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Dictator's Game and Prisoner's Dilemma in an EEG study on money donation

Franklin Back[1], Giovani Carra[2], Marilda Spindola Chiaramonte[2] and Alcyr Oliveira[1]

1 Universidade Federal de Ciências da Saúde de Porto Alegre, Brazil

2 Universidade de Caxias do Sul, Brazil

Abstract

Knowledge is currently scarce about what happens in the brain when a decision is made to make a donation. This intriguing donation behavior is often assumed to relate to social relationships. The present study used simulated situations in which participants had to decide how to manage money when possibilities for donation were available. Electroencephalographic signals were recorded while participants were exposed to two cognitive situations, the Dictator's Game and the Prisoner's Dilemma, to simulate money exchange between people. Brain activity was measured to determine whether correlations could be made with decisions to donate. Sixty volunteers were assessed, and stimuli were presented randomly. After the presentation of the cognitive tests, the participants were allocated to two groups for the respective cognitive situations. The data showed significant differences in the left prefrontal cortex between questions with a donation context and questions not related to donations. Participants who heard a question related to donation had higher activation in the left prefrontal cortex. These results are consistent with recent functional magnetic resonance imaging studies, suggesting that greater activation in the prefrontal cortex could be produced by the logical evaluation of dilemmas. These results suggest that logical evaluation occurs when faced with a reasonable donation situation. Keywords: altruism, donation, EEG, decision-making.

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Introduction

Psychology and cognitive science hardly present justifiable reasons for donation behavior. People voluntarily choose to give their time, money, or even bodily organs without the smallest hint of later reciprocation. Highly related to empathy (de Waal, 2008), altruism has been the focus in recent years of studies in different research areas, such as psychology, ethology, evolutionary biology, and neuroeconomics. Some findings have led researchers to uncover a series of factors able to influence altruism (Barclay & Willer, 2007; Dawes, Fowler, Johnson, McElreath, & Smirnov, 2007; Fehr & Fischbacher, 2003; Jeon & Buss, 2007). Altruism is also hypothesized to underlie several social behaviors, such as care and money-giving, daily social interactions, charity, and organ donation (Landry, 2006).

Franklin Back and Alcyr Oliveira, Departamento de Psicologia, Universidade Federal de Ciências da Saúde de Porto Alegre, Brazil. Giovani Carra and Marilda Spindola Chiaramonte, Centro de Ciências Exatas e Tecnologia, Universidade de Caxias do Sul, Brazil. Correspondence regarding this article should be directed to: Alcyr Oliveira, Universidade Federal de Ciências da Saúde de Porto Alegre, Departamento de Psicologia, Rua Sarmento Leite, 245 - Porto Alegre - Brazil, CEP 90.050-170. Phone: +55-51-3303-8826; Fax: +55-51-3303-8810. E-mail: alcyr@ufcspa.edu.br

Considering the various forms and reasons to give, studying the phenomenon of donation is crucial to understand each manifestation of this behavior. The present study was designed to understand what occurs in the human brain when a decision to donate money is made. The definition of altruistic-related behavior is not intuitive. Several fields of study, from psychology to neuroeconomics, have developed research on this topic. This situation has generated a plurality of descriptions, making the subject somewhat ambiguous. Additionally, many factors are able to modulate responses in donation situations, such as reputation construction, possible future benefits (Barclay & Willer, 2007), worries about what other people may think about those actions (Fehr & Fischbacher, 2004), kinship with the receiver (Jeon & Buss, 2007), and even punishment for being unfair (Brandt, Hauert, & Sigmund, 2003).

From an empirical point of view, whenever a donation act is favorable, the human body reacts. Emotional aspects involved in a binomial decision-making situation to "donate or not donate" and the cognitive effort expended to analyze the consequences might serve as triggers for neural responses. The development of methods to detect the pattern of donation-related responses is important for understanding how this social interaction behavior works and how it is established in humans. Some studies provide evidence that decision-making in economic interactions, such as the stock market, does not exactly follow cost/benefit relationships (Lo & Repin, 2002). Abandonment of cost/benefit relationships in a competitive field such as the stock market suggests that the market economy is guided not only by the quest for maximum profit, but also by emotion. Thus, when playing the Ultimatum Game and Dictator's Game, men who inhaled a solution of oxytocin donated a greater amount of money compared with those who received placebo (Zak, Stanton, & Ahmadi, 2007), suggesting that donation-related behavior is linked to a bounding effect. Although the authors noted the differences between altruism and generosity, they demonstrated correlational evidence for emotion and donation considering oxytocin as a "bounding-neurohormone" that could make donators feel socially connected to the donation recipients.

The present study considered the donation of money in an isolated situation. Important are the different aspects of donation behavior. For example, money donation does not have the same context and parameters as organ donation. Therefore, distinctive references should be analyzed for each kind of choice, and distinct tools should be used for each situation.

Two decision tasks from experimental economics and cognitive situations were used in the present study: the Dictator's Game (Zak et al., 2007) and the Prisoner's Dilemma (Roberts & Renwick, 2003). These are tasks that have generally been used in studies of altruism and social interaction and provide a situation in which participants must cognitively interact through money as a way to maximize profits.

The physiologic response monitored during the tasks consisted of electric potentials on the surface of the scalp measured using electroencephalography (EEG). Beyond utility in clinical diagnosis, EEG has been used in cognitive research, mainly during the past decade, because it involves more direct recording of electric activity in a short timeframe, making the measurement of virtually instantaneous neural activity possible (Laufs, Daunizeau, Carmichael, & Kleinschmidt, 2008; Olejniczak, 2006; Shibasaki, 2008). In fact, considering the timing of data acquisition and the expression of function, EEG has some advantages and disadvantages over other techniques for brain activity assessment. The limitations of EEG include the impossibility of clearly defining specific groups of triggering cells or constructing a structural functional view. The advantages of EEG include the precision of time of an action potential. This is crucial for detecting fast electrical changes and relating them to the reaction to stimuli presentation. Therefore, EEG can play an important role in cognitive studies. The present study investigated brain activity using EEG during cognitive thought activities in which participants were presented with the opportunity to decide to donate money.

Method

Participants

The study was approved by the Ethical Committee from the Universidade Federal de Ciências da Saúde and the Ethical Committee from the Universidade de Caxias do Sul. Undergraduate students from both universities participated in the study and gave written informed consent prior to inclusion in the experiments. During the recruitment process, words such as "help," "donation," and "altruism" were avoided. Moreover, no deception occurred in any part of the experiment. The allocation of participants to groups and the order of task presentation were random. Twenty-seven participants were analyzed from an initial 60 invited volunteers. All of the participants completed a self-report questionnaire to gather health and socioeconomic information and were submitted to testing. To include the participant's data in the analysis, the participant must have been regularly enrolled in a university. Participants that met one or more of the following conditions were excluded from the analysis: smoking, alcohol use within the past 2 days, the use of medicines or other drugs, a convulsive experience or epileptic episode at any time in life, sleeping problems, somnolence at the moment of the experiment, auditory deficiency, and family or participant history of mental illness of any kind. After completing the forms, the entire process and procedure were explained, and subjects went through orientation about the setting conditions and data collection (e.g., remain motionless, seated, eyes closed, and relaxed).

Apparatus

We used a 22-channel EEG recorder developed by the Laboratory of Electrical Engineering, Universidade de Caxias do Sul (Carra, Spindola, Chiaramonte, Balbinot, 2007). The study used only eight target channels. A belt was positioned around the chest of the volunteer to fix the two straps of the cap, which had a 10-20 electrode positioning pattern (American Clinical Neurophysiology Society, 2006). Two electrodes were positioned on the ear lobes so they could be used as neutral reference electrodes. An additional sensor was placed on the left arm, in contact with the skin, as a reference for skin potential. Once the sensors were placed, a conductive gel was applied inside each electrode, with the exception of the arm electrode. The scalp electrodes were positioned at the following points (Fig. 1): FP1 and FP2 (left and right prefrontal cortex, respectively), T3 and T5 (left temporal lobe), T4 and T6 (right temporal lobe), Cz and Pz (sagittal line). These electrodes were selected to detect activation related to rational analysis (prefrontal cortex) and possible emotional involvement (temporal lobe) and cortical references (sagittal line).

The EEG signal was recorded inside a Faraday cage (Fig. 2) using two computers, one in front of the participant, which would present the stimuli, and

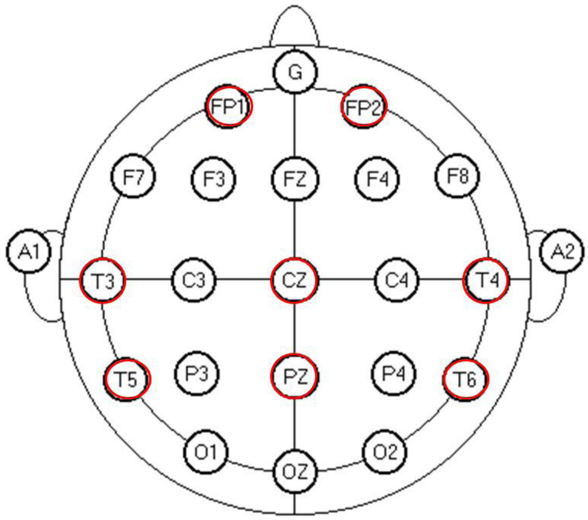

Figure 1. Schematic positioning of electrodes (Guidelines for Standard Electrode Position Nomenclature, 2006).

another behind the participant, which recorded signals from the EEG. Two computers were necessary to diminish artifact delay between stimulus and response by considering the processing of all information by one machine only. For the same reason, the computers were previously synchronized.

Procedure

Participants were randomly subjected to two cognitive tasks: the Dictator's Game and the Prisoner's Dilemma. The tasks were presented to the participants written in their native language. The equivalent text in English is presented in Appendix. In the Dictator's Game, the participants were presented with a situation in which a possible donor (A) had an amount of money equal to $10. A fictional recipient (B) is unable to respond to A. Therefore, A must choose between giving part of his money to B, and if so, how much he would give. The participant knows that A is aware that B can only watch the acts of A. The text is written in such way that the participant should play the role of A.

Similarly, the Prisoner's Dilemma displays to the participant a role to be played as a donor (A). However, in this task, the recipient (B) is able to donate and consequently return the received donation to the donor. The amount donated by A is multiplied by 2 when B receives the money. Therefore, B can pay back the donation in full or increase the amount returned. The Prisoner's Dilemma has an underlying relationship between the two players, who depend on each other to maximize their benefits.

In the present study, the tasks were performed only once, rather than several times as in economics and trust research. The participants played only the A role as the possible donor. The main difference between the tasks was that of the expectations of A about the answers of B. The participants were also asked to imagine themselves in these situations and only think about their answers.

When the participants fully understood the instructions and had the electrodes positioned, they entered the Faraday cage, which was sound- and electrical static-isolated, and sat as comfortably as possible in a chair. Then the cage was closed and the light was shut down. The experimenter connected the cables to the EEG recorder and checked whether all electrodes had a functioning contact. All other electrical devices next to the cage were turned off during the experiment. Both computers inside the cage were powered by batteries to avoid possible interference from alternating current. The experimenter then waited until the capture signal reached stability.

Each participant was subjected to three recording sessions consisting 5 s each. The 5 s sessions were composed of 1 s of silence, 3 s of stimulus, and another 1 s of silence. The stimulus varied for each session. The two intervals between three sessions included the opening of the cage, limited movement (participants could not get up from the chair), and reading. The instructions of the dilemmas were presented randomly while no recording occurred. Recording continued only if the participant admitted to understanding the task. During the entire procedure, the experimenter accompanied the participant, including being inside the cage with the participant while remaining still during recording.

Two groups were formed with different combinations of sessions and were defined by the presentation of the stimuli: SND (group with stimulus not related do dilemmas) and SRD (group with stimulus related to dilemmas). The SND group was subjected to three sessions, each with a different stimulus not linked to dilemmas. Therefore, the SND group was subjected to the first session with an incomprehensible stimulus composed of the sound of a voice for 3 s. This session was created to capture the processing of a sound without direct interpretation. After the recording session had

Figure 2. Faraday cage used in the experiments.

terminated, the cage was opened, and instructions about the first task were randomly chosen and displayed to the participant. The data collection could not restart until the participant had read and expressed understanding of the task. Once this occurred, the door was closed, and the second session was initiated. This session was composed of 5 s of silence. The second session was created to capture only the expectation of a stimulus because the first session contained a stimulus and the second session did not. After recording was completed, a similar procedure was applied during the interval, with only the task instructions changing, referred now to the other game. A third session was composed of a comprehensible question not related to the tasks. All of the questions were presented in Portuguese. The question was, “Do you want to jump? If you do, how high would you jump?” This session was created to capture the processing of the sound with direct comprehension but was unrelated to the context. The phrases mimicked the sound produced by the test questions and did not relate to the decision of donating money. After the third session, participants wrote their answers to the tasks on a piece of paper.

The SRD group was equally subjected to three sessions. The first session was the same as that presented to the SND group. In the second and third sessions, participants were asked about what they would do with the money in those situations. Procedures during the intervals were the same for both groups, with the two tasks presented in random order. The second and third sessions were differentiated only by the tasks. In the second session, similar to the third session, the stimuli included the same question (“Do you want to donate? If you do, how much do you want to donate?”). These sessions were created to capture the sound, comprehension, and decision-making process. After the third session, participants wrote their answers on a piece of paper. All stimuli were previously sound-recorded, with an exact duration of 3 s. The incomprehensible stimulus was composed of the test sound presented backwards. To eliminate possible differences in responses caused by intonation or the time intervals of the questions, exactly the same speech as the stimulus was utilized.

Data collection

Signal capture included eight scalp channels during three sessions, with a total of 24 data files of 5 s each for each participant. All data were processed with LabView 8.0 software. The 3 s periods corresponding to the stimuli were extracted and analyzed to detect biological, mechanical, or electrical artifacts. Data exhibiting artifacts were excluded from the analysis. The electrical signal detected during those 3 s was displayed in graphics mode, relating amplitude with time. Some mathematic manipulations were conducted to apply a statistical method of analysis. The software was programmed to calculate the module of the signal, transforming all negative amplitudes into positive amplitudes, while maintaining the units (Fig. 3). The software was then programmed to calculate the area of the resulting figure, limited by the zero amplitude as a base and the maximum amplitude. The area was directly related to the total amplitude of the signal during the 3 s of analysis.

Statistics

The resulting area related to each session was plotted with GraphPad Prism 5 software to perform the statistical analysis. Two sessions were compared, and *t*-test was used to detect differences between sessions. Values of $p < .05$ were considered statistically significant.

Results

From the initial 60 participants, 33 were excluded from the analysis because they met at least one of the exclusion criteria. Data from the remaining 27 participants were subjected to artifact detection by a statistical data preview. This method comprehends a visual analysis of graphics and may indicate signals with high variations or no amplitude. When these signals were detected, the data were excluded to avoid misinterpretation (Fig. 4).

The average areas are shown in Table 1. When comparing the areas of the third session in the SND group (1875 ± 208.6 mm^2, $n = 10$) with the Dictator’s Game session in the SRD group (1401 ± 86.0 mm^2, $n = 11$), a significant difference ($p = .0426$) in the FP1 electrode was detected. A similar comparison was made with the Prisoner’s Dilemma, with an average area of 1373 ± 74.36 mm^2 ($n = 13$) in the SRD group, which was significantly different from the third session in the SND group ($p = .0207$).

Considering the FP2 electrode, only a tendency toward a difference between the third session in the SND group and the Prisoner’s Dilemma in the SRD group was detected. The SND group had an area of 1749

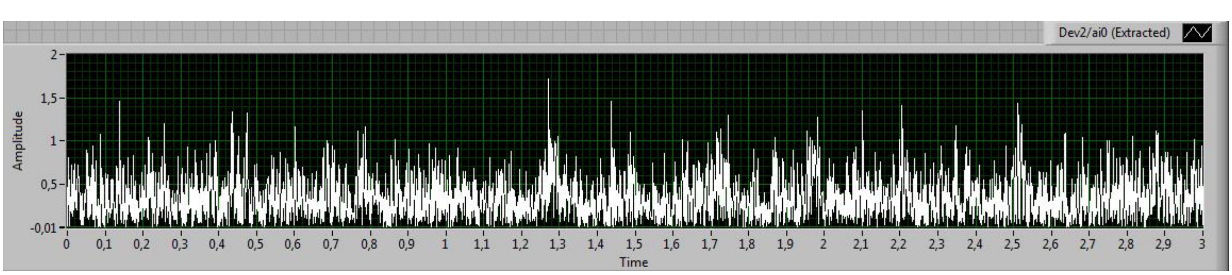

Figure 3. Example of 3 s modulated signal. From graphs such as this, the area to be used in the statistical analysis was calculated.

Table 1. Average areas of detected signals (mm2).

	Control Group			Test Group		
	Fist Session	**Second Session**	**Third Session**	**First Session**	**Second Session + Third Session**	
		DG + PD	**DG + PD**		**DG**	**PD**
FP1	1702 ± 111.3	1432 ± 89.3	1875 ± 208.6*,**	1337 ± 85.2	1401 ± 86.0*	1373 ± 74.3**
FP2	1651 ± 91.3	1409 ± 91.5	1749 ± 201.7	1400 ± 104.2	1455 ± 106.4	1368 ± 79.7
T3	1348 ± 90.5	1254 ± 89.0	1256 ± 59.57	1208 ± 62.2	1301 ± 67.1	1310 ± 99.8
T4	2508 ± 388.0	1823 ± 180.4	2052 ± 143.3	1632 ± 244.5	1912 ± 207.0	1787 ± 263.0
T5	1317 ± 126.2	1197 ± 84.1	1243 ± 118.3	1276 ± 90.5	1319 ± 82.0	1301 ± 94.1
T6	1366 ± 93.2	1406 ± 69.5	1261 ± 103.0	1194 ± 84.4	1402 ± 162.5	1384 ± 119.7
Cz	1531 ± 164.6	1311 ± 144.8	1448 ± 279.4	1468 ± 122.7	1283 ± 76.7	1492 ± 143.0
Pz	1535 ± 114.7	1212 ± 82.6	1510 ± 118.7	1567 ± 182.3	1338 ± 85.9	1506 ± 120.9

*p = 0.0426, **p = 0.0207. DG, Dictator's Game; PD, Prisoner's Dilemma.

± 201.7 mm^2 (n = 9), and the SRD group had an area of 1368 ± 79.71 mm^2 (n = 13, p = .0611). Electrodes T3, T4, T5, T6, Cz, Pz, and FP2 in the Dictator's Game did not exhibit significant difference when compared with the SND stimulus session.

Discussion

The present study provides insights into decision making, and more specifically, decision making for money donation. Extending these findings to other forms of decision making to donate would certainly be premature. Therefore, the data shown here should only be interpreted within the framework of decision-making in a monetary donation situation. Considering that the method used in the present study achieved the proposed objective to isolate decision-making in a monetary donation situation, the results indicated significant activation of the left prefrontal cortex during the decision "to donate or not donate." Importantly, the data refer to activation in brain areas as a consequence of significant neuronal activation. However, the results cannot be specifically related to only one type of neuron or even a specific cortical location, which is a known limitation of EEG. The main objective of using EEG as a tool was to record events at a precise moment. Although finding evidence of cognitive changes has been difficult using this method, our study showed that the choice of whether to donate was able to produce electrical field changes in contrast to situations in which such a demand did not occur.

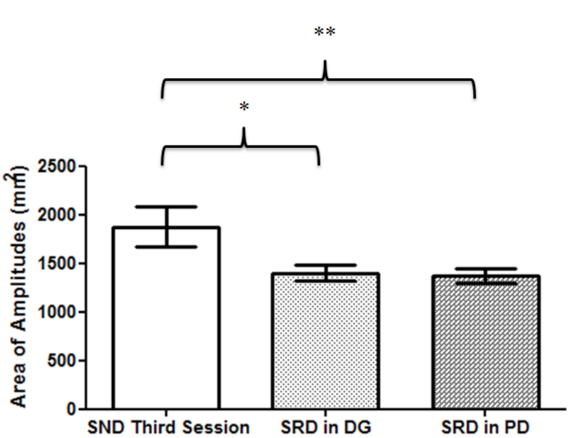

Figure 4. Electrode FP1, SND, stimulus not-related to dilemma group; SRD, stimulus related to dilemma group; DG, Dictator's Game; PD, Prisoner's Dilemma. *p = 0.0426, **p = .0207.

When the participants were subjected to an unrelated context stimulus, the resulting amplitude in the prefrontal cortex was larger than in participants subjected to a stimulus related to the context. In the case of participants subjected to the question related to the context, the signal exhibited reduced amplitude. This result indicates an increase in neural activity in a cognitive donation context. When processing decision-making, the group of cells in the left prefrontal cortex in these participants was activated in specific series of directions, recorded by reference electrodes. This activation generated both positive and negative electrical signals. Therefore, when the recordings were summed, a reduced signal was displayed. This activation possibly included a larger number of neurons than the activation generated by an unrelated stimulus. Significant activation was detected in the left prefrontal cortex, an area reportedly involved in logic and integrative evaluation (Goel, Shuren, Sheesley, & Grafman, 2004; Moll et al., 2006), suggesting that this reflects the evaluation of the decision "to donate or not donate." Supporting this possibility, a recent study on social reasoning demonstrated left-to-right cortical dominance (Goel et al., 2004), which corroborates our results because the FP2 electrode (over the right prefrontal cortex) indicated a tendency toward a significant difference.

Unexpectedly, significant differences in temporal electrodes T3, T4, T5, and T6 were not found. Recent findings by Zak et al. (2007) indicated an emotional component in donation decision-making, but our method did not have sufficient sensitivity to detect such differences.

The present results suggest that the reduced amplitude resulting from a related stimulus was produced by activation of a series of circuits in the right prefrontal cortex and reflected the captured signal as a sum of positive and negative electrical activity. These results indicate that facing the choice of a possible donation generates cognitive demands capable of enhancing electric activation in the left prefrontal cortex. Therefore, the results imply the existence of logical evaluation during this type of decision-making, implying that these acts are logically driven and consciously conducted. The difference between sessions was the question that was asked, suggesting that logical evaluation occurred at the moment participants were asked about their decision. This implies that even in a fictional situation about the decision to donate money, participants calculated the risks and benefits of the act.

The limitations imposed by the participant selection criteria in the sample greatly reduced the amount of available data, but such criteria were necessary to distinguish conditions that could interfere with the measurements. Another methodological point was the decision to not record while participants were reading the dilemmas. The pre-decision could possibly predispose participants to a specific decision while reading. However, nevertheless, eye, hand, and head movements could generate confounding artifacts.

Differentiating between decision-making and working memory is impossible, and defining the exact moment of decision-making is difficult. In fact, activation of the left prefrontal cortex has been found during the evaluation of cost tasks using functional magnetic resonance imaging, which was interpreted as short-term memory activation (Mitchell et al., 2008). The present study raises new questions, and more studies are needed to clarify the differences between short-term memory, emotion and decision-making.

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APPENDIX Cognitive Tasks

Dictator's Game

You have $10. During the task you will have the opportunity to donate this amount, or part of it, to a stranger. You are free to choose whether to donate or not. The donated amount will be deducted from the initial $10. The person who will receive this amount is incapable of any form of return. You will be asked if you wish to donate part of the $10, and if you decide to donate, how much you will donate. At the moment the question is asked, you will decide your answer. You will provide your answer at the end of the task.

Prisoner's Dilemma

You have $10. During the task you will have the opportunity to donate this amount, or part of it, to a stranger. You are free to choose whether to donate or not. The donated amount will be deducted from the initial $10. The donated amount will be multiplied by 2 when received by the stranger, who can choose whether or not to return the donation. You will be asked whether you wish to donate part of the $10, and if you decide to donate, how much you will donate. At the moment the question is asked, you will decide your answer. You will provide your answer at the end of the task.