Master's Thesis

Neurocinematics as passive-BCI based Applicaition : The EEG study on neural responses of human during watching movie

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ABSTRACT

Traditionally, brain-computer interface is mostly composed of researches for the rehabilitation of paralyzed patients with the objective of controlling bio-signal through external devices. However, recently the concept of the research has widened to understand the user's processing of cognitive emotional information for non-medical purposes and has classified this as manual brain-computer interface. Among these, neurocinematics is a manual brain-computer interface's applied research field which tries to understand the changes in the cognitive or emotional state of the viewer while watching a movie. There are two main reasons why this field of study is receiving particular attention recently. First, movies do not only have audio-visual stimulus, but are composed of different factors such as culture and environment, and it can help in studying the human's social cognitive process. Another reason is that the original survey or post-interview method of audience reviewing about movies has a limitation - audience should be aware of their conditions; so the credibility is low. On the other hand, neurocinematics studies observe it through bio-signal and believes that a more objective verification is possible. However, in existing researches, they mostly used the method of validating findings by comparing the results of the neurocinematics research through bio-signal with the original result from the survey. Also, a lot of researches were done to know if most subjects made the same reaction while watching the same movie, but they obtained the bio-signal through individual viewing.

This research has verified the objectivity of engagement index extraction through the introduction of psychophysical methods to overcome the limitations of existing studies. While the subjects were watching a movie in one room, their brainwaves were measured. Changes in the brainwave synchronization levels between the subjects were also checked. Moreover, we proved the changes in the level of brainwave synchronization in two conditions: when people are watching individually and when they are watching in a group.

In the first experiment, we used a psychophysical method called Secondary Task Reaction Time (STRT), which is known for representing concentration to evaluate Neural Engagement Index (NEI). STRT is used to check the reaction speed for a tactile stimulus given additionally while the subject is doing the main task. It is known that the reaction rate gets slower when the subject is more engaged to the main task. In this experiment, we measured the STRT and NEI while the subjects are watching 8 movie trailers that are not yet out in the cinema. After watching each trailer, the subjects completed the survey. As a result, there was a significant correlation between STRT and NEI, but in the survey, there was no meaningful correlation.

In the second experiment, while four subjects were simultaneously watching the Chaser (2008, Silk road), their brainwaves were measured and analyzed 5 per frequency band different inter

subject correlation (ISC). Moreover, using sliding show method, we analyzed the correlation between time: Delta2~4Hz), Theta (4~8Hz), Alpha (8~13Hz), low Beta (13~18Hz), high Beta(18~23Hz). Also, to verify the derived correlation's significance, the result of checking the correlation of the data that had been time shifted on each window and its 95% range through non-parametric permutation analysis, the researchers observed time slots that had specific significance on each band correlation. As a result, in the span of the movie's whole running time, researchers observed that there were parts where a significant correlation increased between the subjects' band power. Especially there were a lot of meaningful correlations found in the movie when it reaches the emotional climax, and they were important scenes in the movie when it comes to development of plot, these scenes the same with the scenes picked by the majority of the audience.

In the third experiment, based on the result of the second experiment, the researchers checked if the audience's reaction changes depending on the viewing conditions when watching the same movie content by applying a brainwave-based response model. The viewing conditions were divided into a group of people who watched the movie together, and the viewing group who watched the movie in separate rooms. We proceeded with the experiment after recruiting 8 subjects per group. The data of two groups watching together and one group watching individually was built. We analyzed the collective responses to the applied brainwave frequency inter subject correlation coefficient of each group: Delta (2~4Hz), Theta (4~8Hz), Alpha (8~13Hz), low Beta (13~18Hz), high Beta (18~23Hz). During the whole period of watching the movie, as the result of analyzing the rate of ISC increased significantly, the rate of ISC increase of the group that watched the movie together had a higher ISC increase rate than the group that watched the movie individually, in all frequency bands.

PUBLICATIONS

Journal

Kang, D., Kim, J., Jang, D. P., Cho, Y. S., & Kim, S. P. (2015). Investigation of engagement of viewers in movie trailers using electroencephalography. *Brain-Computer Interfaces*, 2(4), 193-201.

Conference

Paper 1

Kang, D. Y., Kim, J., Shin, Y. S., Jang, D. P., & Kim, S. P. (2014, October). Coherent neural responses of human populations during watching movie. In *Control, Automation and Systems (ICCAS), 2014 14th International Conference on (pp. 272-274)*. IEEE.

Paper 2

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Paper 3

Kang, D., Kim, J., Jang, D. P., Cho, Y., & Kim, S. P. (2015). Measuring engagement in movie trailers using behavioral and neural responses. SFN, Neuroscience 2015, Chicago, USA.

Paper 4

Kang, D. Y., & Kim, S. P. (2016). Investigation of group-wise neural responses during watching the movies in different conditions. ESK 2016 June 1-4, Jeju, ROK.

Patent

Cho, Y. S., Park, W.J., Kang, D.Y., & Kim, S. P. (2015). Apparatus and method for engagement of viewers in movie contents, Korea patent, 10-2015-0156842, November. 11, 2015 (in progress)

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Chapter 1. **Introduction**

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1.1 Measuring brain activity for Brain-computer interfaces

Initially, the aim of brain-computer interfaces (BCIs) was to establish additional communication channels that can control computers or machines for the people who have motor disabilities through acquisition brain signals from users, extracting features from those signals and translate features into output signals (Schalk et al., 2004; Graimann et al., 2010). BCIs use brain activity, instead of mechanical manipulation or muscular movements, as direct input into artificial systems for the control of external devices (Wolpaw, Birbaumer, McFarland, Pfurtscheller, & Vaughan, 2002). There are several different types of methods which can measure brain activity. Functional magnetic resonance imaging (fMRI) measures change of blood oxygenation level-dependent. Near infrared spectroscopy (NIRS) also measures hemodynamic responses of human cortex. Megnetoencephalography (MEG) records magnetic fields from brain activity. Electroencephalography (EEG), electrocorticography (ECoG) and intracortical neuron recording measure electrical activity of the brain (Graimann, Allison, & Pfurtscheller, 2010; Nicolas, 2012)

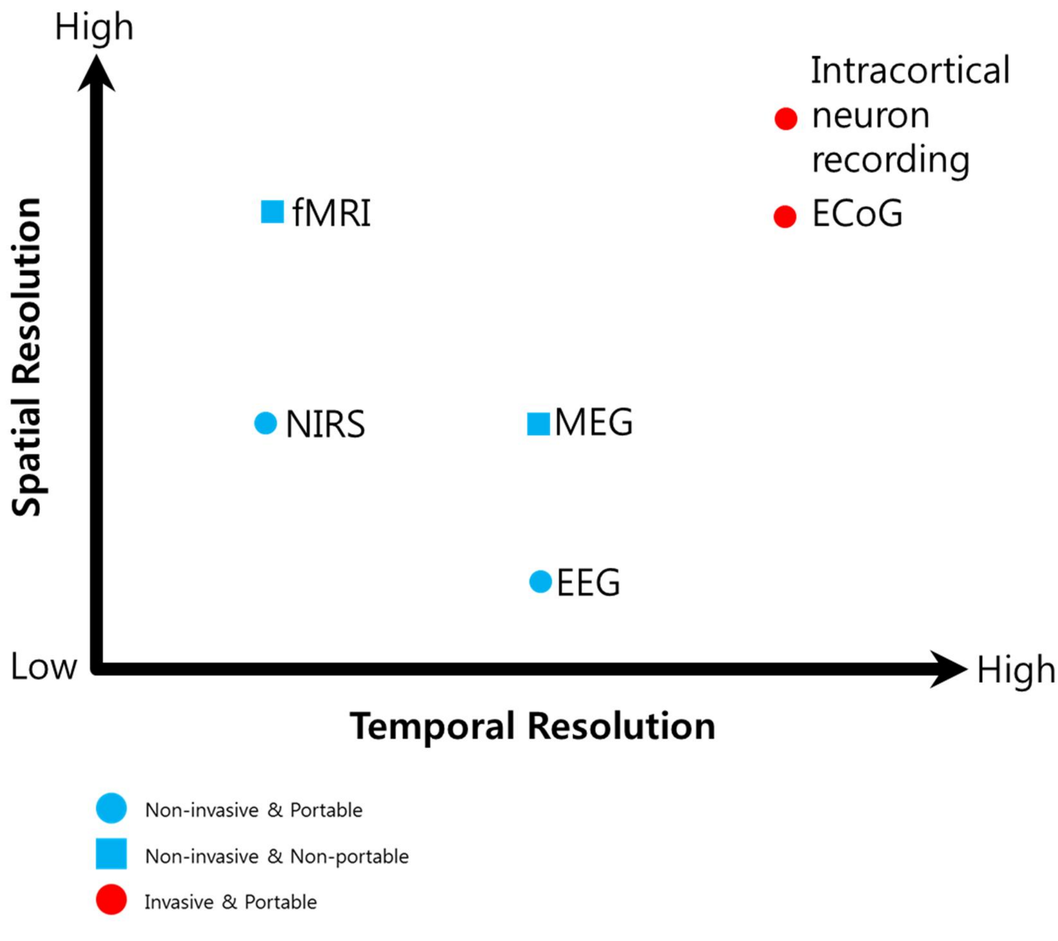

Figure 1 Overview of BCI measurement methods.

Figure 1 shows an overview of BCI measurement methods (Nicolas, 2012). fMRI and NIRS have a high spatial resolution but they have a poor time resolution. fMRI and MEG are large, expensive and non-portable. Intracortical neuron recording and ECoG have high spatial and temporal resolutions. However, they are invasive recording techniques which need surgery since intracortical neuron recording measures brain activity within cortical tissue and ECoG from the surface of the cortex. EEG is a non-invasive and portable measurement that records electrical activity from the scalp (Graimann et al., 2010) Among these methods, EEG-based BCI is most widely used for its application due to its advantages : low cost, easy to use, and acceptable signal quality (Nicolas, 2012)

1.2 Brain computer interfaces for non-medical uses

These days, BCIs can be applied for non-medical uses by the monitoring of user states in order to construct cognitive and affective human-computer interfaces. This is a broader view of BCIs that encompasses seven areas of applications: device control, user-state monitoring, evaluation, training and education, gaming and entertainment, cognitive improvement, and safety and security(van Erp, Lotte, & Tangermann, 2012) For these applications, Zender et al. (2011) categorize BCI applications for non-medical uses into active, passive, and reactive BCI (Zander & Kothe, 2011). Active BCIs and Reactive BCIs are a type of BCI that focuses on clinical applications to empower disabled people to be able to control artificial systems (George & Lécuyer, 2010; van Erp et al., 2012). Passive BCIs infer output from brain activity in response to external stimuli (Zander & Kothe, 2011)

Table 1 Features and Application Domains of BCI Interaction Paradigms (Gürkök & Nijholt, 2012).

Type of BCI	Interaction With BCI System	Generation of Brain Activity	Used for	Example Applications
Active	Intended	Consciously	Direct control	Motor imagery-based navigation
Reactive	Intended	In response to stimulation	Direct control	P300 speller, SSVEP-based selection
Passive	Unintended	Through interaction	Supporting systems	User state detection, error handling via ErrPs

1.3 Neurocinematics : An application of passive BCI

Neuromarketing is a well-known example of passive BCIs. The field of neuromarketing aims to understand consumer behavior by examining the implicit and unconscious information to which the brains of consumers are exposed (Ariely & Berns, 2010; Morin, 2011). An application of neuromarketing, neurocinematics, studies how the neural activity, as well as the associated cognitive and affective states, of movie viewers flow while the viewers are watching a movie. Neurocinematics investigates the influence of the movie on the neural responses of the viewers in order to develop tools to evaluate the effect of the movie on the cognitive and emotional states of the viewers (Hasson, Landesman, & Knappmeyer, 2008b).

Studies of groups of individuals watching the same movies have reported that more brain regions are coherently activated (Hasson et al., 2004). There was a definite correlation between neural activity in response to particular scenes and the degree to which those scenes were encoded in the memories of the viewers (Hasson et al., 2008a). One study developed a neural marker to predict the commercial success of movies by using electroencephalography (EEG) (Boksem & Smidts, 2015). Conventional marketing methods, such as surveys, are currently used to evaluate the effectiveness of movie trailers, but neurocinematics has also been applied to the analysis of movie trailers, which have the clear marketing purpose of capturing the attention of an audience and convincing them to watch the movies (Boksem & Smidts, 2015). A study that measured electrical brain activity by EEG estimated the level of the concentration of viewers watching movie trailers (Wang, Huang, & Tsai, et al., 2014). MindSign, a neuromarketing firm based in San Diego, California, the United States, has demonstrated that relevant changes in brain activity can be measured by neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), while viewers were watching a movie trailer. Hasson et al. investigated correlation between behavioral response and neural response patterns on most memorable scene(Hasson et al., 2008b)

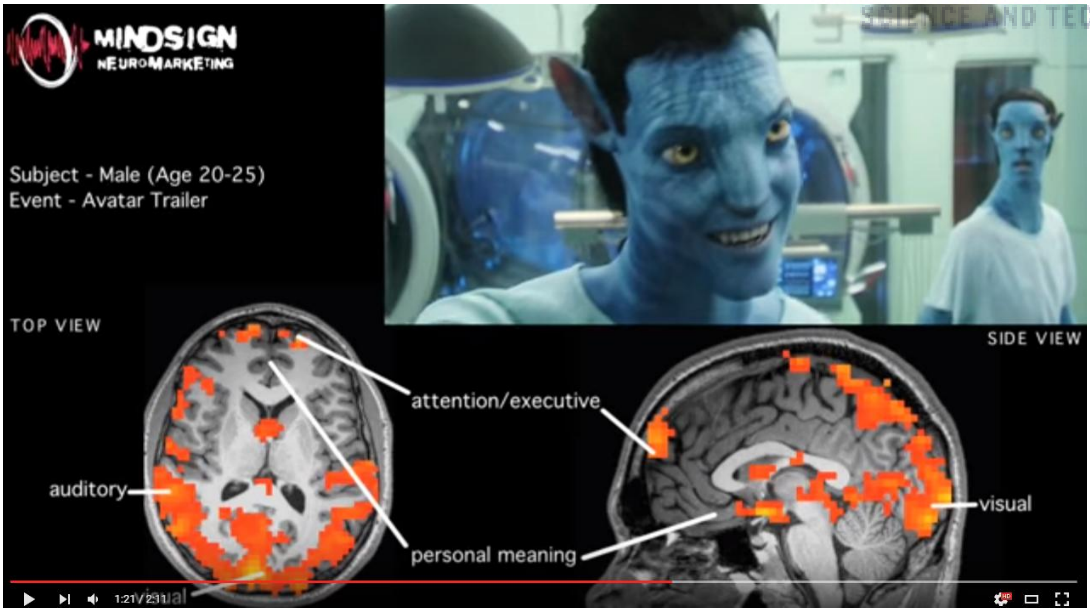

Figure 2 Brain responses while watching the 'Avatar' teaser trailer from Mindsign neuromarketing (San Diego, USA)

1.4 Research Objectives

Neurocinematics has emerged as an important topic based on some reasons. Firstly, movie is a multi-facet stimuli which can arouse a variety of emotional and cognitive states in viewers. So study on how the human brain reacts to cultural experiences such as cinema can widen our understanding of social interactions in humans. Secondly, despite growth of movie market, the method to evaluate movie has not been changed from survey.

The studies in this thesis have two main objectives. The primary objective is to verify the validity of measuring engagement to movie via neural data which is unconscious response to movie. The second objective is to investigate group-wise responses of viewers by measuring brain signals simultaneously and compare them with that of individual viewers.

1.5 Thesis Organization

Overall structure of this thesis is presented in Figure 3. Below is the summary of the five chapters contained in this thesis.

In chapter 1, the research background and objectives were discussed including literature reviews.

In chapter 2, investigation of engagement to movie using neurophysiological data, psychophysical data, and traditional survey result.

In chapter 3, group-wise neural responses during watching movie was measured simultaneously. Also, based on the result of results of previous study, we compared the group wise neural response to movie in different conditions, watching together or alone.

In chapter 4, we discussed the limitation of experiments and future works.

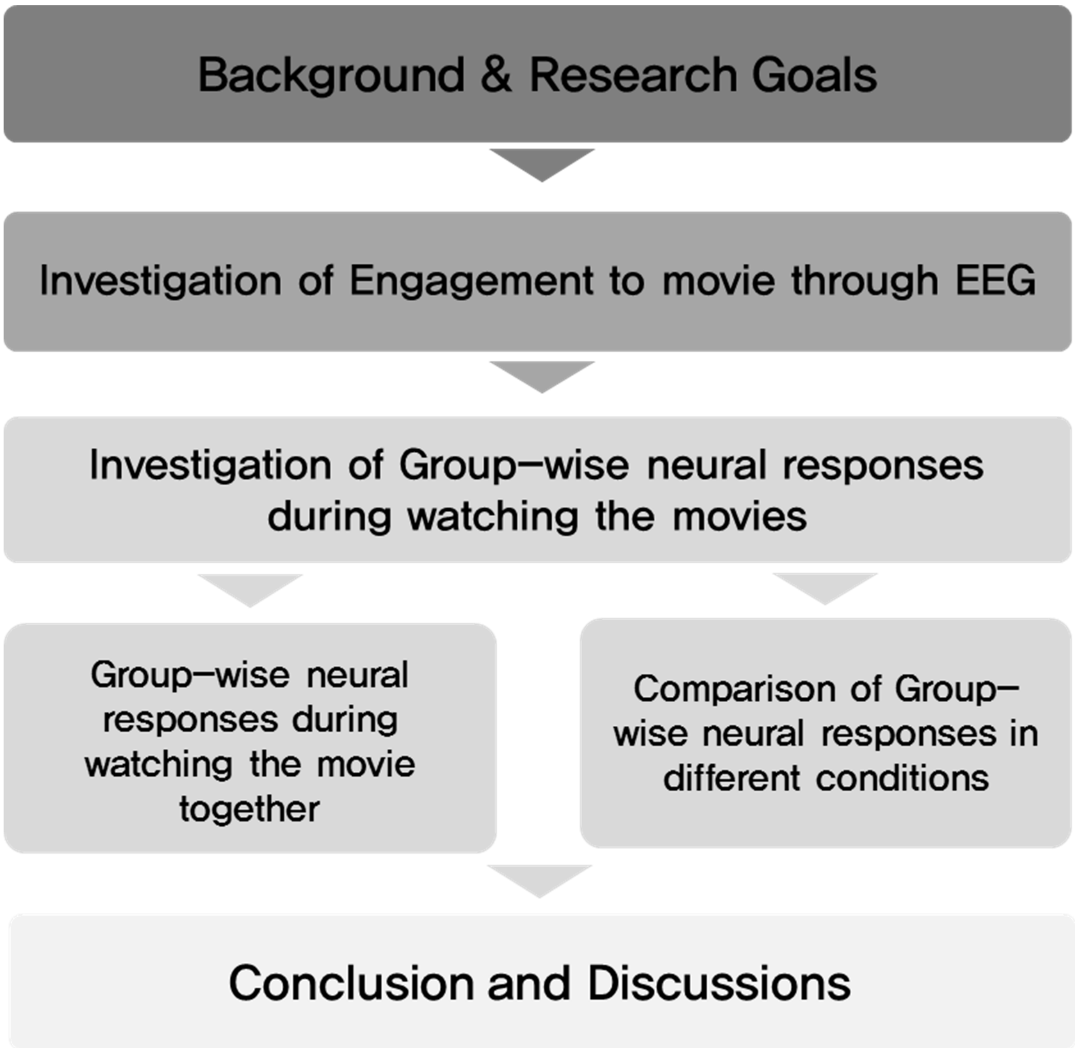

Figure 3 Overall structure of thesis

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Chapter 2. **Investigation of Engagement to movie through EEG**

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2.1 Objective

One of the particular subjects studied by neurocinematics is the correlation between the success of a movie and the degree to which the movie engages its viewers. Hasson et al. showed that the most engaging movie could be found by analyzing inter-subject correlations (ISCs) and how they were affected by the way in which a film was edited (Hasson et al., 2008b; Hasson, Nir, Levy, Fuhrmann, & Malach, 2004). Previous studies attempted to find neural correlates of engagement in a more direct way by investigating the brain activities of single viewers who watched movies independently. The modulation of brain oscillations in specific frequency bands features strongly in gauging the neural correlate of engagement in viewers. It was observed that EEG alpha activity decreased as attentional demands increased, and beta activity increased during active cognitive processes(Ray & Cole, 1985).

Neurocinematics assumes that after watching a movie, the viewers would be unable to explain their emotional and cognitive states precisely, and so, such subjective self-reported data would not be highly reliable. Neurocinematics seeks to address these limitations by harnessing brain signals and measuring the emotional and cognitive states of viewers more objectively. Neural indices, such as the neural index of engagement, of emotional and cognitive states are developed for the purpose of assessing the changes in the relevant mental states of viewers as they watch a movie. However, the self-reported data of viewers is still utilized by many studies to confirm the validity of neural indices by examining how close the data compares to the indices. For instance, one study investigated correlations between the brain activities of viewers watching TV commercials and the subjective interests the viewers had in the commercials(Smith & Gevins, 2004). Such an approach is somewhat contradictory to the goal of neurocinematics, which is to address the problem of subjective self-reports by using neural information to develop independent and objective assessments of the media. In other words, neural information is supposed to be a more objective means than self-reported information for assessing the impact of movies. For instance, the data gathered from neural responses of people listening to new pop songs predicted the commercial success of the songs more accurately than did the self-reported information given as feedback by the listeners themselves(Koelsch, 2014).

The present study aims to investigate the evaluation of neural indices used in neurocinematics in order to address the problem posed by direct comparisons of the indices to subjective self-reports. To this end, in addition to brain activity and self-reports, another engagement index was measured by the use of a psychophysical method known as secondary task reaction time (STRT), which is commonly used to measure the situational awareness of movie viewers or the demands made on their attention (Baumann, Rösler, & Krems, 2007; Cepeda, 1996). The use of STRT assumes that the reaction of a person to a secondary task is slower than to a primary task for which more cognitive resources have already been used(Wróbel, 2000). This study assigned the primary task of watching a movie trailer to viewers, whose secondary task was being subjected to unpredictable tactile stimuli. The STRTs, as well as EEG readings, were recorded during the watching of the movie trailers and compared to the self-reports of the viewers made after having seen the trailer. It was assumed that the trailers that had engaged the viewers more would have resulted in lower STRTs, as well as increases in the neural index of engagement. A neural index of engagement was developed on the basis of spectral power differences in the alpha and beta frequency bands. Correlations between three different measures – neural index, STRT, and self-reports – were also evaluated in order to investigate the relations between these objective and subjective measures.

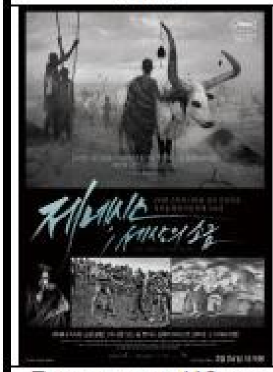
2.2 Method

2.2.1 Participants and Materials

Eleven university students (mean 22.4 ± 0.89 years old; 5 female) with right participated in the experiment. All participants had no neurological disorder and normal or corrected to normal vision. The institutional review board of Ulsan National Institute of Science and Technology (UNISTIRB-15-04-C) approved the present study and all participants provided informed consent prior to the experiment.

Eight movie trailers that were supposed to be released in Korean theaters after the day of the experiment were used as stimuli (S1: The salt of the Earth, Brazil, France and Italy, 2014; S2: Project Almanac, Back to the beginning, USA, 2014; S3: Gi-Hwa, Korea, 2015; S4: Terminator Genesis, USA, 2015; S5: C'est Si Bon, Korea, 2015; S6: The Avengers : Age of Ultron, USA, 2015; S7: Dog eat dog, Korea, 2015; and S8: Plemya, The Tribe, Ukraine, 2014. See Table 1). In addition, we used a ninety-second long video clip consisting of white noise only as a control stimulus. Each trailer had a different running time, ranging from 70 to 152 seconds (mean 107.625 ± 30.142 seconds). In order to minimize an unexpected effect from the participants' preference to or aversiveness against a specific genre, stimuli were chosen from five different genres (S1: Documentary; S2, S7 and S8: Thriller, S3and S5: Melodrama; and S4 and S6: Science Fiction). Trailers were edited as an official version in Korea in which the Korean subtitles were provided in the trailer if the movie was made outside Korea. All participants were native Koreans and had no deficit in reading and hearing Korean language. None of participants watched the whole movie or any trailer before the experiment except two of them who reported that they had watched the trailer S6 before.

Table 2 The title, official poster, genre and running time of the eight movie trailers selected in the study.

S1: The salt of the Earth	S2: Project Almanac, Back to the beginning	S3: Gi-Hwa	S4: Terminator Genisys
			
Documentary, 112 sec	Thriller, 82 sec	Melodrama, 120 sec	Science fiction, 145 sec
S5: C'est Si Bon	S6: The Avengers : Age of Ultron	S7: Dog eat dog	S8: Plemya, The Tribe
			
Melodrama, 98sec	Science fiction, 152 sec	Thriller, 82 sec	Thriller, 70 sec

2.2.2 Experimental paradigm

The experiment consisted of nine sessions in each of which participants were shown one of the eight movie trailers or the control video clip (Figure. 4). Before the experiment, participants received an explanation about the experimental procedure and experienced the tactile stimulation for practice. Each session began with a five-second fixation period where a cross appeared at the screen to let participant fixate their eyes on it. After the fixation period, a movie trailer or control clip was presented. In the middle of the video presentation, a tactile stimulus was given to the left index finger tip of participants to measure STRT (Baumann et al., 2007; Cepeda, 1996). The participants were asked to respond as soon as possible when they perceived the stimulation by tapping the space bar on a keyboard with their right hand. Reaction time for every session was measured as a difference between the time of keyboard pressing and the time of tactile stimulus onset. The time to present the tactile stimulus was randomly set for each participant within a range from 15 to 60 seconds after the onset of video to provide sufficient time for participants to follow the trailer. This relatively large range of the tactile stimulation onset was designed to prevent participants from estimating anticipatory tactile stimulation during watching a trailer. The average tactile stimulation time was 32 ± 15 seconds after the onset of video. The stimulus presentation time was pre-determined for each trailer at which an independent group of viewers reported a most attentive scene through the trailer; it was 31, 18, 20, 48, 32, 60, 15 and 31 seconds after the onset of video for S1, S2, S3, S4, S5, S6, S7 and S8, respectively. There was no correlation between the stimulus presentation time and any evaluation result reported in this study. The stimulus was presented at 30 seconds after video onset for the control clip. Every participant received the tactile stimulus at the identical moment for the same video clip. The video clip was continuously played to the end of the trailer regardless of the tactile stimulation.

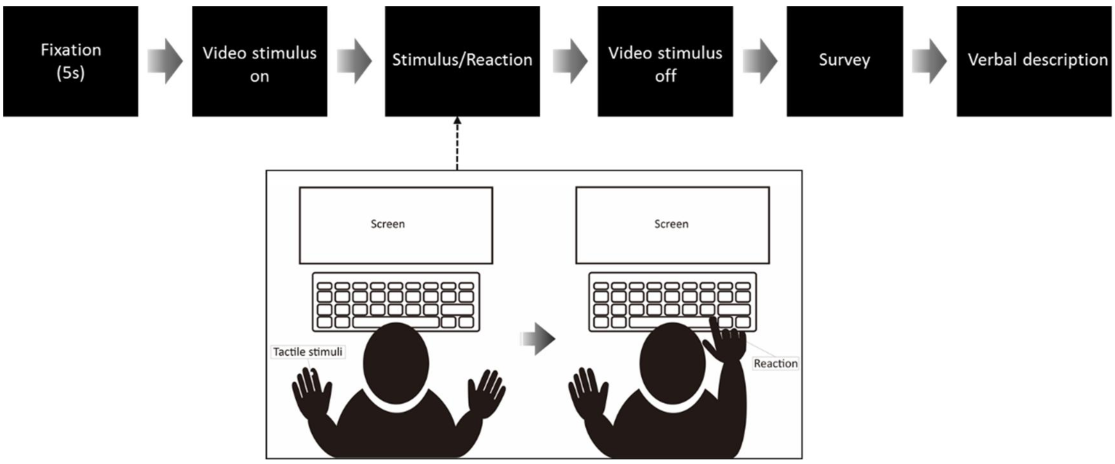


Figure 4 An illustration of the experimental procedure

At the end of each session, we asked participants to report: 1) how fun the trailer was; 2) how attentive the trailer was; 3) and how eagerly they anticipated seeing the film after having watched the trailer, except for the control video clip. The Likert 11-point scale (1~11) was used to assess the degree of fun, attentiveness and anticipation. After all the sessions ended, participants were asked to rank the trailers in the order of their preference. In order to maintain participants' attention to the video clip, participants were asked to verbally describe about the trailer they had watched at the end of every session.

2.2.3 Experimental apparatus

During the experiment, the EEG signal of every participant was recorded using a wireless EEG headset equipped with 21 dry sensors (DSI-1 20, Wearable Sensing, San Diego, USA). EEG electrodes were positioned in accordance with the international 10/20 System locations: Fp1, Fp2, Fz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, T5, T6, P3, P4, O1, O2, A1 and A2. The electrodes at the locations of A1 and A2 (left and right earlobes) were used as the reference electrodes. An additional common mode follower sensor was located at Pz, used as the ground electrode. The analogue EEG signals were digitized at a 300-Hz sampling rate.

Figure 5 A wireless EEG headset equipped with 21 dry sensors (DSI-1 20, Wearable Sensing, San Diego, USA)

The movie trailers were presented on a 27-inch monitor (QH270-IPSM, Achieva Korea, Incheon, Korea) with a speaker (BOS-BS100, BonoBos, Seoul, Korea). The entire experiment was conducted in the shielding room. The tactile stimulus was a weak 50-Hz vibrotactile stimulus 10 that lasted 0.5 seconds. It was generated by a vibrotactile transducer (TL002-14-A, TactileLabs, Montreal, Canada).

2.2.4 Data Analysis

The independent component analysis (ICA) was applied to raw EEG signals to remove the putative sources of artefacts such as eye blinks (Delrome & Makeig, 2004; Hyvärinen & Oja, 2000) . Then, the reconstructed EEG signals were band-pass filtered with a frequency range between 0.1 and 50 Hz. The filtered EEG data were split into non-overlapping 1-second segments and windowed (using the hamming 17 window). The spectral power of each windowed data was calculated using the short-time 18 Fourier transform (STFT) with respect to two non-overlapping frequency bands that covered parts of the frequency bands of alpha and beta oscillations: 7 -10 Hz (alpha) and 12 -14 Hz (beta).

As previous studies have shown that EEG alpha activity decreased as attentional demands increased and beta activity increased as emotional and cognitive processes were invigorate (Koelsch, 2014; Ray & Cole, 1985; Smith & Gevins, 2004), we determined a neural correlate of engagement (NCE) using alpha and beta activities from EEG as follows:

$$\text{Neural Correlate of Engagement} = (\beta - \alpha)/(\beta + \alpha) \qquad (1)$$

where β represents the spectral power within the beta band and α represents that within the alpha band. We measured the NCE at frontal cortical areas, Fp1 and Fp2, according to the previous reports on dominant fr 1 ontal cortical responses to movie trailers(George & Lécuyer, 2010; Wang, Huang, Tsai, Lu, & Teng, 2014). Then, we defined a neural engagement index (NEI) as a temporal change of the NCE from the initial 3-second period after movie trailer presentation to the last 3-second period right before tactile stimulation, in order to evaluate how much a movie trailer modulated engagement-related neural activity. It was calculated simply by subtracting the NCE in the initial period from the NCE in the last period. Hence, positive values in the NEI indicated increases in the NCE during movie trailer presentation while negative NEI values indicated decreases in the NCE.

The self-report data for each participant was normalized by subtracting the mean and dividing by the standard deviation in order to eliminate potential differences between each participant's subjective rating scales. We quantitatively assessed the self-report data in terms of three categories, including fun, attentiveness and anticipation. The trailer ranking data based on preference in each participant was converted into integer values between 1 and 8 such that the preference of the first ranked trailer was evaluated as 8, the second to 7 up to the last to 1.

A statistical analysis of differences in reaction time among stimuli was performed using a repeated measures ANOVA with the stimulus type as a factor. Pairwise multiple comparisons of reaction time following the ANOVA were performed with Bonferroni correction. The same repeated measures ANOVA analysis was applied to find differences in the NEI, fun, attentiveness, anticipation and preference data, respectively.

We also evaluated correlations between different the NEI, STRT and self-report data. Linear (Pearson) correlation coefficients were calculated among all possible pairs of six measures (thus, a total of 15 pairs). The statistical significance of each correlation coefficient was assessed by the F-test ($p < 0.05$). Note that the data from the control stimulus was only included for the correlation coefficient between the reaction time and NEI since no data was acquired about the control stimulus for the self-report and preference ranking.

2.3 Results

The repeated measures ANOVA analysis showed that STRT as well as the self-reports of fun and anticipation were different across the movie trailers ($p < 0.05$) but no difference was observed in NEI and attention. The average reaction time to the control video clip was 1.01 ± 0.16 seconds whereas the movie trailers yielded it from 1.22 ± 0.21 (shortest, S3) to 1.29 ± 0.15 (1 longest, S8) seconds. The post-hoc multiple comparison analysis showed that the reaction times of the trailers except S1 and S3 were longer than that of the control clip (Bonferroni correction, $p < 0.05$). Figure 6 also describes a relationship between the reaction time and other self-report data such as the rank and the anticipation score. The anticipation score tended to increase as the rank increased (correlation coefficient, $r = 0.76$, see Table 2). Notwithstanding the anticipation score, the reaction time did not show a correlation with the rank or the anticipation score. In fact, as highlighted in Figure 6 below, the reaction time was not significantly correlated with any of the self-report data (i.e. anticipation, fun, attentiveness, and rank scores). Since other self-report data were highly correlated with the anticipation score, too, we only depicted the anticipation score along with the reaction time in Figure 6 as a representative self-report result.

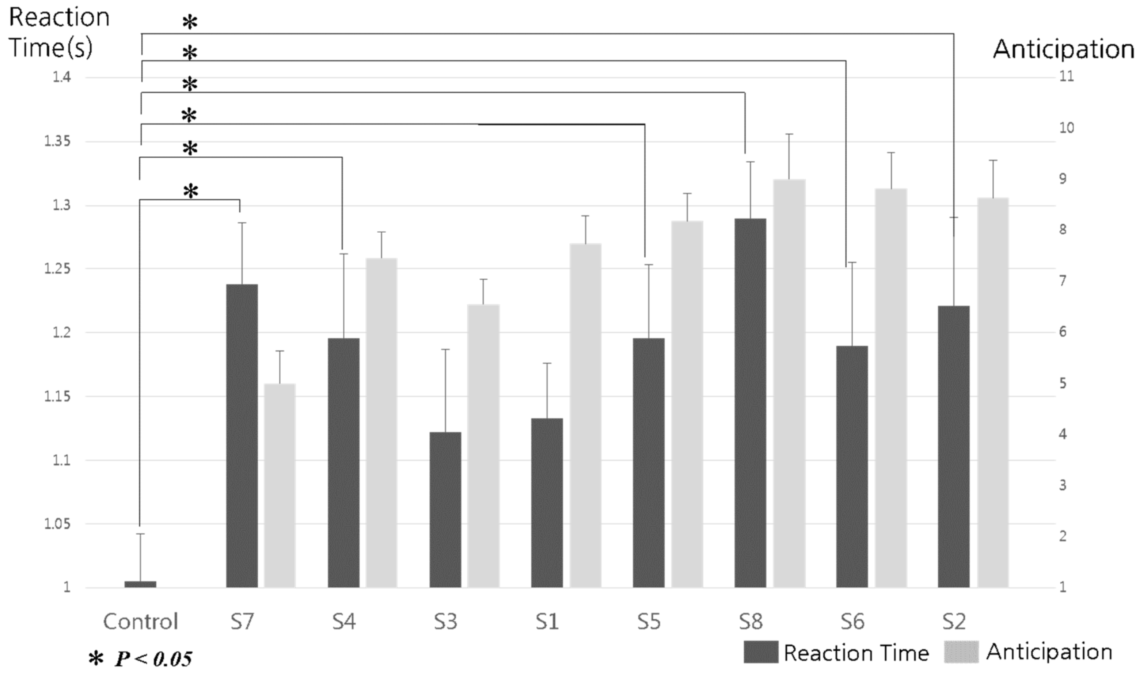


Figure 6 The average of the reaction time and the self-reported anticipation score (i.e. how eagerly participants anticipated seeing the original movie after having watched its movie trailer). Note that the movie trailers (S1 – S8) were arranged horizontally in the ascending order of the raking of preference resulted from the survey; S7 was least preferred and S2 most preferred. The control movie clips was a simple white noise display. The dark bars and the vertical lines represent the average and standard error of the reaction time for each trailer. The light bars represent the average of the anticipation 1 score. The left vertical axis shows the reaction time while the right one shows the anticipation score.

The correlation analysis result was illustrated in Figure 7 between the fifteen pairs of all six variables: NEI, STRT, rank, fun, attention and anticipation. The correlations among the self-report data including the rank, fun, attentiveness and anticipation scores were fairly strong ($0.70 < r < 0.95$, $p < 0.05$). However, none of these self-report scores showed a significant correlation with STRT ($0.05 < r < 0.50$, $p > 0.05$). The weakest correlation was found between STRT and the rank ($r = -0.002$, $p > 0.05$). On the contrary, STRT exhibited a relatively significant correlation with the NEI ($r = 0.72$, $p = 0.047$). No significant correlation between the NEI and any self-report data was observed ($0.30 < r < 0.61$, $p > 0.05$). The correlation analysis result is summarized in Table 3.

Table 3 Summary of correlation coefficients and p-value among neural engagement, reaction time and self-reported data. Significant correlations were marked as shaded areas ($p < 0.05$).

r	Neural Engagement	Reaction Time	RANK	FUN	ATTENTION	EXPECT
Neural Engagement	1.000					
Reaction Time	0.714	1.000				
RANK	0.369	-0.002	1.000			
FUN	0.605	0.426	0.441	1.000		
ATTENTION	0.595	0.470	0.534	0.822	1.000	
EXPECT	0.528	0.240	0.764	0.839	0.744	1.000
p	Neural Engagement	Reaction Time	RANK	FUN	ATTENTION	EXPECT
Neural Engagement	1.000					
Reaction Time	0.047	1.000				
RANK	0.369	0.996	1.000			
FUN	0.112	0.293	0.274	1.000		
ATTENTION	0.120	0.240	0.173	0.012	1.000	
EXPECT	0.179	0.567	0.027	0.009	0.034	1.000

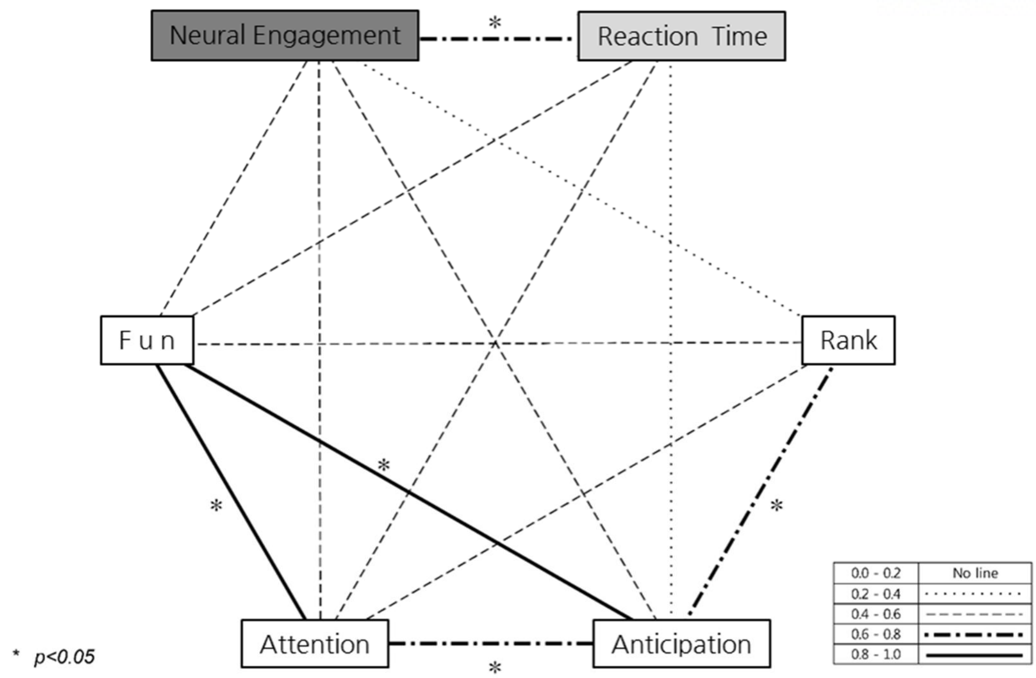


Figure 7 A diagram representing correlations among neural (dark grey box), psychophysical (light grey box) and self-reported data (white box): i.e. the neural engagement index, reaction time, ranks, fun, attentiveness and anticipation scores. Different line types denote the strengths of the correlation (refer to the inserted table). Statistical significance of each correlation is marked by stars ($p < 0.05$).

The results of the NEI for each trailer and its relationship with STRT are shown in Figure 8. Note that the NEI represented the changes in the neural correlate of engagement (i.e. the difference between the beta and alpha band power) from the beginning of the trailer to the middle of the trailer just before the tactile stimulus was given (see Methods for more details). The movie trailers producing longer STRT also increased the NEI. A significant correlation was found between the NEI and STRT ($r = 0.85$, $p < 0.05$). Even when we excluded the data of the control clip, the correlation remained significant ($r = 0.714$, $p < 16\ 0.05$). Especially, the NEI for the control clip as well as the trailer with the shortest reaction time (S3) were negative, indicating that the participants' engagement level might even decrease over time during watching S3 or the control clip.

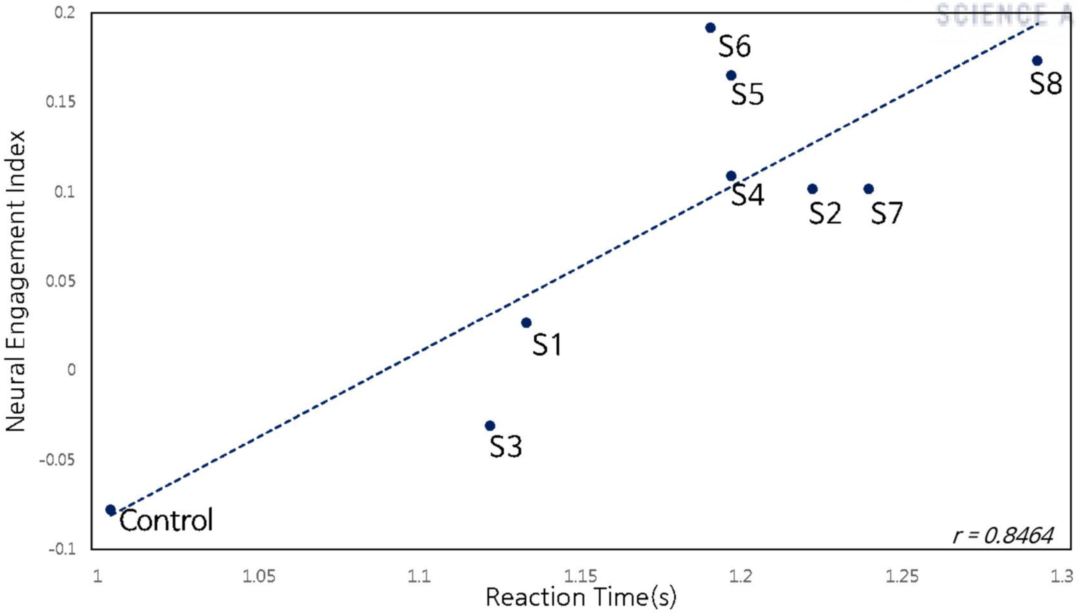


Figure 8 A linear relationship between reaction time and neural engagement. The x-axis denotes reaction time and the y-axis denotes the neural engagement index. Each dot indicates eight movie trailers plus the control video clip.

2.4 Discussion

The responses of viewers to eight movie trailers were measured by three different methods: secondary task reaction times (STRT), the neural engagement index (NEI), and self-reporting. The evaluation of the results using the three methods showed that the NEI results were significantly correlated with the STRTs, but the two types of results showed no correlation with self-reporting or with each other. The evaluation suggests the development of alternative measurements to self-reporting in order to validate the neural index developed for studies in neurocinematics. The lack of correlation between self-reporting (specifically for attentiveness) and the other two factors demonstrates how limited are the subjective statements of viewers in the reporting of their cognitive responses to movie trailers. In contrast, the higher correlation of NEI, based on a reactive BCI, with STRT implies a more accurate reflection by NEI of the unconscious cognitive states of the engagement of the viewer. In this study, STRTs to tactile stimuli during the viewing of a control video clip were observed to be significantly lower in comparison with those during the viewing of the movie trailers. Such short STRTs for the control clip suggest that the content of video clips affects the allocation of attentional resources in the brain(Baumann et al., 2007; Wickens & LAB., 1981). Thus, different STRT values for individual movie trailers can be used to indirectly assess how much a movie trailer engages a viewer's attention. A longer STRT may indicate a higher level of engagement.

As the subjective ratings of the self-reported data did not correlate with STRT, this discordance may imply that self-reported data did not suitably reflect the more autonomous and unconscious immersion of the viewers when watching the movie trailers.(Boksem & Smidts, 2015) Unlike the self-reported data, the NEI significantly correlated with STRT, demonstrating conformity between the two objective measures and the existence of a possible discrepancy, which is a primary issue that neurocinematics attempts to address, between the conscious and unconscious responses of the viewers to the trailers.(Brunner, Bianchi, Guger, & Cincotti, 2011) Previous studies had used subjective self-reported data as validation of the neural indices of cognitive states, but this created a paradox of using subjective data to validate objective measurements, which were developed in the first place to overcome the limitations of subjective self-reported data.(Hasson, Furman, Clark, Dudai, & Davachi, 2008a; Koelsch, 2014; Smith & Gevins, 2004) For the above reasons, the adoption of a psychophysical measure, such as STRT, could be a more objective way of measuring a viewer's engagement in movie trailers, and be used to evaluate the NEI. The particular NEI developed in this study may reflect engagement more objectively than do traditional self-reports, and can be validated by other behavioral data. However, there is always the possibility that measuring the STRTs and neural responses had produced incorrect results, while self-reporting had, in fact, provided more accurate responses from the viewers. The results of this study may mean that assessments in neurocinematics, and even more broadly in neuromarketing, may have to be applied differently depending on the type of data or information that is to be collected. The more autonomous and non-conscious responses, such as immersion or the engagement, of viewers to a movie may be better reflected by neural data, while the rational and conscious responses, such as interests or anticipation, may be better represented by self-reporting. The study demonstrates the ability of NEI to be a more objective measurement of a viewer's engagement in a movie trailer.

A previous study also identified the possibility of predicting the commercial success of a movie from the EEG data recorded from the neural responses of viewers as they watched a movie trailer.(Boksem & Smidts, 2015) In contrast, this current study did not address the making of such predictions, but rather focused on finding a specific index regarding the level of a viewer's engagement in order to develop a solid evaluation measure for use in neurocinematics.

There are potential issues that can be addressed as a complement to the current study. The first issue is the surveys that were conducted on the four categories of fun, attentiveness, anticipation, and rank. In contrast, the collection of neural data measured only engagement, which is largely related to the results of the survey regarding attentiveness. Engagement was measured using only EEG, since STRT cannot measure the magnitude of fun or anticipation. However, it would be possible to assess other viewer responses, such as fun, if other implicit behaviors, such as facial expression or eye blinks, are measured.

The second issue is the use of only two EEG channels to develop the NEI, but it is possible for there to be different channels and frequency bands that could represent engagement better for each participant. A future study on such an individual neural engagement index is proposed.

The third issue is the participation of only 11 people in this experiment, so the generalizability of the NEI is in question. However, according to Parra et al., the assessment of TV drama in laboratory settings was successfully applied to population assessment.(Dmochowski, Bezdek, & Abelson, 2014). It is envisioned that the experimental results of the NEI in this current study may have a potential application to a population-level evaluation. Additionally, previous studies similar to the current study have also collected data from a similar number of subjects.(Hasson et al., 2004; Kwon & Lee, 2012; Wang et al., 2014; Yanagisawa, Iida, & Amasaka, 2014). The main purpose of this current study was to prove the utility and feasibility of using STRT, as well as a neural engagement index to evaluate the impact of movie trailers on viewers.

The final issue is the application of a tactile perception method to measure STRT interrupts the watching of a movie, even though it measures the implicit statements made by the viewers. We will develop secondary tasks that will assess a viewer’s engagement more reliably. One may utilize our index, in addition to other neural and behavioral responses, to evaluate the overall effectiveness or aid in the editing of movie trailers. For a given trailer in the editing phase, the time of a secondary task can be varied, while STRT and NEI can be used to identify which scenes engaged the viewers the most. In follow-up studies, we will continue the investigation of this application of neurocinematic techniques. We will also extend the NEI to assess the engagement of viewers during the viewing of whole movies or TV commercials.

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Chapter 3. Investigation of group-wise neural responses during watching movie in different conditions

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3.1 Coherent neural responses of human population during watching movie

3.1.1 Objective

Many neuroscientific studies have explored regional diverse brain functions in response to movies. Especially, previous studies focused on group-wise brain responses to movie based on an assumption that cinema induces a cultural experience rather than as well as an individual experience. These studies have used a group analysis technique such as the inter-subject correlation (ISC) that measures how a group of viewers coherently responses to a particular given scene movie (Kauppi, J. P., J1UiskeHiinen, I. P., Sams, M., & Tohka, J, 2010; Hasson, u., Furman, 0., Clark, D., Dudai, Y, & Davachi, L., 2008b). The ISC has been primarily used in finding significantly correlated voxels from functional magnetic resonance imaging (fMRI) data (Hasson, U., Nir, Y, Levy, I., Fuhrmann, G., & Malach, R, 2004). It has also been applied used to analyze electroencephalography (EEG) data to derive correlations over time between among viewers (Hasson, U., Landesman, 0., Knappmeyer, B., Vallines, I., Rubin, N., & Heeger, D. J.,2008a). Previous studies acquired group responses typically in a serial experimental protocol where the brain response in individuals was measured one at a time, except a few recent studies (Lankinen, K., Saari, J., Hari, R., & Koskinen., M, 2014; Kasuppi et al., 2010,). However, in order to investigate group responses in a more sociocultural context, in which the effect of cinema on human social cognition may be more accurately represented, one needs to collect the brain activities of multiple people simultaneously during watching a movie.

In this study, we simultaneously measured brain activities of multiple subjects while they were watching a Korean movie (The Chaser, 2008, Bidangil, Inc., South Korea) together at the same place. We analyzed spectral ISC in five distinct frequency bands: Delta (2~4Hz), Theta (4~8Hz), Alpha (8~13Hz), low Beta (13~18), and high Beta (18~23Hz). A non-parametric permutation analysis was used to assess statistical changes in ISCs over time. We found several time periods throughout the running time of the movie in which the ISCs of all frequency bands exhibited significant changes ($P<0.05$). We examined the contents within these periods and found that they included information essential to the development of the plot or the maintenance of emotional intensity. Our results demonstrate that the spectral inter-subject correlation analysis of EEG signals simultaneously recorded in multiple people may provide insights on how a movie elicits common brain responses in accordance with the contents of the movie.

3.1.2 Method

3.1.2.1 Experimental Procedure

Four university students (All males, Mean age= 26.5, SD = 1.73) participated in the experiment. All participants had normal or corrected to normal vision. The movie stimulus used in this study was a Korean movie, The Chaser (2008) (119 minutes and 55 seconds long). Since all participants were native Koreans, we used chose a Korean movie as a stimuli in order to remove the influence of the subtitle. All participants watched this movie for the first time.

Participants were shown this movie together in the same time and space at once. The experiment was conducted in a little theater that has 100 seats, large screen and a sound system located at Hanyang University. During the movie presentation, the EEG of all participants were simultaneously recorded using a 2-channel EEG headband type system (Braino, SOSO Inc., South Korea). The EEG was attached on participants' forehead. We used this dry EEG sensor so as to provide participants a more practical and comfortable environment for watching movie. Four laptop computers were located on the back seat of each participant to receive data from the EEG device through a wireless link.

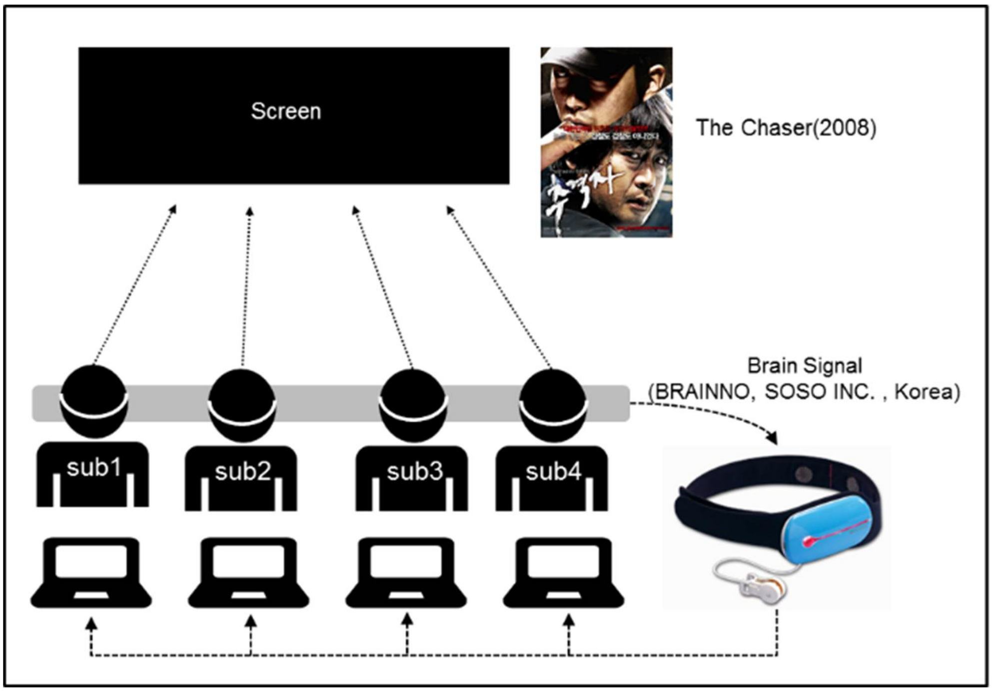

Figure 9 Experimental design

3.1.2.2 Data Analysis

A sampling rate of EEG recording was 256 Hz. Signals from 2 channels were band pass filtered using five frequency bands: Delta (2~4 Hz), Theta (4~8 Hz), Alpha (8~13 Hz), Low beta (13~18 Hz), and High beta (18~23 Hz). We calculated the ISC of a pair of participants between the temporal patterns of the spectral power within each band (Figure 10, left). These frequency-specific ISCs were repeatedly measured among all possible six pairs of participants (Figure 10, right).

The ISC at a given time was calculated within a sliding window. Each window spanned 2 minute, and overlapping with by a 100 seconds step. We performed a non-parametric permutation analysis to test significance of the ISC in each window. Permutation was conducted by shuffling a temporal order of the spectral power data in one subject of a given pair throughout the entire period of the movie. Then, we computed the ISC from the shuffled data. This procedure was repeated 500 times. We established to obtain the mean and a 95% interval from the permuted data for each window. We tested whether the ISC from the real data exceeded the 95% confidence interval or not.

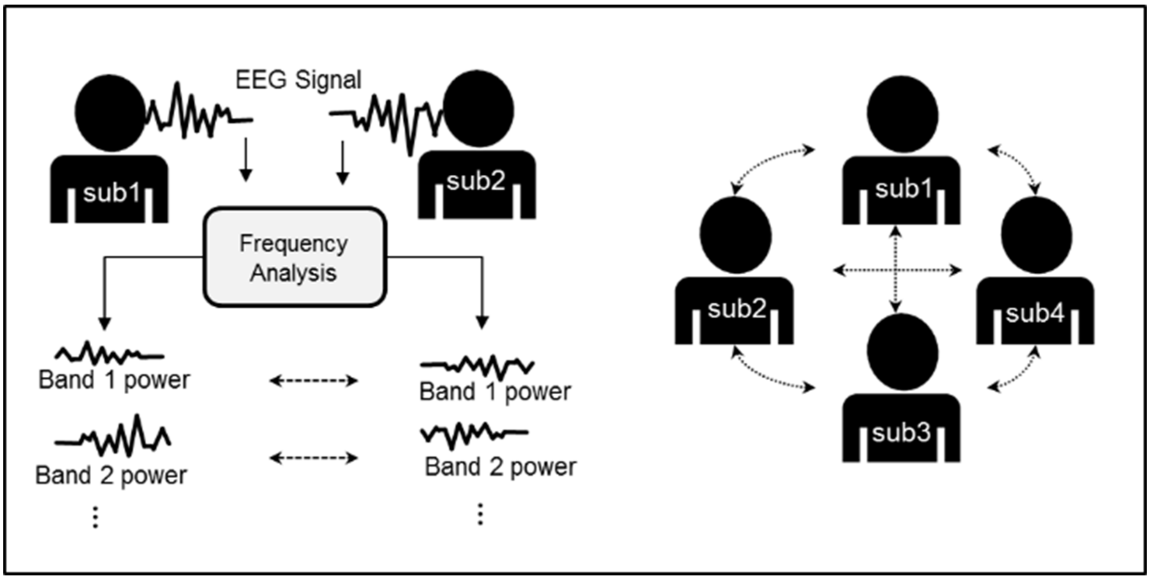

Figure 10 A diagram of spectral inter-subject correlation analysis procedure.

3.1.3 Result

Figure 11 and 12 show the ISC for each of 5 spectral bands in the early and late parts of the movie, respectively. They illustrate the temporal sequences of the ISCs. We particularly focused on the time slots where we observed significant increases in the ISC across in every most power frequency bands ([1] and [2] in Fig. 11 and [3] to [5] in Figure. 12).

We compared the five selected time slots, which showed the significant increase in all five power bands, with the corresponding movie scenes (Figure. 13). We observed that The ISC seemed appeared to increase when the scene was likely to arouse emotional responses or provide key information in understanding comprehending the plot of the movie. The first scene in Fig. 5 depicted the occurrence of the murder for the first time in the movie; the victim begged for her life to the murderer. It obviously aroused emotional responses in the viewers. The murder was committed in the toilet so as to increase the tension. The two main characters (the murder and detective) confronted each other for the first time in the second scene of Figure. 13. From this scene, viewers might become more immersed in the plot to see whether the detective would notice murderer. This scene foreshadowed upcoming conflicts between characters. In third and fourth scenes, the murderer expressed his emotional reaction for the first time. The last scene in Figure. 13 was the climax of the movie. The woman who was supposed to be killed at the early phase of movie was alive and tried to run away but captured by the murderer again. This scene was recalled very well from the viewers for making the viewers be in a fidgety. Also figure 14, screenshot of one of the largest Korean website, shows the most impressive scene reviewed by general viewers of the same movie that is used in experiment. Among the most impressive ten scenes, six scenes were corresponded with the five time slots selected from our experiment. That is, our result shows a possibility to extend general response to movie from not only the subjects but also general viewers of this movie.

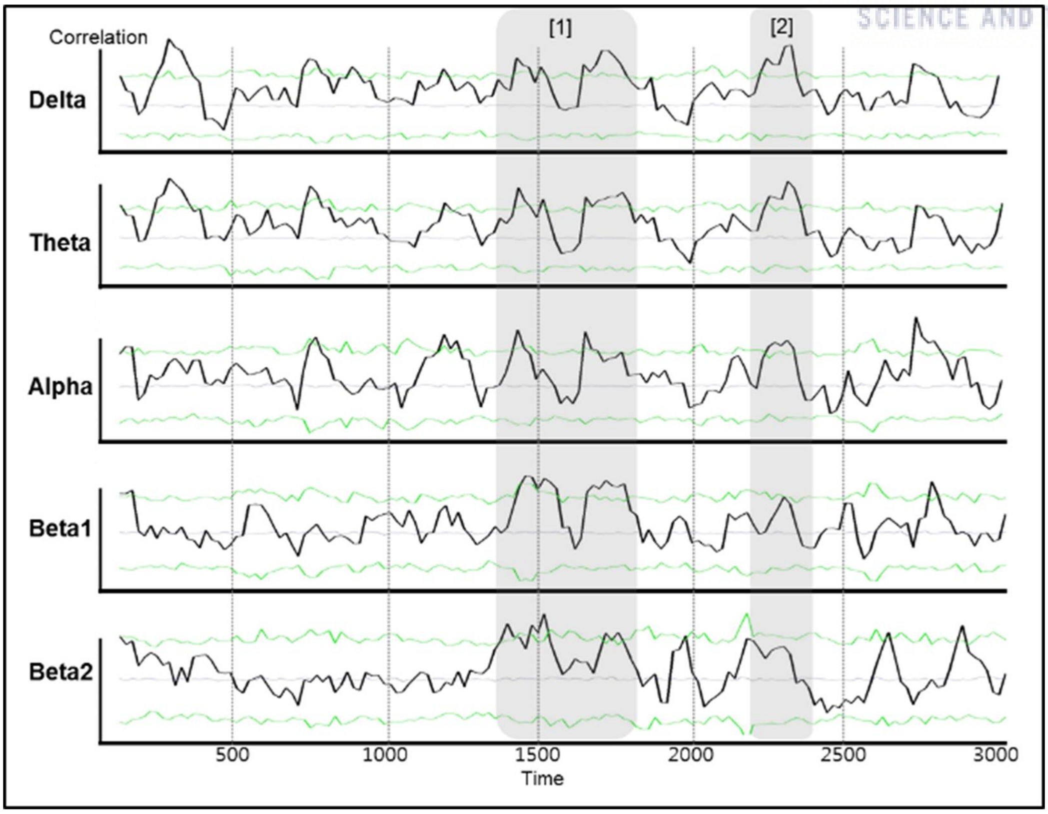

Figure 11 An illustration of the temporal changes in the inter-subject correlations (TSCs) of each frequency band in the early part of the movie (0~3000s)

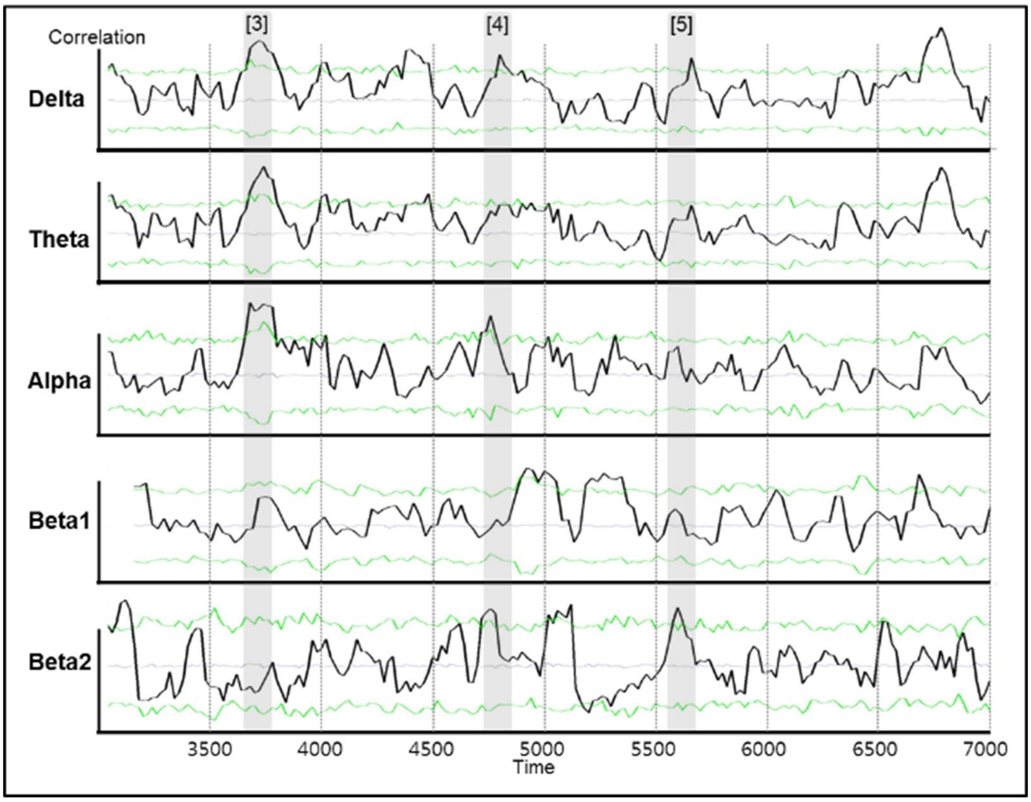

Figure 12 An illustration of the temporal changes in the inter subject correlations of each frequency band in the late part of the movie (3001~7000s)

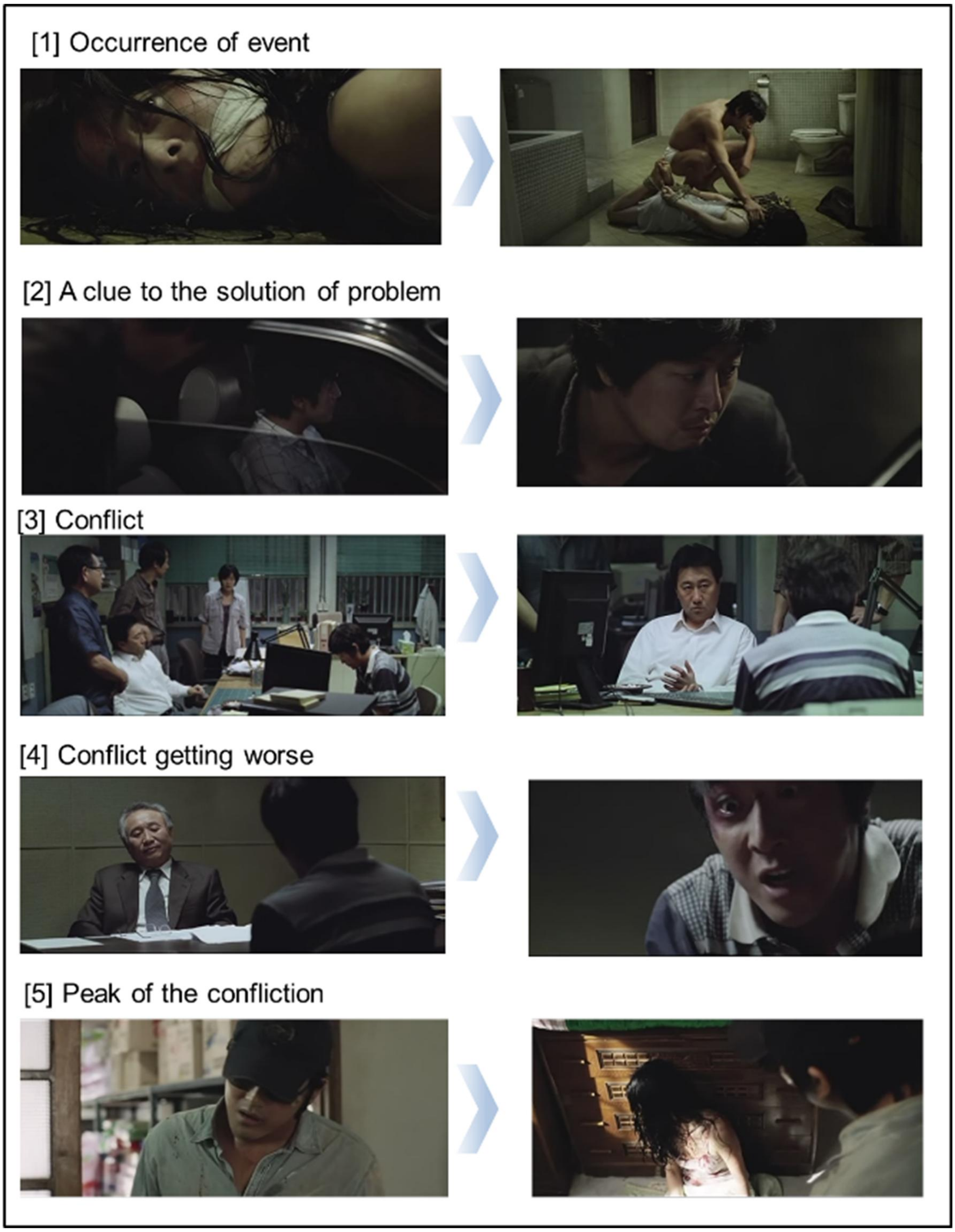

Figure 13 Examples of movie scenes (The Chaser, 2008, Bidangil, South Korea) corresponding to collective increases in the ISCs.

Figure 14 Screen shot of most impressive scenes in movie (The Chaser, 2008, Bidangil, South Korea) reviewed by users of Korean website NAVER(Sungnam, South Korea)

3.1.4 Conclusion

In order to investigate group-wise brain responses, this study used spectral ISC to observe the brain activities of a group of people as they watched a movie. Increases in the ISC were observed during scenes inducing emotional arousal or providing key information regarding the plot of the movie. The results show that simultaneous group-wise brain activities may develop into an index that can be used to reveal the assimilation of cognitive or emotional states of the viewers during a specific part of a movie. This index may prove useful for evaluating the level of common affective and cognitive responses that a movie induces in viewers (Hasson, U., Landesman, 0., Knappmeyer, B., Vallines, I., Rubin, N., & Heeger, D. J. 2008a).

3.2 Investigation of group-wise neural responses during watching movie in different conditions

3.2.1 Objective

Studying the reactions of the human brain to cultural experiences, such as cinema, has helped to understand the social cognitive functions of humans. A variety of emotional and cognitive states in viewers can be aroused by the multifaceted stimuli that are embedded in a movie (Mühl, C., 2008). Many neuroscientific studies have been conducted to explore how the diverse functions of the brain respond to movies (Hasson et al., 2004). Previous studies tended to focus on group-wise brain responses and had assumed that a movie induces not only individual experiences, but also cultural experiences. Group analysis techniques, such as inter-subject correlations (ISC), have been used by such studies to measure how a group of viewers coherently respond to a particular movie (Hasson et al., 2004; Hasson, Furman, Clarc, Dudai, & Davachi, 2008). ISC has been used to investigate data regarding significantly correlated voxels that had been gathered by functional magnetic resonance imaging (fMRI) (Hasson et al., 2004; Hasson, U., Landesman, 0., Knappmeyer, B., Vallines, I., Rubin, N., & Heeger, D. J., 2008; Bartels, A., & Zeki, S.,2004; Hasson, U., Yang, E., Vallines, I., Heeger, D. J., & Rubin, N., 2008). From the analysis of electroencephalographic (EEG) data, ICS has also been used to derive correlations over time among viewers (Dmochowski, J.P., Sajda, P., Dias, J. & Parra, L.C., 2015). In order to acquire group responses, most previous studies conducted a serial experimental protocol that typically measured the brain responses in individuals one at a time (Dmochowski, J.P., Sajda, P., Dias, J. & Parra, L.C., 2015). However, the investigation of group responses in a more sociocultural context would represent the effects of movies on human social cognition more accurately, and require the simultaneous collection of data on the brain activities of a group of people while they are watching a movie.

The present study addressed this issue by measuring brain activities of multiple subjects while they were watching a movie together and compared with brain activities of individual subjects alone. In this study, we measured two groups of subjects' brain responses during watching a movie. One group watched movie in a real theater with other people and measured brain responses at the same time. Another group watched the same movie in laboratory alone. Both two groups also conducted survey after watching a movie. We investigated inter-subject correlations (ISCs) for each five frequency bands, Delta (2~4hz), Theta(4~8Hz), alpha(8~13Hz), low Beta(13~18Hz), and high Beta(18~23Hz). Statistical significance was verified by non-parametric permutation method.

3.2.2 Method

Three groups of participants were recruited in the experiment. Each group had eight participants. Total twenty four university students (Female : 13 , Mean age = 25.63, SD =) participated in the experiment. All participants had normal or corrected normal vision. The stimulus used in this experiment was Inside men (2015)(126minutes 16 seconds long). Two groups watched this movie in real theater with other viewers who didn't participated this experiment simultaneously. One group watched this movie in laboratory alone. Figure 15 shows two different experimental environment

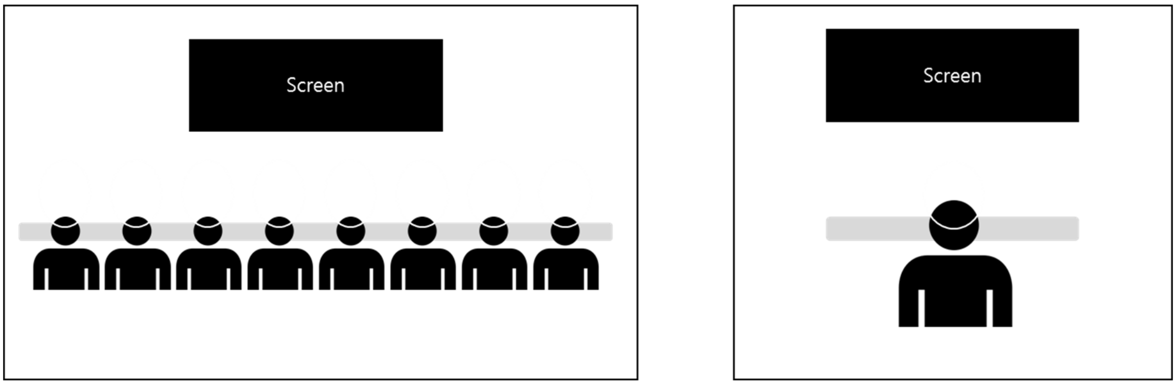

Figure 15 Different condition of watching movie; watching together(left) or watching alone(right)

During the movie was presented, participant's EEG signal was recorded using 2 channel EEG headband-type system(Braino, SOSO Inc., Daegu, South Korea). We recorded brain signals from prefrontal area of participants. After watching the movie participants did survey about the most and the least impressive scene in this movie

Figure 16 Poster of Inside men(2015)(left), and Braino(SOSO Inc, Daegu, South Korea) (right)

EEG was recorded with 256 Hz sampling rate. We removed EOG from raw data using least mean square method. In the grey box of figure 17 blue line shows raw data and redline shows data removed EOG

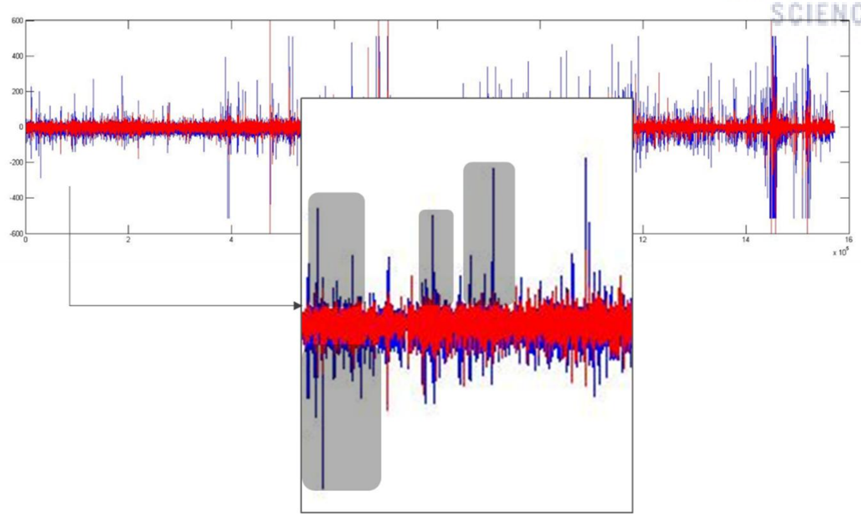

Figure 17 Raw data (Blue line) and data after removing EOG using Least mean square(Red line)

EEG signals from prefrontal area were bandpass filtered within five frequency bands: Delta (2~4hz), Theta(4~8Hz), alpha(8~13Hz), low Beta(13~18Hz), and high Beta(18~23Hz). We calculated ISC of a pair of participants, in each group, between temporal patterns of the spectral power within each band. The procedure of calculating ISC and testing significance of them were repeated after the Chapter 3.1

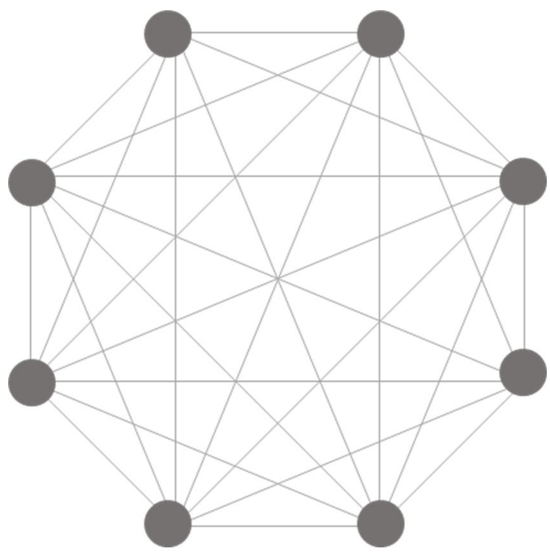

Figure 18 Spectral Inter-subject correlation analysis of one group

3.2.3 Result

We found that the number of scene that exhibited significant changes (P<0.05) among the group watched movie together was larger than alone. Figure 19 is temporal changes in the ISC of low beta frequency band of all group. Group A and Group B are the participants who watched movie together in the theater simultaneously. Individual group are the participants who watched movie alone in the laboratory.

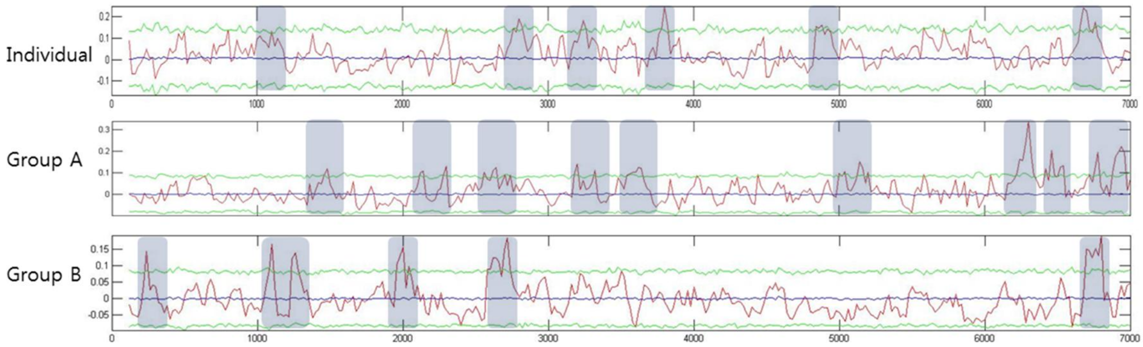

Figure 19 An illustration of the temporal changes in the inter subject correlations of low beta frequency band of all groups

Figure 20 shows survey result of most impressive scene recalled by the participants. The number of participants in group A and group B chose the same scene as the most impressive scene is bigger than that of individual group.

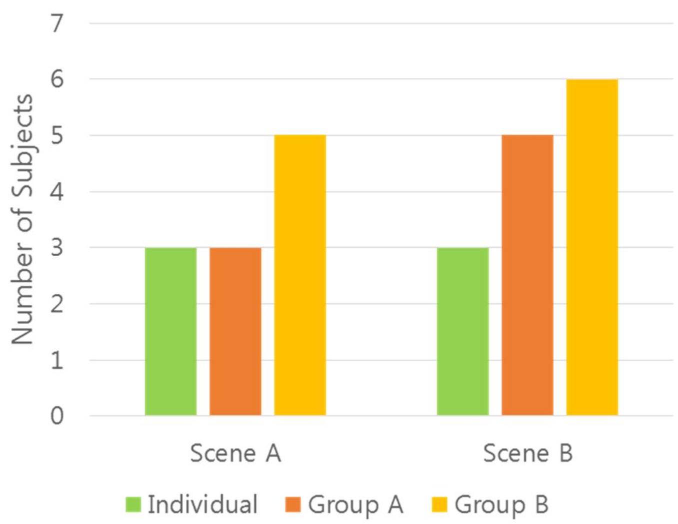

Figure 20 Survey result of most impressive scene recalled by participants

Figure 21 is capture of movie that are chosen as the most impressive scene by participants. In scene A, one of the main character is cut off his wrist. The scene was very brutal so many participants answered as most memorable scene. In scene B, a reversal in plot twists happened. One main character, who looked as betrayer, appeared like a hero and succeeded a revenge.

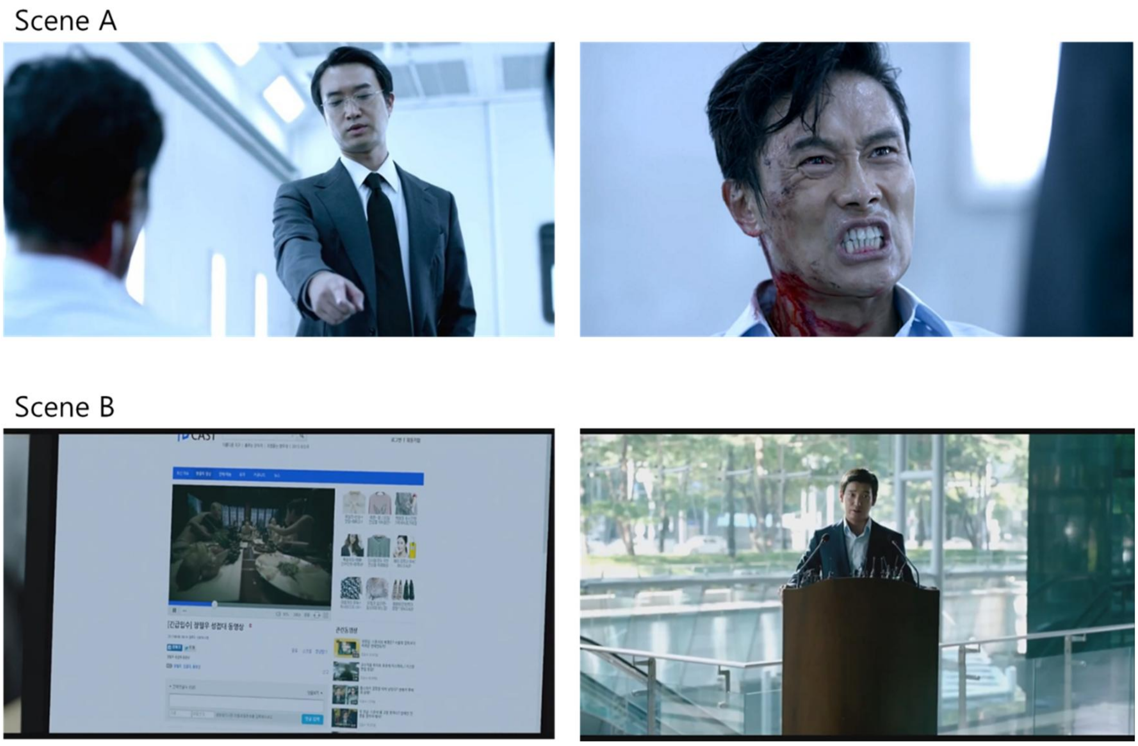

Figure 21 The most impressive two scenes recalled by experiment participants

3.2.4 Discussion

In this experiment, we investigated group-wise neural responses during watching movie in different two conditions, watching the movie together or alone. The spectral ISC was used to find group-wise responses to movie. According to the result, we suspect the assimilation of cognitive and emotional state of viewers much increases when the viewers watch movie together than watching alone. The survey result also supports this.

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Chapter 4. **Conclusion**

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4.1 Overall Discussion

Neurocinematics has recently emerged as an interdisciplinary field to probe affective and cognitive states of audiences by analyzing neural responses to movie. It aims to understand social cognitive interactions with cultural environments and effects of cinema experiences on cognitive processes in human populations. During watching a movie composing of multi-modal stimuli, viewers may experience dynamical changes in their cognitive and emotional states. Such dynamical cognitive and affective states are likely to be best examined at the level of a population of people as the movie is supposed to elicit social and cultural responses in viewers.

This study has its own meaning from two perspectives. First, it proved that the absorption degree of the movie can be objectively verified by measuring existing audience's brainwave through not the traditional survey but the psychophysics methods. In here, people can advance their opinion about measuring the absorption degree with human's brainwave is how meaningful it would be when choosing the movie by a subjective judgment. However, it becomes possible to objectively prove the absorption degree before the screen, so that it can show more reliable investment value to movie investors, which can be utilized to secure a theater. Also, it can give benefit about which scene should be utilized when producing the move trailer. New information on whether to select any movie can be provided by introducing biometric score rather than a subjective rating in the website of movie reviews. Reliability on that score is rather low because even people who did not watch the movie can participate in its evaluation as most films have been rated with a subjective evaluation.
Next, we checked the synchronization levels of the brainwave standard by simultaneously measuring brainwaves of multiple people when they watch movie. According to a study, in the case of the genre such as horror, thriller, and action film, the responsiveness of the audience is an important factor determining the success of the film. In this study, we could check that the scenes of many spectators are synchronized are the important scenes in the movie's story development, which did correspond with the scene of not a subject but many movie spectators remember that it is the main scene based on a review of a large portal site. Also, we could check that the synchronization levels of many spectators are increased in the main scene from this study. Lastly, we could check that the synchronization levels of the brainwave are changed according to the watching conditions. This means that it appears relatively different in between watching a movie with other people in a theater and watching a movie alone at home under the condition of the same movie.

4.2 Limitations and Further Work

There are several limitations in the current study. First, we verified the absorption index of the brainwave through the psychophysical methods, pointing out the limitations of the traditional survey in the first experiment. However, we started again to compare the index of the brainwave and the traditional survey in the third experiment. However, there are limitations not to analyze the entire movie when carrying out other task while watching the entire movie. In order to compensate the problem, it is necessary to use other measuring methods for the unconscious reaction of the audience as well as the brainwave and the traditional survey. For example, there is a research result that the absorption levels can be changed according to the blink rate in one study. It seems like being able to overcome the limitations of this experiment by measuring another physiological signal of these together. Also, the watching condition of many subjects and individual spectators in the last experiment may be influenced by not whether or not there are any people who watch movie together but the place of a theater or a laboratory. In order to make it sure, it is necessary to compare the reactions in watching a movie alone or with others in a theater. Neurocinematics are a filed which is highly likely to be practically applied in its nature. For example, there is a possibility to develop indicators for an age restriction rating about the film through the synchronization levels or the physiological response of the spectators. Also, studying about whether or not the absorption degree is changed depending on the responses of the surrounding spectators of colleague while watching a movie will be an interesting topic. For example, studying about “which one makes the audiences feel more interesting between the surrounding spectators burst into big laughter at a funny scene, on the other hand, and they show no response at the situation?” can be a new research topic.

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APPENDIX

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APPENDIX : 국문요약

전통적으로 뇌-컴퓨터 인터페이스는 생체신호를 통해 외부 기기를 제어하는 것을 목적으로 마비환자의 재활을 위한 연구들이 주로 이루어져 왔다. 하지만 근래에 들어서는 비 의료용 목적으로 사용자의 인지 감성적 정보 처리 과정을 이해하려는 연구로 그 개념이 확장되었고 이를 수동 뇌-컴퓨터 인터페이스 분류하였다. 그 중 뉴로시네마틱스는 수동 뇌-컴퓨터 인터페이스의 응용 연구 분야로 영화를 시청하는 동안 관람객의 인지 또는 감성 상태의 변화를 이해하고자 하는 연구 분야이다. 뉴로시네마틱스가 최근 특히 주목받고 있는 데에는 크게 두 가지 이유를 들 수 있다. 그중 하나는 영화는 시청각 자극뿐만 아니라, 문화나 환경과 같은 다양한 요소가 복합적으로 구성되어 있기 때문에 사람의 사회인지적 과정을 연구하는데 도움을 줄 수 있을 있기 때문이다. 다른 하나는 기존의 설문조사나 사후 인터뷰 방식을 통한 영화에 대한 리뷰는 관람객이 스스로 자신의 상태를 인지하는데 한계가 있기 때문에 그 신뢰도가 떨어지는데 반해 뉴로시네마틱스 연구에서는 생체신호를 통해 이를 관찰하기 때문에 보다 객관적인 검증이 가능해지기 때문이다.

하지만 기존 연구들에서는 생체신호를 통한 뉴로시네마틱스 연구 결과를 다시 기존의 설문조사 결과와 비교를 통해 검증하는 방법을 사용한 경우가 대부분이었다. 또한 다수 피험자가 동일한 영화를 보고 같은 반응을 보이는지에 대한 연구가 많이 이루어 졌는데 모두 개별 관람을 통해 생체 신호를 획득하였다. 본 연구에서는 이러한 점을 기존 연구들의 한계를 극복하기 위해 정신물리학적인 방법을 도입하여 뇌파 데이터를 통해 추출한 몰입도 지표의 객관성을 검증하였다. 그리고 다수 피험자가 동시에 한 공간에서 영화를 관람 하는 동안의 뇌파를 측정하여 피험자간 뇌파 동기화 수준이 어떻게 변화는지 확인하였고 끝으로 개별 관람과 단체 관람 두가지 조건에서의 뇌파 동기화 수준이 달라지는 것을 검증하였다.

먼저 첫 번째 실험에서는 몰입도를 나타낸다고 알려진 정신물리학적 방법 Secondary task reaction time(STRT)를 이용하여 뇌파 몰입도 지표 (Neural Engagement Index, NEI)를

평가하였다. STRT 는 피험자가 주어진 주요 과제를 수행하는 동안 부가적으로 주어진 촉각 자극에 대한 반응 속도를 측정한 것으로 주요 과제에 대한 몰입이 높을수록 반응속도가 느려진다고 알려져 있다. 이 실험에서 피험자는 8 개의 개봉 예정 영화의 트레일러를 시청하는 동안 STRT, NEI 를 측정하고 각각의 트레일러를 시청후 설문조사를 완료 하였다. 그 결과 STRT 와 NEI 사이에는 유의미한 상관관계가 나타났으나 설문조사는 STRT 과 NEI 와 유의미한 상관관계를 보이지 않았다.

두 번째 실험에서는 네명의 피험자가 동시에 추격자(2008, 비단길)를 보는 동안 뇌파를 측정하여 5 개의 서로 다른 주파수 대역별 동기화 수준(Inter subject correlation, ISC)를 분석하였으며 Sliding window 방식으로 시간대별 상관관계를 분석하였다: 델타(2~4Hz), Theta(4~8Hz), Alpha(8~13Hz), low Beta(13~18Hz), high Beta(18~23Hz). 또한, 도출된 상관관계의 유의미성 검증을 위해 non-parametric permutation 분석을 통해 각 window 별 time shifting 된 데이터의 상관계수 평균 및 그 95% 범위를 확인한 결과, 각 밴드 상관계수들이 유의미성을 지니는 특정 시간대들을 관찰하였다. 그 결과 영화 러닝타임 전체에 걸쳐 부분적으로 피험자 밴드파워 간 상관관계가 유의미하게 증가하는 구간이 관찰되었다. 특히 감정적으로 고조되는 구간들에서 유의미한 상관관계가 많이 검출되었으며 이는 영화 전개상 중요 장면에 해당되는 장면들로 다수의 관람객들이 주요 장면으로 꼽은 장면과 일치하였다.

세 번째 실험에서는 두 번째 실험 결과를 바탕으로 뇌파 기반 공감반응 모델을 적용하여 동일한 영화 컨텐츠를 볼 때 관람 조건에 따라 관객의 공감 반응이 달라지는지는 확인하였다. 관람 조건은 영화를 동시에 관람한 관객 그룹과 같은 영화를 별도의 공간에서 개인적으로 관람한 관객 그룹으로 나누었다. 그룹당 8 명의 피험자를 모집하여 실험을 진행하였고 집단으로 관람한 두 그룹 및 개별 관람한 한 그룹의 데이터를 구축하여 각 그룹의 뇌파 주파수 별 Inter subject correlation coefficient 를 적용하여 집단 반응 정도를 분석하였다: 델타(2~4Hz), Theta(4~8Hz), Alpha(8~13Hz), low Beta(13~18Hz), high Beta(18~23Hz). 영화

관람 전체 시간 동안 ISC 값이 통계적으로 유의미하게 증가한 비율을 분한 결과 영화를 동시에 관람한 두 그룹의 ISC 증가 비율이 개별 관람한 그룹의 ISC 증가 비율보다 모든 주파수 대역에서 더 크게 나타남을 확인하였다.