ORIGINAL ARTICLE

The Difference in Brain Processing Between Animate and Inanimate Beings in Moral Violation: An Electrophysiological Evidence

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ABSTRACT

INTRODUCTION: Moral violation is known to elicit negative moral emotions and is associated with the electroencephalography (EEG)-derived P300 wave. However, the neural basis of moral categorisation (immoral behaviors towards animate beings or inanimate beings) has yet to be explored in moral psychology, which may increase knowledge and further understanding of brain function for the rehabilitation process. Thus our study aims to investigate the difference in brain processes between animate and inanimate moral violations. **MATERIALS AND METHODS:** Twenty-six participants (mean age of 24 years old) were involved in the experimental observation that was held in the Neuroscience Laboratory. In the event-related potential (ERP) session, EEG-derived P300 data were recorded while participants viewed a random series of 200 trials of visual stimuli that were distributed according to the odd-ball paradigm. The trials consisted of three image categories (15% of immoral behaviour toward animate beings, 15% of immoral behaviour to non-animate beings, and 70% of neutral images). Participants also pressed the buttons numbered '1' or '2' while responding to animate beings and inanimate beings, respectively. **RESULTS:** When compared to neutral images and non-animate objects, the brain regions that were activated with immoral behavior toward animate beings had the biggest P300 amplitude with stronger neural activation in the temporal and occipital regions. **CONCLUSION:** Immoral behaviour towards animate beings is associated with greater neural cognition, as reflected by the activation in most brain regions. This discovery contributes to a better understanding of the moral foundation. It could be applied in determining the abnormal pattern of brain function and as a baseline reference to be used in the medical rehabilitation field.

Keywords
Immoral behaviour, emotional cognition, P300 brain wave

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Received: 27th Oct 2022; Accepted: 8th March 2023

Doi: https://doi.org/10.31436/imjm.v22i3

INTRODUCTION

Moral violation is described as behavior against social norms that are often judged by the society[1] and linked with three main schools of thoughts that tackle the concept of moral judgment: (i) Piaget's moral cognitive development model, (ii) social intuitionist model and (iii) dual-processing theory.[2] Social intuitionist model and dual -processing theory focus on moral emotions such as anger and disgust that influences moral judgment.[2,3,4] It is commonly hypothesized that the perception of moral violation evokes strong emotion.[1,2] Based on the social intuitionist model, moral emotions can be evoked by the moral violation.[3,4] However, there is a lack of literature to date that examines the effect of different types of moral violations on subsequent emotion processing. Furthermore, past neuroscientific studies on moral disgust and moral anger often focused on morality as a general component. This is imprecise, as morality can be broken down into different categories of moral intuition that each process different types of moral stimuli, as suggested by influential theories like the Moral Foundations Theory (MFT)[5]. The MFT theorizes the different variations of moral intuition and moral judgment in terms of the content and context, which postulates five core dimensions of moral intuition-harm-care, fairness-

cheating, loyalty-betrayal, authority-subversion, and purity -degradation.[5]

MFT emphasizes the relevance of its five domains to a group-living species like humans and the author believes that the evolutionary process is essential for the moral mechanism to take place by making the mechanism innate.[6,7] He describes the process as a form of "learning modules" that aids humans to be equipped with innate moral judgment, to detect moral violation in advance of experience.[6,7,8] These lead to each of the five dimensions and aid in the acquisition of unique responses to social patterns of events.

Recent EEG studies found that the perception of moral violation showed a significant difference in brain wave amplitude and can be influenced by different types of moral violation.[1,9,10] In the study by Zhang et al.[10] the results show that moral elicitors generated larger amplitudes than core disgust and neutral pictures, suggesting that moral emotions are distinctive from core emotions in a neuroscientific sense. Studies in the neuro-cognition field have revealed P300 as a neuro biomarker that can explain the psychophysiological mechanism linked to behaviour problems.[11]

The study was carried out to determine the difference in processing the two categories of moral violation and to verify the neurophysiological basis underlying these two moral intuitions.

MATERIALS & METHODS

Research Design and Participants

This is an experimental observational study design that was conducted in the Neuroscience Laboratory using the Event-Related Potential (ERP) technique. The study participants (N=26) were young Malaysian adults between the ages of 18 to 35 years old. Their inclusion criteria are as follows: no previous chronic medical illness and neuropsychiatric diseases, right-handed, and had normal or corrected-to-normal vision.

Research Procedure

Participants were recruited through social media advertisements. Through a convenient sampling method, participants who met the inclusion criteria were provided with the study information. Consent and socio-demographic data were obtained prior to study commencement.

In the laboratory, participants were asked to view a series of moral behavior-related images and neutral images displayed on a computer screen while the 128 HydroCel Geodesic Sensor Net was applied to their heads. This sensor net was linked to a NetAmps 300 amplifier with a high input impedance to record the EEG that reflected their emotional reaction to the stimuli. The oddball paradigm was used to present the images in a 1:1:3 ratio. The presentation of sequences of repetitive stimuli is occasionally interrupted by a deviant stimulus in the oddball paradigm. Neutral images accounted for 70% of the total images projected from the computer screen. In the meantime, 30% of the images were target images (i.e. animate and inanimate). All images were distributed randomly across 200 trials with three times repetition. Figure 1 depicts the experimental design as controlled by the E-prime programme while the brain potential was recorded. The entire session lasted approximately an hour. The study protocol was approved by Human Ethics Board (USM/JEPeM/20060297).

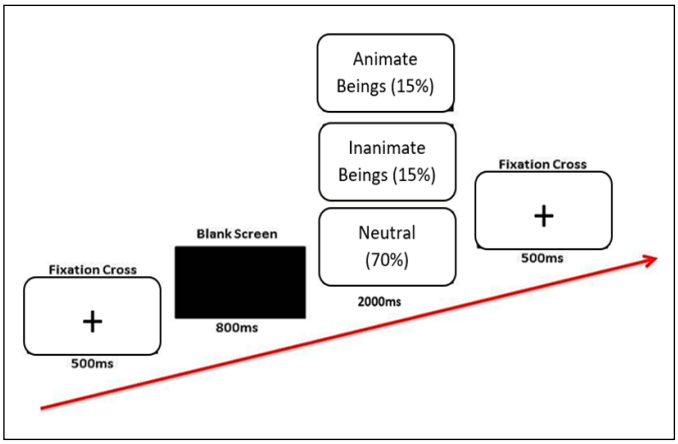


Figure 1. Experimental procedure

Visual Affective Stimulus

In alignment with Moral Foundations Theory (MFT),[5] morally violating visual stimuli are categorized into two: (i) moral violation towards animate beings (10 images); and (ii) moral violation towards inanimate beings (10 images). The animate-related moral-violating pictures consist of elements associated with harm and unfairness (e.g., harming another person/animal, rape, and murder). Meanwhile, the inanimate related moral violating pictures consist of elements associated with subversion and degradation (e.g., theft, vandalism, littering, and destruction of property). Geometrical images (30 images), classified as neutral images, were also displayed, accounting for approximately 70% of the total trial. The content validity of the immoral behaviour (20 images) was evaluated by three experts in the area of moral behavior.[12] Images' brightness and size were standardised to eliminate technical bias. All photographs (images) were collected from the internet and are copyright free.

Data Extraction and Analysis

By applying the standard procedure in recording and data extraction,[13] the ERP P300 brain wave was captured with Ag/AgCl electrodes placed at scalp sites using the international 10/20 system, in five brain areas: fronto-parietal (Fp1, Fp2), frontal (F3, F4, F7, F8, Fz), central (C3, C4, Cz), temporal (T3, T4, T5, T6) and occipital (O1, O2).

Statistical Package for Social Sciences (SPSS) version 27 was used to analyze the variations of the P300 brain wave amplitudes at various brain regions. Adjustment of the degree of freedom (df) was carried out in the case of spherical assumption violation with a new degree of freedom from Epsilon Huynh-Feldt.

RESULTS

The mean age of study participants was 24 years old (SD±2.48) and 62% were males. The Malay race represents the majority of study participants (90%) followed by Chinese and Indians (10%). The participants were mainly completing their first degree.

A significant effect of different types of visual stimulus (i.e., immoral behaviour towards animate beings; immoral behaviour towards inanimate beings; neutral images) on emotional cognition processes was observed in most brain areas. Immoral behaviour toward animate beings had the greatest effect on brain activation as compared to the opposing stimulus, i.e., immoral behaviour toward inanimate beings. As expected, the non-target images (i.e., neutral images) showed little effect on brain activation as compared to the target stimulus (Table 1).

Table 1: P300 Amplitude (Microvolt) in Different Types of Immoral Behaviours and Neutral Stimuli

Brain Region	Mean (Standard Deviation)			*p*-value	Partial Eta Square
	Animate beings	Inanimate beings	Neutral		
Frontoparietal	6.9 (±6.1)	5.3 (±4.2)	3.3 (±2.7)	0.04*	0.19
Frontal	2.5 (±1.4)	2.2 (±1.5)	1.6 (±1.5)	0.06	0.11
Central	2.0 (±1.2)	1.7 (±1.5)	1.2 (±1.0)	0.07	0.10
Temporal	5.2 (±1.9)	3.7 (±1.6)	1.2 (±0.7)	0.00**	0.71
Occipital	8.8 (±3.3)	6.9 (±3.5)	2.0 (±1.0)	0.00**	0.65

*p<0.05; **p<0.001

Specifically, stronger neural activations were observed in the temporal [F (2,50)=61.47; p<0.001] and occipital [F (2,50)=45.47; p<0.001], followed by the fronto-parietal region [F (2,50)=6.09; p<0.01]. However, no significant activation was observed in the frontal [F (2, 50)=3.04;ns] and central regions [F (2, 50)=[2.76; ns] (Figure 2).

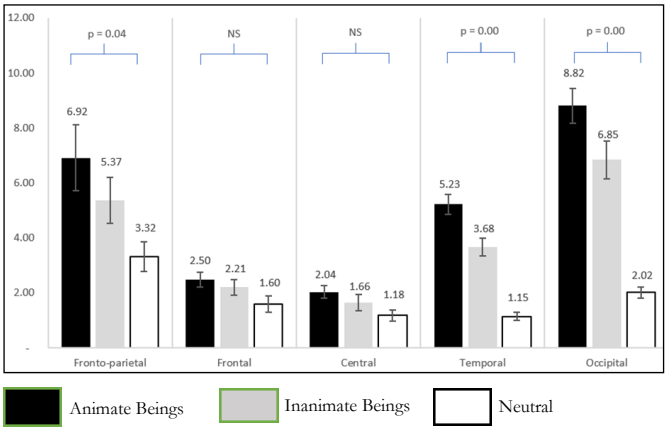


Figure 2. The P300 amplitude (microvolt-μv) difference in various brain regions associated with emotional cognition responds to different moral and neutral stimuli.

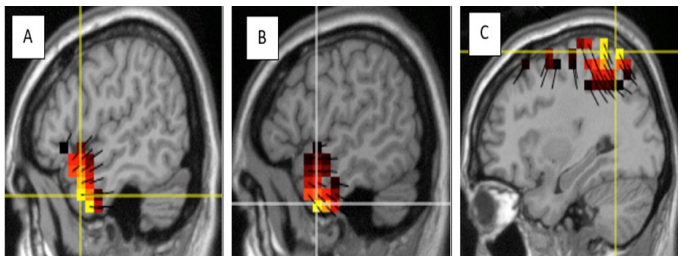
A pairwise comparison (Bonferroni method) was performed to determine the significant difference of each visual stimulus at the bivariate level, focusing on two regions (temporal and occipital) that indicated strong significant effects. The results are as below:

Temporal region: The immoral behaviour towards animate beings induced significantly higher amplitude than neural images (mean difference=4.08; SE=0.38). The immoral behaviour towards animate beings also induced a significantly higher amplitude than the immoral behaviour towards inanimate beings (mean difference=2.53; SE = 0.36). Both immoral behaviours (animate and inanimate) induced higher amplitude than neutral images.

Occipital region: The images of immoral behaviour towards animate beings induced significantly higher amplitude than neutral images (mean difference=6.79; SE=0.70). Similarly, immoral behaviour towards inanimate beings also induced higher amplitude than the image of inanimate beings (mean differences=1.97; SE=0.75). Both immoral behaviours (animate and inanimate) induced higher amplitude than neutral images.

The current study also shows that participants responded to images of immoral behavior toward animate beings more quickly than images of immoral behavior toward inanimate beings. The reaction time to images of animate beings was 611 (±126.3) milliseconds, while the reaction time to images of inanimate beings was 634 (±126.5) milliseconds - [t (25)=3.3, p<0.01]

Localisation data revealed different activation areas concerning different types of stimulus. In contrast to animate and inanimate beings, a neutral stimulus (G-shape) revealed different brain activation regions and source localisation. Similar brain regions were activated in both animate and inanimate beings, but the source localisation varied slightly. Figure 3 displays the brain area activation that was captured from the sagittal side.



Animate beings (A) - *Middle temporal gyrus (location:-52,10,-34)*
Inanimate beings (B) - *Middle temporal gyrus (location:53,3,-41)*
Neutral (C) - *Superior Parietal Lobule (Location:-31,-60,64)*

Figure 3. Brain localisation differences in three conditions-immoral behaviour towards animate beings, immoral behaviour towards inanimate beings, and neutral images.

DISCUSSION

The findings of this study provide an understanding of the human moral dimension as conceptualised in earlier moral theories such as the Moral Foundation Theory (MFT).[5] MFT examines how moral intuition can be contextualised and how people make judgments about proper behavior and right versus wrong. As our data shows, the type of moral stimuli, whether animate beings or inanimate beings, has a significant impact on the judgement of right and wrong.

The MFT is based on the idea that people make moral judgments spontaneously and without thinking about them.[14,15] However, the magnitude of spontaneous action could be motivated by the nature of moral stimuli as we suggested in this study. Moral judgments, like many other psychological processes, are made using the "dual-process system," in which intuitions come before and affect more reasoned explicit cognition. This is the critical argument we are postulating, that a difference like moral stimuli results in a variation in the cognition mechanism.

This finding has important implications for understanding human brain function concerning moral empathy. Decety & Cowell[16] suggested that moral empathic concern, along with other factors such as emotion contagion, and motivational and cognitive aspects, is crucial in determining how an individual responds to others. In the normal brain-moral development model, empathic concern has been deemed beneficial towards prosocial behaviour which is attributable to several factors, including sex, age, inhibitory network function, neuromodulator systems, and psychological traits.[17] Our brain has a remarkable capacity to reorganise itself in response to various sensory experiences. Brain functional theory, such as neuroplasticity, considers the brain anatomy to be capable of modifying, changing and adapting both structure and function throughout life and in response to experience.[18] Evidence suggests that neuroplasticity mechanisms vary greatly across individuals and throughout a person's life.[19] Thus, a thorough understanding of neuroplastic mechanisms concerning environmental stimuli variation can influence how clinicians and researchers approach effectively to a wide range of

neurological and neurodevelopmental disorders.

In the case of abnormal brain function, such as temporal lobe injury (TBI), the quality of sensory inputs (such as moral empathy) reaching the brain affects the rules of plasticity within cortical sensory areas. For example, it was found that TBI patients manifested a deficit in emotional responsivity and indicated fewer empathic responses with lower emotion recognition than controls.[20,21] Other studies have found that TBI patients with a reduced ability to empathize emotionally have a reduced physiological response to emotional expressions of anger.[22]

It is to emphasise that, the importance of P300 as a cognition biomarker should be recognised. The ERP modulations elicited by emotional contents are often depicted in higher activation of primary sites, not only the P300 component but including N100, N200, P200, and late positive potential brainwaves (LPP).[23] Moral disgust stimuli elicited higher P300 amplitude, as well as N200 and LPP amplitudes.[10,24] Meanwhile, P200 and P300 showed greater positive deflection in negative conditions than in neutral conditions consistently in multiple studies.[25,26,27] In older ERP studies, the P300 (often overlapping with LPP) is often associated with memory processes[25] and attentional processes.[26] In more recent studies, P300 amplitude has been known to be typically higher during disgust visual cues and less so for angry visual cues when compared against neutral cues.[27]

CONCLUSION

Immoral behavior toward animate beings is associated with increased neural cognition, as evidenced by the activation of P300 amplitude in the most important regions of the brain. The P300 amplitude is an endogenous potential that is elicited in the process of decision-making and reflects processes involved in stimulus evaluation or categorisation. This discovery contributes significantly to the field of moral psychology, for a better understanding of moral foundation. The P300 amplitude could be an important baseline reference for the medical rehabilitation specialist in order to understand the normal and abnormal patterns of moral empathy that are connected with brain function.

ACKNOWLEDGEMENT

This work was supported by a Universiti Sains Malaysia, Research University Individual (RUI) Grant Scheme with Project No: 1001/PPSP/8012352, Project Code: UO1934 (Reference No: 2020/0202).

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