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Original Article

Social and Economic Decision-Making Utility Based on EEG Signals Analysis in Women

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Abstract

Introduction: One of the new fields of study is Neuroeconomics which investigates the effect of human brain on economic decision makings. In the current study, economic decision making was examined, using the Prisoner's Dilemma Game among females followed by electroencephalogram (EEG) analysis.

Materials and Methods: Female participants were chosen based on their ability of making rational decision examined in Prisoner's Dilemma Game for each group. Based on the data obtained from the Prisoner's Dilemma Game, two groups existed: one includes female with good decision making in economic field in Prisoner's Dilemma Test and group 2 consists of females who did not chose appropriate economic decision during the game. Also EEG analysis was performed at the end of EEG recording, participates were asked if they feel utility about their economic decision making in their entire life or not.

Results: The current results showed that the Economic Decision-Making Utility was more in group with better economic decision in Prisoner's Dilemma Game. EEG analysis shows that Alpha/Beta ratio is %16.5 and Theta/Beta ratio is %12.5 less in group 2 who stayed silent and did not betray other suspect (***P<0.001).

Conclusion: According to the current data, utility about economic decisions may affect decision-making and EEG or vice versa, as Alpha/Beta and Theta/Beta ratio are less in the group who stayed silent and did not betray other suspect.

Keywords: Choice behavior, Neuroeconomics, EEG data, Prisoner's Dilemma Game

1. Introduction

Electroencephalography (EEG) is a noninvasive and an electrophysiological method to analyze electrical activity of neurons with the electrodes placed along the scalp[1]. EEG assesses voltage fluctuations resulting from ionic current within the neurons. Recent literature in Neuroeconomics uses EEG to investigate choice behavior[1]. The interest of economists to evaluate neurophysiological data to study human economic decision making has remarkably increased. Neuroeconomics has tried to explain different models of decision making analysis[2]. However, there are limited ways to study economic behavior[3]. Behavioral and experimental economics rely on some experiments and tasks to predict behavior. Prisoner's Dilemma Game theory can provide a mathematical framework to study economic decision-making processes in humans. In the game, the players adopt one action among a set of possible actions (strategies), leading to gaining or losing money [4-6]. Also the

Prisoner's Dilemma Game has been considered as a good task to evaluate social behavior as individuals should choose between self-interest (economic decision making) and social benefit. Human rational decision making is affected by neural network activates[7]. Some published articles suggest that EEG pattern in decision making is liable to change [8]. The four basic frequency bands are Delta (frequency< 4 Hz), Teta (4-7 Hz), Alpha (8-15 Hz), and Beta (16-31 Hz), Gama (frequency > 32Hz). Delta's waves tend to occur during deep and unconscious sleep. Whenever someone is in light sleep or is focusing on something, Theta wave is running. Meanwhile, Beta waves are more in normal consciousness, alertness or active concentration. Following this Alpha wave shows the state of consciousness and good mood during relaxation state with eyes closed (not asleep). Mental cognitive state like attentiveness and fatigue can be evaluated by Alpha/Beta ratio. In addition, attention deficit/hyperactivity disorder can be studied through Theta/Beta ratio[1].

As human behavior is directly influenced by sex and different cultures, it is important to investigate economic decision making in different countries. In this study, EEG tools have demonstrated the use of brain signals to distinguish its relation to Neuroeconomics decision making through Prisoner's Dilemma Test.

2. Materials and Methods

2.1 Participants

Female participants were recruited via advertisements in social media. Following telephone screening from more than 150 women, potential participants [115 women] came to the research center for more extensive psychiatric and medical interviews. Forty women were chosen for experiment. Two groups were considered: group one were woman with good decision making in economic field in Prisoner's Dilemma Test and group two consisted of females who did not chose appropriate economic decision in game.

All included participants gave written consent to participate in this study. For both groups, age was between 20–35, with no history of addiction or any kind of illness, a minimum of two years of academic education.

2.2 Prisoner's Dilemma Test

The Prisoner's Dilemma test has been explained before [23]. Female subjects are imaginary members of a criminal group who are arrested by police and prisoned. Police gives each one the offer to examine if the other committed a crime or not and, if one cooperates with the other by remaining silent or not. Table 1 shows optional offers to each participant. According to pervious works and the theory of game, the best economic decision for each participant would be defection, because it offers a better payoff than cooperation (remaining silent). So from economic point, it is supposed that cooperation is an irrational choice, since it does not result in the highest amount of intimate utility.

Table1. Payoff matrix used in the Prisoner's dilemma [9]

		Player1	
		Betray	Cooperate
Player2	Betray	Both players lose one million dollars	Player 1 loses 3 million dollars and player 2 wins 5 million dollars
	Cooperate	Player 1 wins 5 million dollars and player 2 loses 3 million dollars	Both players win 3 million dollars

Each player has two options, cooperate or betray, and there are four outcomes based on both players' decisions. The payoff scheme is designed to encourage betrayal, as betraying assumes the other cooperates to be associated with the highest gains.

2.3 Electroencephalography [EEG]

Electroencephalography (EEG) was measured using a 22-channel sensor, high-input impedance amplifier in a shielded and soundproofed room .For the EEG data acquisitions, the participants were comfortably seated on a reclining chair in an electrically shielded and dimly lit room. Sciencebeam system was used to record EEG signals. EEG activity was recorded continuously using a 0.3–100 Hz bandpass filter at a sampling rate of 500 Hz. The recorded EEG data were digitally filtered using a 0.3–30 Hz bandpass and re-referenced to the average reference. Also, epochs contaminated by artifacts such as eye blinks were omitted by the threshold of peak-to-peak amplitude of ± 70 μV from the eye channels.

This study presents the utilization of EEG tool in conjunction with signal processing technique in term of Alpha/Beta ratio and Theta/Beta ratio in females who chose to betray other participant in Prisoner's dilemma test vs females who did not betray other imaginary participant. EEG signals were first obtained, followed by data pre-processing. Then, bands of specific frequencies were extracted from the pre-processed data. At the end suitable features were extracted and have chosen to analyse.

2.4. Economic Decision-Making Utility

Self-reporting about individuals' Economic Decision-Making Utility after EEG recording (from 1 to 10).

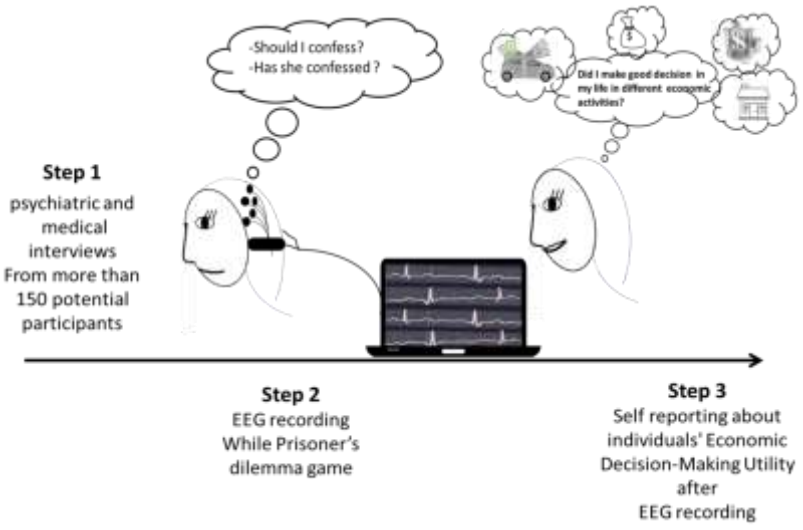

Figure 1. Timeline of the experiment

2.5 Data Analysis

Mean ± SEM (standard error of mean) was used in order to express the data, which was processed by Graph Pad Prism® 5.0. T-Test was used. P value less than 0.05 ($P < 0.05$) was considered as statistically significant.

3. Results

Economic Decision-Making Utility was more in group with better economic decision in Prisoner's Dilemma Game

Between-groups comparisons on socio-demographic data are presented in Table 2. There was not any significance difference in age and academic education between participants of group 1 and 2.

Data from last row in table 2 shows that in the Prisoner's Dilemma Game, participants of group 2 opted significantly more often to remain silent (cooperate) compared with group1 (***$P < 0.001$). This data indicates non-rational decision making in group 2 compared to group one (Table 2)

Table 2. Group1 (cooperate or betray) and Group2 (silent or not betray) Socio-demographic report and between-group comparisons regarding social and economic decision-making experiment in the Prisoner's Dilemma Game.

	Group1 (betray) n=20	Group2 (stay silent or not betray) n=20	p-Value
Self-reporting about individuals' Economic Decision-Making Utility	8.05 (0.9)	6.02 (1.05)	0.03
Age (years) – mean (SD)	20 (3)	20 (4)	0.416
Years of academic education – mean (SD)	2(1)	3(1)	0.9
Remain silent or cooperation [means do not betray other participant] – %(n)	0%	100%	0.0001

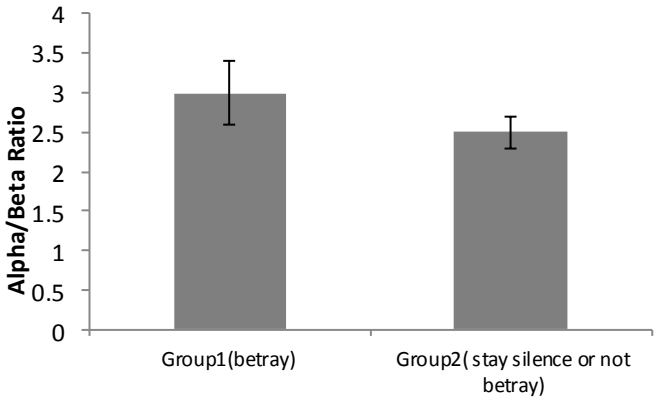

Figure 2

Figure 2. Alpha/Beta ratio.

Figure 2 shows that the value of Alpha/Beta ratio is less in group 1 (*P>0.05) but it was not statistically significant, which indicates Alpha activity is decreased, appearing as an increased relative Beta activity. The bigger value of the ratio means the greater percentage of Alpha activity.

The Theta/Beta ratio in Figure 3 as well reveals the value was 1.14 fold more in group1 (***P<0.001).

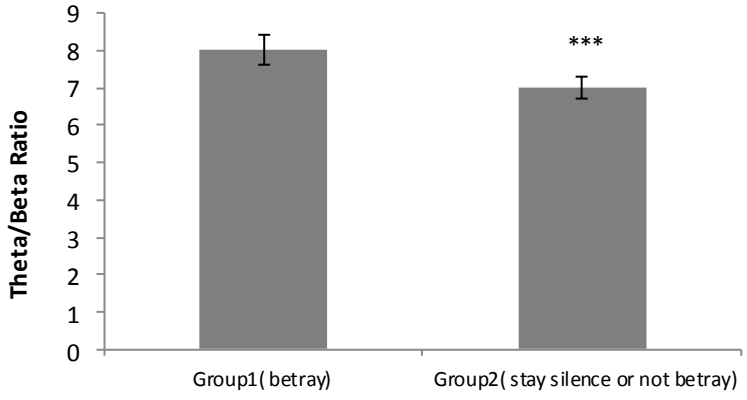

Figure 3

Figure 3. Theta/Beta ratio. (***P<0.001)

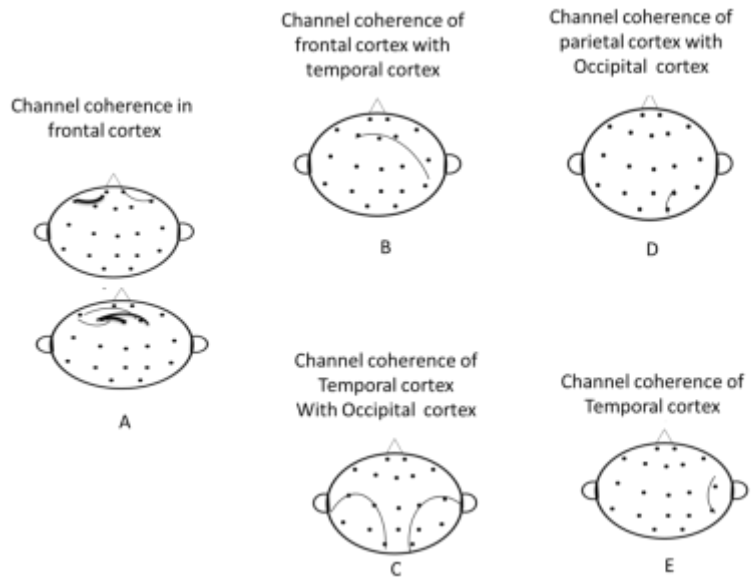

Figure 4. EEG coherence was used to assess functional connectivity in human cortex. Significant ($p<0.05$) coherence indicated by thin line and Significant ($p<0.01$) coherence indicated by thick line.

Also figure 4 shows EEG coherence in human cortex.

4. Discussion

Economic and social decision making in females are examined, using the Prisoner's Dilemma Game. Also, EEG was recorded to investigate the ratio of slow wave over fast wave (Alpha/Beta ratio and Theta/Beta ratio). These two ratios are used to consider a way to evaluate the individual's brain cognition state.

The key finding is that group1 which betrays the other imaginary suspect, reported more **utility** in their economic decisions in their life. Upon the game theory, it is suggested that "cooperation or stay silent" in the Prisoner's Dilemma Game is not a good economic decision and is an irrational choice, as it does not gain the highest amount of individual utility [10]. It has been suggested that economic decision-making is related to the environment that people has been grown. Also human emotions and feelings can change logical decisions [11]. One way to study Neuroeconomics is electroencephalography [12]. EEG data was used to study decisions related to purchase behavior also in preferences and attraction to advertisements[13]. Subsequent studies have linked Alpha/Beta and Theta/Beta ratio to various aspect of executive cognitive performances in individuals.

The current results showed that the Alpha/Beta ratio and Theta/Beta ratio are less in group 2 who stayed silent and did not betray other suspect. Alpha oscillations emerge when the brain is not in active mode and is relaxed and Beta oscillations appear when the brain is in active. Higher Alpha/Beta ratio reflecting increased Alpha power and/or decreased Beta power were associated with a decreased level of alertness or arousal level**.** Theta oscillations manifest brain activity that regulates motivational and emotional processes.

5. Conclusion

Different psychological tasks have been used in the present study and clinical practice was utilized for getting information about economic decision making and utility, one of which is EEG due to its ability to represent the changes of brain activity under different conditions [14]. EEG records electrical activity in short time; it is also affordable for clinical and research

laboratories and is easy to use [11]. To address our interest about neurophysiological data about economic decision we observed EEG signals between two female groups with good or bad economic decisions evaluated by Prisoner's Dilemma Game. According to the current data, utility about economic decisions may have effects on decision-making and EEG or vice versa, as Alpha/Beta and Theta/Beta ratio are less in group who stayed silent and did not betray other suspect.

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Conflict of interest

The authors declare no conflict of interest.

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