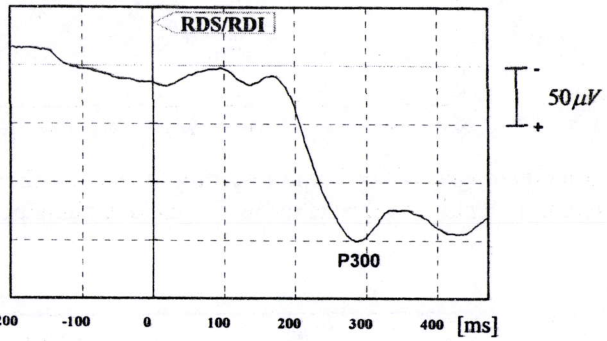


Figure 11: Event related potential evoked by the RDS/RDI presentation (stimuli onset) at Fz position.

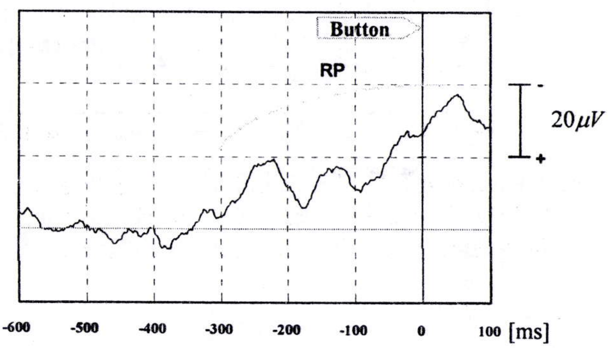


Figure 12: A typical readiness potential (RP) evoked by the button press. Negative modulation (RP) emerges from 300 ms before button press and 50 ms after that.

3.4 Readiness Potential (RP) Evoked by Button Press

Readiness Potential (RP), or bereitschaftspotential (BP), is another kind of ERP, but it is evoked by voluntary movement and emerges prior to the movement (target events)

[14]. Moreover, RP is evoked even a subject intends to move without any actual movement.

In our experiment, RP is expected to emerge prior to the subjects' button press after they cognised the embedded figure. To estimate the contamination of RP with the obtained brain potentials at SRT, we analysed RP by averaging of brain waves with referring the button press records for each subjects and RDSs. Figure 12 shows the averaged profiles of EEG of a subject from 600 ms before button press to 100 ms after that. As the figure shows, negative modulation (RP) emerges from 300 ms before the button press and lasts just after that, which is quite consistent with the previous RP studies. But there is no such a profile on two subjects, which is also supposed as the possible contamination of the eye movements.

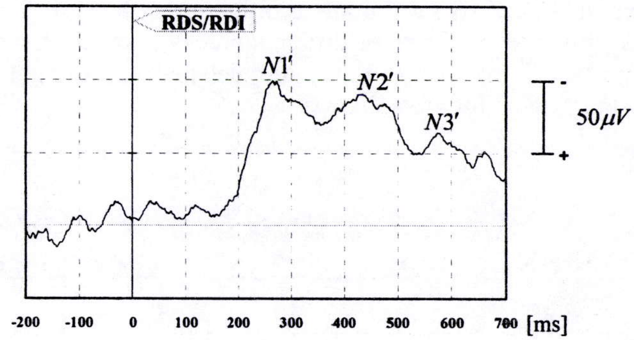


Figure 13: The grand average of brain potentials evoked by RDS/RDI presentation at O1 by referring to Fz.

4 Discussion

The previous RDS studies reported the negative peaks with the latencies in 100-600 ms in the form of monophasic, biphasic, and triphasic as mentioned in Introduction. But in those studies, subjects were aided to fuse the embedded figures of RDS by supportive devices such as stereoscopes, and thus the embedded figures are automatically emerges. By contrast, we designed the experiment, in which subjects were required to fuse two images of RDSs by themselves and find out the embedded figures, thus the perception of RDS presentation and cognition of RDSs' embedded figures is expected to be distinguishable. To compare the results with previous studies, we analysed ERP evoked by RDS/RDI presentation. Because, in the previous studies, the active and the reference electrodes were frequently placed at O1 and O2, and parietal position (Fz and/or Cz) or near inion (e.g., [7,8,9]), respectively, while the reference electrodes in our studies were placed at both ear lobules, we subtract the EEG profiles at O1 and O2 from that of Fz. As the result, triphasic negative peaks with the latencies in 260 ms, 450 ms, and 580 ms is obtained in O1 as shown in Figure 13 (denoted as $N1'$, $N2'$ and $N3'$) and O2. The profile of O2 was almost the same as O1. Those negative potentials evidently reflect the

P300 observed at Fz (Figure 11). Although we don't imply such negative potentials are the VEP regarding to be evoked by subjects' stereopsis in the previous RDS studies, but the remarkable P300 evoked by stimuli onset (RDS presentation) could possibly mask the target brain wave components evoked by purely stereopsis because the perception of stimuli onsets and the cognition of three-dimensional figure cannot be distinguishable.

On the other hand, because the reference times, FRT and SRT, in our study is posterior over 500 ms to RDSs presentation and prior over 500 ms to the button press as shown in Figure 14, the remarkable brain potentials observed with referring to the FRT and SRT cannot be masked by the VEP evoked by RDS presentation and RP evoked by the button press either. Therefore it suggests that those potentials could reflect purely cognitive process of stereopsis in time series. Comparing with corresponding each EEG profiles of right and left hemisphere of the brain, no remarkable phase differences observed except for between T5 and T6 at SRT. T5 and T6 were the electrodes placed at the most external (lateral) site in our recording procedure, so it can be supposed that such a phase difference reflects the different processes or functions within the right and left hemisphere of the brain. But more detailed recording and analysis like as topography is expected for more discussion.

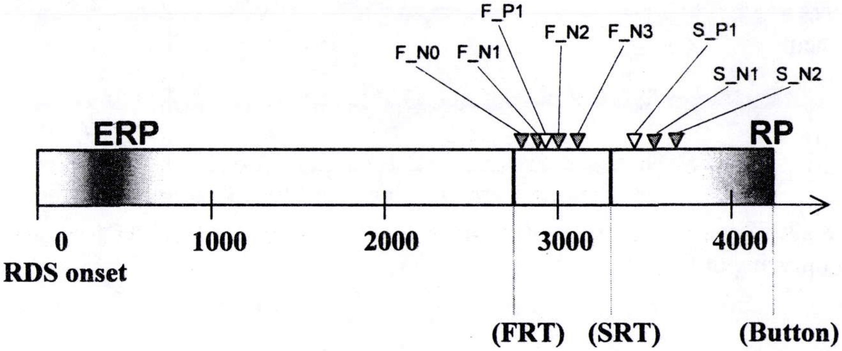


Figure 14: Time course relation of the ERP evoked by RDS/RDI presentation, brain potentials with referring to FRT and SRT, and RP evoked by button press in our experiment.

According to EOG analysis, the duration of RDS presentation to the button press shows the significant time difference within individuals. That within individual difference is assumed to be simply comes from the time differences with subjects' convergence, thus the duration between RDS presentation to the FRT because no main effects are found in the other durations. Actually, the duration of RDS presentation to the FRT and that of to the button press shows high correlation. Those facts complement our hypothesis that the characteristic EOGs' discontinuous fluctuation, defined as the FRT, indicates the moment that the subjects successfully fused on the embedded figure with the appropriate focal depth. In shot, one can say that subjects' cognition of the embedded figures of RDS starts at FRT. In addition, no significant effects are found with regards to RDS types between FRT to SRT and SRT to the button press, and the duration of FRT to SRT has no correlation with that of RDS presentation to the button press and that of RDS presentation to FRT, respectively. In short, the time duration of FRT to SRT is independent with individuals and RDS types.

In consequence, we suggest following two points: 1) FRT is the adequate reference time (moment) indicating subjects' internal process of the cognition of the RDS' embedded figure, and 2) the cognition process of stereopsis can consist of several succeeding processes in time series, and the remarkable brain potentials observed with referring to the FRT and SRT can reflects those processes.

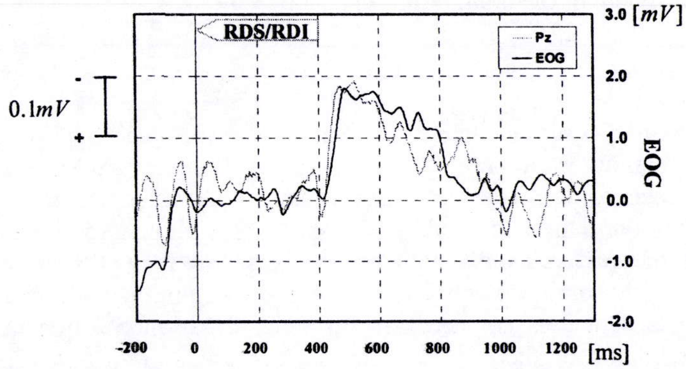


Figure 15: Example of the EEG profile at Pz contaminated with rapid eye movement shown as the fluctuation of EOG.

We admit there are several methodological problems in our experiments. First, the stimuli RDIs can stand as the control stimuli just for the button press in RDS and ERP analysis. In other words, there is no reference EEG directly comparing with the brain potential observed at FRT and SRT. But it is rather fundamental problem accompanying with the definition of FRT and SRT, i.e. one cannot define such reference times on EOG profiles in RDI trials. Second, the number of subjects is very small. It might affect the appearance of grand averages of EEG profiles at FRT (Figure 7 and 8) and SRT (Figure 9 and 10). Several distinguishable peaks are observed in those profiles but those peaks are not found for all subjects. Because the smoothing effects by grand averaging are relatively low in our study caused by low number of subjects, sharp peaks of EEG of different latencies of each subject might be appeared as several peaks in grand averages, i.e. F_N2 and F_N3 in Figure 7 and S_N1 and S_N2 in Figure 9 might reflects the same components of the cognition processes. But it is still unclear and additional experiments with more number of subjects are needed. Third, because subjects are required to voluntary adjust convergence to find out the embedded figures of RDS, EEG profiles are easily contaminated by rapid and discontinuous EOG profiles. In the analysis of EEG, we have to exclude such contaminated profiles (a typical profile is shown in Figure 15). However it is rather a trade-off issue, if we limit the subjects' eye movement introducing a fixed point on the screen like as most of previous studies, the moment of the perception of RDS presentation and that of the cognition of RDSs' embedded figure would much closer in time series, thus the evoked potentials cannot be any more distinguishable. Methodological modification, for example, introducing the fixed point with differentiating in the position at each trial, would be need. Finally, no variety of disparity and the method to fuse, convergence and divergence, are assessed in our study. The angular disparity of right and left figures of RDSs is set to11′ in our experiment. Although the angular disparity of our study cannot directly compare with that of previous studies because subjects were not required to try adjusting their eyes in those studies, there several RDS studies reporting the difference in the disparity or the fusion methods bring forth the difference in the latency and amplitudes and/or response in the right and left hemisphere of the brain [2,6,7,8].

5 Conclusion

The perception of RDS presentation and cognition of embedded figure of RDS might be processed separately in a brain. Our experimental procedure can successfully illuminates such succeeding processes within a brain. Although some methodological problems are left in our experiment and it is rather to be a pilot study, it can be a new methodology for the research on a human stereopsis. Future works promises more prices detection of the brain potential concerning the cognition processes of three-dimensional objects. But it is not necessary to believe that such a human cognitive process is an integration of those meta-processes because a brain potential is just a superficial and relative output of the complex function of the human cognition.

Acknowledgements

All of this work was conducted in Satellite Venture Business Laboratory at Muroran Institute of Technology. I would like to express special appreciation for all of staffs and colleagues of the laboratory. I would like to thank Yukiko Nomura and Kofuki Nomura for useful comments.

References

[1]Regan D & Spekreijse H. (1970) Electrophysiological correlate of binocular depth perception in Man. Nature 225, pp.92-95.

[2]Regan D & Beverley KI. (1973) Electrophysiological evidence for Existence of Neurones sensitive to direction of depth movement. Nature 246, pp.504-506.

[3]Julesz B, Kropfl W, and Petrig B. (1980) Large evoked potentials to dynamic random-dot correlograms and stereograms permit quick determination of streopsis. Psychology 77, pp.2348-2351.

[4]Fukai S. (1985) Topographic visually evoked potentials induced by stereoptic stimulus. Br J Ophthalmol 69, pp.612-617.

[5]Julesz B. (1986) Stereoscopic vision. Vision Research 26, pp.1601-1612.

[6]Miyawaki, Y, Yanagida Y, Maeda T, and Tachi S. (1999) The characteristics of two negative peaks on visual evoked potentials with depth perception. Denshi jyoho tsushin gakkai shi [Journal of The Institute of Electronics, Information and

Communication Engineers] (*in Japanese*) J82-D-II, pp.691-672.
[7]Sahinoglu B. (2004) Depth-related visually evoked potentials by dynamic random-dots stereograms in humans: negative correlation between the peaks elicited by convergent and divergent disparities. Eur J Appl Physiol 91, pp.689-97.
[8]Sahinoglu B. (2002) The effect of disparity change on binocular visual evoked potential parameters elicited by convergent dynamic random-dot stereogram stimuli in humans. Eur J Appl Physiol 88, pp.178-84.
[9]Fiorentini A & Maffei L. (1970) Electrophysiological evidence for binocular disparity detectors in human visual system. Science 169, pp.208-209.
[10]Hayashi E, Kuroiwa Y, Omoto S, Kamitani T, Li M, and Koyano S. (2004) Visual evoked potential changes related to illusory perception in nourmal human subjects. Neuroscience Letters 359, pp.29-32.
[11]Nakagawa K, Nomura S, and Nagashima T. Estimation of the exact moment of human cognition of RDS. ASIASENSE 2005 and The International Conference on New Techniques in Pharmaceutical and Biomedical Research, IEEE Conference Proceedings. (*In Press*)
[12]e.g., Verleger R. (1997) On the utility of P3 latency as an index of mental chronometry. Psychophysiology 34, pp131-156.
[13]e.g., Rugg MD & Coles MGH (Eds.) (1995) Electrophysiology of Mind: Event-Related Brain Potentials and Cognition. Oxford University Press.
[14]Miyata, H. (1998) Shin seiri shinrigaku (Vol. 1) [New Physiopsychology] (*in Japanese*). Kitaoji Shobo.