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Prevalence of a Late Readiness Potential During a Deliberate Decision-Making Task

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Abstract: *This study investigated the hypothesis that neural markers associated with arbitrary decision-making are present in higher order, deliberate decisions. Furthermore, the study aimed to investigate the effect of higher order decision content on neurophysiological markers such as the late readiness potential and the P300 potential. An experiment was designed to measure, evaluate, and compare these electroencephalographic potentials under both arbitrary and deliberate choice conditions. Participants were presented with legal cases and had to convict and acquit criminal offenders. Distinct readiness potentials and P300 potentials were observed for both arbitrary and deliberate decisions across all participants. These findings support the hypothesis that the readiness potential and the P300 potential are present in the neurophysiological data for higher order deliberate decisions. The study also showed initial findings of how the readiness potential may inherently relate to decision content. Increased readiness potential amplitudes were observed for participants with previous exposure to violent crime when they had to acquit or convict criminals accused of violent crimes.*

Keywords: *Decision-making; readiness potential; P300 potential; trauma; deliberate decision-making; electroencephalography.*

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1. Introduction

The Readiness Potential (RP) is generally believed to be in some way or form related to the preparation of voluntary movement. It was originally identified by Kornhuber and Deecke (1965) and is revealed by averaging many trials (>30) of electroencephalography (EEG) data recorded during experimental tasks involving spontaneous self-initiated movement. It reliably precedes movement and is clearly distinguishable into two components; an early RP that can start up to 2 s before movement onset and a late RP that starts about 300 ms before movement (Verbaarschot et al., 2019; Shibasaki & Hallett, 2006). The early RP consists of a slow decrease in negative potential that is symmetrically distributed and maximal at the midline centro-parietal cortex (Shibasaki & Hallett, 2006). The later negative slope of the late RP is much larger over the central region of the cortex contralateral to the movement (Shibasaki & Hallett, 2006). Both components are related to preparation/execution of voluntary movement and not associated with involuntary movement (barring the rare exceptional cases) (Shibasaki & Hallett, 2006). The early RP is visible in and precedes self-paced motor tasks, whereas the late RP has mainly been seen in choice reaction time tasks (Verbaarschot et al., 2019; Shibasaki & Hallett, 2006). Furthermore, it has been shown that the RP amplitude increases with intentional engagement (Kornhuber & Deecke, 1965).

Although the RP may not be the cause of movement, it does seem to correlate with the conscious experience of the intention to move. However, in 1983 Libet at al. found the (early) RP onset to occur even before the moment of conscious intention to move, questioning the role of consciousness in human action and thereby placing the RP at center stage in modern discussions about free will. In the Libet experiments, participants were asked to act on the urge to flex the wrist of their dominant hand while reporting on the moment of awareness of intent (Libet et al., 1983). The moment of intention was determined by noticing the position of a revolving dot on a special clock face. Even though no reported "preplanning" occurred, the recorded EEG-data showed a clear spike in neural activity 350 ms before the reported urge to move (i.e. moment of conscious choice), and 550 ms prior to movement (i.e. moment of action). Libet et al. used this finding as basis to question the notion of conscious will. They reasoned that the rise of the RP – observable 350 ms prior to awareness of intent in this "free" self-initiated task – supported their argument that free will is an illusory construct absent in self-initiated human action. Due to the contentious nature of the results, the findings of their study received extensive criticism. Critics argued that to act on the urge to flex a muscle cannot be considered a true measure of free choice (Wolpe & Rowe, 2014).

In 2008, Soon et al. conducted a similar experiment using functional Magnetic Resonance Imaging (fMRI). The experiment was adapted to include a choice task, thereby addressing one of the main criticisms of the original Libet study. The recorded neural responses enabled Soon et al. to predict the outcome of the choice, with slightly above chance accuracy, up to seven seconds prior to the participants' reported subjective awareness (Soon et al., 2008). Moreover, Soon et al. considered brain areas and mechanisms other than the supplementary motor area (SMA) and the RP to inform a more holistic understanding of the cortical networks underlying decision-making. In a later study, Soon et al. adapted their original experiment by increasing the complexity of the choice task, asking participants to add or subtract two numbers per choice trial (Soon et al., 2013). Since then, the Libet and Soon experiments have been recreated for other EEG and fMRI studies with findings that support the original findings (Lavazza, 2016; Verbaarschot, et al., 2015). A different study by Alexander et al. found that the RP is present even in the absence of movement and that motor-related neural processes do not significantly affect the RP (Alexander, et al., 2016). Another study by Jo et al. corroborated these findings by setting up an experiment with a self-initiated movement condition as well as a no-movement condition (Jo, Hinterberger, Wittmann, Borghardt, & Schmidt, 2013). They found that there was no significant difference between the movement condition RP and the no-movement condition RP. Herrmann et al. observed a clear RP build-up prior to stimulus presentation in a task where participants had to press one of two buttons depending on the stimulus presented (Herrmann et al., 2008). Further adding to the debate regarding the role of consciousness and the RP, Schlegel et al (2015) showed the prevalence of the RP in subjects who were hypnotized to move their wrists without conscious intention. These studies were all limited to choosing between arbitrary alternatives, bereft of any consequences, drawing into question their ecological validity. To be relevant in the debate on free will, choices must be deliberate, meaningful, consequential, and morally relevant (Maoz et al., 2019).

The neurophysiological architecture that underlies deliberate decision-making has been mostly studied in the field of Neuroeconomics (Bossearts & Murawski, 2015). In 2019, Maoz et al. introduced the concept of deliberate decisions into the neuroscience of human volition. They argued that the arbitrary decisions presented in previous studies were void of purpose, reason and consequence and that it therefore remains unknown to what extent the previous findings are applicable to decisions that matter (Maoz et al., 2019). Maoz et al. defined deliberate decisions as decisions of interest, with ecological and real-life relevance. They developed an EEG choice task in which participants were instructed to donate money to one of two non-profit organisations (NPOs) (Maoz, Yaffe, Koch, & Mudrik, 2019). The experiment consisted of deliberate and arbitrary trials: for deliberate trials, the chosen NPO would receive a donation of $1000 and the NPO not chosen would receive $0. For arbitrary trials, regardless of the choice, both NPOs would receive an equal amount of $500. For arbitrary choice trials, clear RPs were observed while the deliberate choice trials were marked by an absence (or strongly diminished prevalence) of RPs. They argued that their results support the stochastic accumulator model of the RP as put forward by Schurger et al (Schurger et al., 2012). This model suggests that the RP is a result of ongoing stochastic fluctuations in neural activity and that movement occurs when the slow build-up of negative potential crosses a threshold. The stochastic fluctuations in neural activity is always present, but we only see it before movement onset because of biased sampling (experimenters typically do not probe the EEG in the absence of movement).

However, a study specifically looking for RP-like events in EEG data at times other than immediately preceding movement came out empty handed (Travers et al., 2020). The authors suggest that their findings do not support a purely stochastic model of RP generation and that the RP is linked to voluntary actions. In yet another study, Verbaarschot et al. (2019) found clear RPs during both deliberate and arbitrary actions when participants were asked to play one of two games with identical self-paced movements; one game required deliberate actions to progress while the other game only required arbitrary actions. In the end their findings contradict those of Moaz et. al. as they found no difference between the deliberate and spontaneous actions.

It is clear that there is still a lot of uncertainty regarding the RP and its relation to movement, especially during deliberate actions such as those required for free will and moral responsibility. The current study aimed to further increase our understanding of the RP, and especially the late RP, in relation to deliberate actions loaded with moral content. We further also investigated the P300 potential and evaluated the neurophysiological response of the RP and P300. It is the intention of the current study to add more data to the debate regarding the RP and its significance to free will without supporting any specific perspective.

2. Materials & Methods

2.1. Participants

Twenty-nine healthy participants (7 females; 22 males) aged 21 to 28 years, volunteered for the study. Three participants' data were excluded from the study due to excessive noise and two participants were removed from consideration for being left-handed. Participants were recruited via email and institutional permission from Stellenbosch University was obtained to support the recruitment process. The experiment was approved by Stellenbosch University's Health Research Ethics Committee (HREC) and was conducted in accordance with the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research. Informed consent was obtained from all participants before taking part in the study. The sample of participants was further divided into different groups for cross-comparisons within the study.

2.2. Procedure

The study consisted of two parts, completed on two separate days. During the first part, participants were required to fill out a questionnaire illustrating their relationship to crime and violent crime throughout their lives. Since the study addressed issues with psychological valence, such as rape and murder, it was important to consider the respective participants' histories with violent crime. Furthermore, since the study was conducted in South Africa, it was statistically likely that participants might have been affected by violent crime throughout the course of their lives – either directly or indirectly.

During the second part of the study, EEG data were collected while participants completed a choice task. Participants completed their EEG sessions individually. Upon arrival at the lab, participants were informed of the session's proceedings and encouraged to ask questions if anything was unclear to them. Participants were also reminded that they could withdraw from the study at any point. For the EEG recordings, participants were asked to keep as still as possible and not to move their heads, or blink, excessively during the experiment. EEG noise due to eye movements while reading, were removed during data pre-processing. Participants were told to make themselves comfortable but to move only their corresponding index fingers as far as it was possible. Thereafter, the testing procedure was explained. Once the instructions had been communicated, participants were asked to assume their testing positions in front of the computer screen. All the verbal instructions were again presented in a written form. Following the instruction screens, participants were presented with a practice round during which they responded to three choice tasks. Once they understood how the practice round worked, testing began. Since the EEG setup made it possible to unplug the EEG cap, participants were also encouraged to take breaks. At the end of the lab session, everyone was remunerated for their participation.

The choice task asked participants to compare two different crimes, simultaneously presented on the left (criminal F) and the right (criminal J) sides of computer screen. They then had to choose who to convict/acquit for each scenario pair, i.e. per choice trial. All participants completed 360 choice trials, divided into 6 blocks of 60 trials each. Participants were randomly divided into two equal participant groups: one group had to decide whether to acquit criminal F or criminal J; the other group had to decide whether to convict criminal F or criminal J. They were told to place their index fingers of their left and right hands on the ridged "F" and "J" keys, respectively. The crimes presented contained the summarised case details of the competing offences (see Figure 1). The summaries provided enough detail for participants to make an informed decision, while still easy to read and understand. The crimes were reconstructed using the details of existing criminal cases. Participants had access to a sheet summarising relevant legal terminology, however, the cases presented were self-explanatory. The cases related to criminal scenarios such as theft, arson, murder, rape, assault, attempted crimes, and crimes committed in self-defence. For each choice trial, participants had 10 seconds to respond after which a different screen prompted them to make a choice. They were told to take their time while responding but they were also informed that the computer would prompt them to respond if they were unresponsive for too long. The prompt was to ensure that participants remained focused throughout the task. Figure 1 graphically illustrates the typical sequence of a single choice trial, along with the display times per frame.

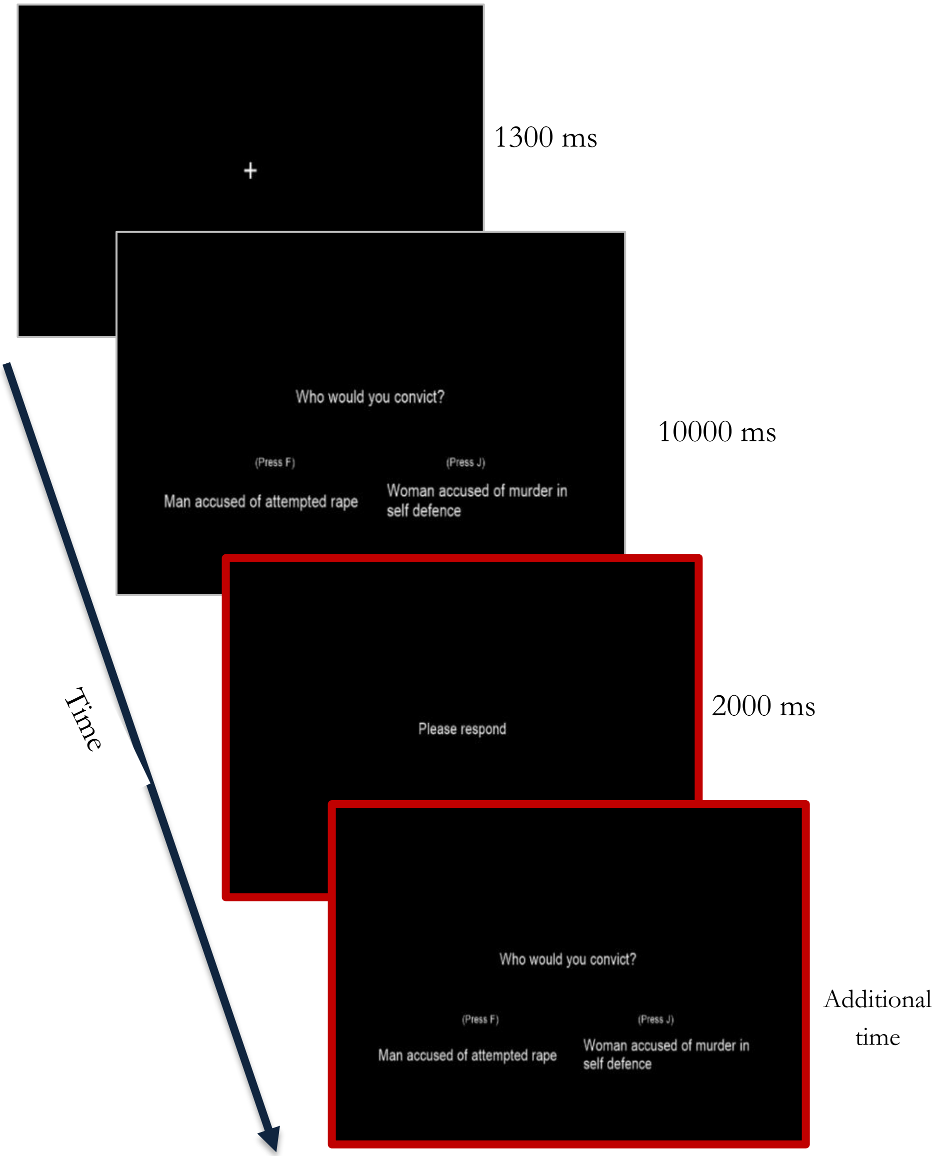

Figure 1. Typical sequence of a decision trial (the red frames indicate screens displayed if participants take longer than 10 s to make a choice)

In similar recent studies conducted by Maoz et al. and Verbaarschot et al., the researchers made a clear distinction between arbitrary and deliberate choices (Maoz, et al., 2019; Verbaarschot et al., 2019). This distinction served to separate the arbitrary choices found in previous Libet-type RP studies from deliberate decisions with real-world consequences.

Consequently, the choice trials in this study were divided into two blocks: arbitrary and deliberate. At the start of each block, the programme informed participants whether they were responding to an arbitrary or a deliberate decision block. To eliminate potential experimental biases, participants performed the task blindly. They were told that the experiment was designed to evaluate whether EEG can be used to improve the jury selection process for prospective legal trials. This misdirection was necessary to maintain the integrity of the study, since knowledge of the deliberate decision-making investigative component may have influenced participants' responses and biased the results (Bode et al., 2014). Not knowing the full scope of the study did not pose any harm to participants. They believed the task was an audition for compiling a jury of 12 jurors for a mock legal trial and that their neurophysiological data collected during the EEG task would serve as selection criteria for the jury selection process. Furthermore, they were informed that for deliberate blocks, their responses would be evaluated for the jury selection process and that they were responding to unsolved cases; and for arbitrary blocks their responses would not be evaluated and they were responding to solved cases. These distinctions aimed to ensure that participants would consider evaluated/unsolved cases with more deliberation than non-evaluated/solved cases.

For the EEG recordings, a 128-channel Brain Products active channel amplifier (actiCHamp) EEG system (Brain Products, Germany) was used. For this study, 64 electrode channels were utilised - with a separate ground electrode channel located at FPz. The EEG data were sampled at 500 Hz, with a common reference located at Cz in the standard 10/20 system electrode positioning locations. The stimuli were presented on a 21-inch Dell monitor with a refresh rate of 60 Hz and a resolution of 1024x768 pixels. The experimental script was written using PsychoPy2 v1.90.2 (Peirce, 2009). Participants completed the experiment while sitting in a dimly lit, quiet room. All distractions, such as cell phones and smart watches, were removed for the duration of the experiment. All participants had normal, or corrected to normal, vision and were positioned 60 cm from the screen. The study was conducted at the Central Analytics Facility (CAF Unit), located at Stellenbosch University.

2.3. Data analysis

For the pre-processing of event-related potential (ERP) and EEG data, EEGLAB (a Mathworks MATLAB R2018a graphical user interface) was used. The recorded data were re-referenced to electrodes symmetrically placed across the scalp and located just inward of the mastoid electrodes (P7 and P8). Since Cz is a general area of interest when considering the RP, the mastoids are typically used as reference. For this study, the best results were obtained using linked mastoid (LM) referencing. However, since the data that was recorded from the typical mastoid sites, TP9 and TP10, was on average too noisy to produce reliable results, electrode sites P7 and P8 were used instead.

A digital finite impulse response (FIR) filter was used to filter the data between 1 and 40 Hz, using a band-pass filter. A lower cut-off frequency of 1 Hz was purposefully chosen to get rid of any slow potential build-up that could be due to stochastic fluctuations. This radical approach will probably also affect the early RP, but not necessarily the late RP which is our main interest. The late RP is known to be prevalent in choice reaction tasks (Shibasaki & Hallett, 2006) such as the task in this study and the one conducted by Moaz et al. (2019). EEGLAB's built-in independent component analysis (ICA) function, in conjunction with the multiple artefact rejection algorithm (MARA) plug-in, was used to remove all marked artefacts prior to analysis. Channels that were marked for removal, were replaced using interpolation. Data epochs were extracted from 3000 ms before to 350 ms after the button press event, and the data were time-locked to the button presses. Lastly, the epoched data were run through an artefact detection algorithm that eliminated trials with peak-to-peak amplitude differences exceeding 100 μV. This also ensured that noise due to excessive eye movements was removed.

The data were divided into several different groups for comparison. Firstly, the differences between the acquit and convict trials were evaluated, then the differences between the left and right button press responses, and thereafter the differences between the deliberate and arbitrary blocks (see Table 1). Lastly, the information gathered from the participant questionnaires was considered. The questionnaires were designed to determine the respective participants' relationship to violent crime. Based on these findings, participants were divided into separate groups where participants had personally been exposed to violent crime (Crime I); and where participants had close relatives who had been exposed to violent crime (Crime II). Each of the Crime I and Crime II groups contained Yes (Y) and No (N) subcategories, i.e. someone who, for example, had personally been exposed to violent crime would be in the "Yes" subcategory of the Crime I group (Crime I: Y) and someone who had not would be in the "No" subcategory of the Crime I group (Crime I: N). For the purposes of this study, violent crimes were defined as assault or sexual assault.

Table 1. Different statistical power values for different participant groups (where the sample totalled 24 participants)

Group	Sample size	Statistical power
Acquit	12	0.95
Convict	12	0.95
Left button presses	24	0.99
Right button presses	24	0.99
Arbitrary	24	0.99
Deliberate	24	0.99
Crime I: Y	6	0.65
Crime I: N	18	0.98
Crime II: Y	13	0.96
Crime II: N	11	0.92

The parameters evaluated within the study were EEG scalp potentials, button press responses and response times. The relevant ERPs considered for analysis were the RP and P300 peaks. The statistical significance of the RP and P300 scalp potentials was evaluated using the 95% confidence interval (CI), while the statistical significance of the button press responses and participant response times were evaluated using the 95% CI, analysis of variance (ANOVA) and Wilcoxon ranked sum (WRS) tests. The button press event was taken as time zero (Maoz et al., 2019). The P300 peak was taken as the maximum peak occurring at any position 250 to 350 ms post button press.

The results of a power calculation showed that the sample size required for statistically significant difference with a power of 0.85, was roughly 10 participants (Table 1 shows the sizes of the different participant groups and subgroups compared in the study) (Noordzij et al., 2010). Thereafter, descriptive univariate statistics was used to identify the mean, median, standard deviation, interquartile range, minimum and maximum values per variable. During univariate analyses, tests for normality were performed to determine which bivariate analysis procedure subsequently needed to be followed. Lastly, multivariate analyses determined the statistical significance between different participant subgroups. All statistical analyses were done using SAS (SAS Institute Inc., 2017), NCSS (Dawson & Trapp, 2004) and SAS Enterprise Miner (SAS Institute Inc., 2011).

3. Results

3.4. Acquit vs convict

No statistically significant difference was found comparing the response times for the acquit and convict participant groups (ANOVA = 0.03, p = 0.8587), i.e. there are no statistically significant differences between the red and yellow error bars of the two different participant groups shown in Figure 2. This finding demonstrates that participants considered acquit and convict trials without distinction. Additionally, there was no overlap in the 95% CI between the RP and P300 amplitudes of the acquit and convict trial types, indicating no statistically significant neurophysiological difference between the two trial types (see Figure 3). Subsequently, the data of the two participants groups were grouped together for further analysis.

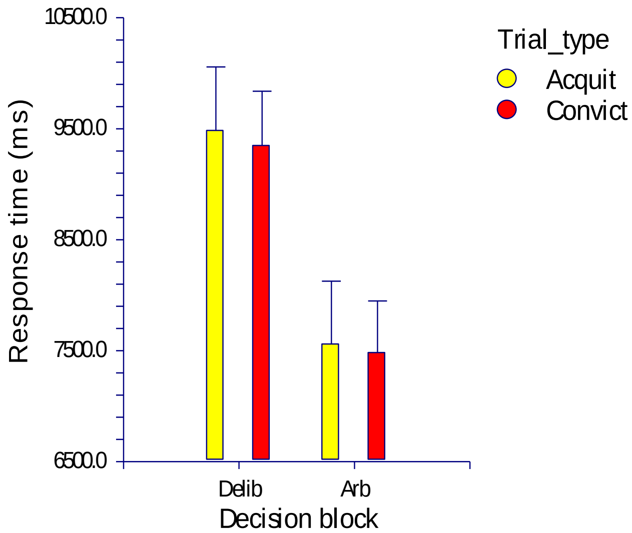

Figure 2. Error bars of response times for acquit and convict trials for deliberate (delib) and arbitrary (arb) decision blocks

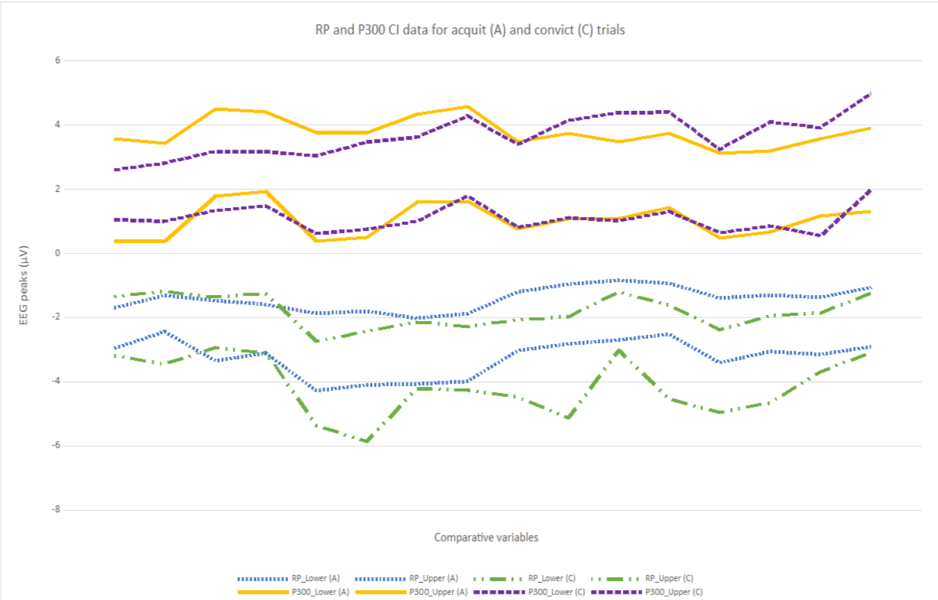

Figure 3. 95% CI of the mean RP and P300 peaks for acquit and convict trials

3.2. Left vs right

Similarly, comparing all participants' left and right button press responses, the 95% CIs showed no statistically significant neurophysiological differences between left and right (see Table 2). Practically, this confirms that participants did not favour one hand over the other and the data was not skewed in favour of either hand's button press responses. Subsequently, the button press responses were grouped to produce one set of results for further analysis.

Table 2. 95% CI of the mean RP and P300 peaks for left and right button press responses

Variable	Left CI (µV)		Right CI (µV)	
	Lower 95%	Upper 95%	Lower 95%	Upper 95%
RP_Cz_arb	-2.81	-1.79	-2.69	-1.51
RP_Cz_delib	-2.84	-1.71	-2.81	-1.71
P300_Cz_arb	1.08	2.72	1.09	2.73
P300_Cz_delib	1.92	3.48	2.03	3.45

3.3. Arbitrary vs deliberate

To compare the responses recorded during the arbitrary and deliberate decision blocks, the average response times and button press responses were considered. These parameters were used to statistically validate the initial distinction made between arbitrary and deliberate decisions. For this validation, the logic of the responses was plotted.

The trials were structured in a way that the questions in the convict trials exactly matched the questions in the acquit trials, for the two respective participant groups. Despite there being no wrong or right answers, in most cases the questions favoured one answer over another. Therefore, since the acquit and convict groups consisted of 12 participants each, it was expected that across all trials the average number of left button presses for the acquit trials should roughly match the average number of right button presses for the convict trials (see Figure 4).

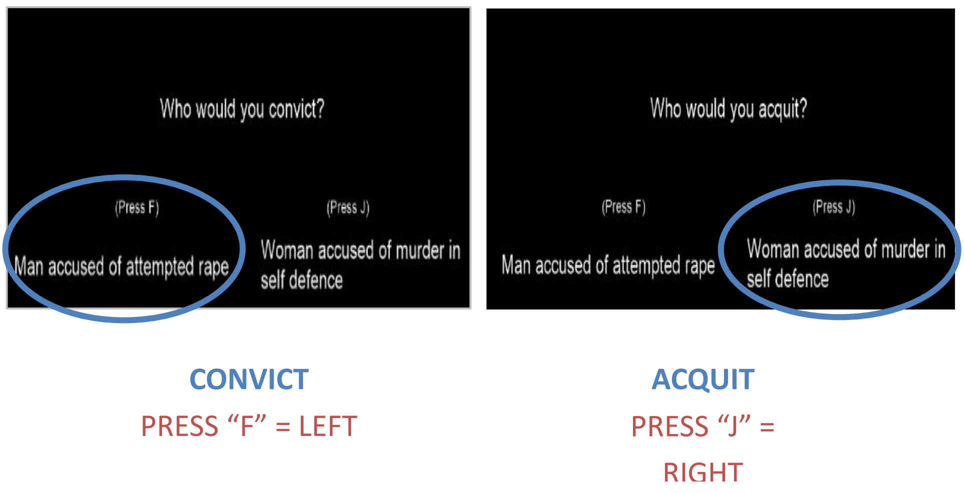

Figure 4. Comparative acquit and convict trials illustrating the expected logical outcome of the two trial types

It was interesting to note that for the deliberate decision blocks this assumption proved correct. However, in the case of arbitrary decision blocks, there was a far less pronounced trend between the left button presses of one trial type and the right button presses of the other. Figure 5 graphically shows the cross-group similarity for deliberate blocks and discrepancy for arbitrary blocks. Looking at Figure 2, the response times also show a distinct difference between arbitrary and deliberate blocks. The 95%

CIs of the response times confirm that participants responded significantly faster to arbitrary blocks than to deliberate blocks.

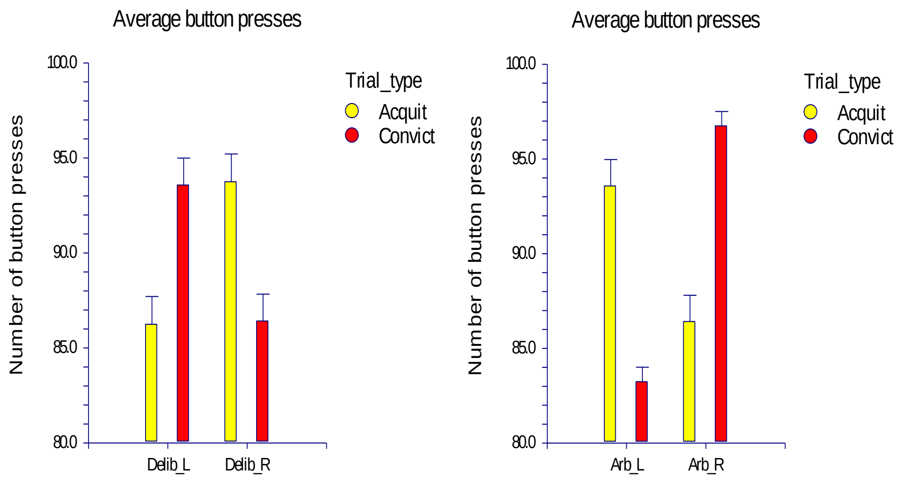

Figure 5. Number of button presses for a) deliberate (delib) and b) arbitrary (arb) decision blocks, for acquit and convict groups for all decision trials, averaged across all participants

To evaluate and compare the ERPs for the different decision blocks, scalp data at electrode Cz were considered. Figure 6 shows a clear late RP build-up for the arbitrary decision blocks, with an onset roughly 300 ms before the button press event. Figure 6 also shows a pronounced P300 peak 250 ms post button press. From Figure 6, the same late RP build-up and P300 peaks are present for the deliberate decision blocks. This trend can be found for all participants across all trial types. Although the P300 peak was slightly attenuated in the case of arbitrary blocks, the RP trends between the two blocks were very similar. The black line in Figure 6 plots the difference between the two decision blocks. Looking at this line, the difference is minimal at the points of interest, i.e. where the RP and P300 peaks occur. The shaded grey areas in Figure 6 show regions of significance where the p-values were less than 0.05. The calculated difference fluctuates around zero, with unremarkably small null line deviations. Figure 6 shows the RP and P300 trends at electrode Cz. The same trends were found at electrode Fz, Fp1 and Fp2.

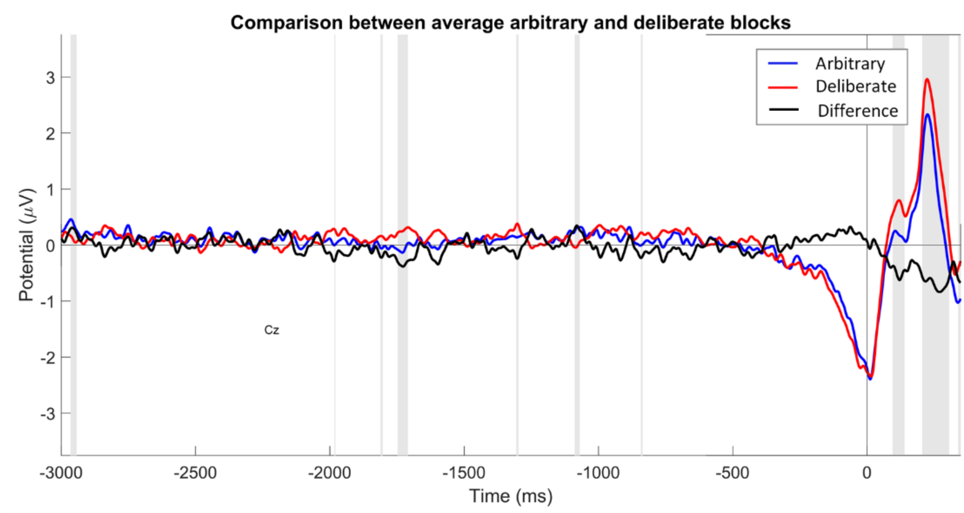

Figure 6. EEG scalp data comparison between RP and P300 peaks for arbitrary and deliberate decision blocks recorded from electrode position Cz

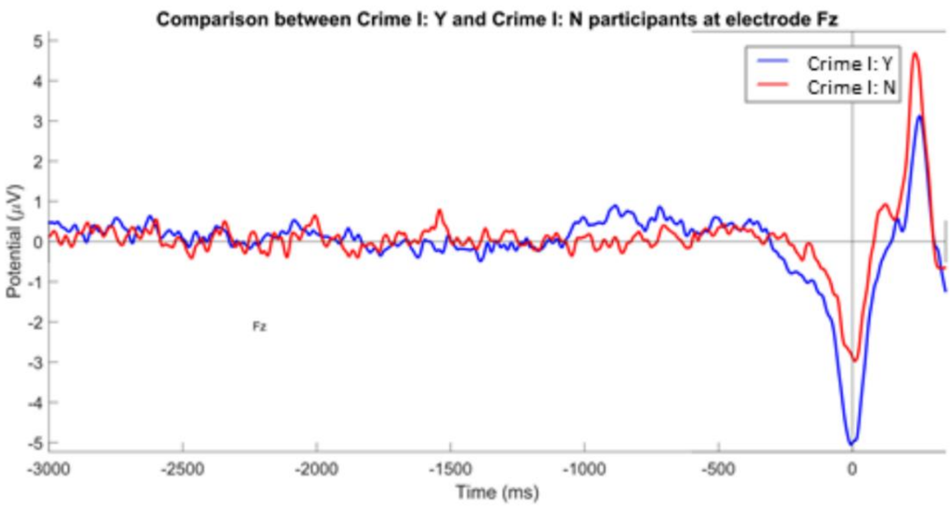

Figure 7. EEG scalp data comparison between 1st person (Crime I: Y) and non-1st person (Crime I: N) exposure to violent crime recorded from electrode position Fz

Figure 7 illustrates the RP and P300 amplitudes for the Crime I group, i.e. participants with 1st person exposure to violent crime (Crime I: Y) and participants with no 1st person exposure to violent crime (Crime I: N).

Since electrode Fz is responsible for recording activity from the intentional and motivational centres of the brain (Teplan, 2002), the Crime I comparative data is shown at electrode Fz. Looking at Figure 7, there are evident observable differences between the two groups, however the p-value differences were not statistically significant.

4. Discussion

The aim of this study was to investigate the neurophysiological correlates underlying deliberate decision-making. This study defined two distinct decision classes, namely arbitrary and deliberate decisions. The experimental protocol aimed to investigate the neuro-physiological differences between these two decision classes. Figure 2, Figure 4 and Figure 5 validate that participants considered deliberate and arbitrary blocks differently. The findings for the deliberate blocks concur with the anticipated outcome of the button press responses. The longer response times for deliberate decision blocks also support the notion that participants categorically added more value to these decisions. The findings for the arbitrary blocks show a more random distribution in terms of button presses, as well as much shorter response times. This suggests that choices in these blocks may have been made haphazardly instead of deliberately, further validating our experimental protocol. Participants were therefore effectively influenced by the distinction made between arbitrary and deliberate blocks. However, there was no statistically significant difference between the neurophysiological data of the respective decision types. It is important to note that a failed understanding of the decision types in the presented experiment would more likely result in both types of decisions being considered deliberate and not arbitrary. This is precisely because of the emotive component present in the choices. The content of the choices presented in this study comprises of the emotional and moral components of real-world choices. It can therefore be stated that the RP is present in the neurophysiological data of deliberate decision-making, where deliberate decisions are defined as choices with consequences.

Our findings contradict those of Moaz et al. (2019). In their study participants had to choose which one of two NPOs they would like to donate money to. A limitation of their study, as pointed out by Verbaarschot et al. (2019), is that the experimental protocol could have led to a stimulus-response action as participants pre-defined their preferences at the start of the experiment and only responded to their already chosen preferred NPOs. Such stimulus-response actions are usually not preceded by an early RP. The 2019 study by Verbaarschot et al. opted for self-paced actions and investigated the early RP for deliberate and arbitrary actions. They constructed an experiment where participants performed choice tasks in two separate computer game environments (an arbitrary environment and a deliberate environment). In these artificial environments, participants had to act to free a digital avatar. Upon analysis, they also found the presence of the intention to act arose before the awareness of the intention to do so across both arbitrary and deliberate decision classes (Verbaarschot et al., 2019). They found a clear RP for both deliberate and arbitrary actions. Our results are coherent with the findings of Verbaarschot et al. (2019). Our experimental setup is more like that of Moaz et al. (2019) though arguably more ecologically valid as it was not as straight forward for participants to form pre-defined preferences; they were forced to deliberate on each choice trial. However, we decided to investigate only the late RP due to the fact that our experiment is not of the classic self-paced type. Our findings are still noteworthy in that we showed clear late RPs for deliberate, morally relevant, decisions.

Other studies have previously suggested that the RP may be more indicative of the preparation to react (Alexander et al., 2016) or the expectation to make a choice (Herrmann et al., 2008) rather than the actual content of the choice, i.e. only indicative of a cortical build-up in anticipation of an executive decision task. However, the observed differences in ERPs between different participants, depending on their respective relationships to violent crime, demonstrated that the content of the decision may influence the RP and P300 amplitudes. Consequently, the RP may not be a neurophysiological phenomenon that simply arises because a choice task is present. The study suggests that personal experiences, specifically traumatic personal experiences, observably influence neurophysiological responses during the decision-making process. Although not statistically significant, these observations were evident for both the peak RP and peak P300 amplitudes. It was interesting to find that within the Crime I group the peak RP amplitude was observably increased while the peak P300 amplitude was observably decreased at electrode Fz for individuals with 1st person exposure to violent crime. Electrode Fz records from the intentional and motivational centres of the brain (Teplan, 2002). The amplitude of the P300 peak may therefore resemble the emotional valence of a response, and a similar trend seen for the RP, may suggest that the RP too is influenced by response content. This finding, however, requires further research to confirm and will form part of future studies.

The study succeeded in showing that there were no neurophysiological differences between arbitrary and deliberate decisions when considering the late RP and the P300. The study also demonstrated that there were no neurophysiological differences between the convict and acquit trials or the left- and right-hand button presses. There was also a clear RP build-up prior to the button press events for both arbitrary and deliberate decisions. Furthermore, the choices presented in this research were more representative of choices with consequences than the choices presented in previous RP studies. Moreover, since the presented questions comprised of a moral component, the emotional context of participants' responses could be evaluated. This served to establish a clear correlation between the peak amplitudes exhibited in scalp potentials and certain emotional triggers.

It must be acknowledged that this study only considered a limited number of electrode sites. This study also focussed on specific ERPs. There might be value in expanding the scope of ERPs, as well as number of electrode sites, and implement machine learning algorithms to detect other neurophysiological regions and markers significant to deliberate decision-making. The Crime I: Y and Crime I: N groups consisted of 6 participants (power = 0.65) and 18 participants (power = 0.98), respectively. The limited sample size for the Crime I: Y group may have influenced the statistical significance of the cross-group comparison. Yet, despite the lack of statistical significance, the RP amplitudes indicated attenuation in the case of Crime I: N. Conversely, the P300 amplitudes showed attenuation in the case of Crime I: Y. The more pronounced RP amplitudes for Crime I: Y participants could suggest that the RP may be interrelated to decision content. However, the Crime I: Y sample size was too small to have relevant statistical power. Therefore, to properly investigate the effect of personal exposure to violent crime on the neurophysiological markers of decision-making, a larger group of participants with 1st person exposure to violent crime needs to be studied.

Although inconclusive with regards to the role conscious will has to play in deliberate choice, the study provides a glimpse into the delicate architecture underlying higher order, deliberate and emotional decision-making. Our findings suggest that deliberate choices are also preceded by brain activity in the form of the RP, a phenomenon that has been confirmed for arbitrary choices. Furthermore, we suggest that the RP and P300 might be influenced by the content of the decisions and are therefore not merely indicative of the expectation of a choice task. This claim needs to be confirmed by future research which includes more participant in balanced subgroups. If confirmed this can initiate several future studies investigating the influence of

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