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An Investigation of the Effects of Emotional Experience Induction on Mirror Neurons System Activity with Regard to Spectrum of Depressive Symptoms

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***Abstract*—**The aim of the present study was to assess the effect of emotional experience induction in the mirror neurons systems (MNS) activity with regard to the spectrum of depressive symptoms. For this purpose, at first stage, 449 students of Kharazmi University of Tehran were selected randomly and completed the second version of the Beck Depression Inventory (BDI-II). Then, 36 students with standard Z-score equal or above +1.5 and equal or equal or below -1.5 were selected to construct two groups of high and low spectrum of depressive symptoms. In the next stage, the basic activity of MNS was recorded (mu wave) before presenting the positive and negative emotional video clips by Electroencephalography (EEG) technique. The findings related to emotion induction (neutral, negative and positive emotion) demonstrated that the activity of recorded mirror neuron areas had a significant difference between the depressive and non-depressive groups. These findings suggest that probably processing of negative emotions in depressive individuals is due to the idea that the mirror neurons in motor cortex matched up the activity of cognitive regions with the person's schema. Considering the results of the present study, it could be said that the MNS provides a substrate where emotional disorders can be studied and evaluated.

***Keywords*—**Emotional experiences, mirror neurons, depressive symptoms.

I. Introduction

IN the last decades, the discovery of the MNS has been one of the most important discoveries in the basic neuropsychology field [1]. These discoveries reflect that the human ability for theory of mind and social cognition can be studied more objectively [2], [3]. Indeed, social performance is one of the most important criteria to define psychiatric disorders [4]. Individuals who have normal function in their social environments can easily share their emotions and cognitive and mental representations [5]. In addition, studies suggest that the MNS may serve as a common neural substrate for linguistic, motor, emotional, and other higher-order cognitive information processes [6]. Thus, it can be assumed that the MNS has increased the human ability for emotional processing as well as emotion regulation [7]. Therefore, activity of the MNS likely correlates with psychopathology. Generally, this includes depression or mood disorders. Emotional disorders such as depression can be separated into several groups: dysfunction in understanding and interpreting of emotions; dysfunction of a neural-cognitive system that is responsible for experiencing emotions; and dysfunction in controlling of emotions and experiences, which may be attributed to mixed distress. Given the important role of the MNS in perception of emotions, disturbance in this system may lead to the first group of symptoms [8].

Given the crucial role of the MNS in emotional processes [7], it is not inconceivable to assume that these neurons are important neural substrate in emotion regulation. Since anxiety disorders [9] and mood disorders have been broadly evaluated as a result of emotional processes [10]-[12], it can be stated that the MNS plays an important role in this mechanism. Therefore, it is assumed that, for people who have emotion dysregulation, their MNS has some dysfunction. In some emotional disorders, it is possible that dysfunction of the MNS leads to facilitate emotion dysregulation. The brain regions related to the MNS, including the inferior frontal cortex (IFC) or insula, not only connect to emotional aspects such as facial imitation [13], emotional induction [14], emotional regulation [15] and memory material selection to interpret others feelings [16], but also link to working memory [17] and linguistic processes. These findings support the idea that the MNS can be involved in both cognitive and emotional processes during human interactions. On the other hand, depression is abnormal changes in neural activity [18]. These pathological changes are not only associated with depressive symptoms, but research has also shown that the frontal and prefrontal regions and their functions are involved in cognitive symptoms [19], [20]. The theoretical implications and research findings, that are mentioned earlier, suggest that the MNS is a neural mechanism involved in emotion processing and may play a decisive role in drawing attention to affective stimuli. It is well known that the EEG records spontaneous cortical electric activities. The EEG rhythms are classified by rhythm frequency. One of these rhythms called mu that indicated that the mu rhythm is desynchronized not only by the execution of actions but also by the sight of actions carried out by others. On the other hand, after the discovery of MNS, studies have shown that the MNS activity can be assessed using the activity of Mu rhythm [21]. For example, studies have shown that the EEG mu frequency, more precisely the reduction of the mu power in individuals with autism, is considered to be an index for mirror neuron functioning [22]. Also, it has shown that the

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EEG mu frequency is an indicator for activity of the MNS in individuals with schizophrenia. These studies suggest that the EEG mu frequency increases in people with negative symptoms of schizophrenia, such as delusions and hallucination [23]. Therefore, in the present study, we used the EEG mu frequency as an indicator for the MNS activity. Although the relationship between emotion regulation and the MNS activity has not been studied directly, previous studies indicate that individuals with mood disorders can develop schizophrenia and autism symptoms [8], that these disorders are classified as an emotional dysregulation disorders [4], [24]. In the present study, our purpose was to assess the effect of emotional experience induction on MNS activity with regard to the spectrum of depressive symptoms.

II. Methods

A. Subjects

The statistical population of this study consists of all university students in Kharazmi University who were enrolled in school year 2014. As mentioned earlier, at the first stage of the study, 440 students of Kharazmi University were selected randomly and screened using the BDI-II. Then, 36 students who had depressive symptoms as well as non-depressive symptoms were selected. The research sample consisted 36 students (15 males and 21 females) who were obtained equal or higher than +1.5 and equal or lower than -1.5 standard Z score in the BDI-II and were selected using simple random sampling. The age average of participants was 22. The inclusion criteria for this study, which was investigated using personal reports of subjects and the questionnaires (made by the researcher), included: (1) Aged 18-35, (2) Lack of physical diseases, (3) Lack of epilepsy history, (4) Lack of the psychiatric disorders (in the past and now), (5) Lack of brain trauma history, (6) Lack of the alcohol and substance use. Also, informed consent was obtained from the subjects.

B. Procedure

In the first step and using initial telephone contact, an appropriate feedback about the obtained scores in the inventory was provided, and then the screened students were invited to the next stage of research. At this stage, after informed consent (with completion of a form), the subjects completed the BDI-II again. Then, according to the 10/20 positioning system, the EEG cap was placed on the subject's scalp. Before recording the brain activity, the following instruction was presented to the subjects: "During the baseline, try to close your eyes and recline on your seat in a relaxed state and do not move as much as possible. The researcher will inform you with a little sound when you can open your eyes and after a moment, through the same sound, you will be informed when to close your eyes again until the sound is made."

After recording the waves at the baseline, one of the positive or negative video clips (as alternate positive and negative) was presented, and the subjects simply watched. At this stage, during the presentation of the video clips, the subject was not provided any instruction or stimulus. EEG was recorded from different brain regions simultaneously during the watching of the video clips. During the three stages (baseline, negative and positive emotional states), subjects took some rest in order to eliminating the effect of previous emotional experiences and also if they were tired. The duration of the experiment lasted approximately 1.5 to 2 hours. All experiments were conducted during the 9:00 a.m. to 17:00 p.m. time frame.

Subjects were seated in a comfortable sound and light attenuated room, while at least eight minutes of eyes-closed alert/resting EEG data were collected from the eight monopolar electrode sites (Fz, left frontal pole (FP1), right frontal pole (FP2), left middle frontal (F3), right middle frontal (F4), left ventral frontal (F5), right ventral frontal (F6), left lateral frontal (F7) and right lateral frontal (F8).). The International 10/20 System (referred to linked earlobes) [25] for electrode placement was used to eWave 16b 2014. The eye movement artifact was monitored (by electrooculogram) with a bipolar electrode montage using two electrodes of 9 mm diameter attached superior to, and on the external canthus of, the right eye. The impedances for the EEG and electrooculogram electrodes were under 5 and 20 kΩ, respectively. The amplifier band pass was 0.5–70 Hz (3 dB points), with a 60 Hz notch filter, and data were processed at 200 Hz with a 12-bit resolution [26]. The data were analyzed using mixed variance analysis.

C. Beck Depression Inventory- II

The BDI-II is the revised form of the BDI, which has been developed to measure the severity of depression. This version, like the first version, consisted of 21 items that subjects selected one of the four options which represent severity of depressive symptoms about themselves. Items are scored between 0 and 3, and thus the total score ranges from 0 to 63. The psychometric studies have shown that the inventory has optimal reliability and validity, and generally is an appropriate substitute for its first edition. Reference [27] reported the internal consistency of this instrument in ranging from 73 to 92% with an average of 86% and also alpha coefficient for the patient group was 86% and 81% for non-patient. In Iran, Porshahnaz in his study of 112 people examined the psychometric properties of the BDI-II. The correlation coefficient between each section and the total score was ranged from 23% to 29%, and its internal consistency was 85%. The reliability of the inventory was 81% using the split-half method as well as Spirman/Brown Prophecy Formula, and also the Cronbach's alpha coefficient for the post-test of depression inventory was 76%.

D. EEG

EEG belongs to electrobiological imaging tools widely used in medical and research areas. EEG measures change in electric potentials caused by a large number of electric dipoles formed during neural excitations. The EEG signal consists of different brain waves reflecting brain electrical activity, according to electrode placements and functioning in the adjacent brain regions [28]. In the present study, the brain

waves were recorded by EEG- eWave 8 (the ScienceBeam company). This 16-channel device can record EEG and QEEG. In this device, some software codes are embedded for quantifying the brain waves. These software codes allow the brain waves convert, using FFT operation, from the time domain (coordinate of range according to time) to the frequency domain (coordinate of range according to frequency). According to the international 10/20 standard positioning system [29], the brain waves recorded in eight regions include left frontal pole (FP1), right frontal pole (FP2), left middle frontal (F3), right middle frontal (F4), left ventral frontal (F5), right ventral frontal (F6), left lateral frontal (F7), and right lateral frontal (F8). In addition, an electrode was also installed as a "Ground" on the foreheads of the subjects. Using a Fast Fourier Transform (FFT) operation, existing applications allowed brain waves to be converted to the frequency domain (range coordinates based on frequency) from the time domain (range coordinates based on time).

E. Emotional Video Clips

In the present study, in order to induce positive and negative emotional experiences, emotional video clips were used. Development and use of the video as a method to evoke and induce emotion have taken place parallel to vast maturity of knowledge [30]. More than half a century ago, researchers often used emotional video clips to evoke a scattered anxiety or stress state using unofficial standards [30]. Reference [31] evaluated the reliability and validity of the video clips and indicated that these emotional video clips have an appropriate reliability and validity.

F. The Statistical Design and Data Analysis

According to groups, basic variables, and the data scale, statistical design of the study was mixed design. Given the research design (pretest- posttest control group design), the data were analyzed through repeated measures, Mix Variance Analysis. This design is used when a group of participants is examined at different intervals of time as well as in different conditions of an experiment [32].

TABLE I
THE RESULTS OF MIX VARIANCE ANALYSIS

	Electrodes	depressive Group		non - depressive Group		Source variance					
		Average	SD	Average	SD	the main effect of group		main effect of emotion induction		interaction effect	
						F	η	F	η	F	η
	Baseline	2.40	2.38	2.44	1.53						
F1	Negative emotions	2.68	1.35	1.68	0.69	0.232	0.007	1.14	0.033	9.63	0.221
	Positive emotion	1.86	0.69	3.37	1.74						
	Baseline	2.55	2.43	2.43	0.78						
F2	Negative emotions	2.56	1.29	1.62	0.65	0.002	0.000	1.98	0.055	11.91	0.171
	Positive emotion	2.08	0.96	3.10	0.62						
	Baseline	3.75	1.30	4.38	1.75						
F3	Negative emotions	4.75	2.00	2.57	1.97	0.040	0.001	0.719	0.021	16.65	0.329
	Positive emotion	2.87	1.31	4.65	1.86						
	Baseline	4.07	1.27	4.43	1.98						
F4*	Negative emotions	4.35	1.75	2.46	1.07	0.003	0.000	3.89	0.103	0.001	0.313
	Positive emotion	2.95	1.09	4.42	1.93						
	Baseline	5.56	2.25	5.80	1.99						
F5*	Negative emotions	5.13	1.64	2.47	1.76	0.111	0.003	10.22	0.231	21.60	0.389
	Positive emotion	3.14	2.02	5.96	1.54						
	Baseline	7.36	6.57	6.09	1.93						
F6*	Negative emotions	5.02	1.74	2.48	1.72	0.634	0.018	9.67	0.222	6.03	0.151
	Positive emotion	3.46	1.91	5.62	2.13						
	Baseline	5.21	2.05	5.38	1.85						
F7*	Negative emotions	5.04	1.72	2.40	1.60	0.011	0.000	8.15	0.194	19.26	0.362
	Positive emotion	2.99	1.64	5.32	2.16						
	Baseline	5.15	2.31	4.76	1.98						
F8	Negative emotions	5.13	2.46	3.08	1.30	0.386	0.011	2.52	0.069	0.001	0.215
	Positive emotion	3.31	1.42	4.96	1.91						

III. RESULTS

The number of people in the depressive group and the non-depressive group was 18. These two groups were matched in terms of education, handedness, footedness as well as age. The age average of the sample was 21.75 (SD= 2.76). The age range of the sample was between 18 to 28. Mix Variance Analysis of descriptive statistics related to frontal lobe of the mu wave showed that the average and standard deviation of mu wave activity are different in the two groups at baseline and emotional conditions. Indeed, this significant difference was related to F4, F5, F6, and F7. That is, when individuals in the depressive group encountered negative emotions, their EEG mu frequency was increased, and when they encountered positive emotions, their EEG mu frequency was decreased. On the other hand, when individuals in the non-depressive group

encountered negative emotion, their EEG mu frequency decreased and when they encountered positive emotion, their EEG mu frequency increased (see Table I). In this analysis, the two groups (depressive and non-depressive) were considered as a between-subjects factor, and emotion induction (baseline, negative and positive emotions) considered as a within-subjects factor. The dependent variable was also the 8 scores of the electrodes in the EEG.

TABLE II
THE RESULTS OF BONFERRONI POST HOC TEST CORRECTION FOR COMPARISON THE ACTIVATION OF ELECTRODES

Electrodes	Phase I	Phase J	I-J	Standard error	Significant
F4	Baseline	Negative emotions	0.84	0.33	0.046
		Positive emotion	0.56	0.21	0.042
	Negative emotions	Positive emotion	-0.27	0.35	1
F5	Baseline	Negative emotions	1.87	0.37	0.001
		Positive emotion	1.12	0.41	0.033
	Negative emotions	Positive emotion	-0.74	0.45	0.333
F6	Baseline	Negative emotions	2.97	0.77	0.002
		Positive emotion	2.18	0.79	0.028
	Negative emotions	Positive emotion	-0.79	0.49	0.356
F7	Baseline	Negative emotions	1.57	0.34	0.001
		Positive emotion	1.13	0.41	0.029
	Negative emotions	Positive emotion	-0.43	0.44	0.993

IV. DISCUSSION

The results of the present study are consistent with [6], [17], [33]-[37], [14] based on that premotor neurons or mirror neurons are activated for understanding an emotion and an action in different conditions of mental states. It can be said that the neural system as a whole is associated with understanding and planning the actions which are related to emotions.

Overall, the results of these observations indicate that strong evidence supports the role of mirror neurons. This means that they play a role in the inclusion of the others subjective states within individual states. For example, research in a clinical population suggests that the MNS is associated with the emotional process [7]. Indeed, emotions are considered an important part of social cognition and the ability to recognize and respond to the other's emotional states. Studies related to TMS suggest that there is a positive relationship between the quality of recognizing emotion and MNS activity [38], while studies related to FMRI indicate that the activity of the ventral motor cortex [39] and inferior frontal sulcus [14], exist during observation the facial expression in participants. It was shown, using TMS, that exposure to negative or positive emotion could moderate emotional balance in emotional activity of mirror neurons.

As a result, according to the present study, it can be said that processing of negative emotions in the depressive individuals is due to mirror neurons in motor cortex matching up the activity of cognitive regions with person's schema. According to this, mirror neurons probably have an effect on emotion regulation strategies. Looking at the results of the present study, it can be concluded that the MNS provides a substrate, where emotional disorders can be studied and evaluated.

One of the main limitation of this study is the lack of using a clinical depression group as well as a control group. According to the above discussion and due to some limitation of the present study in methodology, we hope that future studies will be able to examine and evaluate the function and activity of these neurons in a broader scope and through various techniques, with regard to the hypothesis of the mirror neurons' role in cognitive and metacognitive functions. Since, in this study, emotion is examined generally, future research can examine and evaluate the relationship of each emotion with mirror neurons, separately.

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