Observation of Human Brainwave Signals Due to Mobile Phone Usage

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Abstract – There is ongoing discussion whether the cellular or mobile phone usage causes any health effects. The aim of this research is to investigate the effects of mobile phone usage on human brainwaves using electroencephalograph (EEG). The brainwave signals were analyzed using Statistical Package for the Social Sciences (SPSS). Thirty samples were interviewed prior to EEG recording. Then, the EEG recordings were performed for three sessions; before, during and after the phone calls. The findings show that alpha is dominant compared to the other frequency bands. In addition, value for the left brainwaves always higher than the right for all frequency bands which means that the samples were left brain dominant. The overall correlation between left and right brainwaves signal for all bands shows decrement for during and after phone calls, thus reducing brainwaves balancing. Therefore, there is evidence that the usage of mobile phones affect the brainwaves.

Keywords - EEG, Brainwaves, Radiofrequency

I. INTRODUCTION

Mobile or cellular phones are now an integral part of modern telecommunications. In many countries, over half the population use mobile phones and the market is growing rapidly [1]. Given the large number of mobile phone users, it is important to investigate, understand and monitor any potential public health impact [1-2].

Mobile phones communicate by transmitting ultra-high-frequency radio waves through a network of fixed antennas called base stations. Radiated power from an antenna is approximately up to 125mW [3]. Antennas within phones emit the waves while the strength tails off quickly as distance from the antenna increases, a sizable chunk of it is emitted through the brain [4]. With a distance of within 2cm from a user’s head, mobile phones can radiate radiofrequency (RF) signals in the range of 450 to 2500 MHz [5]. RF waves are electromagnetic fields, and unlike ionizing radiation such as X-rays or gamma rays, cannot break chemical bonds or cause ionization in the human body [1].

II. LITERATURE REVIEW

A. Brainwaves and EEG

The brainwave is defined as arrhythmic of electric potential between brain cells called neurons and proficiently captured by EEG equipment [6]. Brainwave signals are grouped into four types which are Alpha, Beta, Theta, and Delta. The frequency of alpha wave is from 8 to 12 Hz and significantly present when the person is in a relaxed condition or reflecting with closed eyes [7-8]. During this state, a person is still awake yet resting. Slightly higher from alpha, beta wave’s frequency, ranges from 12 to 30 Hz. Beta wave is indicative of active, busy or anxious thinking and active concentration [7]. Thus, related to the alert or working state. Delta wave is the lowest frequency range starting from almost zero and can be only up to 4 Hz. It is higher during sleeping mode, whereas Theta ranges from 4 to 7 Hz. It is dominant when someone is feeling tired and depressive [7-8].

EEG is the recording of electrical activity along the scalp produced by the firing of neurons within the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a certain period of time [7-8]. EEG test is harmless and painless and can be repeated [9]. Electrodes are placed on specific sites on the scalp to detect and record the electric signal impulses within the brain. EEG electrodes transform ionic current from cerebral tissues into electrical current used in EEG preamplifier [9]. This device will detects and amplifies the electrical signals and record them onto software in the computer. Some applications of EEG are as diagnostics tools for the case of epilepsy, coma and brain death [9-10].

B. Mobile Phone Exposure

During operation, mobile phones emit energy in the form of electromagnetic fields known as radio waves. A
GSM mobile phone can emit waves with a peak power of 2 watts and parts of these waves are absorbed by the user’s head [3] as well as the human’s body [11-13]. Tissue heating is the principal mechanism of interaction between radiofrequency energy and the human body. At the frequencies used by mobile phones, most of the energy is absorbed by the skin and other superficial tissues, resulting in negligible temperature rise in the brain or any other organs of the body [1].

Usage of mobile phones particularly for a long period of time is known to have some effects on the users [1-5]. Some users complained that the usage of mobile phone indicate certain negative effects on their bodies especially in the heads. Thus, several investigations to observe biological effects of mobile phone exposures have encompassed the investigation of potential connections to cancer, cell division, blood pressure alteration, induction of epilepsy, depression, effects on the eyes, and human cognitive alteration [14-15].

Another study suggested that mobile phone users had a 30% increased risk of brain tumors which occurred close to the ear used for mobile phone listening [2-3]. Furthermore, previous studies had shown that growth of leukemia cells could be increased dramatically after exposure to mobile phone radiation [2]. Therefore, various studies have been going on to investigate the effects of these conditions on the human body [1-5, 14-15]. However; it is presently unclear whether this electromagnetic energy can really cause biological consequences or adverse health effects [11, 15].

III. PROPOSED NEW IDEAS

To date, it is assessed that there are over 1.7 billion mobile phone users world-wide. Thus, if there were to be adverse health consequences due to contacts from mobile phones, the effects could be pervasive amongst huge populations. Therefore, it is essential to examine and to resolve the possibilities of biological effects due to mobile phone radiated fields [15-20]. Thus far, scientific evidence on the effect of mobile phone radiation exposure to the brainwave signals using EEG is not conclusive [11, 15]. Hence, this research will identify and investigate the human brainwave patterns due to the usage of mobile phone using EEG. In addition, the difference between the left hemisphere and the right hemisphere of the brainwaves will be observed and correlated to investigate the brainwave balancing condition [21-22]. Furthermore, interview sessions will be carried out to investigate the usage trend of mobile phone to be more comprehensive in the data collection and data analysis.

IV. METHODOLOGY

Experiments were performed at the Biomedical Research and Development Laboratory for Human Potential, Faculty of Electrical Engineering, Universiti Teknologi MARA, Malaysia. This laboratory has been recognized by the Malaysia Book of Record as the first research and development laboratory for human potential in Malaysia. 30 participants were recruited from undergraduate students of the Faculty of Electrical Engineering, Universiti Teknologi MARA, Malaysia. All participants were in healthy conditions and also not consuming any medicine or drug prior to the test. A combination method consisting of interviews and EEG analysis has been used for this project to be more comprehensive in gathering the information to analyze the effects of mobile phone usage.

A. Interviews

Before recording the EEG measurements, all samples were interviewed concerning their usage of mobile phone. Samples have to answer 11 questions such as number of call that they normally have per day, duration per call and the effects that they experience when using mobile phone for a long period of time. The results were analyzed to observe the trend of mobile phone usage among samples.

B. EEG Experiment

The EEG signals were recorded under three conditions which are before, during and after call using mobile phone. Figure 1 shows the flowchart of the experiment.

![Figure 1: Flow Chart of the Experiment](image_url)

<table>
<thead>
<tr>
<th>Time Frame Protocol of the Experiment</th>
</tr>
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<tbody>
<tr>
<td>Before call</td>
</tr>
<tr>
<td>5-10min</td>
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<tr>
<td>Interview session</td>
</tr>
</tbody>
</table>
Table 1 shows the time frame protocol of the experiment, involving three stages which were before, during and after usage of mobile phone. Initially, samples will undergo the interview sessions to answer 11 item questionnaires related to their usage of hand phones. The interview session is normally conducted between five to ten minutes. The EEG recording duration was five minutes for each stage with one minute rest period in between, giving a total of approximately 22 to 27 minutes for each sample. During EEG recordings, samples were asked to close their eyes, relax (but not sleep), not allowed to talk, thus to minimize artifacts in the EEG signal.

The phone is strapped to the right ear while the phone is in active session. Although the line is open to another party, no conversation took place between them. Observation of brainwave was conducted for both brain hemispheres, though only the right ear is engaged with the phone. In future, the research can be extended by placing the phone to the other ear to observe the effect.

Figure 2: Electrodes and WaveRider Connection

EEG data acquisitions were carried out using EEG equipment (WaveRider Mind Peak model P-0609-5E022) as shown in Figure 2. A bipolar connection is employed using four electrodes, 2 channels and in accordance to International Standard 10-20 electrode placement system. Sampling frequency is 128 Hz with electrode impedance maintained below 5 kΩ. Simultaneously, EEG raw data were transmitted to the processing device. The same processing device was used throughout the signal analysis to maintain consistency.

Electrode from channel A positive was connected to the right forehead and channel B positive to the left forehead. Electrodes from channel A and B negative were connected to the right ear lobe. Finally, electrode from the reference port of the Wave Rider was also connected to the left earlobe.

Figure 3 shows a sample undergoing EEG experiment. In the picture, the sample is in the second stage where the brainwaves are captured during usage of the mobile phone. The phone is activated by making a call to another party; however both parties remain quite for five minutes which means there is no conversation.

V. RESULTS AND DISCUSSION

The analysis is divided into two parts which are the interview results and the EEG analysis.

A. Analysis of the Interview

Figure 4 shows the percentage of the samples that have dialed or received calls per day. From the interview session, the result shows that 54% of the samples have less than two calls in a single day. On the other hand, only 10% of the samples dialed or received calls 5 to 6 times daily.

The percentage of duration per call is depicted in Figure 5. Only 3% of the samples having the highest period of call which is more than 1 hour per call. 40% of the samples spend less than 5 minutes per call. The majority spend five to twenty minutes per call.

The interview session also gave the percentage of samples that have dizziness after having a conversation for a long period of time as shown in Figure 6. It indicates that 60% of samples having dizziness and depression symptom if they use the phone for more than one hour. While the rest, (12 samples) did not feel dizziness. The findings support previous results, which reported that people exposed to mobile phone showed increased levels of exhaustion and depression [16].
B. Analysis of the EEG Signals

The EEG signals analysis is divided into three stages: before call, during call and after call. The analysis was performed using statistical tools, SPSS version 17.0. The analysis of the data from EEG test focused on the comparison between the three stages and also the correlation between left and right brainwaves for each band individually as well as overall. Figure 7 clearly depicts that the alpha level of the right side decreases significantly during call and further decreases within the period of five minutes after call. However, the alpha level of the left side remains consistent throughout the experiment. It also shows that the waves for alpha left almost overlap for all stages. Figure 8 shows the graph for beta right and beta left brainwaves. For beta right, the mean amplitude levels almost overlap in all stages for before, during and after call with 1.87% increment during mobile phone usage and 0.46% decrement after the exposure. Compared to beta left, the mean amplitude levels increases from 11.94% to 13.65% in between the activities.
Figure 9 depicts the delta level of all stages for the laboratory experiment. There are no significant changes of the brainwaves due to the effects of exposure for both sides of the right and the left brain. The brainwaves pattern is also similar with theta waves as shown in Figure 10. Overall, delta and theta bands show slightly higher levels during and after calls for both left and right brainwaves. This observation agree with previous results which found that after 20-40 seconds exposure to mobile phone, a slow wave activity (2.5-6 Hz) appeared in the contra lateral frontal and temporal areas and suggested that mobile phones may affect the human brain [23]. It is concluded that mobile phones may reversibly influence the human brain, inducing abnormal slow waves in EEG of an awaken person [23].

Table 2: Brainwaves mean value between stages

<table>
<thead>
<tr>
<th>Band</th>
<th>Right Brainwaves (µV)</th>
<th>Left Brainwaves (µV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>During</td>
</tr>
<tr>
<td>Alpha</td>
<td>9.67</td>
<td>6.81</td>
</tr>
<tr>
<td>Beta</td>
<td>4.28</td>
<td>4.36</td>
</tr>
<tr>
<td>Theta</td>
<td>7.96</td>
<td>8.05</td>
</tr>
</tbody>
</table>

Table 2 shows the mean values of left and right brainwaves. It is known that alpha wave increase during relax and closed eyes. The left alpha brainwave increases slightly from 11.18 micro volts (before call) to 11.71 micro volts (during call) and further increases to 12.35 micro volts (after call). Thus, the increment of alpha left in the result shows samples are more relaxed [17].

In contrast, significant result shows that mean values for alpha right decreases during call, from 9.67 micro volts to 6.81 micro volts and further decreases to 5.76 micro volts after call. This decrement could be due to the effect of radiation from the mobile phone attached to the right ear during call. This observation is in line with findings from [18] which concluded that in the case of a person using a mobile phone, most of the heating effect will occur in the surface of the head, causing its temperature to increase by a fraction of a degree. Once the temperature is back to normal, there will be no radiation effects. Scientist have shown that this radiation might cause human biological damage through heating effects since human body is made up of approximately 65-70% water, electrolytes and ions [19].

Further analysis using paired T-test was carried out to compare between right and left brainwaves for each stage to deduce the correlation and brainwave balancing as shown in Figure 11. Correlation values for all frequency bands decreases during calls and further decreases five minutes after calls. The most significant results occur in alpha wave. The results agree with another research which found that EEG spectral power was influenced in some bins of the alpha band [20]. This effect was greater when the Electromagnetics Field (EMF) was on during the EEG recording session than before it [20]. It follows that the correlation between the left and the right alpha brainwaves signal decreases significantly from 0.983 (before call) to 0.824 (during call) and further decreases to 0.741 within the period of five minutes after call as shown in Figure 11. Initially, the alpha brainwaves were highly balanced before call. However, due to usage of mobile phone on the right side, the brainwaves became left dominant.
VI. CONCLUSION

By conducting this research, the effects of mobile phone usage on human brainwaves were studied using EEG. It was found that the alpha level of the right side (where the phone is attached) decreases significantly during the calls and further decreases within the period of five minutes after the calls were ended. However, the alpha level of the left side remains consistent throughout the experiment. The result from this research somewhat agrees with findings from [10-11], that is alpha wave decreases while exposure to radiation. Whereas, other frequency bands of the brain signals increased for both left and right side. It follows that the overall correlation between left and right brainwaves signal for all frequency bands decreases significantly during the calls and further decreases within the period of five minutes after calls. Therefore it reduces brainwaves balance. There is evidence that the usage of mobile phones affect the brainwaves.

In future, this research could be expanded to observe whether usage of mobile phones has some effects on other physiological variables such as heart beat, heart condition and lung condition. In addition, the observation can also be extended by attaching the phone to the left ears. Another interesting experiment is to compare the effect on the brainwaves due to different types of mobile phone (2G, 3G, iPhones, Samsung, Nokia etc.).

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REFERENCES


