Evaluation of Biomedical Signals Data from Moviegoers

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***Abstract*—Moviemakers must be able to estimate moviegoer's level of engagement while watching the movie. Thus far, however, most studies have focused on the story itself from the viewpoints of subjective reviewers. In this study, we tried to estimate the engagement of moviegoers objectively by measuring their physiological signals. The physiological signals include electroencephalogram and photoplethysmogram. However, it is difficult to measure biomedical signals compared to subjective review questions. Therefore, many researchers want to share the biomedical signal data. For this reason, it is important to evaluate the reliability of the biomedical signal data. In this research, we invented a new formula for engagement and evaluated the reliability of the biomedical signals measured from moviegoers as participants. The reliability of our data is verified by its consistency between electroencephalogram and photoplethysmogram as well as by comparison to subjective review results.**

Keywords- biomedical signals; moviegoers; reference data; reliability; consistency

I. INTRODUCTION

For the movie industry to be successful, movies must fully engage moviegoers. The engagement appears to emerge from the interaction between message structure and content [1]. Although the moviegoer engagement may have observable behavioral correlates such as the direction of gaze, it is not itself directly observable by others. As a result, judgments about whether, or how much, a movie succeeds in engaging the moviegoer are typically inferred by indirect or *post hoc* measures such as subjective ratings [2]. Standard marketing techniques employed so far have involved the use of interviews and the compilation of questionnaires for the subjects after viewing the movie. Nowadays, however, the focusing of attention can be monitored by measuring associated changes in brain electrical activity with the electroencephalogram (EEG). Thus, in principle, EEG measures have the potential to provide a more direct and objective method for gauging the intensity and nature of moviegoer engagement [3].

Because the EEG is mainly due to the activity generated on the cortical structures of the brain, it is almost impossible to precisely infer the moviegoer's emotions being processed in the deep brain [4]. Hence, it is practical to infer the internal emotional state of the moviegoer by using indirect signs, such as the activity of the sweat glands on the hands and/or the variation of the heart rate [5]. Therefore, when we evaluate the reliability of the biomedical signals data, the biomedical signals of the autonomic nervous system as well as the EEG of the central nervous system are considered together. If we measure and evaluate the EEG alone, it is a one-dimensional assessment of the data because it focuses on the replication of a single observation. According to National Institute of Standards and Technology (NIST), higher-dimensional assessments, yielding correspondingly higher levels of confidence, may be constructed using correlations with other measurements and theoretical models. In the NIST approach, multiple independent observations of related properties are used together to assess the reliability of any one of them. Since each property represents a different measurement perspective, a higher level of confidence may be ascribed to these data collectively, owing to the consistency of the observations across the multiple properties, than could be ascribed to any one of the properties individually. The dataset is viewed through its relations to other data, particularly through trends, correlations, and known material property relations. The central focus of this evaluation is on consistency [6].

In this study, we analyzed the brain activity as well as the autonomic nervous activity of the moviegoer while watching the movie. To measure both the brain activity and the emotional engagement of the 38 healthy participants, we used simultaneous EEG and photoplethysmogram (PPG) measurements during the entire experiment. We hope to link significant variations of EEG and PPG measurements with the subject's review results. Previous studies have shown that the moviegoer is in an engaged state when pleasure accompanies the moviegoer's concentration on the movie. As an index for concentration, the power of the 'low beta' frequency band, 13 to 20 Hz, of EEG is increased while that of the 'theta' frequency band, 4 to 8 Hz, is decreased [7]. By the Wendy Heller model [8], when the moviegoer feels pleasure, the left frontal cortex is more activated compared to that of the right, i.e., the power of the 'alpha' band, 8 to 13 Hz, of the EEG on the right side of the frontal cortex is larger than that on the left side of the frontal cortex. This study examines whether changes in the biomedical signals of the peripheral nervous system as well as the spectral composition and regional cortical distribution of the EEG might be systematically related to the degree of a moviegoer's engagement in the movie. In this study, we defined the engagement index which is the sum of the concentration index and the pleasure index.

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II. METHOD

A. Experimental Design

Thirty-eight healthy volunteers (range = 18 to 38 years old, mean age 23.3 ± 4.7 years; 14 women) living in Orlando, Florida in the USA were recruited for this study. When the participants arrived at the University of Central Florida Center for Emerging Media (UCF CEM), they were fully informed of the purpose of the experiment and its procedure and subscribed on the consent form, which was approved by the institutional review board (IRB) of UCF. Next, they were guided to an audio-video room (AV room) for the experiment. The AV room was an electrically-shielded, dimly-lit room. As an AV system, a Sony 1,000 Watt, 5.1 Surround Sound, Blue Ray Home Theater System (BDVE580) was used.

The procedure of the experiment consisted of two parts. The first part was to measure biomedical signals from participants during watching the 112-minute American film, *Iron Man.* During this first part, subjects were requested to pay attention to the movie and not move their fingers, etc., if possible. The second part, after watching the movie, was to evaluate how the participant felt while watching the movie. In this second part, subjects were asked to recall when and why they felt the most pleasure, most anger, most engaged, etc., in the film. The experiments were carried out three times a day: the first session was from 8 am to 12 pm, the second session was from 1 to 5 pm, and the last session was from 6 to 10 pm. In each session, three or four participants attended simultaneously (refer to Fig. 1).

After the participants sat down on the comfortable chairs in the AV room, the electrodes of the biomedical signals were attached to the participants. To measure two channels of the EEG, the AgCl electrodes were attached at Fp1 and Fp2 for active signals, at A1 and A2 linked for reference, and at Fz for a ground according to the international 10-20 electrode placement system. EEG conduction cream was applied to attach the electrodes and kept the impedance below 5 kΩ. To measure one channel of the PPG, its sensor was attached on the index finger. A strap was used to attach the PPG sensor. The conduction gel was used to enhance the conduction. After attachment of the electrodes, the participants took a 10-minute baseline state. Then, the main experiment of measuring biomedical signals was begun. The biomedical signals, two channels of EEG and one channel of PPG, were recorded for each participant. Therefore, 12 channels of biomedical signals from four participants were recorded during 112 minutes by means of MP150 and Acq*Knowledge* software version 4.2 (Biopac, USA, [9]).

Figure 1. The audio- video room for the movie engagement experiment.

To minimize any contributions from offset effects and any uncertainty about the temporal alignment of the movie presentation with the biomedical signals' time series, the first 1 minute of each signal was eliminated. After that, the starting points of each of the 38 signals were aligned for the EEG and for the PPG, respectively. Finally, the power spectrum was analyzed over equal length to the shortest length of 38 signals for the EEG and for the PPG, respectively.

B. Recordings for Central Nervous System

Raw EEG traces were first band pass filtered (high pass = 0.5 Hz; low pass = 30 Hz). We collected the EEG activity to a personal computer at a sampling rate of 1,000 Hz. The EEG traces were then segmented with 30-second windows to remove the segments containing severe noises due to eye movements, blinks, and muscular artifacts. The criteria of rejection was larger than + 80 µV or less than - 80 µV. Fast Fourier transforms (FFT) were then computed on 50%-overlapped groups of 512 sample (0.5 second) Hanning windows for all artifact-free data segments, providing estimates of spectral power with 0.125 Hz frequency resolution. Then, the FFT was applied to obtain the power spectral density (PSD) for each segment of a good signal-to-noise ratio. The PSD for a 30-second window moving with a 10-second interval was calculated for the entire 112 min.

C. Recordings for Autonomic Nervous System

Autonomic activity, the variations of the peak intervals of PPG, was recorded with an MP150 system and Acquisition software version 4 (Biopac, USA) with a sampling rate of 1,000 Hz. The PPG sensor was attached to the palmar side of the second finger of the participant's non dominant hand by means of a velcro fastener. Before applying the sensors, the subjects' skin was cleaned. The PPG signals were continuously acquired for the entire duration of the movie, and its PSD was calculated. In this way, we obtained a signal in the frequency domain for the biomedical signals from moviegoers. In particular, the whole interval was spanned with a series of time windows of 5 min each.

Spectral components were identified and then assigned, on the basis of their frequency, to one of two bands: Low Frequency (LF), 0.04 to 0.15 Hz, or High Frequency (HF), 0.15 to 0.4 Hz. These components were obtained in absolute values of power (ms^2). The Very Low Frequency (VLF) band, 0.01 to 0.04 Hz, was excluded from the present analysis since it is not of interest for our purpose. Several studies indicate that the LF band corresponds to baroflex control of the heart rate and reflects mixed sympathetic and parasympathetic modulation of Heart Rate Variability (HRV); instead, the HF band corresponds to the vagally mediated modulation of HRV associated with respiration. The ratio LF/HF was used as the index of the balance between the sympathetic and vagal activity [10]. For emotion, previous study showed that the ratio MF/(LF+HF) reflects positive emotion while the ratio LF/HF reflects negative emotion, where the MF is a Middle Frequency band of 0.08 to 0.15 Hz [11].

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III. RESULTS AND DISCUSSIONS

A subjective review result of when and why the participant was most engaged is shown in Table 1 for five representative participants among 38 participants, and the corresponding scenes are shown in Fig. 2. In this study, we invented a new formula evaluating the participant's engagement as follows:

$$Z \equiv aX + bY \quad (1)$$

where the Z : index of engagement, X : index of concentration, Y : index of pleasure, a and b are the weighting factors. In this research, the a and b are set to 1.

$$X \equiv Fp_{[1+2]}(\beta_L/\theta) \equiv \frac{Fp_1(\beta_L)+Fp_2(\beta_L)}{Fp_1(\theta)+Fp_2(\theta)}, \quad (2)$$

where,
$Fp_1(\beta_L)$: EEG power of low beta band, 13 to 20 Hz, at Fp_1
$Fp_2(\beta_L)$: EEG power of low beta band, 13 to 20 Hz, at Fp_2
$Fp_1(\theta)$: EEG power of the theta band, 4 to 8 Hz, at Fp_1
$Fp_2(\theta)$: EEG power of the theta band, 4 to 8 Hz, at Fp_2

$$Y(central) \equiv nFp_{[2-1]}(\alpha) \equiv \frac{Fp_2(\alpha)-Fp_1(\alpha)}{Fp_2(\alpha)+Fp_1(\alpha)}, \quad (3)$$

where,
$Fp_1(\alpha)$: EEG power of the alpha band, 8 to 13 Hz, at Fp_1
$Fp_2(\alpha)$: EEG power of the alpha band, 8 to 13 Hz, at Fp_2

$$Y(pheriperal) = \frac{MF}{(LF+HF)}, \quad (4)$$

where,
MF : PPG power of 0.08 to 0.15 Hz
LF : PPG power of 0.04 to 0.08 Hz
HF : PPG power of 0.15 to 0.4 Hz

By using from (1) to (4), the concentration from EEG and the pleasure from EEG and PPG were calculated, averaged over 38 participants, and shown in Fig. 3. Between 70 and 75 minutes, the concentration index of EEG as shown in the upper part, the pleasure index of EEG as shown in the upper part, the pleasure index of PPG as shown in the middle part, and the pleasure index of PPG as shown in the lower part are relatively very high. These peaks are shown in red rectangular boxes in Fig. 3. Moreover, most of subjective review results in Table 1 also showed the strongest engagement during this time interval. The EEG and PPG measured from 38 participants showed consistency from the viewpoint of engagement. Therefore, the reliability of our dataset as well as the new formula for engagement is verified. To represent the participant's emotion precisely, it is necessary to measure the biomedical signals from the peripheral nervous system as well as from the central nervous system. Our results also support the previous hypothesis that if the participant is in the engagement state while watching the movie, the pleasure accompanies the concentration on the movie.

TABLE I. RESULTS OF REVIEW QUESTIONAIRE FOR *IRON MAN*

Participants	**Time period of maximum engagement**	**Subject evaluation: *(The reason why the most engaged)***	**Physiological signals**
1	72 m 07 s ~ 81 m 01 s	This is the scene where the newly finished/painted Mark 2 suit is first being used. Tony uses it to destroy the terrorist village and save innocent people.	In Fig. 3 between 70 and 75 minutes, the concentration from EEG (upper part) and the pleasure from EEG (middle part) and from PPG (lower part) averaged over 38 participants are relatively very high.
2	72 m 50 s ~ 72 m 51 s	Iron man suit with new color scheme.	
3	74 m 13 s ~ 80 m 48 s	Iron man was cool to see fighting.	
4	73 m 00 s ~ 78 m 00 s	This was an action scene.	
5	74 m 14 s ~ 79 m 12 s	It makes me happy that Tony perfected his project and he can help others and fly anywhere he likes.	

Figure 2. Corresponding scenes of *Iron Man*, selected from each time intervals in Table 1, when the participants were most strongly engaged.

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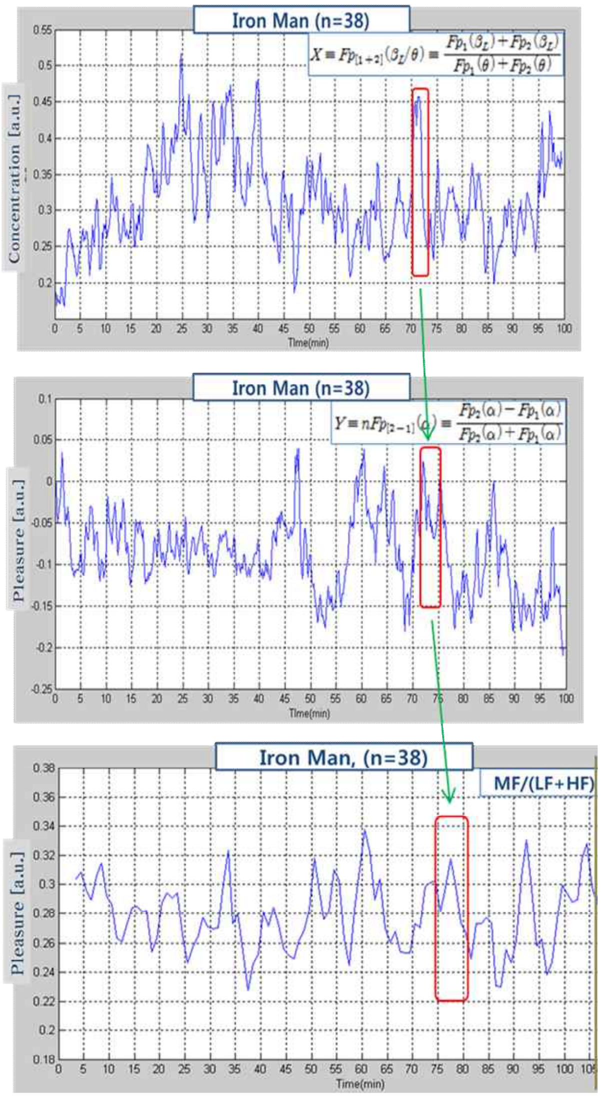

Figure 3. Change of participant's concentration (upper) evaluated from EEG, pleasure evaluated from EEG (middle) and from PPG (lower).

IV. CONCLUSION

For the same time interval, the concentration from EEG and the pleasure from EEG and PPG calculated from the new formula were relatively very high. This show that not only the pleasures calculated from the EEG and the PPG separately are consist but also it accompanies the concentration simultaneously. Moreover, most of subjective review results also showed the strongest engagement during this time interval. Therefore, the validity of our dataset as well as our formula are verified. Our results also support the previous hypothesis that if the participant is engaged in watching the movie, pleasure accompanies this concentration on the movie.

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