URALG., Wavelet Phase Coherence Estimation of EEG Signals for Neuromarketing Studies

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**ABSTRACT**

This paper presents an Electroencephalography (EEG), Pulse Plethysmography (PPG) and Galvanic Skin Response (GSR) study for neuromarketing studies, which are related to analysis of relationship between electrodes and emotional stress across to commercial advertisement. Neuromarketing is a field of study with respect the application of neuroscience methods to analyze consumer behavior related to markets. Wavelet coherence (WC) and phase difference (PD) were used for investigating how the marketing stimuli induced the degree of information flow occurs between electrodes of EEG.

Pulse rate variability (PRV) obtained from finger PPG and computed the powers in high frequency (HF), low frequency (LF). The powers in the LF and HF bands are regulated by Autonomic nervous systems (ANS) and then, Skin conductance level (SCL) computed from GSR by measuring changes in the conductivity of the skin. These electrophysiological measurements computed to evaluate emotional stress.

The signals were recorded simultaneously from 30 subjects for two stages: prior to advertising stimuli (control stage) and during advertising stimuli (experimental stage) using iMotions system in Uskudar University (Istanbul, Turkey).

The WC and PD for each electrode pairs were computed for five frequency sub-bands (delta, theta, alpha, beta and gamma) of EEG. While the value of WC was generally higher in experimental stage than control stage especially in the theta, alpha and beta frequency, the value of PD was generally lower especially in gamma band. An increase of interhemispheric coherence in experimental stage occurred in the anterior frontal -temporal-parietal- area. At the same time, the LF/HF ratio and SCL were generally higher in experimental stage. We investigated whether there were statistically significant differences in WC, PD, the LF/HF ratio and SCL between the experimental and control stage. Results were demonstrated significant differences in WC and PD, LF/HF ratio between experimental stage and control stage, but there was not in SCL.

**Key Words:** Neuromarketing, Wavelet- Phase Coherence, Pulse Plethysmography, Galvanic Skin Response, Emotional responses

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**Introduction**

The applications of neuromarketing studies include neuroimaging techniques to analyze consumer behavior after the exposition to advertising effects (Vecchiato *et al.*, 2013). The brain imaging and signal processing techniques can detect the subject's cognitive experience, consumer attention, preference and adoption from the activations of different cerebral areas related to unconscious, mental states, emotional responses of consumers (Vecchiato *et al.*, 2013, Zurawicki, 2010). The marketing induced-consumer behavior such as consumer choices,
consumption of certain products were investigated in literature. The most popular methods used in literature are functional magnetic resonance imaging (fMRI), positron emission tomography (PET), EEG, magnetoencephalography (MEG), Eye tracking (ET), Face reading (FD), Skin Conductance (SC) methodology (Lee et al., 2007). It has been tried to be discovered how people are responding to products and different marketing stimuli such as sound, smell, images, touch, taste (Gani et al., 2015) and what exactly influences on their decision making, even the things that are unaware to them (Andrejevic, 2013) by practicing the use of different technologies.

The electrical activity of the neurons in the cortex of the brain creates complex electrical signals, it is measured by placing electrodes on the scalp. The recording these signals from the scalp surface of the brain is called EEG (Vecchiato et al., 2011). In most of previous research EEG usually used for identifying the key point of advertising or video material, testing and developing advertisements, testing new campaigns, product moment of correlation, in-store experience, testing websites design and usability, testing taglines by measuring emotional valence, cognition, memory encoding, recognition, attention, excitement. (Lee et al., 2007, Zurawicki, 2010). Previous research with respect to EEG showed that the cortical activity elicited during the observation of the TV commercials (Fallani et al., 2007, Astolfi et al., 2006). In these studies, the statistical differences in the power spectral density (PSD) for the principal brain areas and particular frequency bands were investigated by using Fourier transform (FT) (Astolfi et al., 2008, Vecchiato et al., 2010), but wavelet-based estimation of coherence, or wavelet coherence were used in this study. In this paper, we want to investigate the relationship between electrodes that carries significant information about different cortical areas, and to compare along with variations of the activity of the autonomous nervous system while showing an advertisement stimuli (Hramov et al., 2015). Therefore, wavelet coherence were used to measure the synchronization between the two time series of EEG electrode pair. Coherence reflects the degree of information flow between groups of neuron generating these EEG signals. Wavelet coherence gives insights into the way functional networks cooperate with each other during various cognitive processes (Hramov et al., 2015). The inconsistent coherence rising by problems due to non-stationarity can be dealt with the use of wavelet analysis. Therefore, wavelet-based coherence analysis were used to evaluate interhemispheric coherence and phase difference from all combinations of electrode pairs.

Additionally, skin conductance level (SCL) and pulse rate variability (PRV) were computed from GSR and PPG signals and then, were compared with wavelet coherence and phase difference values to evaluate the activity of the autonomous nervous system while showing an advertisement stimuli. SC is based on the analysis of subtle changes in galvanic skin responses (GSR) when the autonomic nervous system (ANS) is activated. It measures the emotional states and arouses the responses on different circumstances while showing an advertisement stimuli (Gani et al., 2015). PRV is can be evaluated from peak to peak time intervals of the PPG and it can be used to investigate the estimation of variations in heart rate while showing an advertisement stimuli. One of the main features computed from PRV using frequency domain analyzing methods is calculating the power in the 0.15– 0.40 Hz (high frequency – HF) band and 0.04 – 0.15 Hz (low frequency – LF). The powers in the LF and HF bands are regulated by Sympathetic (SNS) and parasympathetic nervous systems (PNS) respectively (Okkesim et al., 2016). To this end, the ratio of LF/HF were computed to evaluate the activation of autonomic nervous system while showing an advertisement stimuli. The objective of this study is to investigate wavelet-phase coherence based brain connectivity in neuromarketing experiments and to associate to variations of the activity of the autonomous nervous system. The overall results were statistically tested to observed any significant difference between the experimental and control stage.

**Methods**

**Materials**

The experimental part of this study were completed in Uskudar University. All signals were collected...
synchronously with iMotions technology. EEG signals were recorded using an Emotiv Epoc 14-channel wireless EEG at a sampling frequency of 128 Hz and other signals were recorded using iMotions system at a sampling frequency of 1 kHz. EEG recording was performed using 14 electrodes (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4) according to the international 10-20 system.

EEG, PPG and GSR signals were recorded from 30 subjects at the age of \((36.87\pm 11.09)\) years. All subjects were volunteers who gave informed consent to undergo neurophysiological recording. EEG, GSR and PPG recordings were completed during two stages as "prior" to advertising stimuli (control stage) and "during" the advertising stimuli (experimental stage) from a group consist of 30 subjects. Control stage signals were recorded for 1 min followed by a 2-min experimental stage. Black screen were used prior to advertising stimuli as a control stage. Commercial advertisement were used as experimental stimuli during the advertising stimuli for experimental stage. The study was conducted in a quiet room. Each subject was sat in front of the computer and then, black screen for 1 min and experimental stimuli for 2 min was shown, respectively. Consequently, each subject's signal recordings when showing black screen were used as a control stage. In contrast, each subject's signal recordings when showing experimental stimuli were used as experimental stage.

Data Analysis and Processing

Wavelet Phase Coherence Analysis

In this study, evaluation of phase-coherence was performed using continuous wavelet transform (CWT) by convolving the data with the Morlet mother wavelet. Coherence is a linear measure of the correlation between two signals as a function of frequency. Coherence can be interpreted as a measure of the degree of synchronization between the brain signals in specific brain areas (Nunez et al., 1999, Nunez et al., 1997). The CWT was used to compute of spectral characteristics since it provides highly overlapping windows which improve the reliability of the coherence estimate. The wavelet transform has been used time series analysis that contains nonstationary power, such as the EEG signal at many different frequencies (Alexandridis and Zapranis, 2014). The CWT of a discrete sequence \(x_n\) with time spacing \(\delta_t\) and N data points \((n = 0 \ldots N-1)\) is defined as the convolution of \(x_n\) with consecutive scaled and translated versions of the wavelet function \(\varphi_0(n)\):

\[
W_n^x(s) = \sqrt{\frac{s}{\pi}} \sum_{n'=0}^{N-1} x_{n'} \varphi_0(\frac{n'-n}{s}) \frac{\delta_t}{s} \tag{1}
\]

\[
\varphi_0(n) = \pi^{-1/4} e^{i\omega_0 n} e^{-n^2/2} \tag{2}
\]

where \(n\) and \(\omega_0 = 6\) is a non-dimensional “time” parameter and frequency, respectively. \(\varphi_0(n)\) Identifies the normalized complex Morlet wavelet (2). The power spectrum of the WT is identified by the square of coefficients (1) of the wavelet series as \(|W_n^x(s)|^2\) (Alexandridis and Zapranis, 2014). Scaling \(s\) is a mathematical procedure that stretches or compresses a function. In the way of frequency, while low scales by a compressed wavelet function detect high frequencies, high scales by a stretched wavelet function detect low frequencies. Scales was converted to approximate frequencies in hertz for the Morlet wavelet by formula given below in order to define frequency bands of EEG (delta, theta, alpha and beta, gamma).

\[fr = \text{scal}2 \text{frq}(\text{scales}', \text{mor1} - 1', 1'/\text{fs}) \tag{3}\]

Similarly to Fourier (Sakkalis et al., 2006), given two time series \(X\) and \(Y\), with wavelet transforms \(W_n^X(s)\) and \(W_n^Y(s)\) one can initially identify the cross-wavelet spectrum as \(W_n^{XY}(s) = W_n^X(s)W_n^{*Y}(s)\), where * denotes the complex conjugate. The cross-wavelet power is demonstrated by \(|W_n^{XY}(s)|\). And then, the wavelet coherence \(R_n^2\) of two signals may be defined as:

\[
R_n^2(s) = \frac{|S(s^{-1}|W_n^{XY}(s)|)^2}{S(s^{-1}|W_n^X(s)|^2)S(s^{-1}|W_n^Y(s)|^2)} \tag{4}
\]

where \(S\) is a smoothing operator in time \(S\), and scale \(S_s\) such as \(S(W) = S_s(S_s(W_n(s)))\) which for the Morlet wavelet is given by a Gaussian and a boxcar filter of width equal to 0.6, (the scale-decorrelation length) respectively (Grinsted et al., 2004).

\[
S_s(W_n, s) = \left(W_n(s) \ast c_{1^{-2/2s^2}}\right) \tag{5}
\]

\[
S_s(W_n, n) = \left(W_n(s) \ast c_{2\Pi(0.6s)}\right) \tag{6}
\]

Where \(c_1\) and \(c_2\) are normalization constants and \(\Pi\) is the rectangle function. From complex cross-wavelet transform, the power \(|W_n^{XY}(s)|\) and individual real, \(R\), and imaginary, \(I\), components are used in determining the similarity of power between two time series. The complex cross-wavelet
transform is used to determine the wavelet phase difference and its formula was given in equation (4,7) (Torrence and Compo, 1998).

\[
\phi_n(s) = \arctan \left( \frac{I \{ S(s^{-1}W_n^\psi(s)) \}}{R \{ S(s^{-1}W_n^\psi(s)) \}} \right)
\]

Additionally, to obtain confidence in coherence results were used Monte Carlo methods to estimate the statistical level of significance against a background spectrum (Grinsted et al., 2004). The squared WC time-frequency transformed scalogram was demonstrated the following plots, Fig. 1. While green dashed outline indicates the 5% significant regions over the time-scale transform, the outer elliptical region at the edges of the second graph indicates the cone of influence where edge effects may become important because of the finite duration of the time series (Bloomfield et al., 2004). The relative phase relationship is shown as arrows with in phase pointing right.

**PRV and GSR signals Analysis**

The ratio of the low-to high frequency power (LF/HF) were calculated to evaluate emotional stress or autonomic assessment while showing an advertisement stimuli. Firstly, maximum points of the PPG signal (Pmax) were detected due to the Pmax equivalents to R peaks acquired from the electrocardiography (ECG). Consequently, PP intervals of the length in time domain from one Pmax to the next one were determined. So to enable detection of the Pmax, we used an algorithm generated in the previous study (Okkesim et al., 2016). Cubic interpolation was applied to PP intervals to get uniformly sampled PRV. And then, the power of the PRV in the LF and HF band was obtained using the algorithm which is based on the Welch method. As a frequency domain feature, the ratio of the low-to high frequency power (LF/HF) was calculated.

The average of SCL were calculated to evaluate emotional stress or autonomic assessment while showing an advertisement stimuli. All the data processing was carried out using MATLAB's own library developed under MATLAB R2016b Software (Math- Works Inc., Natick MA, USA).

**Statistical Analysis**

SPSS for Windows was used for statistical data analysis. We investigated statistically significant differences in wavelet-phase coherence between the control stage and the experimental stage by using the one way ANOVA test according to (Stoline, 1981). Since we had two stages of subjects (control and experimental) and six different parameters (delta, theta, alpha, beta, gamma and average coherence-phase values) for each electrode pairs, we have carried out statistical comparisons of these parameter values across two stages (Okkesim et al., 2016, Vecchiato et al., 2013). We used one way ANOVA to estimate of all pairwise comparisons with a 95% confidence limit and a p-value of less than 0.05 was considered as statistically significant. Because six different parameters for each electrode pairs across two stages, are normally distributed and there are homogeneity of variances. Finally, we compared statistically significant differences SCL, the ratio of LF/HF and all interhemispheric coherence values at the same time by using one-way MANOVA. Essentially MANOVA computes a composite variable based on the several dependent variables and then tests to see whether the means of the groups on the combined

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**Figure 1.** The WC time-frequency transformed scalogram at the all frequencies for AF3 and AF4 (experimental stage) of one subject.

Red color demonstrate regions with significant interrelation, while blue color signify the significant areas represent time and frequencies with no dependence in the series. An arrow in the WC plots represents the lead/lag phase relations between the examined series. While arrows point to the right when the time series are in phase, which means they move in the same direction, arrows point to the left when the time series are anti-phase means that they move in the opposite direction. Arrows pointing to the right-down indicate that the first variable is leading.
dependent variables differ significantly. It helps deal with the problems created by multiple significance tests being applied to the same data (Chatfield, 2018).

**Results**

The following figures present contour plots of the wavelet coherence and phase in EEG bands (scale 1 to 5) experimental stage. As shown in Fig. 2, firstly the wavelet spectrum and its corresponding coherence (blue line), secondly a contour plot of coherence smoothed in scale and thirdly a contour plot of the phase were demonstrated. While the color bar denotes that blue corresponds to 0 for coherence whereas red to 1, in phase contour plot denotes that blue corresponds to zero phase. A zero phase difference means that the two time series move together on a particular scale. are plotted for two electrodes (Auth, 2013).

The total spectral coherence for the all combination of electrode pair showed alpha, beta and theta coherence in the experimental stage greater than control. The maximum interhemispheric coherence was observed at the electrode pairs AF3-AF4 (anterior frontal area), T7-T8 and P7-P8 (temporal and parietal area). Normally, the coherence in pairs of adjacent electrodes showed higher values. Conversely, the coherence was reduced as a function of the spatial distance between pairs of electrodes (Handayani et al., 2018). Nevertheless, distal coherence for T7-T8 electrode pair showed higher values. When we look at the last section of the table 1, it is seen average coherence values at the all electrode pairs were increased for experimental stage.

Comparisons of the phase difference from the experimental and the control stage are respectively presented in Table 2. The phase difference is expressed in radians and takes the possible values \( \phi_s \in [-\pi, \pi] \). According to (Auth, 2013), 0, \( \frac{\pi}{2} \) in phase and first variable leading. All phase difference values are in this given range. Therefore, electrodes in left side (first) lead right side electrodes (second). There is not significant difference of phase for delta band. As for the other lower frequency band, there is a significant difference of phase in the all electrode pairs for theta band. As for the higher frequency band, there is a significant difference of phase difference in the all electrode pairs for alpha, beta and gamma.

![Wavelet Coherence and Phase](image)

**Figure 2.** Wavelet coherence and phase for F7 and F8 (experimental stage) for one subject.

Fig. 1 were presented wavelet coherence over the all-time-scale, but Fig. 2 were demonstrated wavelet coherence and phase in EEG bands (delta, theta, alpha, beta and gamma-scale 1 to 5) for experimental stage. We aim to create this plot was to investigate the time when the effect of advertisement occurred and which sub-bands of EEG (delta, theta, alpha, beta and gamma) were affected by this advertisement simultaneously.

Table 1 demonstrate the results of the interhemispheric coherence statistical test for control and experimental stage. There is not a significant difference of coherence in the all electrode pairs for the delta band except for (T7-T8 and P7-P8). As for the other lower frequency band, there is a significant difference of coherence in the all electrode pairs for theta band. As for the higher frequency band, there is a significant difference of coherence in the all electrode pairs for alpha, beta and gamma. The total spectral coherence for the all combination of electrode pair showed alpha, beta and theta coherence in the experimental stage greater than control.

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Fig. 3 demonstrate the results of the interhemispheric coherence, SCL and the ratio of LF/HF between the control and the experimental stage. As shown, the best coherence difference were obtained COH5 (T7-T8), temporal area and COH6 (P7-P8), parietal area.

Another notable results are related to the LF/HF ratio and SCL. An increase in the LF/HF ratio and SCL corresponds to the increase of activity in the ANS. As seen from Fig. 3, LF/HF ratio and SCL have a slightly bigger value for experimental stage. At the same time, SCL computed GSR and the ratio of LF/HF computed PRV and all interhemispheric coherence values were compared by using one-way MANOVA statistical test for experimental and control stage.
These results demonstrated that SCL values between experimental and control stage were not statistically significant (p=0.526). But all interhemispheric coherence values and LF/HF ratio are statistically significant.

### Discussion and Conclusion

Interhemispheric wavelet-phase coherence for electrode pairs of EEG, their sub-bands were investigated in this paper, and then were compared SCL and LF/HF ratio. In the present research, firstly wavelet coherence and phase difference in EEG sub-bands (delta, theta, alpha, beta and gamma) for experimental stage were illustrated as a plot in Fig. 2. The purpose of this plot was to investigate the time when the effect of advertisement occurred as an increasing in wavelet coherence and which sub-
The interhemispheric coherence in experimental stage increased according to control stage. The maximum interhemispheric coherence was observed at the anterior frontal area, temporal and parietal area. The interhemispheric coherence of the experimental stage took the maximum value for the alpha, beta and theta bands. And these increasing are statistically significant between control and experimental stage. EEG coherence is a statistical measure of correlation between signals from electrodes and functional connectivity is defined as the temporal correlation between the activity of different neural assemblies (Handayani et al., 2018, Sakkalis and medicine, 2011). Therefore, interhemispheric wavelet coherence can be used to

### Table 2. The mean value ± standard deviation of the interhemispheric phase difference and p-value for all frequency bands and average phase difference

<table>
<thead>
<tr>
<th>Electrode pairs</th>
<th>Delta phase</th>
<th>Theta phase</th>
<th>Alpha phase</th>
<th>Beta phase</th>
<th>Gamma phase</th>
<th>Average phase</th>
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<tr>
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<td>experimental</td>
<td>p-value</td>
<td>control</td>
<td>experimental</td>
<td>p-value</td>
</tr>
<tr>
<td>AF3-AF4</td>
<td>0.43 ± 0.09</td>
<td>0.27 ± 0.23</td>
<td>0.062</td>
<td>0.27 ± 0.25</td>
<td>0.1 ± 0.05</td>
<td>0.002</td>
</tr>
<tr>
<td>F7-F8</td>
<td>0.38 ± 0.31</td>
<td>0.29 ± 0.26</td>
<td>0.251</td>
<td>0.37 ± 0.31</td>
<td>0.11 ± 0.10</td>
<td>0.0001</td>
</tr>
<tr>
<td>F3-F4</td>
<td>0.59 ± 0.42</td>
<td>0.25 ± 0.23</td>
<td>0.1</td>
<td>0.35 ± 0.30</td>
<td>0.312 ± 0.08</td>
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</tr>
<tr>
<td>FC5-FC6</td>
<td>0.41 ± 0.32</td>
<td>0.27 ± 0.26</td>
<td>0.069</td>
<td>0.35 ± 0.30</td>
<td>0.22 ± 0.16</td>
<td>0.038</td>
</tr>
<tr>
<td>T7-T8</td>
<td>0.39 ± 0.31</td>
<td>0.27 ± 0.25</td>
<td>0.1</td>
<td>0.35 ± 0.32</td>
<td>0.10 ± 0.14</td>
<td>0.0001</td>
</tr>
<tr>
<td>P7-P8</td>
<td>0.60 ± 0.37</td>
<td>0.31 ± 0.26</td>
<td>0.1</td>
<td>0.44 ± 0.26</td>
<td>0.14 ± 0.15</td>
<td>0.0001</td>
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<tr>
<td>O1-O2</td>
<td>0.39 ± 0.31</td>
<td>0.28 ± 0.25</td>
<td>0.168</td>
<td>0.39 ± 0.32</td>
<td>0.22 ± 0.17</td>
<td>0.021</td>
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<td>experimental</td>
<td>p-value</td>
<td>control</td>
<td>experimental</td>
<td>p-value</td>
</tr>
<tr>
<td>AF3-AF4</td>
<td>0.22 ± 0.19</td>
<td>0.10 ± 0.11</td>
<td>0.005</td>
<td>0.13 ± 0.15</td>
<td>0.06 ± 0.05</td>
<td>0.020</td>
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<tr>
<td>F7-F8</td>
<td>0.31 ± 0.26</td>
<td>0.10 ± 0.07</td>
<td>0.0001</td>
<td>0.20 ± 0.18</td>
<td>0.05 ± 0.04</td>
<td>0.0001</td>
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<tr>
<td>F3-F4</td>
<td>0.28 ± 0.25</td>
<td>0.05 ± 0.03</td>
<td>0.0001</td>
<td>0.17 ± 0.14</td>
<td>0.07 ± 0.07</td>
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<tr>
<td>FC5-FC6</td>
<td>0.29 ± 0.25</td>
<td>0.10 ± 0.07</td>
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<td>0.19 ± 0.14</td>
<td>0.06 ± 0.04</td>
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</tr>
<tr>
<td>T7-T8</td>
<td>0.27 ± 0.24</td>
<td>0.11 ± 0.09</td>
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<td>O1-O2</td>
<td>0.30 ± 0.25</td>
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<td>0.0001</td>
<td>0.18 ± 0.14</td>
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<td>experimental</td>
<td>p-value</td>
</tr>
<tr>
<td>AF3-AF4</td>
<td>0.09 ± 0.06</td>
<td>0.05 ± 0.05</td>
<td>0.005</td>
<td>0.14 ± 0.10</td>
<td>0.06 ± 0.05</td>
<td>0.001</td>
</tr>
<tr>
<td>F7-F8</td>
<td>0.10 ± 0.06</td>
<td>0.04 ± 0.03</td>
<td>0.0001</td>
<td>0.12 ± 0.09</td>
<td>0.05 ± 0.05</td>
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<td>F3-F4</td>
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<td>FC5-FC6</td>
<td>0.11 ± 0.06</td>
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<tr>
<td>O1-O2</td>
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<td>0.001</td>
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<td>0.05 ± 0.07</td>
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</tbody>
</table>

bands of EEG (delta, theta, alpha, beta and gamma) were affected by this advertisement simultaneously.

As shown Fig. 2, wavelet coherence was increased all sub-bands of EEG for one electrode pair (F7-F8) in the 2 -3 and 6. seconds and in the 5. seconds wavelet coherence was increased beta and gamma bands (scale 4-5). Coherence analysis of bioelectrical signals recorded from different electrodes has been used extensively for studying “anatomical connections”, “functional coupling”, “information exchange”, functional co-ordination” between different cortical structures (Fein et al., 1988, Thatcher et al., 1986). Therefore, increasing in wavelet coherence demonstrated that there was an information exchange in the frontal area.
investigate marketing stimuli induced the degree of information flow. Phase coherence is an expansion of coherence that allows to investigate on the phase-relationships between two signals. Therefore, we investigated phase-relationships in interhemispheric region of brain. All phase difference values are in \( \left[ 0, \frac{\pi}{2} \right] \) range. Therefore, EEG signals obtained from electrodes of left area (first) and right area (second) are in phase, and electrodes of left region leads electrodes of right region. The expressions in phase and out of phase, can be understood respectively as positively and negatively correlated (Auth, 2013). The interhemispheric phase difference values in experimental stage decreased according to control. Interhemispheric phase difference for delta band was not statistically significant, but there was a significant difference of phase difference for the higher frequency band.

Finally, we calculated SCL and the ratio of LF/HF to investigate the electrophysiological circumstance of subjects while showing advertisement stimuli. The powers in the HF and LF bands are regulated by Sympathetic (SNS) and parasympathetic nervous systems (PNS) respectively (Okkesim et al., 2016). The ratio of LF/HF obtained PRV increased for experimental stage, which means increasing the activation of ANS. At the same time, SCL computed GSR increased for experimental stage which means increasing the activation of ANS. Average interhemispheric coherence values for all electrode pairs, SCL and the ratio of LF/HF were compared by using MANOVA statistical test. According to results, average interhemispheric coherence and the ratio of LF/HF demonstrated statistical significant between control and experimental stage, but SCL were not statistical significant.

Electro-neurophysiological measures such as coherence, phase difference and LF/HF ratio may provide an alternative evaluating method for neuromarketing studies which are related to analysis of relationship between electrodes and emotional stress and across to commercial advertisement. In the next research, will be studied in more detail about GSR data analysis and interhemispheric coherence analysis.

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