Relationship between Bio-signals and Motion Speed of Video Images

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Abstract—Healing music and Musicotherapy attract attentions recently. They are beginning to be used in the medical treatment. On the other hand there are little practical utilization to relax with video images compared with music. Visual information is said to occupy about the whole of 80% humans receive from five senses. Therefore it has some potential that visual information affects human’s mental and physical state as well as aural information does. This paper attempts to investigate the relation between characteristics of video images and mental relaxation. The one of characteristics we focus is motion speed of video images. It is considered that it might correspond to tempo of music. This paper investigates the relaxation effect by using the index calculated by heart rate variability analysis. The experimental results and analysis confirmed that viewing video images might have higher effect of reducing stress than eyes closed state and the relaxation effect might depend on motion speed.

I. INTRODUCTION

Recent stressed society becomes more serious than before. Many people are suffering from some stress and living surrounded by several stressors, e.g., working, studying, human relationships and so on. In such a stressed society, some goods and services, which give relaxations to people, are in great demand: body massage, reflexology, healing music and healing video. Especially, relaxation with music has attracted attentions recently. And there were various researches with regard to relaxation with music. Healing music is used in the medical treatment as “Musicotherapy”. In “Musicotherapy”, there are psychological treatments based on “Iso-principle” that is one of the most famous theory of music psychology. It is empirically said that music which has the similar characteristics to the negative mood in listening is effective in relaxation[1]. Holbrook had investigated the relationship between listener’s situational arousal and effects of music tempo[2]. His experimental result is shown in Fig.1. His experiment confirmed that the participants in high arousal preferred faster tempo music than ones in low arousal. Murayama had investigated the relationships between the relaxing effects of music and biological rhythm in the human body[3]. His experiment confirmed that there were the relationships between them. Thus, there are some verification and research about relaxation with music.

On the other hand visual information is said to occupy about the whole of 80% humans receive from five senses, and there are little practical utilization to relax with video images. Therefore it might have some potential that visual information affects human’s mental and physical state as well as aural information does. Besides, recent mobile computers and cell phones can easily display visual information such as high-quality video images. The aim of our study is to investigate the relation between characteristics of video images and relaxation. We expect that the videos, which have the characteristics we will find, reduce viewers’ stress.

Here, we assume the suitable situation the users can view the videos. It is difficult for you to do some other things while viewing the videos. In other words it might be impossible for you to view the videos while you are under some mental workload, e.g., taking some examination and working hardly. Therefore we assume the situation that the user takes a short break at work, class or examination. In the situation the user may not be directly under mental workload, but its bad influences must remain on mental and physical aspects of him.

As a first step of our study, this paper attempts to investigate the relation between motion speed of video image and relaxation effect. As already stated, some studies have explained the relationships between music tempo and relaxation effect, and we suppose that music tempo corresponds to motion speed of...
video images. This paper investigates the relaxation effects by using the index calculated by heart rate variability analysis.

II. EVALUATION OF RELAXATION

There exists some ways to evaluate effects of relaxation. For example, electroencephalography (EEG) analysis and heart rate variability (HRV) analysis. The evaluation of relaxation with EEG analysis measures $\alpha$-brainwave activity. $\alpha$-wave activity increases during closed eye conditions and mental rest, and visual stimuli cancel $\alpha$-wave activity. This phenomenon is called “$\alpha$-wave blocking”[4]. Therefore evaluation with EEG analysis seems to be unsuitable for our study using video images. Some researchers used evaluation of relaxation with HRV analysis [5]. The power spectra of heart rate variability are contained the low frequency components (LF) from 0.04 to 0.15Hz and the high frequency components (HF) from 0.15 to 0.4Hz. HF is said to be mainly affected by components originated human breathing called “Respiratory Sinus Arrhythmia (RSA)”. HF reflects the activity of the parasympathetic nerves. LF is said to be mainly affected by components originated blood pressure called “Mayer Wave related Sinus Arrhythmia (MWSA)”. LF reflects the activity of the sympathetic nerves and parasympathetic nerves. The ratio of LF to HF reflects the activity of sympathetic nerves. It is said that the sympathetic nerve activity becomes higher while feeling comfortable. Therefore HF is used as an index of relaxation. The power spectrum analysis, such as FFT, AR method and wavelet transform are generally used to calculate HF in HRV.

Yokoyama proposed a method which is able to estimate HF component of HRV based on local characteristics in time series[6]. Of course it has no need of power spectrum analysis. Yokoyama verified that there was high correlation among the average values of HF detected with her proposed method, AR method and wavelet transform. In this paper we adopt the method and HF calculated by the method is called TPA (Turning Point Amplitude), which Yokoyama defined[6]

III. EXPERIMENTS

The experiment attempted to verify the relationship between relaxation effect and motion speed of video images. Our study aims to reduce stress by viewing video images. The participants are subjected to a treadmill stress test, which is a mental arithmetic, before viewing video images. TPA, which is indicated in section II, is used to investigate the relaxation effects. The participants are 6 males and 1 female in their 20s. Every participant doesn’t have the abnormal vision and can visually confirm the motions of video images. Hereinafter details of the experiment are explained.

A. Experimental environment

The experiment is conducted in the environment shown in Fig.2. The participants keep sitting on the chair during the experiment. The video images are projected to the screen. The participants view the video images which are generated and controlled by the computer for replaying the video images. The computer for displaying mathematical questions asks questions which enhance the participants’ mental workload. The pulse waves of participants are measured by the pulse sensor and the computer for measuring pulse wave. In this experiment the pulse sensor illustrated in Fig.3 is used.

B. Experimental Procedure

The experimental procedure is shown in Fig.4. Our experiment consists of two steps, the whole time is 10 min. In the first 5 min, participants solve mathematical operations in their heads (mental arithmetic). While their constraining mental arithmetic, they may be directly under mental stress. Then they finish it and in the next 5 min they close their eyes or view the video image. In this 5 min they are not directly under mental stress, but its influences must remain. Here we call the first 5 min and the next 5 min “stress state” and “resting state” respectively. In our experiment we prepare eyes closed state and 3 kinds of video image, each of which has different motion speed, for the latter 5 min resting state as shown in Fig.4. Participants perform all the experiments (1–4) in a different random order for each. A 2 min break is given to the participants between each experiment. Mental arithmetic is used as mental workload in this experiment. The details of
mental arithmetic are mentioned later. The details of the video images are also mentioned later.

C. Mental Workload

In this experiment, mental arithmetic was used as mental workload. This method of arithmetic refers to [7]. The experiment requires participants to repeat solving the mathematical questions: Subtract 13 from a four-digit figure \( X \). The first figure \( X_0 \) is given at random and you answer \( X_1 = X_0 - 13 \). Next you answer \( X_1 - 13 \). Thus the \( i \)-th question will be \( X_{i+1} = X_0 \). When participants make a mistake in such an arithmetic, it restarts over from the beginning: \( X_i = X_0 \) illustrated in Fig.5. Participants perform mental arithmetic on a computer (Fig.6).

D. Video Image

We adopt “ripples appearing on the water surface” as a video image. The ripples, which we use a CG technique for generating, are displayed on the screen. Ripples appear from the center of the image and disappear outside of the image. A capture image of the video is shown in Fig.7. The video has two parameters \( T_G \) and \( v_R \). \( T_G \) is the term of ripples generated. \( v_R \) is the velocity of ripples progressed. \( T_G \) and \( v_R \) are defined as follows and actually \( T_G \) and \( v_R \) are controlled by \( v_P \). \( v_P \) corresponds to motion speed of the video. \( \lambda_R \) is assumed to be a constant. (See Fig.8).

\[
T_G = \alpha v_P \quad (\alpha = 4) \\
v_R = \frac{\lambda_R}{v_P}
\]

In this experiment 3 kinds of the video with different motion speed are prepared: \( v_P = 0.6, 0.8, 1.0 \).

E. Analytical Method

We analyzed the effect of relaxation by the use of TPA. As the value of TPA increases, human beings become into rather relaxed. TPA time-series data is calculated from R-R interval time-series by the method Yokoyama defined[6]. R-R interval almost corresponds a heartbeat interval. Generally human heartbeat varies at each time and the time between the two peeks (R-R interval) also changes at each time. Pulse waves are measured from pulse sensor. Fig.9 illustrates TPA time series which is a noticeable example.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

TPA time series TPA(t) are obtained for each participant. TPA\(_S\) is calculated with (1), indicates TPA average of TPA(t) from \( T_0 \) to \( T_1 \). TPA\(_R\), which is calculated with (2), indicates TPA average of TPA(t) from \( T_0 \) to \( T_1 \). In each equation, \( T_0 = 0sec \), \( T_1 = 300sec(5min) \) and \( T_2 = 600sec(10min) \).

\[
TPA_S = \frac{1}{T_1 - T_0} \int_{T_0}^{T_1} TPA(t)dt \quad (1) \\
TPA_R = \frac{1}{T_2 - T_1} \int_{T_1}^{T_2} TPA(t)dt \quad (2)
\]

We will use TPA\(_S\) to refer the group of TPA(t) from \( T_0 \) to \( T_1 \) and TPA\(_R\) to refer the group of TPA(t) from \( T_1 \) to \( T_2 \) after this.
TPA(t)

Stress state
Resting state

Time[sec]

TPA(t)

Fig. 9. Example of TPA time series

A. Mental workload

First of all we attempted to confirm whether participants felt stress or not in our experiments. In other words it means whether our mental arithmetic is an appropriate mental workload or not. The experiment procedure consists of two steps, the whole time is 10 min (5 + 5 min). In the first 5 min participants perform mental arithmetic and in the next 5 min either they close their eyes or view video images. A statistical significant test was used for analyzing the difference of TPA(t) between for the first 5 min and for the next. Fig.10 shows TPA_{S} and TPA_{R} over all participants. Every TPA_{R} is higher than the corresponding TPA_{S}. Kruskal-Wallis test was carried out to compare the two groups TPA_{S} and TPA_{R} of seven participants (the bottom table of Fig.10). Consequently there are significant differences between every two groups. Thus the participants, who are either closing their eyes or viewing a video, are in more relaxed state in comparison with in their performing mental arithmetic. From the analysis one may say that our method of mental arithmetic is appropriate one of the mental workloads.

To make a detailed analysis Kruskal-Wallis test was also carried out to compare between TPA_{S} and TPA_{R} of each participant. 1st row of Table.I illustrates the number of participants x/7 with a significant difference at the 1% level. The denominator ‘7’ of x/7 indicates the total participants in our experiments. 2nd row of Table.I illustrates the number of participants y/x with the relation of “TPA_{S} > TPA_{R}” out of x with a significant difference, that is to say, 20 out of the total 28 data showed significant differences were found, and 20 out of the 20 data had the relation of “TPA_{S} > TPA_{R}”. The detailed analysis for each participant also seems to show that the mental arithmetic is appropriate.

B. TPA average

Fig.11, which is extracted from Fig.10, shows TPA_{R} over all participants. Kruskal-Wallis test was carried out to compare between TPA_{R} of seven participants (the bottom table of Fig.11). There was a significant difference between v_{p} = 1.0 and eyes closed state, and TPA_{R} for v_{p} = 1.0 is lower than the one for eyes closed state. On the other hand there were no significant differences between v_{p} = 0.6, 0.8 and eyes closed state, and TPA_{R} for v_{p} = 0.6, 0.8 were as same as the one for eyes closed state.

To make a detailed analysis Kruskal-Wallis test was carried out to compare between TPA_{R} of each participant. 1st row of Table.II illustrates the number of participants x/7 with a significant difference at the 1% level. The denominator ‘7’ of x/7 indicates the total participants in our experiments. 2nd row of Table.I illustrates the number of participants y/x with the relation of “TPA_{R}(viewing video)
TPA_{R}(eyes closed)” out of x with a significant difference, that is to say, 17 out of the total 21 data showed significant differences were found, and 7 out of the 17 data had the relation of “TPA_{R}(viewing video) > TPA_{R}(eyes closed)”. But in the case of \( v_p = 0.8 \), the majority of participants had the relation of “TPA_{R}(viewing video) > TPA_{R}(eyes closed)” out of 7 data with a significant difference. In another case of \( v_p = 0.6 \) the half of participants had the relation of “TPA_{R}(viewing video) > TPA_{R}(eyes closed)” out of 4 data. Therefore viewing the video images(\( v_p = 0.6, 0.8 \)) seems to be at least as effective as eyes closed state.

This analysis doesn’t consider the state of the mental workload (the first 5 min) and isn’t entirely fair and sufficient to evaluate the differences of relaxation effect between \( v_p = 0.6, 0.8, 1.0 \) and eyes closed state. The mental workload affects mental and physical aspects of the participants, and the effects and the influences remained must be different among the experiments.

C. TPA Changing Rate

As mentioned above we have to consider the state of mental workload(stress state). Comparing with TPA changing rate for each video the effects of relaxation are evaluated. \( \varphi \text{TPA}_{R} \), which is defined and calculated with (3), indicates the average changing rate between \( \text{TPA}(t) \) (\( T_1 \leq t \leq T_2 \)) and \( \text{TPA}_{S} \).

We will use \( \varphi \text{TPA}_{R} \) to refer the group of \( \varphi \text{TPA}(t) \) from \( T_1 \) to \( T_2 \) after this.

\[
\varphi \text{TPA}_{R} = \frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \varphi \text{TPA}(t) \, dt \\
\varphi \text{TPA}(t) = \frac{\text{TPA}(t) - \text{TPA}_{S}}{\text{TPA}_{S}} - 1.0(T_1 \leq t \leq T_2) \tag{4}
\]

Fig.12 shows \( \varphi \text{TPA}_{R} \) over all participants. Kruskal-Wallis test was carried out to compare between \( \varphi \text{TPA}_{R} \) of seven participants (the bottom table of Fig.12). There were significant differences between \( v_p = 0.6, 1.0 \) and eyes closed state, and each \( \varphi \text{TPA}_{R} \) for \( v_p = 0.6, 1.0 \) is higher than the one for eyes closed state. On the other hand there was no significant difference between \( v_p = 0.8 \) and eyes closed state, and \( \varphi \text{TPA}_{R} \) for \( v_p = 0.8 \) was as same as the one for eyes closed state.

Kruskal-Wallis test was carried out to compare between \( \varphi \text{TPA}_{R} \) of each participant. TableIII, which uses the same data format of Table.II, shows analysis. 13 out of the total 21 data showed significant differences were found at the 1% level, and 9 out of the 13 data (about 70%) had the relation of “\( \varphi \text{TPA}_{R}(\text{viewing video}) > \varphi \text{TPA}_{R}(\text{eyes closed}) \)”. In all the cases, the majority of participants had the relation of “\( \varphi \text{TPA}_{R}(\text{viewing video}) > \varphi \text{TPA}_{R}(\text{eyes closed}) \)” out of the data with a significant difference. Therefore viewing the video images seems to be more effective than eyes closed state.

In addition to this we could find significant differences between viewing videos as illustrated in Fig.12. The motion speed of video seems to make a difference for relaxation effect.
participants had the relation of “\(\Delta TPA_{R}(\text{viewing video}) > \Delta TPA_{R}(\text{eyes closed})\)” out of the data with a significant difference. Therefore viewing the video images seems to be more effective than eyes closed state.

In addition to this we couldn’t find significant differences between viewing videos as illustrated in Fig.13.

V. CONCLUSION

This paper focuses on relaxation by using video images and attempted to investigate the relation between motion speed of video and relaxation effect. The aim of our study is to reduce the stress by viewing the video images. The implications of the study mean that (a) mental stress might be reduced by eyes closed state and viewing video images, (b)viewing video images might have higher stress reducing effect than eyes closed state, (c)the effect of relaxation and stress reducing might depend on motion speed. There are many future works remained. First of all we need to prepare more participants and improve the accuracy of statistical analysis. Secondly it is desirable that motion speed of video images is dynamic controlled. TPA\((t)\) can be obtained as time series data. In order to utilize the characteristic of TPA\((t)\), dynamic motion control could display the video images with appropriate motion speed to TPA\((t)\) at each time and more effectively relax peoples. Thirdly in the near future we will generate video images with music and investigate the properties to relax the people under mental stress.

**REFERENCES**


**TABLE III**

<table>
<thead>
<tr>
<th>Eyes Closed vs Video Image</th>
<th>Video (0.6)</th>
<th>Video (0.8)</th>
<th>Video (1.0)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant ((v_p))</td>
<td>6/7</td>
<td>4/7</td>
<td>3/7</td>
<td>13/21</td>
</tr>
<tr>
<td>Video Image&gt;Eyes Closed</td>
<td>4/6</td>
<td>3/4</td>
<td>2/3</td>
<td>9/13</td>
</tr>
</tbody>
</table>

**TABLE IV**

<table>
<thead>
<tr>
<th>Eyes Closed vs Video Image</th>
<th>Video (0.6)</th>
<th>Video (0.8)</th>
<th>Video (1.0)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant ((v_p))</td>
<td>5/7</td>
<td>4/7</td>
<td>3/7</td>
<td>12/21</td>
</tr>
<tr>
<td>Video Image&gt;Eyes Closed</td>
<td>3/5</td>
<td>3/4</td>
<td>2/3</td>
<td>5/13</td>
</tr>
</tbody>
</table>

**Fig. 13.** \(\Delta TPA_{R}\) (above), Kruskal-Wallis test results between each \(\Delta TPA_{R}\) (below) over all participants.

**D. TPA Difference**

In addition to TPA average \(\varphi TPA_{R}\) and changing rate \(\varphi TPA_{R}\), another criterion is introduced. \(\Delta TPA_{R}\), which is defined and calculated with (5), indicates the average finite difference between \(TPA(t)(T_1 \leq t \leq T_2)\) and \(\varphi TPA_{R}\). We will use \(\Delta TPA_{R}\) to refer the group of \(\Delta TPA(t)\) from \(T_1\) to \(T_2\) after this.

\[
\Delta TPA_{R} = \frac{1}{T_2 - T_1} \int_{T_1}^{T_2} \Delta TPA(t)dt \quad (5)
\]

\[
\Delta TPA(t) = TPA(t) - \varphi TPA_{R}(T_1 \leq t \leq T_2) \quad (6)
\]

Fig.13 shows \(\Delta TPA_{R}\) over all participants. Kruskal-Wallis test was carried out to compare between \(\Delta TPA_{R}\) of seven participants (the bottom table of Fig.13). There were significant differences between \(v_p = 0.6, 0.8, 1.0\) and eyes closed state, and each \(\Delta TPA_{R}\) for \(v_p = 0.6, 0.8, 1.0\) is higher than the one for eyes closed state.

Kruskal-Wallis test was carried out to compare between \(\Delta TPA_{R}\) of each participant. TableIV, which uses the same data format of Table.II and Table.III, shows analysis.

12 out of the total 21 data showed significant differences were found at the 1% level, and 8 out of the 12 data (about 67%) had the relation of “\(\Delta TPA_{R}(\text{viewing video}) > \Delta TPA_{R}(\text{eyes closed})\)”. In all the case, the majority of

\[\text{Eyes Closed vs Video Image} \quad \text{Video (0.6)} \quad \text{Video (0.8)} \quad \text{Video (1.0)} \quad \text{Total} \]

\[\begin{array}{c|c|c|c|c}
\hline
\text{Significant } (v_p) & 6/7 & 4/7 & 3/7 & 13/21 \\
\text{Video Image>Eyes Closed} & 4/6 & 3/4 & 2/3 & 9/13 \\
\hline
\end{array}\]