Centre for Cognitive Science
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PROJECT REPORT 2
Correlating WujiBrainwave data with Standardized Emotional Pictures
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Executive Summary

The purpose of this project was to test the validity of the data obtained through the WujiBrainwave algorithms pertaining to different brain waves and other states like Joy, Attention etc. In a study conducted for this purpose, participants were shown 60 positive and negative emotional pictures while they wore the Neurosky headset. They were also asked to rate valence and arousal for each picture. The overall activity within each participant's session in different WujiBrainwave variables for all participants was correlated with activity in every other WujiBrainwave variable as well as overall Valence and Arousal ratings. These correlations showed desirable results. For instance, Stress reduction had a moderate positive correlation with Joy which is expected because Joy usually indicates reduction of stress. Also, there was a weak positive correlation between Joy and Valence that was expected because half the pictures shown to the participants were negative which would not lead to Joy. Delta and Deep meditation have a strong positive correlation as expected and similarly, as expected, Alpha has weak positive correlation with Attention as attention is effortless during the Alpha state. These findings, along with others discussed in the previous section, point towards the validity of the data presented by WujiBrainwave algorithms.

Study

To test the validity of the WujiBrainwave variables through a behavioral study involving emotion induction through emotional pictures

Method:

Participants: 45 students (Age group: 18 to 27 years, 33 males and 12 females) participated in this study. These students enrolled for the study through a email sent to them informing them about this study. They were paid Rs. 50 as compensation for participation.

Emotional Pictures as stimuli: In our study, participants were shown emotional pictures from the International Affective Pictures System (IAPS) Database. IAPS is a database of standardized pictures depicting different kinds of positive and negative pictures and is widely used in Emotion Research within Affective Sciences. The pictures in this database have been standardized on male as well as female participants and their normative data have been published in the IAPS manual (Lang, P. J., Bradley, M. M., & Cuthbert, B. N., 2008) that is used for assessing the effectiveness of these pictures for emotion induction in psychological studies to study effects of emotions on different kinds of attitudes and behaviors. The normative data consist of ratings by males and females on two characteristics of these images:

- Valence: Valence refers to the amount of pleasantness or unpleasantness one experiences. Generally people can distinguish between whether they experience pleasantness (i.e.- they feel like something is positive) or unpleasantness (i.e.- they feel something is negative). For each picture the participants rated the extent to which the picture was pleasant or unpleasant for them on a 9-point rating scale. A value of 0 means 'Extremely unpleasant'. It means the picture makes one feel unhappy, annoyed, unsatisfied, melancholic, despaired or bored. Value of 10 means 'Extremely pleasant'. It means the picture makes one feel happy, pleased, satisfied, contented or hopeful.

- Arousal: Arousal refers to the extent to which one feels activated or deactivated. Very often people can distinguish between whether they are feeling sleepy or excited. For each picture the participants rated the extent to which the picture was arousing for them on a 9 point rating scale. A value of 0 means 'Extremely low arousal'. It means the picture makes one feel relaxed, calm, sluggish, dull, sleepy or unaroused. Value of 10 means 'Extremely high arousal'. It means the picture makes one feel stimulated, excited, frenzied, jittery, wide-awake or aroused.

Design of current study: In our study, participants were shown emotional pictures selected from IAPS database while they wore the WujiBrainwave solution headset. For our study, 60 pictures were selected from the IAPS database based on their valence and arousal ratings reported in the IAPS manual. Out of 60 pictures, 30 indicated positive emotions and 30 indicated negative emotions. For each set of 30 pictures, 15 pictures were related to high Arousal and 15 were related to Low arousal. The following diagram describes the kinds of pictures shown:
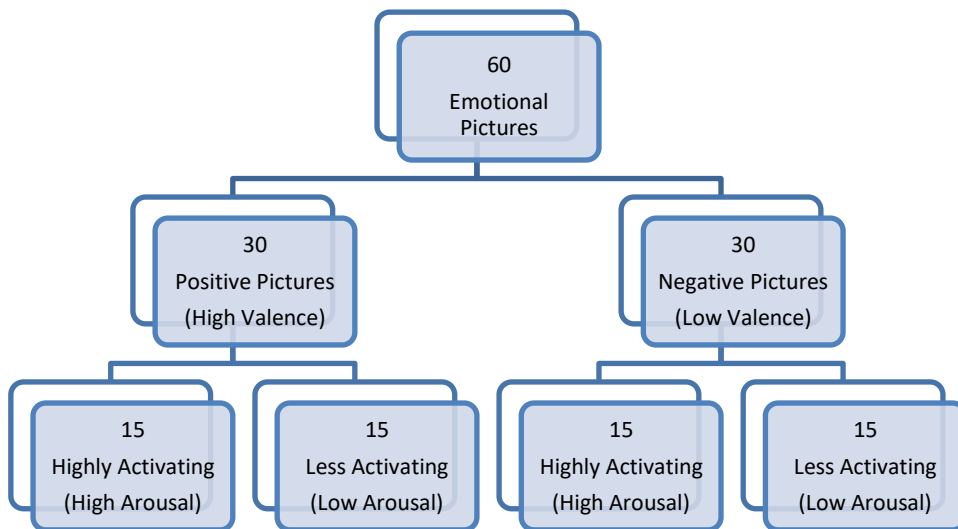

Figure 1: Kinds of Emotional Pictures presented for the study

All the 45 participants were shown all 60 pictures in random order through MATLAB Psychtoolbox. Thus, there were four conditions that each participant went through. There were 15 pictures pertaining to each condition. The four conditions were as follows:

- High Valence High Arousal (HH)

- High Valence Low Arousal (HL)

- Low Valence High Arousal (LH)

- Low Valence Low Arousal (LL)

The participants were asked to rate each of the 60 pictures in terms of Valence and Arousal on a 10 point rating scale that was depicted in form of a line as shown below:

Extremely Unpleasant   **Extremely Pleasant**

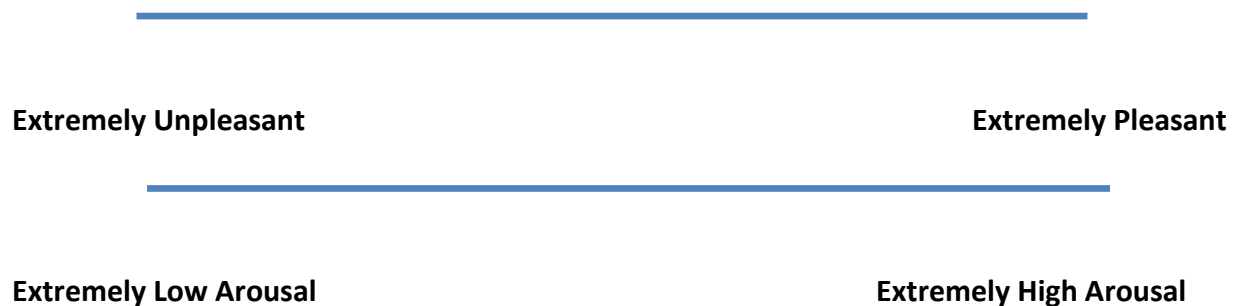**Extremely Low Arousal**   **Extremely High Arousal**

Figure 2: Rating scales for obtaining behavioral responses for each picture.

The participants were asked to click anywhere on the line to indicate how Positive/Negative the picture was or how High/Low their level of arousal on seeing the picture was.

Study Procedure: Participants read and signed a consent form that informed them about the purpose of the study. They were given standard instructions to explain the meaning of Valence and Arousal as reported in the IAPS manual. They were then seated in front of a computer and asked to wear the WujiBrainwave solution headset.

They were then given a practice session consisting 3 trials. During each trial, a fixation cross appeared for 2 seconds, followed by one of three pictures (one HH, one LH and one Neutral picture) lasting 6 seconds. After each picture, two questions were presented on screen separately where they were asked 'Rate this picture in terms of its valence' and 'Rate this picture in terms of its level of Arousal'. Below each question, the concerned rating scale as shown in Figure 2 was presented and the participants were supposed to click on the concerned point on the line. The line started with a score of 0 (least or no arousal/extremely negative picture) and ended with a score of 10 (highest possible arousal/extremely positive picture).

After the practice session, the main session started. During the main session, care was taken to see to it that the MATLAB session and the WujiBrainwave session started at the same time so that we could get the WujiBrainwave activities during the time participants viewed the pictures so that the brain activity during the picture viewing and Behavioral ratings could be correlated. The main session consisted of 60 pictures shown during 60 trials. Each trial started with a fixation cross that lasted 2 seconds, followed by a picture that lasted 6 seconds after which the participants were asked to rate the level of valence and arousal separately. The procedure was similar to the one described in the practice session. The procedure is described in Figure 3 below.
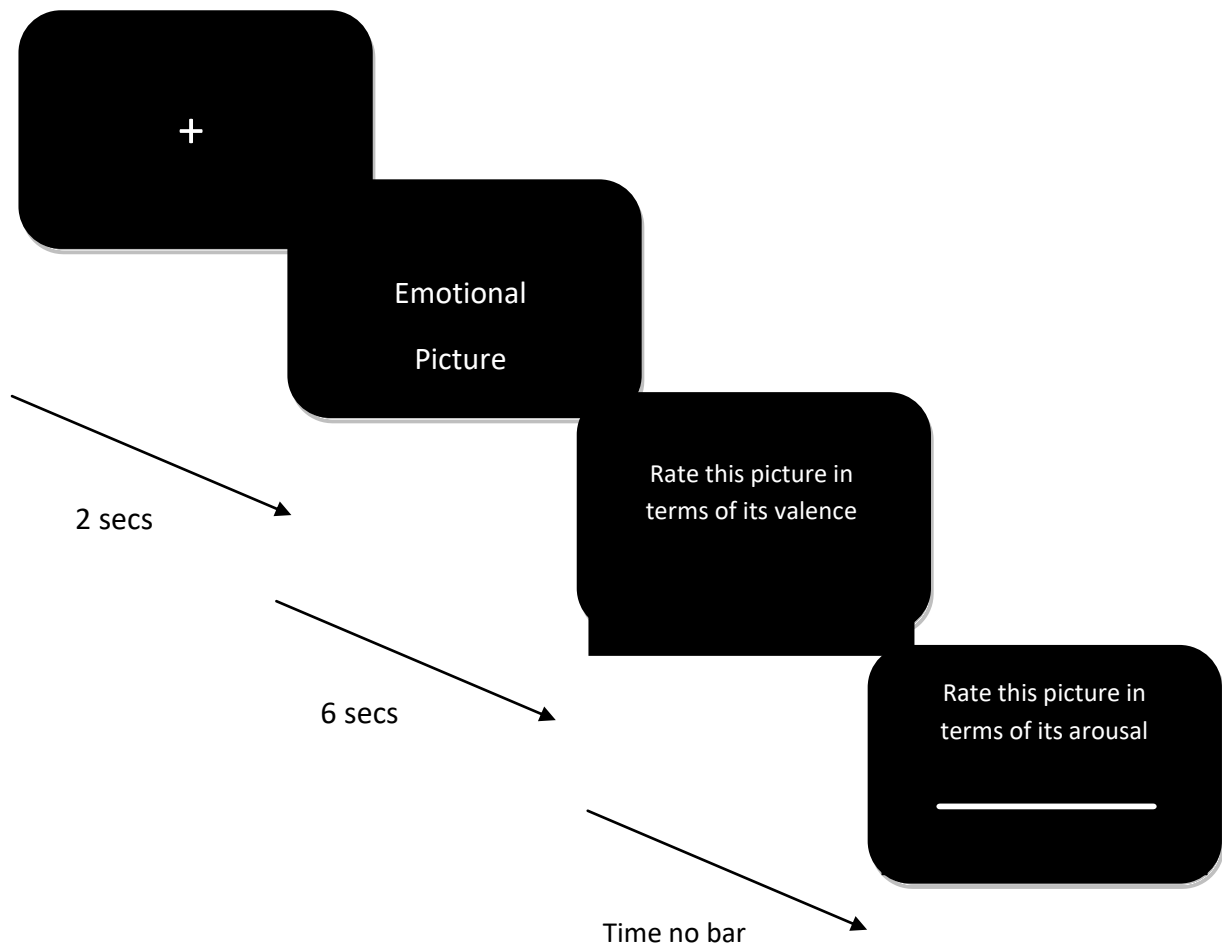
Figure 3: The procedure used to show Emotional pictures and get behavioral responses in the study on a computer screen.

Results:

The aim of this study was to correlate valence and arousal ratings given by all participants to each picture to the WujiBrainwave activity corresponding to the 6 seconds which they spent

looking at the picture. However, due to technical problems, the WujiBrainwave data for entire session were not recorded by the WujiBrainwave Application due to problems with the Bluetooth. Thus, the sync between timings of the WujiBrainwave activity and timings during which pictures were viewed was lost. The above mentioned correlation was not possible.

Data Preparation: Also, the WujiBrainwave data for one of the participants had to be removed as the corresponding Valence and Arousal ratings through MATLAB output file was not available. The Valence and Arousal ratings of each participant across all 60 pictures were averaged. Thus, we created one data point for Valence and one for Arousal per participant. Similarly, data obtained through the WujiBrainwave Application for each session per participant was averaged across all data points (seconds) for all the WujiBrainwave variables like Joy, Empathy etc. Thus, we obtained one data point for each of the WujiBrainwave variables like Joy, Empathy etc for each participant. In all, we obtained 44 data points (pertaining to 44 participants) for each of the 17 variables including the following: Delta, Theta, Alpha, Beta, Gamma, Joy, Attention, Inner Calm, Study Focus, Stress Reduction, Schumann Resonance, Creative Relaxation, Deep Meditation, Inner Peace, Empathy, Arousal and Valence.

Data Analysis: SPSS 20 and MATLAB were used for undertaking analysis. We correlated each of the 17 variables with all of the other 16 variables to obtain a correlation matrix as shown in Appendix 1. The correlation matrix has been presented diagrammatically as shown in Appendix 2.

Major findings: Summary

- Theta has a moderate positive correlation with Delta (r=0.561, p=0.00)

- Attention has moderate negative correlation with Delta (r=-0.406, p=0.006)

- Inner Calm has a strong positive correlation with Delta (r=0.820, p=0.00)

- Deep Meditation has a strong positive correlation with Delta (r=0.743, p=0.00)

- Inner Peace has a moderate positive correlation with Delta (r=0.568, p=0.00)

- Alpha has a moderate positive correlation with Theta (r=0.420,p=0.004)

- Attention has a weak positive correlation with Theta (r=0.369,p=0.014)

- Inner Calm has a weak positive correlation with Theta (r=0.372,p=0.013)

- Deep mediation has strong positive correlation with Theta (r=0.914,p=0.00)

- Inner Peace has weak positive correlation with Theta (r=0.351,p=0.02)

- Beta has strong positive correlation with Alpha (r=0.744,p=0.00)

- Attention has weak positive correlation with Alpha (r=0.348,p=0.021)

- Study Focus has strong positive correlation with Alpha (r=0.937,p=0.00)

- Stress Reduction has a moderate positive correlation with Alpha (r=0.646,p=0.00)

- Deep Meditation has weak positive correlation with Alpha (r=0.366,p=0.015)

- Inner Peace has weak positive correlation with Alpha (r=-0.330,p=0.029)

- Gamma has strong positive correlation with Beta (r=0.883,p=0.00)

- Attention has a moderate positive correlation with Beta (r=0.593,p=0.00)

- Inner Calm has moderate negative correlation with Beta (r=-0.695,p=0.00)

- Study Focus has strong positive correlation with Beta (r=0.876,p=0.00)

- Stress Reduction has a moderate positive correlation with Beta (r=0.593,p=0.00)

- Inner Peace has strong negative correlation with Beta (r=-0.772,p=0.00)

- Attention has a moderate positive correlation with Gamma (r=0.590,p=0.00)

- Inner Calm has moderate negative correlation with Gamma (r=-0.612,p=0.00)

- Study Focus has a moderate positive correlation with Gamma (r=0.611,p=0.00)

- Stress Reduction has a moderate positive correlation with Gamma (r=0.443,p=0.003)

- Inner Peace has strong negative correlation with Gamma (r=-0.718,p=0.00)

- Stress Reduction has moderate positive correlation with Joy (r=0.456,p=002)

Major Findings: Discussion

Delta and Theta WujiBrainwave Activities

- Delta waves are associated with deep sleep and meditation (Nisar, H., & Yeap, K. H., 2014).

- Theta waves have been, in general, associated with states of drowsiness and low arousal as well as meditation (Nisar, H., & Yeap, K. H., 2014). It has also been associated with activity of Hippocampus. Variations in theta activity are associated with variations in memory performance (e.g.-discrimination between old and new stimuli, improvement in task performance) (Rippon, G., 2006).

- Since Delta waves are associated with sleep and Theta waves with drowsiness and low arousal, as are typically observed during stages between sleep and full wakefulness, the moderate positive correlation between Theta and Delta waves is unsurprising.

- A strong positive correlation between Deep meditation and Delta waves is as expected.

- Since Delta is associated with deep sleep, negative correlation between Attention and Delta is also natural.

- Notably, the correlation between Deep meditation and Theta waves is higher compared to correlation of Deep meditation and Delta waves. This is also understandable as meditation is not exactly equivalent to sleep (even though there are similarities in terms of reduced overall sensori-motor and cardiovascular activities among others). Meditation can be considered more similar to a state of drowsiness, somewhere between sleep and wakefulness.

- A weak positive correlation between Attention and Theta waves is also understandable, given that a person moves from sleep to waking during which a slow rise in attention levels is to be expected.

- Another set of findings indicate that the Inner Calm and Inner Peace have higher correlations with Delta activity compared with Theta activities. This can also be explained through the transition from sleep to wakefulness where Inner Calm/Inner Peace is expected to get perturbed by external stimuli due to gradual wakefulness.

Alpha and Beta WujiBrainwave Activities

- Alpha activity in general, indicates steady or unengaged cortical state exemplified during wakefulness, effortless alertness and creativity (Nisar, H., & Yeap, K. H., 2014). It is associated with an increase in the Alpha event related synchronization (ERS). The presence of Alpha ERS during skilled performance may be associated with synchronization of task irrelevant networks caused through interruption or inhibition (or steadying and synchronization) of thalamocortical information transfer that has something to do with task irrelevant activities (Rippon, G., 2006).

- Beta waves are associated with synchronization of activities of neurons having longer axons and higher excitatory transfer velocities in the sensory motor areas. It is mostly associated with motor processing (Rippon, G., 2006). In general, they accompany active attention, thinking, solving critical problems and a general focus on the outside world (Nisar, H., & Yeap, K. H., 2014).

- Considering that Theta waves are associated with the phase somewhere between sleep and wakefulness and Alpha waves are associated with wakefulness and effortless attention that accompanies it, the moderate positive correlation between Theta and Alpha waves is unsurprising.

- In a similar vein, the strong positive correlation between Alpha and Beta waves is understandable considering the transition from effortless attention (associated to Alpha activity) to motor processing and action (associated to Beta activity).

- This kind of transition also explains the reduction in correlation between Inner peace and Alpha waves and that between Inner peace and Beta waves. The increase in active attention (as associated to Beta waves) leads to increased perturbation due to external stimuli.

- Also notable is the fact that the correlation coefficient reduces gradually from Sleep (Delta) to arousal (Theta) to wakefulness (Alpha) to activity (Beta) due to gradual increase in perturbation due to external stimuli.

- The finding that Attention has a weak positive correlation with Alpha waves is expected, considering that attention during Alpha activity is effortless and so, attentional resources need not be allocated.

- However, as brain wave activity shifts from Alpha to Beta, attentional becomes more effortful and that explains greater correlation between Beta waves and Attention compared to that between Alpha waves and Attention.

- Study focus has a strong positive correlation with both: Alpha and Beta waves which is expected, considering the increased attentiveness associated with both states.

- The lower level of positive correlation of Deep Meditation with Alpha waves (compared to the Theta state) is also expected due to increase in attention to external stimuli as indicated by Alpha state compared to the Theta state.

Gamma WujiBrainwave Activities

- Gamma waves are high frequency waves and have been associated with integration of activity in neighboring neuronal assemblies (such as during cross-modal processing). Gamma waves have been associated with perceptual representation in the brain and activation of these representations for perception and memory (Rippon, G., 2006).

- As seen previously, Beta activity is associated with active cognitive processes like attention and thinking while Gamma activity is associated with more complex cognitive processes like sensory integration and activation of sensory-motor representations that aid perception and memory. Since perception (at subliminal level) and memory may be considered basic to active attention and thinking respectively, the strong positive correlation of Gamma activity with Beta activity is understandable.

- Attention facilitates sensory integration and activation of representations that aid creation of percept and thus, the moderate positive correlation between Attention and Gamma activity is also understandable.

- Studying requires comprehending study material that is inevitable without access to information already stored (memory) and appending new information or integrating new with old information. All these processes should be facilitated with increased Gamma activity leading to a positive correlation between Study Focus and Gamma activity. Indeed, that is what we found.

- Techniques of stress reduction can vary from accepting reality and learning to live with it to evaluating reality and seeking to change it. Both these processes would require an accurate perception and understanding of the current stress producing situation that should make use of stored knowledge (memory) and the current knowledge and integration of the two so that the better one is at this process, more effective would one be at reducing stress. A positive correlation between Gamma activity and Stress reduction can thus be expected and that is what we found.

- Inner peace and Inner calm have a negative correlation with Gamma waves which is understandable given the intense perturbation associated with complexity of cognitive/mental processing that Gamma activity indicates.

Other Findings

- Stress Reduction has a moderate positive correlation with Joy and Valence is weak positively correlated with Joy. Both these findings are in line with the nature of the task presented to the participants.

- Inner Calm is negatively correlated with Attention, Study focus, Beta activity and Stress Reduction which indicate cognitive processing on external stimuli. Similarly Inner Peace is also negatively correlated with Attention and Study focus. This indicates, as expected, that attention on and processing of external stimuli perturbs the internal peace and calmness resulting in the observed relationships. Inner Peace and Inner Calm as concepts are fairly similar as indicated by a strong positive correlation between the two. Both have a positive correlation with Deep meditation, which is unsurprising.

- Another intuitive result is the positive correlation between Study focus and Attention. Similarly, Stress reduction has positive correlations with Study focus and Joy. It also has positive correlations with Alpha and Beta activities which indicate active cognitive processing which, as discussed above, are an important part of Stress Reduction techniques.

Concluding Remarks

When each of the 17 variables pertaining to this study including Delta, Theta, Alpha, Beta, Gamma, Joy, Attention, Inner Calm, Study Focus, Stress Reduction, Schumann Resonance, Creative Relaxation, Deep Meditation, Inner Peace, Empathy, Arousal and Valence, calculated using the WujiBrainwave algorithms were correlated with each other some very robust and expected relationships were found. For instance, Stress reduction had a moderate positive correlation with Joy which is expected because Joy usually indicates reduction of stress. Also, there was a weak positive correlation between Joy and Valence that was expected because half the pictures shown to the participants were negative which would not lead to Joy. Delta and

Deep meditation have a strong positive correlation as expected and similarly, as expected, Alpha has weak positive correlation with Attention as attention is effortless during the Alpha state. These findings, along with others discussed in the previous section, point towards the validity of the data presented by WujiBrainWave algorithms.

References

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