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Research article

Exploring psychopathy traits on intertemporal decision-making, neurophysiological correlates, and emotions on time estimation in community adults

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HIGHLIGHTS

- There are certain characteristics of psychopathy that may be related to changes in IC.
- Higher meanness values are associated with smaller N1 amplitude in the pleasant emotional condition (TE task).
- Higher disinhibition values are associated with greater N1 amplitude in the pleasant emotional condition (TE task).
- Higher disinhibition values were associated with a smaller LPP amplitude in the unpleasant emotional condition (TE task).

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ABSTRACT

There are certain characteristics of psychopathy that may be related to changes in intertemporal choices. Specifically, traits such as impulsivity or lack of inhibitory control may be associated with a more pronounced discounting function in intertemporal choices (IC) and, in turn, this function may be based on changes in the basic mechanisms of time estimation (TE). Therefore, this study aimed to examine potential differences in neurophysiological correlates, specifically through N1, P3, and LPP measurements, which may be related to TE and IC, examining their modulation according to psychopathic traits, different emotional conditions, and different decision-making conditions. This experimental study included 67 adult participants (48 women) from the northern region of Portugal, who performed an intertemporal decision-making task and, of those, 19 participants (16 women), with a mean age of 25 years (*SD* = 5.41) and a mean of 16 years of schooling (*SD* = 3.37) performed the time estimation task. The instruments/measures applied were MoCA, used as a neurocognitive screening tool; the Triarchic Psychopathy Measure (TriPM), a self-report instrument with 58 items that map the core features of psychopathy along three facets – boldness, meanness, and disinhibition – and considers them continuously distributed among the general population; intertemporal decision-making and time estimation tasks – for the time estimation task, the stimuli consisted of 45 color images extracted from the Nencki Affective Picture System (NAPS). In the TE task, there was an almost significant effect of disinhibition on the values of θ, with higher values on this variable associated with greater values of θ in the unpleasant emotional condition. In the IC task, there were no significant effects of any psychopathy measure on the values of the gains and losses ratios. In addition, the analysis of the neurophysiological correlates of the IC task did not reveal a main effect of the decision-making condition, nor effects of any psychopathy measure on the N1 and P3 amplitudes. The analysis of the neurophysiological correlates of the TE task revealed that higher meanness values are associated with smaller N1 amplitude in the pleasant emotional condition, whereas higher disinhibition values are associated with greater N1 amplitude in the pleasant emotional condition. Still in this task, higher disinhibition values were associated with a smaller LPP amplitude in the unpleasant emotional condition. The increase in the distribution of attention

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resources towards time and/or the increase in activation states, including those originated by responses to emotional stimuli, may be the main factor that alters the way impulsive individuals and, presumably, individuals with high psychopathy, consider time when making decisions.

1. Introduction

Psychopathy is a personality structure characterized by behavioral, emotional, and interpersonal problems (Patrick et al., 2009; Venables et al., 2014). At the emotional level, individuals with psychopathy often exhibit characteristics such as a lack of self-blame or guilt, superficial emotions, and a lack of empathy (Tuvblad et al., 2017). At the behavioral level, these individuals exhibit antisocial traits, impulsiveness, parasitic lifestyles, and difficult-to-control behaviors (Thompson et al., 2014). At the interpersonal level, traits such as surface charisma, manipulation, and egocentricity are evident (Tuvblad et al., 2017). As such, psychopathy is viewed as a personality construct that is often associated with antisocial behavior, use of alcohol and other psychoactive substances, and often with membership in antisocial peer groups (Wu and Barnes, 2013). This personality structure is often associated with childhood experiences and traumas: children who experienced abuse in childhood are more likely to develop behavioral problems in childhood and personality problems in adulthood (Wu and Barnes, 2013), namely of a psychopathic type (Moreira et al., 2020).

When comparing people with and without a diagnosis of mental illness, it can be concluded that the former has higher rates of offending and are more likely to reoffend (Santana, 2016). The prevalence of psychopathy in the general population ranges from 0.6% to 4.0%, with evidence of higher prevalence in men than in women (Tuvblad et al., 2017). Therefore, understanding psychopathy is critical as it is associated with disruptive behaviors such as crime, aggression, recidivism, substance (abuse) and sexual crime (Somma et al., 2016).

Cleckley (1941) defined psychopaths in his work *The Mask of Sanity*, based on his own experience with such individuals. Thus, the author defines 16 characteristics evidenced by psychopathic individuals, dividing them into three distinct categories: positive adjustment (intelligence, rationality, and absence of delusions or nervousness), behavioral deviance (distrust, irresponsibility, promiscuous, antisocial, impulsive behaviors, and without life goals), and emotional and interpersonal deficits (lack of remorse/shame, egocentricity, disloyalty, loss of insight, negative emotional reactions, and absence of genuine feelings) (Cleckley, 1941; Crego and Widiger, 2016; Patrick et al., 2009).

Men and women differ in the behavioral presentation of psychopathy (e.g., Falkenbach et al., 2017). In men, individuals with high psychopathy tend to exhibit externalizing behaviors, such as antisocial and aggressive behavior, and often use psychoactive substances (Falkenbach et al., 2017). Women with high psychopathy are often more aggressive and emotionally unstable, manipulative, seductive, and often manage to deceive others to achieve their goals than close family members (Almeida and Moreira, 2020; Colins et al., 2016). Women with high levels of psychopathy are also more likely to suffer from anxiety, depression, and borderline personality disorder (Colins et al., 2016).

Psychopathy has been characterized using personality traits as described above (Verschuere et al., 2018), and tools such as the Psychopathy Checklist-Revised (PCL-R) have been used to characterize psychopathy, grouping them into four aspects: emotions, relationships, lifestyle, and antisociality (Thompson et al., 2014). According to various characteristics typical of this personality structure, these aspects are divided into two factors: Factor 1 includes interpersonal and emotional aspects, and Factor 2 includes lifestyle and antisocial aspects (Thompson et al., 2014). Specifically, Factor 1 at the interpersonal level includes traits such as surface charisma, grandiosity, pathological lies, and manipulative styles (Thompson et al., 2014; Verschuere et al., 2018). The affective level includes superficial affect, callousness/lack of empathy, not taking responsibility for one's behaviors, and the absence of remorse/guilt (Thompson et al., 2014; Verschuere et al., 2018). Furthermore, Factor 2, and specifically the antisocial facet, includes early problematic behaviors, impulse control deficits, juvenile delinquency, revocation of conditional release and criminal versatility (Thompson et al., 2014; Verschuere et al., 2018). As for lifestyle, it includes sensation-seeking/boredom, impulsivity, irresponsibility, parasitic lifestyle, and absence of long-term goals (Thompson et al., 2014; Verschuere et al., 2018).

In another approach, Patrick et al. (2009) hypothesized that psychopathy is based on biological and behavioral traits. Therefore, the authors developed a triarchic model of psychopathy that includes three dimensions: boldness, meanness, and disinhibition (Patrick et al., 2009; Somma et al., 2016). Disinhibition is manifested by difficulty controlling impulses and behavior, lack of planning, difficulty influencing, and the need for instant gratification (Patrick et al., 2009; Somma et al., 2016). Meanness is characterized by a lack of empathy, contempt, lack of intimacy, and the need to be awakened by cruelty to others (Patrick et al., 2009; Somma et al., 2016). Boldness is manifested in the ability to remain calm in the face of danger and to recover quickly from stress, including high levels of self-confidence, social efficacy, and tolerance for threats (Patrick et al., 2009; Somma et al., 2016).

There are certain characteristics of psychopathy that may be related to changes in intertemporal choices. Specifically, traits or characteristics such as impulsivity or lack of inhibitory control may be associated with a more pronounced discounting function in intertemporal choices and, in turn, this function may be based on changes in the basic mechanisms of time perception, namely of time estimation. For example, Ainslie (1974) calls the smaller, more immediate reward "impulsive", and the larger, delayed reward "self-controlled". Based on this distinction, it is possible to formulate the thesis that individuals with lower scores on the disinhibition facet of psychopathy manifest a less pronounced discounting function (they are more self-controlled) than individuals with higher scores on the disinhibition facet (they are more impulsive). If so, the latter may have a less accurate time estimation mechanism.

Nothing is known about the perception of time in highly psychopathy. However, it is known that patients with Borderline Personality Disorder (BPD) appear to estimate significantly higher time intervals between events than healthy controls (Berlin et al., 2005), suggesting an accelerated subjective sense of time in these patients. However, the results reported in the literature are inconsistent. Berlin and Rolls (2004) found that patients with BPD perceive time more accurately than patients with schizophrenia, producing time intervals that are closer to the target time interval (10, 30, 60, and 90 s), but significantly shorter than normal time interval controls do. These patients also overestimated time intervals, supporting the argument for accelerated subjective time perception, although no statistically significant differences were observed compared to controls. In a further study, people with borderline or schizotypal personality disorder also showed preserved functioning in time perception compared to healthy individuals (Berlin et al., 2010). Although inconsistencies were found, some core features of BPD, particularly impulsivity, may be associated with changes in time perception, especially an accelerated subjective sense of time, but the available evidence is inconclusive.

Regarding Antisocial Personality Disorder (ASPD), Schulreich et al. (2013), designed to examine a dual-process model of psychopathy, implemented an experimental paradigm in which participants had to guess a 1-s pass and at the end received positive or negative feedback based on their performance. Egocentric impulsivity, assessed by the Psychopathic Personality Inventory-Revised (PPI-R) (Alpers and Eisenbarth, 2008; Lilienfeld and Andrews, 1996), was the only personality trait that had an impact on time perception. Participants with higher impulsivity scores showed longer estimated time intervals (Havik et al., 2012). Additionally, individuals with higher impulsivity also estimated longer time intervals than individuals with lower impulsivity (Correa et al., 2010). Consequently, patients with personality disorders, or at least those with markedly impulsive traits, tend to overestimate time intervals.

When deciding, it is necessary to analyze the cost and revenue elements that occurred over different time periods. Since perceptions of monetary value and the utility associated with monetary outcomes change depending on the point in time at which they were obtained, adjustments are needed to make these intertemporal moments comparable. This adjustment is made using a discount rate. This allows us to calculate discount factors, which in turn can be used to convert current or "foreseeable" prices, accumulating their present value in the future (Dasgupta et al., 2000).

Koopmans (1960) pioneered the concept of time preference, although research on the subject had been conducted as early as 1912 (Fishburn and Rubenstein, 1982). Several subsequent contributions have significantly expanded the depth of knowledge on this topic. The concept of lag discounting derives from the behavior of economic agents and is expressed by a set of standard economic axioms. These axioms construct individuals' intertemporal preferences by introducing various formalized assumptions that are at the heart of any discounting model. As behavioral assumptions change, so does the discounting model.

One of the key behavioral axioms defines impatience and procrastination. If the result is positive, a shorter time interval is better than a longer one. If the result is zero, the person does not care about the time period in which the result occurred. If the result is negative, thus causing resentment, a longer period is preferred, which means procrastination.

Findings from intertemporal decision-making studies suggest that people generally avoid risk-taking when faced with a choice between options related to possible or specific outcomes, and that the time interval between choosing and achieving win/loss is an important factor in decision-making because individuals prefer to profit first and then lose. However, few studies have focused on the details of decision-making in individuals with overt psychopathic personality traits, and only one study has examined intertemporal decision-making in these individuals (Blackburn et al., 2012). The literature suggests that frontal-limbic processes are affected in psychopathy, which can support patterns of disinhibition and impulsivity that influence the way these individuals make decisions and organize them over time. It would be plausible that individuals with greater disinhibition would show a more marked tendency than normal for smaller immediate gains and greater postponed losses. This tendency would not be as pronounced in individuals with greater boldness and meanness, as they are not as impulsive as the former.

Changes in intertemporal choice processes are thought to be associated with a wide range of decision-making dysfunctions and failures in planning (Angeletos et al., 2001). Since the neurophysiological correlates of these dysfunctions are common to psychopathy (Fowles, 1980; Perry and Carroll, 2008; Plichta et al., 2009), it is possible to assume there are also changes in intertemporal choice processes among individuals with high psychopathy. However, a pattern of preference, which is more pronounced than the norm, for a smaller immediate reward or a larger loss in the future, among individuals with higher scores on the disinhibition facet of psychopathy, still needs to be demonstrated. Once demonstrated, it is important to understand whether it is associated with characteristics of psychopathy related to basic emotional and cognitive aspects, such as time perception, which can be studied through time estimation tasks. The neurophysiological correlates of these basic mechanisms can be examined through electroencephalography (EEG) techniques and the extraction of event-related potentials (ERP).

In its raw form, EEG provides crude measures of brain activity, and EEG tracings represent the accumulated activity from different neural sources (Luck, 2014). However, neural responses can be related to specific sensory, cognitive, and motor events and it is possible to extract these responses from the EEG, usually through a simple averaging technique. These responses are called ERP, to indicate the fact that they are electrical potentials associated with specific events or stimuli (Luck, 2014). Concretely, ERPs are extracted from the electroencephalographic signal, synchronizing time with the occurrence of a relevant stimulus and calculating the average of several trials (Luck, 2005). Generally, both the mean or peak amplitude, as well as peak latency, of the waves are measured (Polich, 2012).

The literature refers to four main ERP components induced by early stimuli, in the case of visual stimuli (e.g., C1, P1, N1, and P2), which are induced in the parietal-occipital electrodes, roughly in the first 250 ms after the presentation of the stimulus. Specifically, N1 is a negative wave that reaches its peak between 150 and 200 ms (Folstein and Van Petten, 2008; Houston and Stanford, 2001; Lijffijt et al., 2009) and which reflects the selective amplification of sensory information to encode the stimulus (Hillyard et al., 1998). The N1 amplitude is also sensitive to attention (Näätänen and Picton, 1987) and there is evidence that the amplitude of the auditory N1 appears increased in individuals with more pronounced psychopathic traits of facets 1 (interpersonal) and 4 (antisocial) of the Psychopathy Checklist-Revised (PCL-R) (e.g., Anderson, et al., 2015). Many studies have shown that stimulus parameters, such as lighting, contrast and spatial attention, influence N1 (Hillyard et al., 1998; Mangun, 1995; Luck et al., 2000), as well as the task being performed (Hopf et al., 2002; Vogel and Luck, 2000) and the state of activation (Vogel and Luck, 2000). Increased N1 amplitudes have been associated with high levels of impulsivity. For example, impulsive-aggressive participants exhibited an increased N1 in response to visual stimuli, indicating improved attentional orientation (Gehring and Willoughby, 2002). More recently, increased N1 amplitude has been observed when participants with pronounced anxiety traits made an immediate decision (vs. a delayed decision), which also indicates that more attentional resources are being allocated. This result can be considered evidence that early attentive orientation contributes to the impulsive choices of anxious individuals (Xia et al., 2017).

N1 and P3 have been used as indicators of attention, cognitive performance, and elaborative processing, in healthy individuals and in clinical or subclinical samples, including in individuals with high psychopathy. P3 is a prominent neural signature, used to index higher-order cognitive processing and has even been used as a diagnostic tool.

P3 is a positive wave that occurs between 300 and 1000 ms after the stimulus presentation; it was also called a late positive complex (Barceló, 2003; Brydges and Barceló, 2018; Donchin and Coles, 1988; Friedman et al., 1978, 2001; Simson et al., 1977), because it includes several components with different times, topography, and functional correlates. P3 has been associated with attention processing (Cuthbert et al., 2000; Fan and Han, 2008; Martín, 2012) and indexes the brain activity underlying the review of a mental model, induced by a stimulus (Donchin and Coles, 1988). If a stimulus provides information inconsistent with the mental model, this model will be updated and the amplitude of P3 will be proportional to the number of cognitive resources recruited during the update (Martín, 2012). Previous results show that higher levels of activation or the greater relevance of tasks lead to higher P3 amplitudes, reflecting a greater allocation of attention (Nieuwenhuis, 2011). This wave is sensitive to a variety of global factors and its amplitude and latency change throughout life (Picton, 1992; Polich, 2004, 2007; Polich and Kok, 1995; Verleger, 1997). Specific experimental conditions (such as oddball tasks with frequent, rare and target stimuli) allow the separation of two main components with different distributions over the scalp, which correlate with different functions: a frontal P3a that reflects the orientation of attention to unexpected events in the environment, and a central-parietal P3b that can reflect rapid information processing when attentional and working memory mechanisms are involved (Barceló and Cooper, 2017; Polich, 2007). Thus, P3b has been associated with context updating (Vogel and Luck, 2000; Vogel et al., 1998), to the evaluation of stimuli (Kutas et al., 1977), the speed of allocation of attention resources (Polich, 2007), processes related to response selection (Ouyang et al., 2011, 2013, 2015; Saville et al., 2011, 2014, 2015; Verleger, 1997, 2010) and the closing of a cognitive epoch (Gajewski and Falkenstein, 2011). The estimated neural origin of P3a was in the dorsolateral prefrontal cortex, in the temporoparietal junction (Soltani and Knight, 2000; Friedman et al., 2001) and in the anterior cingulate cortex (Fallgatter et al., 2002, 2004; Polich, 2007). P3b seems to be generated in cortical temporal parietal regions (Di Russo et al., 2016; Polich, 2007; Soltani and Knight, 2000). It has been suggested that P3 reflects the response of the locus coeruleus-norepinephrine system to the result of internal decision-making processes and the consequent effects of noradrenergic potentiation of information processing (Nieuwenhuis et al., 2005). There is already robust knowledge of the effects of various experimental conditions on P3, although there is no clear consensus on the neural and cognitive processes that P3 reflects.

Gao and Raine (2009) published a meta-analysis of 38 studies ($N = 2,616$) to assess P3 modulation in antisocial behavior. A small but significant effect size was reported. Compared to controls, the antisocial group exhibited reduced P3 amplitude and longer latency. The main findings show that prosocial behavior may be compromised in antisocial individuals, due to the lack of inhibitory control, as well as impaired allocation of attention resources to detect infrequent, but relevant stimuli.

Through a systematic review, Pasion et al. (2018) found a clear relationship between antisocial behavior and a decreased P3 amplitude, with this decrease being primarily explained by impulsive-antisocial psychopathy traits. Conversely, affective-interpersonal traits are only associated with reduced P3 amplitudes in tasks with affective-emotional content, while, in cognitive tasks, there is evidence of an enlarged P3 (Pasion et al., 2018). Thus, it is assumed that the higher the scores on the disinhibition facet of psychopathy, the smaller the P3 amplitude in intertemporal decision-making tasks.

P3 and LPP have been identified as electrophysiological responses to emotional events (van Dongen et al., 2018). LPP, which many consider a variant of P3 in visual tasks, is a positive potential evoked by emotional stimuli and reflects top-down processes such as emotional regulation (Schupp et al., 2000). LPP is commonly identified in central and parietal locations, namely in tasks of emotional stimuli observation, approximately between 400 and 1000 ms (Hajcak et al., 2009, 2011). The LPP can continue for several seconds after the presentation of the stimulus, it is characterized by a relative positivity on central-parietal electrodes for emotional *vs*. neutral stimuli, and it reflects the allocation of attention resources to salient events (Schupp et al., 2006; Wiens et al., 2011, 2012).

Individuals with high psychopathic traits exhibit impaired emotional processing, mainly in the processing of negative stimuli, as revealed by deficits in the recognition of negative emotions (Dawel et al., 2012; Jusyte and Schönenberg, 2017; Schönenberg et al., 2016) and reduced autonomic responses after the presentation of negative stimuli (Fairchild et al., 2010; Flor et al., 2002; Levenston et al., 2000; López et al., 2013; Rothemund et al., 2012; Vaidyanathan et al., 2011). Despite these observed behavioral deficits, recent studies on the amplitude of the LPP evoked by visual emotional stimuli, in individuals with high psychopathic traits, reported conflicting results (Medina et al., 2016). For example, unpleasant stimuli evoked a smaller LPP amplitude than did neutral stimuli, among individuals with high psychopathic traits, compared to those with low psychopathic traits (Medina et al., 2016). However, both groups had similar LPP amplitude in response to pleasant and neutral stimuli (Medina et al., 2016). In other studies, individuals with high psychopathic traits did not exhibit differences between emotional and neutral stimuli (Carolan et al., 2014), but individuals with low psychopathic traits showed greater LPP amplitude for emotional stimuli than for neutral stimuli (Carolan et al., 2014; Hajcak et al., 2010). In addition, other studies have revealed no differences between groups with high and low psychopathic traits, in LPP amplitudes evoked by emotional stimuli (e.g., Eisenbarth et al., 2013). A recent meta-analysis (Vallet et al., 2019) suggests reduced LPP evoked by unpleasant stimuli and a normal LPP response to pleasant and neutral stimuli that would be specific to individuals diagnosed with psychopathy or, at least, with high psychopathic traits.

Therefore, this study aimed to examine potential differences in neurophysiological correlates of attentional processes, namely through N1, P3, and LPP measures, which may be related to time estimation and intertemporal decision-making, as well as to examine their modulation by different emotional conditions. Although mainly exploratory, the following predictions for this study were formulated: (a) the higher the score on the boldness and meanness facets, the smaller the N1 amplitude related to images in the time estimation task, regardless of the emotional condition, indicating a deficient processing of these stimuli associated with those facets of psychopathy; (b) the higher the score on the disinhibition facet of psychopathy, the greater the N1 amplitude in the time estimation task, regardless of the emotional condition; (c) the higher the score on the disinhibition facet of psychopathy, the greater the estimation of time intervals (overestimation), especially in the unpleasant emotional condition; (d) an effect of emotional condition on time estimation is not expected, relative to the boldness and meanness facets of psychopathy; (e) the higher the score on the disinhibition facet of psychopathy, the greater the preference for smaller immediate gains over larger future gains, as well as for larger future losses over smaller immediate losses, indexed both by explicit choices (i.e., by a gains and losses ratio; see methodology), or by shorter response times under these conditions; (f) the greater the preference for larger future gains or smaller immediate losses, the greater the amplitudes of N1 and P3 related to the options of choice, indicating greater cognitive effort in decision-making; (g) the longer the estimated time, the greater the preference for smaller immediate gains and larger future losses; (h) the higher the score on the disinhibition facet of psychopathy, the lower the amplitude of P3 in the intertemporal decision-making task; (i) the higher the score on the disinhibition facet of psychopathy, the lower the LPP amplitude in the unpleasant emotional condition, in the time estimation task; (j) the higher the score on the boldness and meanness facets of psychopathy, the lower the LPP amplitude in pleasant and unpleasant emotional conditions, but not in neutral conditions, in the time estimation task.

2. Method

2.1. Participants

This study included 67 adult participants (48 women) from the northern region of Portugal, with a mean age of 26.6 years ($SD = 5.99$) and a mean of 15.7 schooling years ($SD = 3.33$); however, nine participants were excluded, as the wave morphology of their ERP was undetectable. Thus, this study included 58 adult participants (40 women) from the northern region of Portugal, with a mean age of 26.4 years ($SD = 5.24$) and a mean of 15.8 years of schooling ($SD = 3.06$), who performed an intertemporal decision-making task and, of those, 19 participants (16 women), with a mean age of 25 years ($SD = 5.41$) and a mean of 16 years of schooling ($SD = 3.37$) performed the time estimation task. No other participant was eliminated following the application of other exclusion criteria (screened through self-report), namely neuropathologies, psychopathologies or sensory and motor deficits, as well as self-reported substance abuse or use of medication that could interfere with the performance of the experimental tasks. Inclusion criteria included having Portuguese nationality and between 18 and 65 years of age. Neuropsychological assessments were conducted on all participants ($N = 58$).

This study was approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of the University of Porto, and, after a description of the study and respective objectives, a written informed consent was obtained from all participants. No financial compensation was awarded for participation in the study.

2.2. Instruments and measures

2.2.1. Neuropsychological measure

The MoCA (Version 1) was used as a neurocognitive screening tool (Nasreddine et al., 2005; Portuguese version by Simões et al., 2008). The

Portuguese version had an internal consistency of .775, measured using Cronbach's alpha (Freitas et al., 2011). The MoCA was developed specifically for the assessment of milder forms of cognitive impairment (Freitas et al., 2014). According to a validation study conducted with the Portuguese population, this instrument has an ideal cut-off point of 22 for mild cognitive impairment (Freitas et al., 2014).

2.2.2. Psychopathy measure

The Triarchic Psychopathy Measure (TriPM, Patrick et al., 2009; Portuguese version by Paiva et al., 2020) is a self-report instrument with 58 items that map the core features of psychopathy along three facets – boldness, meanness, and disinhibition – and considers them continuously distributed among the general population. The boldness subscale includes the adaptive characteristics of psychopathy, such as social dominance, low anxiety, and an adventurous spirit; the disinhibition subscale contains externalizing factors, such as impulsivity and deficits in the affective regulation of anger and hostility; and, finally, the meanness subscale includes secondary externalizing items, such as lack of empathy and of close ties, insensitivity, and callousness. In terms of application, the TriPM is brief, easy to apply, open access, applicable to large groups, and has already been translated into 12 languages. A higher score in any of the subscales means that a greater number of features of the measured facet are present or that these features are more pronounced. The internal consistency scores on the subscales, in the original study, were boldness (α = .87), meanness (α = .85), and disinhibition (α = .87) (Patrick, 2010). In the Portuguese version, the internal consistency (Cronbach's α) for the three TriPM subscales are boldness (α = .82), meanness (α = .85), and disinhibition (α = .81). The measures considered in this study were the scores on the three subscales of the TriPM.

2.3. Procedure

2.3.1. Experimental tasks

For the time estimation task, the stimuli consisted of 45 color images extracted from the Nencki Affective Picture System[1] (NAPS; Marchewka et al., 2014). The images in this database are pre-evaluated, in terms of valence, on a 9-point scale, where values closer to 1 indicate negative valence and values closer to 9 indicate positive valence (values around 5 are neutral).

The set of stimuli consisted of equal numbers (15) of: (1) positive valence images ($M = 7.94$, $SD = 0.20$), which constitute the pleasant condition; (2) negative valence images ($M = 1.94$, $SD = 0.25$), which constitute the unpleasant condition; and (3) neutral images ($M = 5.07$, $SD = 0.14$), which constitute the neutral condition. This classification was based on the valence classifications provided with the NAPS image database (Marchewka et al., 2014).

In each trial of the time estimation task, the participants evaluated the time elapsed during the exposure of images of a certain emotional value, organized into three blocks – pleasant, unpleasant, and neutral images – administered without pause between them, and in a counterbalanced way, to control effects of order and proactive interference (carry-over effect). In the trials of each block, the duration of the intervals varied between six integer values (from 2 to 7 s) and their order was pseudo-randomized, to avoid two consecutive trials with intervals of the same duration. Fifteen trials were presented for each time interval, totaling 90 trials per block (15 images * 6 intervals). The answer was free (to prevent participants from becoming aware of the different time intervals available). There was a 2.5 s period for the response to be given, followed by an inter-stimulus interval of 500 ms, to prevent an expectation effect and the proactive interference of one trial on the next. Participants were instructed not to count out loud, nor use any type of body movement that could assist in time estimation.

Table 1. Matrix of possible gains/losses in each trial (worth noting three gain/loss values – 5, 10, 15 – and three time conditions – now, after a week, after a month).

Gains					Losses				
Now		Week		Month	Now		Week		Month
5	Or	10			5	Or	10		
	Or	15				Or	15		
	Or			10		Or			10
	Or			15		Or			15
10	Or	15			10	Or	15		
	Or			15		Or			15
		5	Or	10			5	Or	10
			Or	15				Or	15
		10	Or	15			10	Or	15
30 trials * 9 conditions = 270 gains trials					30 trials * 9 conditions = 270 loss trials				

The intertemporal decision-making task was developed specifically for this study and applied as explained in the procedure.

In each trial of the intertemporal decision-making task, the participant had to decide between a certain amount of immediate gain or loss and another amount of delayed gain or loss (after a week, or month) (cf. Table 1).

Thirty trials were administered for each decision pair. As measures of this task, a gains ratio (Gr = frequency of immediate, lower-value choices/frequency of delayed higher-value choices, in gains trials) and losses ratio (Lr = frequency of immediate lower-value choices/frequency of delayed higher-value choices, in losses trials) were calculated, such that $Gr > 1$ indicates a preference for smaller, immediate gains, whereas $Lr < 1$ indicates preference for larger, delayed losses, these cases suggesting more impulsive choices. Mean response times (RT) were also calculated as measures of this task, under the conditions of immediate gain, delayed gain, immediate loss, and delayed loss.

Both the experimental tasks, as well as the blocks within each task, were administered in a counterbalanced way between the participants, to reduce effects of order and proactivity (carry-over), without a pause between the blocks. All participants had the opportunity to perform six training trials to familiarize themselves with the tasks.

Both tasks were programmed using the E-Prime 2.0 (Psychology Software Tools, Inc.) software. All stimuli were presented at the center of a 17″ monitor, positioned approximately 80 cm in front of the participants.

2.3.2. EEG data acquisition and processing

EEG data was collected using a NetAmps 300 amplifier from Electrical Geodesics Inc. (Electrical Geodesics Inc., Eugene, OR, EUA) and a Hydrocel Geodesics Sensor net cap with 128 channels. The scalp electrodes were referenced to Cz, and data was collected with a sampling rate of 500 Hz, using the Netstation V4.5.2 (2008, EGI – Electrical Geodesics Inc., Eugene, OR, EUA).

The raw EEG data was pre-processed in EEGLAB (version 11; Delorme and Makeig, 2004), a toolbox of MATLAB (2017, *The Mathworks Inc.*, Natick, MA, EUA). The sampling rate was reduced to 250 Hz and the data was filtered using a 0.2 Hz high-pass filter and a 30 Hz low-pass filter. The channels with more noise were eliminated (up to a maximum of 10% of the electrodes) and subjected to a decomposition by independent

[1] The images used were: POSITIVE IMAGES: Faces_104_h, Landscapes_035_v, Objects_074_v, Faces_351_h, Landscapes_064_h, Landscapes_166_h, Faces_116_h, People_169_h, People_154_h, Landscapes_097_v, Landscapes_137_h, Animals_131_h, Faces_140_h, People_185_h, People_043_h; NEGATIVE IMAGES: People_238_h, People_198_h, People_237_h, Faces_371_v, Faces_364_v, People_218_v, Faces_143_v, People_208_h, People_221_h, Faces_365_v, People_220_h, Animals_077_h, People_127_h, Faces_010_h, People_200_h; NEUTRAL IMAGES: Faces_167_v, Landscapes_170_h, Animals_133_h, Objects_210_h, Animals_081_h, Objects_147_v, Faces_039_h, Faces_216_h, Faces_305_h, Objects_314_h, Objects_057_h, People_146_h, Objects_213_h, Faces_218_h, Objects_112_h.

component analysis (ICA). Blinking, saccades and cardiac activity were corrected by subtracting the corresponding independent component activity from the data, followed by visual inspection to ensure that the correction did not alter the signal beyond the time windows of the artifacts. The eliminated electrodes were interpolated, and the signal was re-referenced to the average of the electrodes. The EEG recordings were segmented into 1000 ms epochs (−200 to 800 ms with reference to the start of the event of interest) and visually inspected for manual rejection of segments with artifacts not corrected by the ICA decomposition. All epochs underwent a baseline correction (200 ms pre-stimulus) and the potentials are related/synchronized to the appearance of the stimuli, in each of the experimental tasks. We also aimed to analyze the potentials related to participants' responses, but not enough segments were obtained to allow this analysis.

2.3.3. ERP data analysis

The average ERP per condition was inspected to ensure that the expected morphology of the potentials of interest was present. The average amplitudes for each potential of interest were extracted by averaging 200 voltage samples around the peak amplitude identified in the time window of 100–200 ms for N1, and 300–1000 ms for P3, for the intertemporal decision-making task. For the time estimation task, the time windows of 100–200 ms were used for N1, and 400–1000 ms for the LPP. Electrodes 61, 62, 67, 72, 77, and 78 were interpolated for N1, electrodes 61, 62, 67, 72, 77, and 78 for P3, and electrodes 61, 62, 67, 72, 77, and 78 for the LPP. Given the limited signal-to-noise ratio of the present study, we decided to use the average amplitudes as a more reliable way to quantify the components of interest of the ERP (Luck, 2014).

2.3.4. Data analysis

In the first phase of data treatment and analysis, central tendency (*M*) and dispersion (*SD*) measures were calculated. To test the predictions, repeated measures covariance analyses (repeated measures ANCOVA) were performed, using the Statistical Packages for Social Sciences (SPSS, version 26, IBM Corp., Armony, NY).

For the analysis of behavioral data in the time estimation task, the *emotional condition* (pleasant, unpleasant, neutral) was considered an intra-subjects variable and the scores of the TriPM subscales (psychopathy measures) were considered covariables, to examine their effect on *time estimation*, measured using θ (estimated time/real time).

In the intertemporal decision-making task, the decision-making condition (gains, losses) was considered an intra-subjects variable and the scores on the TriPM subscales (psychopathy measures) were covariables, to examine their effect on the *choice preference* of participants (dependent variable), measured by the gains or losses ratios. In a separate model, the *type of choice* (smaller immediate gains, larger delayed gains, smaller immediate losses, and larger delayed losses) was considered an intra-subjects variable and the scores of the psychopathy subscales were covariables, to examine their effect on response times (RT) (dependent variable).

For the analysis of the neurophysiological data of the time estimation task, the emotional condition (pleasant, unpleasant, neutral) was considered an intra-subjects variable, the scores of the TriPM subscales (measure of psychopathy traits) were covariates and the mean amplitudes of the N1 and LPP components were dependent variables (in separate models).

Concerning the analysis of the neurophysiological data of the decision-making task, the condition of choice (gains now-week, gains now-month, losses now-week, losses now-month) was considered an intra-subjects variable, the score on TriPM subscales (measure of psychopathy traits) were covariates and the mean amplitudes of N1 and P3 components were dependent variables (in separate models).

The partial η^2 was calculated as a measure of effect size (Cohen, 1992) and the Holm-Bonferroni *post hoc* test was selected for multiple comparisons, as it is more robust than the Bonferroni test (Holm, 1979).

The assumption of normality was assessed by the Shapiro Wilk test and, when violated, an analysis of skewness (*Sk*) and kurtosis (*Ku*) coefficients was performed. Since the absolute values of these coefficients varied between 2 and 7 (Kim, 2013), these parametric tests were always selected. The sphericity assumption was assessed using the Mauchly test, and when this assumption was violated, the Greenhouse-Geisser correction was applied, and the epsilon value (Ɛ) was reported.

Lastly, in order to explore the relationship between time estimation and intertemporal choices, a Pearson's correlation coefficient was performed, between the time estimation measures in the three emotional conditions (θ pleasant, θ unpleasant, and θ neutral), the scores on the facets of psychopathy (boldness, meanness, and disinhibition), the response times for smaller immediate gains, larger delayed gains, smaller immediate losses and larger delayed losses, and the gains (Gr) and losses (Lr) ratios for the intertemporal decision-making task. We also explored (a) relationships between the thetas (in the pleasant, unpleasant, and neutral conditions) with the ERP amplitudes, and (b) the relationships of Gr and Lr with the ERP amplitudes.

3. Results

3.1. Descriptive statistics

3.1.1. Time estimation task

Table 2 presents the descriptive statistics of the θ values observed in each of the emotional conditions of the time estimation task. To facilitate the comparison between conditions, these results are also displayed in Figure 1.

Table 2. Mean (M) and standard deviation (SD) values of θ in the three emotional conditions (pleasant, unpleasant, neutral) of the time estimation task (n = 19).

Emotional condition	*M*	*SD*
Pleasant	0.963	0.193
Unpleasant	0.961	0.185
Neutral	0.958	0.205

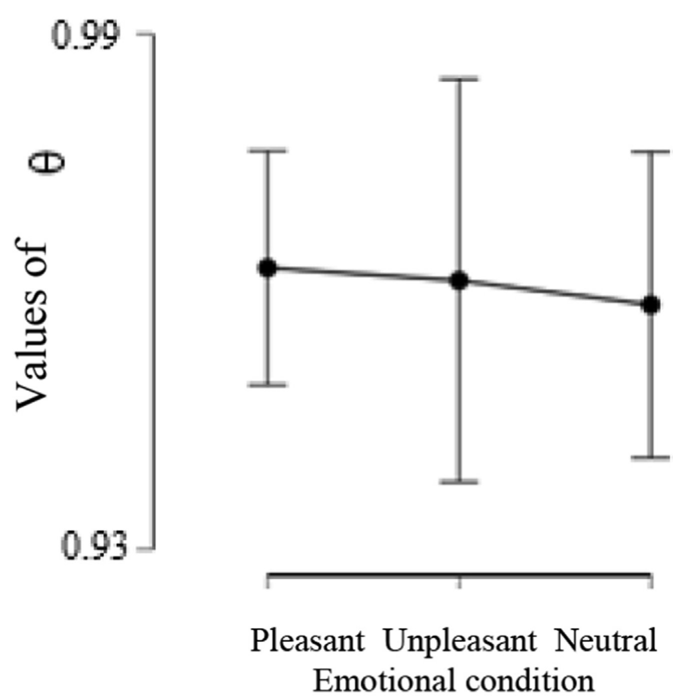

Figure 1. Effect of the emotional condition (pleasant, unpleasant, and neutral) on time estimation, measured by θ (the error bars indicate the confidence interval of 95%).

Table 3. Mean (M) and standard deviation (SD) values of N1 amplitude in the three emotional conditions (pleasant, unpleasant, neutral) of the time estimation task (n = 19).

N1 amplitude	*M*	*SD*
Pleasant	–1.800	2.196
Unpleasant	–1.376	2.841
Neutral	–2.457	2.818

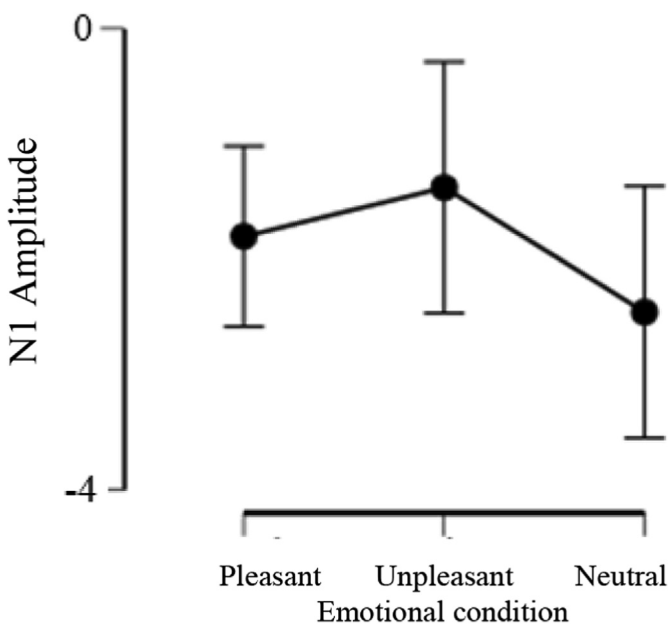

Figure 2. Effect of the emotional condition (pleasant, unpleasant, and neutral) on N1 amplitude in the time estimation task (the error bars indicate the confidence interval of 95%).

Table 4. Mean (M) and standard deviation (SD) values of LPP amplitude in the three emotional conditions (pleasant, unpleasant, and neutral) of the time estimation task (n = 19).

LPP amplitude	*M*	*SD*
Pleasant	0.806	5.506
Unpleasant	3.855	4.198
Neutral	2.195	4.676

Table 3 presents the descriptive statistics of the N1 amplitude in each emotional condition of the time estimation task. To facilitate the comparison of the N1 amplitude in the three emotional conditions, these results are also presented in Figure 2.

Table 4 presents the descriptive statistics of the LPP amplitude in each emotional condition of the time estimation task. To facilitate the comparison of the LPP amplitude in the three emotional conditions, these results are also shown in Figure 3.

3.1.2. Intertemporal choice task

Table 5 presents the descriptive statistics of the gains ratio (Gr) values for the gains condition, and the losses ratio (Lr) values for the losses condition, observed in the decision-making task. To facilitate this comparison, these results are also displayed in Figure 4.

Table 6 presents the descriptive statistics of the response times obtained according to the type of decision, specifically in the choices of smaller immediate gains, larger delayed gains, smaller immediate losses and larger delayed losses. To facilitate this comparison, these results are also shown in Figure 5.

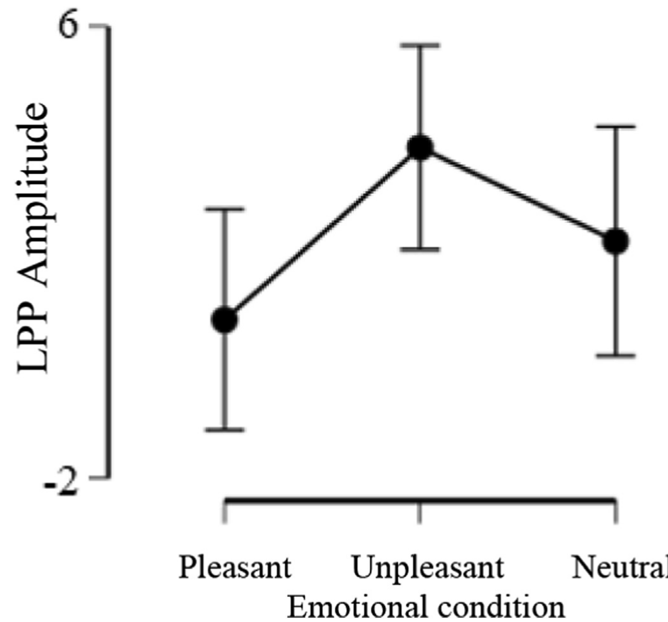

Figure 3. Effect of the emotional condition (pleasant, unpleasant, and neutral) on LPP amplitude in the time estimation task (the error bars indicate the confidence interval of 95%).

Table 5. Mean (M) and standard deviation (SD) values of the gains ratios (Gr) in the gains condition and of the losses ratios (Lr) in the losses condition (n = 58).

Decision making	*M*	*SD*
Gains ratio (Gr)	39.051	61.497
Losses ratio (Lr)	5.809	33.663

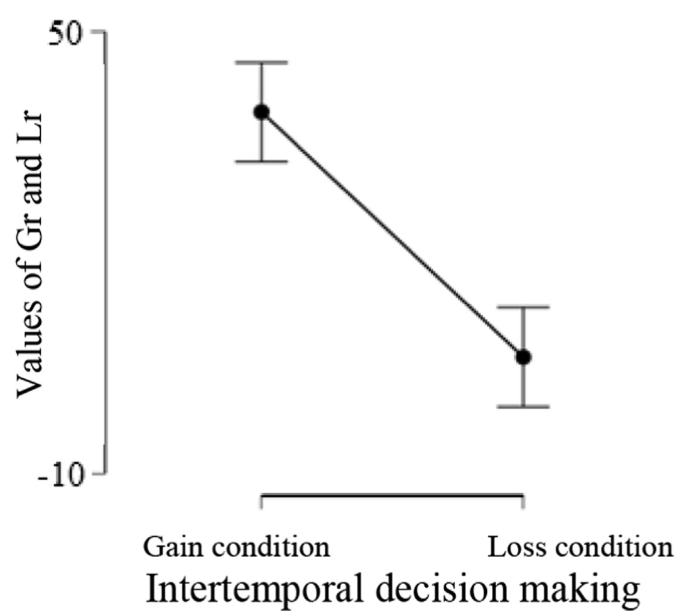

Figure 4. Effect of the decision-making condition (gain, loss) measured by the gains ratio (Gr) for the condition of gains and the losses ratio (Lr) for the condition of losses (the error bars denote the 95% confidence interval).

Table 7 displays the descriptive statistics of the N1 amplitude according to the decision-making condition (gains now-week, gains now-month, losses now-week, losses now-month), in the intertemporal decision-making task. To facilitate the comparison of N1 amplitudes in

Table 6. Mean (M) and standard deviation (SD) values of the response times for the choice of smaller immediate gains, larger delayed gains, smaller immediate losses, and larger delayed losses (n = 19).

Response time	*M*	*SD*
Smaller immediate gains	937.749	356.833
Larger delayed gains	973.083	526.389
Smaller immediate losses	1035.739	456.963
Larger delayed losses	979.870	375.078

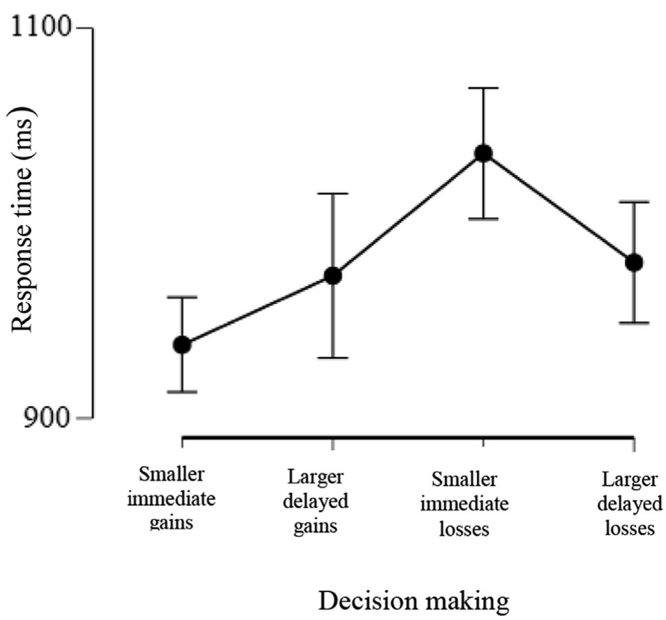

Figure 5. Effect of the type of decision (smaller immediate gains, larger delayed gains, smaller immediate losses, and larger delayed losses) on response time (the error bars indicate the 95% confidence interval).

Table 7. Mean (M) and standard deviation (SD) values of N1 amplitude in each decision making condition (gains now-week, gains now-month, losses now-week, losses now-month) of the intertemporal decision making task (n = 58).

N1 amplitude	*M*	*SD*
Gains now-week	–1.108	2.120
Gains now-month	–1.577	2.286
Losses now-week	–1.485	2.032
Losses now-month	–-0.988	1.854

the four decision-making conditions, these results are also presented in Figure 6.

Table 8 presents the descriptive statistics of the P3 amplitude in each decision-making condition (gains now-week, gains now-month, losses now-week, losses now-month) of the intertemporal decision-making task. To facilitate the comparison of the P3 amplitude in the two decision-making conditions, these results are also displayed in Figure 7.

3.2. Time estimation task

3.2.1. Behavioral results

The repeated measures ANCOVA, in which the *emotional condition* (pleasant, unpleasant, neutral) was an intra-subjects factor and the scores on the TriPM subscales *(boldness*, *disinhibition,* and *meanness)* were covariables, did not reveal a main effect of *emotional condition*, $F(1.44, 21.54) = 0.244$, $p = .712$, $\eta^2_p = .016$, $\varepsilon = .718$, nor significant effects of *boldness* and *meanness* on the values of θ (both $F \leq 1$); however, it revealed an almost significant effect of *disinhibition*, $F(1, 15) = 3.475$, $p = .082$, $\eta^2_p = .188$, with higher values on this variable being associated with higher values of θ in the unpleasant emotional condition.

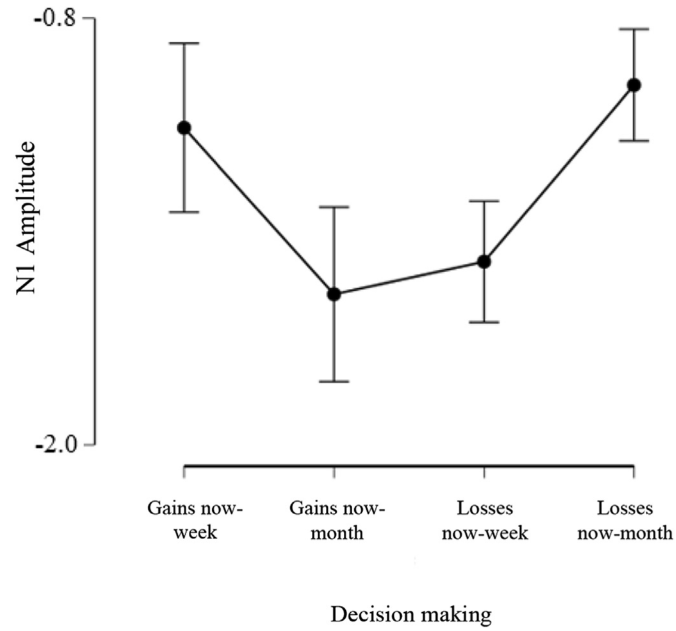

Figure 6. Effect of the decision-making condition (gains now-week, gains now-month, losses now-week, losses now-month) on N1 amplitude in the intertemporal decision making task (the error bars indicate the 95% confidence interval).

Table 8. Mean (M) and standard deviation (SD) values of P3 amplitude in each decision-making condition (gains now-week, gains now-month, losses now-week, losses now-month) of the intertemporal decision making task (n = 58).

P3 amplitude	*M*	*SD*
Gains now-week	1.743	3.364
Gains now-month	0.990	3.508
Losses now-week	1.609	3.839
Losses now-month	1.875	3.924

The interactions of each of the psychopathy measures (*boldness*, *disinhibition,* and *meanness*) with the *emotional condition* did not reveal significant effects on the values of θ in any of the cases (all $F \leq 1$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

The repeated measures ANCOVA, in which the *response times* condition was an intra-subjects factor and the scores on the *boldness*, *disinhibition,* and *meanness* subscales of the TriPM were covariables, did not reveal a main effect of the *response times* condition, $F(1.36, 20.3) = 0.062$, $p = .875$, $\eta^2_p = .004$, $\mathcal{E} = .678$, nor significant effects of any of the psychopathy measures, i.e. the covariables, on the values of the response times (ms) ($F \leq 2.138$, $p > .164$).

The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *response times* did not reveal significant effects on the values of θ in any of the cases (all $F \leq 1$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

3.2.2. Neurophysiological results

The repeated measures ANCOVA, in which the *emotional condition* (pleasant, unpleasant, neutral) and the scores on the *boldness*, *disinhibition,* and *meanness* subscales of the TriPM were covariables, did not reveal a main effect of *emotional condition*, $F(2, 24) = 0.095$, $p = .910$, $\eta^2_p = .008$, nor significant effects of boldness; however, meanness, $F(1, 12) = 3.71$, $p = .078$, $\eta^2_p = .236$ and disinhibition, $F(1, 12) = 4.28$, $p = .061$, $\eta^2_p = .263$, were almost significant for N1 amplitude in the pleasant

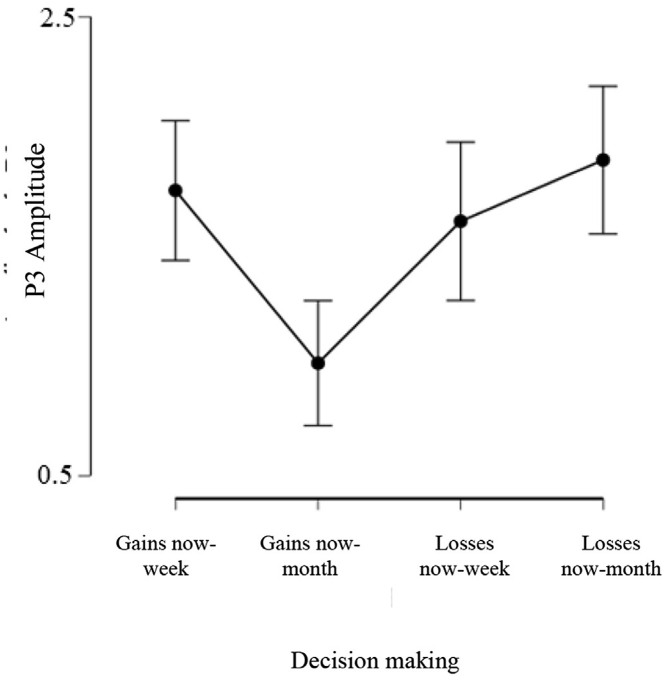

Figure 7. Effect of the decision-making condition (gains now-week, gains now-month, losses now-week, losses now-month) on P3 amplitude in the intertemporal decision making task (the error bars indicate the 95% confidence interval).

emotional condition, with higher meanness values being associated with a lower N1 amplitude in the pleasant emotional condition; and higher disinhibition values being associated with greater N1 amplitude in the pleasant emotional condition.

The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *emotional condition* (pleasant, unpleasant, neutral) did not reveal significant effects in *N1* amplitude, in any of the cases (all $F \leq 1$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

The repeated measures ANCOVA, in which the *emotional condition* (pleasant, unpleasant, neutral) was an intra-subjects factor and the scores on the *boldness*, *disinhibition,* and *meanness* subscales of the TriPM were covariables, did not reveal a main effect of emotional condition, $F(2, 24) = 0.002$, $p = .998$, $\eta^2_p = .002$, nor significant effects of boldness and meanness on LPP amplitude ($F \leq 2.326$, $p > .153$); however, disinhibition, $F(1, 12) = 4.054$, $p = .067$, $\eta^2_p = .253$ demonstrated almost significant LPP amplitude, with greater disinhibition values being associated with lower LPP amplitude, in the unpleasant emotional condition.

The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *emotional condition* (pleasant, unpleasant, neutral) did not reveal significant effects on the LPP amplitude in any of the cases (all $F \leq 1$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

The amplitudes of the ERPs in the time estimation task were calculated on Pz (Figure 8), per emotional condition (pleasant, unpleasant, neutral).

3.3. Intertemporal choices task

3.3.1. Behavioral results

The repeated measures ANCOVA, in which the *decision-making* condition (gains, losses) was an intra-subjects factor and the scores on the *boldness*, *disinhibition,* and *meanness* subscales were covariables, did not reveal a significant effect of intertemporal *decision-making*, $F(1, 54) = 0.462$, $p = .500$, $\eta^2_p = .008$, nor significant effects of any of the psychopathy measures, i.e. the covariables, on the values of Gr and Lr (all $F \leq 1$).

The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with *decision-making* (gains, losses) did not reveal significant effects on the *choice preference* (measured by Gr or Lr) (all $F \leq 2.095$, $p > .154$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

The repeated measures ANCOVA, in which the *type of decision* (smaller immediate gains, larger delayed gains, smaller immediate losses, and larger delayed losses) was the intra-subjects factor and the scores on the *boldness*, *disinhibition,* and *meanness* subscales of the TriPM were covariables, did not reveal a main effect of *type of decision*, $F(3, 156) = 0.041$, $p = .989$, $\eta^2_p = .007$, nor significant effects of any of the psychopathy measures, i.e. the covariables, on the values of RT (ms) (all $F \leq 1.415$, $p > .240$). The interactions of each psychopathy measure with the *type of decision* did not reveal significant effects on RT values (ms), in any of the cases (all $F \leq 2.005$, $p > .116$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

3.3.2. Neurophysiological results

The repeated measures ANCOVA, in which the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month) and the scores on the *boldness*, *disinhibition,* and

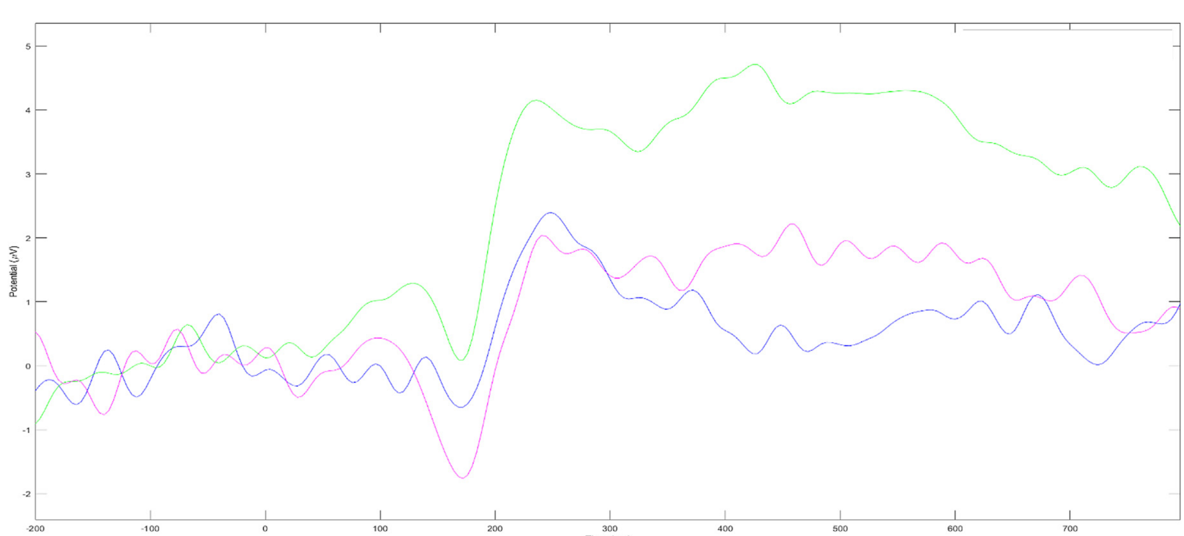

Figure 8. Brain potentials related to pleasant (blue), unpleasant (green), and neutral (violet) stimuli, obtained from Pz, in the time estimation task.

meanness subscales of the TriPM were covariables, did not reveal a main effect of the *decision-making* condition, $F(2.39, 129.24) = 1.286$, $p = .282$, $\eta^2_p = .023$, $\varepsilon = .798$, nor significant effects in any of the psychopathy measures, i.e. the covariables, in N1 amplitude (all $F \leq 1$).

The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month) revealed no significant effects on the amplitude of *N1* in any of the cases (all $F \leq 1.281$, $p > .283$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

The repeated measures ANCOVA, in which the *decision-making condition* (gains now-week, gains now-week, losses now-week, losses now-month) was an intra-subject factor and the scores on the *boldness*, *disinhibition,* and *meanness* subscales of the TriPM were covariables, revealed an almost significant main effect of the *decision-making* condition, $F(2.82, 151.99) = 2.395$, $p = .075$, $\eta^2_p = .042$, $\varepsilon = .638$ on the amplitude of P3; however, no significant effects were found in any of the psychopathy measures, i.e. the covariables, in the amplitude of P3 (all $F \leq 1.175$, $p > .283$).

The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *decision-making condition* (gains now-week, gains now-week, losses now-week, losses now-month) revealed no significant effects on the amplitude of *P3* in any of the cases (all $F \leq 1.949$, $p > .128$). Since there were no significant effects, we did not proceed with *post hoc* analyses.

The Pearson correlation matrix showed an almost significant positive relationship between the scores on the disinhibition subscale of the TriPM and the P3 amplitude, in the decision condition of losses now-month ($r = .236$, $p = .074$), as well as between the scores on the meanness subscale and the P3 amplitude, in the decision condition of gains now-month ($r = .245$, $p = .064$).

There was also a significant positive relationship between the scores on the disinhibition subscale ($r = .317$, $p = .015$), as well as between the scores on the meanness subscale ($r = .288$, $p = .028$) and P3 amplitude, in the decision condition of gains now-week.

The ERP amplitudes in the intertemporal decision-making task were calculated in Cz for four choice conditions: gains now-week, gains now-month, losses now-week and losses now-month (Figure 9).

3.4. Relationship between intertemporal choices and time estimation

The Pearson correlation coefficient revealed a positive and significant correlation between the θ of the pleasant emotional condition and the response time of the smaller immediate gain ($r = .547$, $p < .05$) (Table 9).

3.5. Interpretation

There are characteristics of psychopathy that may be related to changes in intertemporal choices. Specifically, characteristics such as impulsiveness or lack of inhibitory control may be associated with a more pronounced discounting function in intertemporal choices and, in turn, this function may be based on changes in the basic mechanisms of time perception, namely time estimation. Thus, this study aimed to examine potential differences in neurophysiological correlates, specifically through N1, P3 and LPP measurements, which may be related to time estimation and intertemporal decision-making, examining their modulation according to psychopathic traits, different emotional conditions, and different decision-making conditions. Although essentially exploratory, we formulated the following predictions for this study: (a) the higher the score on the boldness and meanness facets, the smaller the N1 amplitude related to the images in the time estimation task, regardless of the emotional condition, indicating a deficient processing of these stimuli associated with those facets of psychopathy; (b) the higher the score on the disinhibition facet of psychopathy, the greater the N1 amplitude in the time estimation task, regardless of the emotional condition; (c) the higher the score on the disinhibition facet of psychopathy, the larger the time interval estimate (overestimation), especially in the unpleasant emotional condition; (d) an effect of emotional condition on time estimation is not expected in association with the boldness and meanness facets of psychopathy; (e) the higher the score on the disinhibition facet of psychopathy, the greater the preference for smaller immediate gains over larger delayed gains, as well as for larger delayed losses over smaller immediate losses, indexed either by explicit choices (i.e., by a ratio of gains and losses; see methodology), or by shorter response times under these conditions; (f) the greater the preference for larger delayed gains or smaller immediate losses, the greater the amplitudes of N1 and P3 related to the choice options, indicating greater cognitive effort in decision-making; (g) the longer the estimated time, the greater the preference

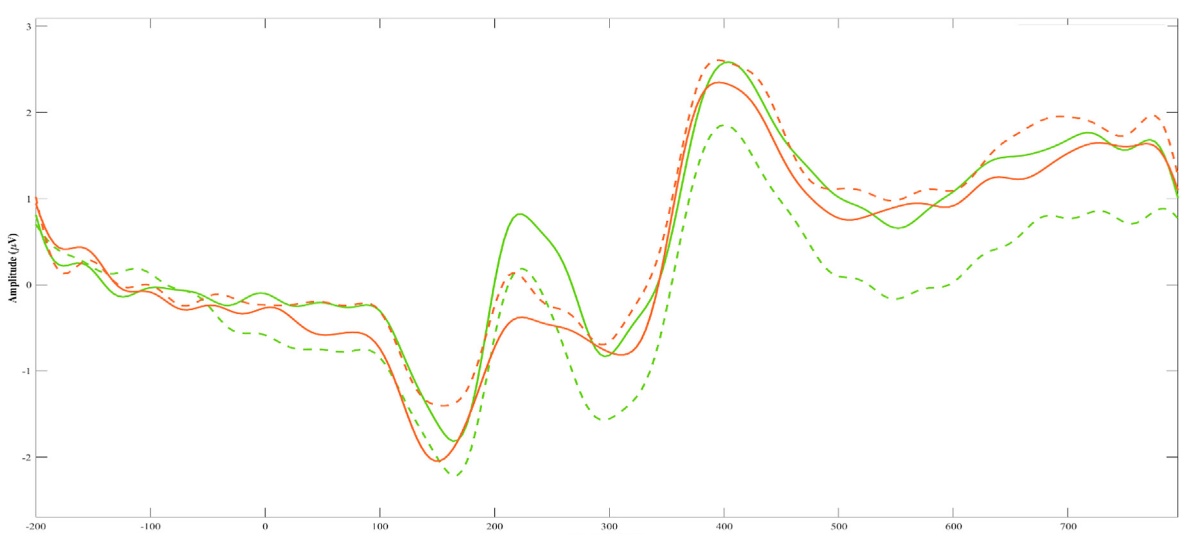

Figure 9. Brain potentials related to the choice between gains now-week (green continuous tracing), gains now-month (green dashed tracing), losses now-week (red continuous tracing), and losses now-month (red dashed tracing), obtained from Cz, in the intertemporal decision-making task.

Table 9. Correlation between scores on the facets of psychopathy (boldness, disinhibition, and meanness), time estimation measures (in the pleasant, unpleasant, and neutral emotional conditions), intertemporal choice measures (gains and losses ratios – Gr and Lr) and the N1, P3, and LPP amplitudes in both experimental tasks (n = 19 in the time estimation task and n = 58 in the decision-making task).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Scores on the psychopathy facets																						
1. Boldness	–																					
2. Disinhibition	–.050	–																				
3. Meanness	–.064	.600**	–																			
Emotional condition																						
4. Pleasant	.038	–.357	–.164	–																		
5. Unpleasant	.102	–.498*	–.223	.796**	–																	
6. Neutral	–.042	–.401	–.140	.929**	.746**	–																
Intertemporal choice ratios																						
7. Gr	.159	.005	–.041	.164	–.043	.116	-															
8. Lr	–.078	–.015	–.039	–.267	–.181	–.138	–.125	–														
N1, P3 and LPP amplitudes in both experimental tasks																						
N1 time estimation																						
9. Pleasant	–.249	–.150	.344	.000	-.033	.130	.146	–.040	–													
10. Unpleasant	–.272	–.124	.229	–.026	.044	.045	.188	–.331	.580*	-												
11. Neutral	–.225	–.284	.064	–.012	.126	.026	–.345	.241	.579*	.391	–											
LPP time estimation																						
12. Pleasant	–.371	–.266	.116	–.133	–.255	.075	.008	–.129	.718	.411	.126	–										
13- Unpleasant	–.307	–.209	.139	–.079	–.006	.078	.222	–.150	.414	.802**	.034	.527*	–									
14. Neutral	–.289	–.351	–.133	–.011	.121	–.006	–.117	.163	.551	.411	.510	.439	.350	–								
N1 decision making																						
15. Gains now-week	.027	–.030	–.038	–.340	–.396	–.208	.032	.145	.385	–.173	.048	.409	–.143	.021	–							
16. Gains now-month	–.072	–.018	.058	–.093	–.122	.099	.068	.048	.082	–.157	.203	.194	–.145	–.187	.168	–						
17. Losses now-week	–.186	–.119	–.179	–.133	–.225	–.017	.009	.186	.141	–.185	–.031	.352	.028	.194	.416**	.487**	—					
18. Losses now-month	–.179	–.089	–.182	–.753**	–.715**	–.733**	–.026	.074	.001	.076	.067	.112	.004	.005	.484**	.436**	.657**	–				
P3 decision making																						
19 Gains now-week	.184	.317*	.288*	–.470	–.183	–.506*	.080	.048	–.093	–.175	–.177	–.258	–.172	–.299	.207	.084	.023	.108	–			
20. Gains now-month	.191	.158	.245	–.294	.037	–.290	.000	.052	–.297	–.079	–.182	–.459	–.004	–.387	–.091	.391**	.093	.179	.680**	–		
21. Losses now-week	.016	.073	.053	–.312	–.029	–.298	.079	.073	–.215	–.008	–.239	–.286	.119	–.114	–.184	.043	.425**	.244	.473**	.580**	–	
22. Losses now-month	–.007	.236	.083	–.606**	–.307	–.623**	.082	.169	–.331	.030	–.188	–.390	.039	–.275	–.023	–.101	.012	.379**	.569**	.611**	.588**	–

*$p < .05$. **$p < .01$. ***$p < .001$.

Note. These are direct correlations, thus, the cross effect of a variable on the relationship between other variables was not controlled.

for smaller immediate gains and larger delayed losses; (h) the higher the score on the disinhibition facet of psychopathy, the lower the amplitude of P3 in the intertemporal decision-making task; (i) the higher the score on the disinhibition facet of psychopathy, the lower the amplitude of the LPP in the unpleasant emotional condition, in the time estimation task; (j) the higher the scores on the boldness and meanness facets of psychopathy, the lower the amplitude of the LPP in the pleasant and unpleasant emotional conditions, although not in the neutral condition, in the time estimation task. Fifty-eight participants (40 women) performed an intertemporal decision-making task and, of these, 19 (16 women) performed a time estimation task, with simultaneous recording of EEG data.

In the time estimation task, participants underestimated time in all emotional conditions. Despite studies showing that emotions alter the subjective sense of time (Campbell and Bryant, 2007; Droit-Volet and Meck, 2007; Smith et al., 2011; Tse et al., 2004; Wittmann and van Wessenhove, 2009), namely between an emotional or neutral context (Dirnberger et al., 2012), there was no main effect of the emotional condition. Moreover, there were no significant effects of boldness and meanness, nor of the interaction of these facets with the emotional conditions, on the values of θ (which meets hypothesis d), but there was an almost significant effect of disinhibition on the values of θ, with higher values on this variable associated with higher values of θ in the unpleasant emotional condition. This means the greater the disinhibition, the greater the tendency to overestimate time in the unpleasant emotional condition, which suggests confirmation of hypothesis c. It is likely the participants in this study did not reveal pronounced traits of impulsivity or, at least, more pronounced psychopathic traits of disinhibition.

The default delay discounting paradigms are based on explicit choices between immediate vs. delayed options. Impulsive individuals usually choose smaller immediate rewards over larger delayed rewards, possibly because individuals with pronounced impulsive traits have an accelerated sense of time (Berlin et al., 2005). A longer perception of time is associated with higher costs, which leads to the selection of alternatives with more immediate results (Frederick et al., 2002; Kalenscher and Pennartz, 2008; Loewenstein and Prelec, 1992; Pimentel et al., 2012).

Emotional factors may also guide intertemporal decisions, namely by influencing the attention devoted to each of the choices. For example, on the one hand, the emotional salience of an immediate monetary reward influences motivational value and, on the other hand, delayed rewards are more "intangible" (Rick and Loewenstein, 2008; Rolls, 1999). This explanation is in line with recent neurobiological reports of self-control mechanisms that emphasize the role of selective attention in choices that have future consequences (Figner et al., 2010; Hare et al., 2009, 2011). Assuming this emotional salience affects decision-making, the greater the insensitivity to that salience, as expected in individuals of high meanness and boldness, the greater the preference for larger delayed gains and smaller immediate losses. As for disinhibition, the associated impulsiveness would predict the opposite pattern of choices. In the intertemporal decision-making task, this study revealed no significant effects of any psychopathic measure (boldness, disinhibition, and meanness) on the values of the gains and losses ratios. There were also no significant effects of any of the psychopathy measures on the response times observed in each type of choice. As such, hypothesis (e) is invalidated.

The N1 amplitude is sensitive to attention (Näätänen and Picton, 1987) and would be increased in individuals with more pronounced disinhibition traits (e.g., Anderson et al., 2015). The repeated measures ANCOVA, in which the *emotional condition* (pleasant, unpleasant, neutral) and the scores on the TriPM subscales of *boldness*, *disinhibition,* and *meanness* were as covariables, did not reveal a main effect of the emotional condition, nor significant effects of boldness; however, meanness and disinhibition proved to be almost significant in the N1 amplitude, in the pleasant emotional condition of the time estimation task, with higher meanness values being associated with lower N1 amplitude in the pleasant emotional condition; and with higher disinhibition values being associated with greater N1 amplitude in the pleasant emotional condition, suggesting the confirmation of hypotheses a and b.

Furthermore, previous findings among individuals prone to hypomania revealed greater N1 differentiation between immediate and delayed rewards, in addition to greater N1 amplitudes for rewards themselves (Mason et al., 2012). Increased N1 amplitudes have also been associated with high levels of impulsivity. For example, impulsive-aggressive participants exhibited an increased N1 in response to visual stimuli, indicating improved attentional orientation (Gehring and Willoughby, 2002). In this study, in the intertemporal decision-making task, the repeated measures ANCOVA, in which the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month) and the scores on the TriPM subscales of *boldness*, *disinhibition,* and *meanness* were covariables, did not reveal a main effect of the *decision-making* condition, nor significant effects of any psychopathy measure, i.e. the covariables, on the amplitude of N1. The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month) did not reveal significant effects on the *N1* amplitude in any of the cases. The repeated measures ANCOVA, in which the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month) was an intra-subjects facto rand the scores on the *boldness*, *disinhibition,* and *meanness* subscales of the TriPM were covariables, revealed a nearly significant effect of the *decision-making* condition on the amplitude of P3. The interactions of each psychopathy measure (*boldness*, *disinhibition,* and *meanness*) with the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month) did not show significant effects on the amplitude of *P3* in any of the cases. These data suggest the invalidation hypothesis (f).

Indeed, the results found were not expected, regarding the P3 amplitude. Through a systematic review, Pasion et al. (2018) found that most studies report reduced P3 amplitude in samples of high-psychopathy individuals, when compared to control groups. Sufficient evidence was found that the impulsive-antisocial characteristics of psychopathy are the main predictor of reduced P3 amplitude. Moreover, evidence of a dissociable effect on the interpersonal-affective characteristics of psychopathy was found, considering the nature of the tasks: these characteristics predicted increased P3 amplitude in cognitive tasks, but emotional-affective tasks were associated with an attenuated P3 amplitude (Pasion et al., 2018). Thus, it was assumed that the higher the scores on the disinhibition facet of psychopathy, the greater the amplitude of P3 in the intertemporal decision-making task. The repeated measures ANCOVA did not reveal a significant effect of any psychopathy subscale on P3 amplitude, in the intertemporal choice task. Nonetheless, the analysis of the correlation matrix shows that, when considering the isolated relationship of each facet with P3 amplitude, that is, without controlling the influence of the other facets, there is an almost significant positive correlation between disinhibition and P3 amplitude, in the losses now-month condition, as well as an almost significant positive correlation between meanness and P3 amplitude, in the gains now-month condition. A significant positive correlation was also found between P3 amplitude in the gains now-week and both disinhibition and meanness. These results may indicate that the greater the meanness, the greater the cognitive effort and attention devoted to the conditions for choosing between immediate gains and gains delayed a week or a month. Regarding disinhibition, the higher the score on this psychopathy facet, the greater the cognitive effort and attention devoted to the choice between losses now or losses delayed one month. To some extent, it is possible these results are compatible with a deficient behavioral inhibition system in high-meanness individuals, making them less sensitive to losses, although normally reward-oriented. These data do not support hypothesis (h).

P3 and LPP have been identified as electrophysiological responses to emotional events (van Dongen et al., 2018). LPP is a positive potential evoked by emotional stimuli and reflects top-down processes, such as emotional regulation (Schupp et al., 2000). Individuals with high psychopathic traits exhibit impaired emotional processing, mainly in the processing of negative stimuli (Dawel et al., 2012; Jusyte and Schönenberg, 2017; Schönenberg et al., 2016) and reduced autonomic responses after the presentation of negative stimuli (Fairchild et al., 2010; Flor et al., 2002; Levenston et al., 2000; López et al., 2013; Rothemund et al., 2012; Vaidyanathan et al., 2011). Despite these observed behavioral deficits, recent studies on LPP amplitude evoked by visual emotional stimuli in individuals with high psychopathic traits reported conflicting results (Medina et al., 2016). For example, unpleasant stimuli evoked lower LPP amplitude than neutral stimuli, in individuals recruited from the community with high psychopathic traits compared to those with low psychopathic traits (Medina et al., 2016). However, both groups exhibited similar LPP amplitude in response to pleasant and neutral stimuli (Medina et al., 2016). In other studies, individuals with high psychopathic traits, recruited from the community, did not show differences between emotional and neutral stimuli (Carolan et al., 2014), but individuals with low psychopathic traits showed a greater LPP amplitude for emotional stimuli than for neutral stimuli (Carolan et al., 2014; Hajcak et al., 2010). In addition, other studies have revealed no differences between groups with high and low psychopathic traits in LPP amplitudes evoked by emotional stimuli (e.g., Eisenbarth et al., 2013). A recent meta-analysis (Vallet et al., 2019) suggests a reduction of the LPP evoked by unpleasant stimuli and a normal LPP response to pleasant and neutral stimuli, specific to individuals with psychopathy. We based the formulation of our hypotheses on this most recent study. The repeated measures ANCOVA, in which the *emotional condition* (pleasant, unpleasant, neutral) was an intra-subjects factor and the scores on the *boldness, disinhibition,* and *meanness* subscales were covariates, did not reveal a main effect of the emotional condition, nor significant effects of boldness and meanness on LPP amplitude, in the time estimation task; however, disinhibition proved to be almost significant in LPP amplitude, with higher disinhibition values being associated with a lower LPP amplitude in the unpleasant emotional condition, suggesting confirmation of hypothesis (i) and invalidation of hypothesis (j).

In the case of intertemporal decision-making tasks, a study examined the electrophysiological correlates of this type of decision (Blackburn et al., 2012). In this study, N1 and frontal related negativity (FRN) were components of interest. N1 was one of the components we analyzed in this task, but we were unable to analyze FRN, because the task did not allow us to induce it. FRN is induced when there is error feedback, when the correct answer is not known, and when a choice result is suboptimal (below the ideal) and passively violates the reward prediction, suggesting a monitoring system that may not be restricted to actions. Only brain potentials related to the appearance of stimuli were extracted (potentials related to responses were also extracted in both tasks, but the reduced number of epochs did not allow their analysis), since the experimental task of decision-making was not programmed to provide feedback and allow the extraction of this type of potential.

4. Discussion

Time perception can be understood as a basic ability of the human mind, and time is an important dimension when individuals make decisions involving gains and losses at different times, of the present or the future. For example, the waiting time before a beneficial result may be received is seen as a cost and is weighed against the benefits of the result. The role that time perception can play in intertemporal decision-making is not well known, nor whether changes in that perception, which are associated with high impulsivity – as is typical of people who score high on the disinhibition facet of psychopathy –, are also reflected in the intertemporal choices. In addition, the existing research suggests that one's emotional state may interfere with basic mechanisms of time perception, but it remains to be clarified whether psychopathy traits that are associated with a lower resonance to emotional stimulation, such as boldness, make time perception mechanisms more immune to said stimulation, as well as how they influence intertemporal choices.

Although there is literature, albeit limited, on time perception in conditions where impulsivity is present, nothing is known about time perception in individuals with high psychopathy. Moreover, time perception and emotions are inexplicably linked to a multitude of external and internal events. Although many studies have shown that individuals are able to accurately measure the passage of time in the range of milliseconds to hours, it remains to be known how our sense of time is altered by emotions (Buhusi and Meck, 2005; Gibbon et al., 1997; Goguen, 2004). Indeed, the analysis of the complex interaction between emotion and time perception remains relatively scarce (e.g., Schirmer, 2004). Given the known emotional deficits in high-psychopathy individuals, exploring the relationship between the core traits of this personality structure and time perception and emotional interference becomes an interesting research question. On the one hand, it is plausible that psychopathy traits related to impulsivity, such as disinhibition, would contribute to an overestimation of time. On the other hand, the low emotional resonance associated with other traits, such as boldness or meanness, suggest that emotional stimulation would have less interference in time perception in these individuals. Thus, the aim of the present study was to examine potential differences in neurophysiological correlates, specifically through N1, P3, and LPP measurements, which may be related to time estimation and intertemporal choices, examining their modulation according to psychopathic traits, different emotional conditions, and different decision-making conditions. To this end, 67 adult participants (48 women) performed a intertemporal decision-making task, of which 19 participants (16 women) performed a time estimation task.

Most studies used idiosyncratic emotional stimuli, which caused problems with interpretation and generalization. Recently, several studies have used sets of standardized stimuli, such as the International Affective Picture System (IAPS; Lang et al., 1997) and the Nencki Affective Picture System (NAPS; Marchewka et al., 2014) and have begun to pay special attention to valence (pleasant, unpleasant, neutral) and intensity or activation (low, high). The pattern of results found by Angrilli et al. (1997), with the IAPS, seemed complex: there was no main effect of activation or valence in the time estimate, but there was a significant interaction between the two dimensions. In the condition of high activation, the duration of negative images was overestimated, while that of positive images was underestimated. In the low activation condition, negative images were underestimated, and positive images were overestimated. This opposite effect of valence as a function of the level of arousal suggests that two different mechanisms are triggered by levels of activation: a controlled attention mechanism for low activation and an automatic mechanism related to motivational survival systems for high arousal (Angrilli et al., 1997). Our data reveal another direction: there was time underestimation in all emotional conditions, which did not meet what was expected (greater overestimation of time in the unpleasant emotional condition, than in the conditions of pleasant and neutral stimulation). Negative images elicited a stronger orientation response than positive images; more attention was paid to negative images than to positive images and the former were judged as being shorter.

Emotions are organized around two basic and independent motivational systems, responsible for avoidance and approach behaviors: the *behavioral inhibition system* and the *behavioral activation system*. On the one hand, the behavioral inhibition system is activated mainly in threatening contexts and basic behavior is built on withdrawal and escape, or attack, especially when the first two alternatives are impractical. On the other hand, the behavioral activation system is activated in contexts such as support, procreation, and nutrition, translating into basic behaviors such as provision of food, sexual intimacy and care. Consequently, unpleasant conditions of high activation, which require defensive behaviors, involve the ability to produce a rapid reaction (attack, escape), causing increased activation of the autonomic nervous system (e.g., pupil dilation, increased blood pressure, muscle contraction) and, possibly, the concomitant acceleration of the "internal clock", leading an over-estimation of the passage of time. Our data suggest the emotional stimuli used induced low activation. In fact, when the passage of time is experienced as faster, the readiness for action is quick. It is likely that mechanisms related to attention prevail in longer durations due to the expected decrease in the autonomic response a few seconds after the presentation of the stimulus (Droit-Volet and Meck, 2007).

The effects of emotions can change systematically over time. Negative images in the condition of high arousal activate the behavioral inhibition system. Consequently, compared to positive images, the "internal clock" will function relatively faster under conditions of high activation for unpleasant images, which causes an overestimation. On the other hand, negative images, in the low activation condition, will be underestimated, possibly because the capture of attention by these images means that less attention will be given to the internal timing system and there will be less accumulated impulses. In conditions of low activation, the capture of attention by the characteristics that define the emotional valence of the stimulus diverts the processing of resources outside the timing system itself (Buhusi and Meck, 2006; Fortin, 2003). Thus, the time perception seems to be a sensitive index of the basic function of emotions, depending not only on its positive or negative valence, but also on its activation potential.

Time perception is a fundamental factor when individuals must make decisions and consider the results associated with their choices. Rewards that are received earlier are often preferred over future rewards, because the subjective value of a result is discounted as a delay function (Ainslie, 1975; Kirby et al., 1999). Results of decision-making experiences show that individuals avoid risk when they must choose between options associated with likely outcomes *vs*. certain outcomes. Specifically, individuals choose something certain over rewards with a probabilistic outcome – even when the probabilistic alternatives have an equal or even greater expected value (Kahneman and Tversky, 1979). The length of time between choosing and receiving the reward is another important factor that influences our decisions. A delayed result of a choice reduces the subjective value of a reward, a phenomenon called delay discounting (Kirby and Santiesteban, 2003; Laibson, 1997). Individuals prefer to receive rewards sooner rather than later. In this study, in intertemporal decision-making task there is no main effect of the type of decision-making conditions (gains, losses), nor significant effects of any of the psychopathic measures on the values of the profit and loss ratios. The interactions of each of the psychopathic measures with the type of intertemporal decision-making also did not show significant effects on the values of the win and loss ratios in any of the cases. There is also no main effect of the type of decision making (gains of smaller immediate value, gains of larger delayed value, losses of smaller immediate value and losses of larger delayed value), nor significant effects of any of the psychopathic measures on the values of response times. The interactions of each psychopathic measure with decision-making also did not show significant effects on the response time values in any of the cases.

Like previous studies, this study presents some limitations. The method was conditioned by instrumental circumstances: the participants provided their answers on a 9-key response box (keys 1 to 9). Therefore, the time estimation task was programmed for exposure times between 2 to 7 s (the 8-second option would have made it too long) and the response options were limited to between 1 and 9 s. If a response box allowing more options had been available, the differences between the participants would possibly be more expressive. Moreover, social desirability was not assessed or controlled. Since the TriPM contains a considerable number of items pertaining to deviant attitudes and acts, particularly in the meanness and disinhibition subscales, it is important that future studies assess the presence of social desirability and test possible moderating effects of this variable.

In tasks such as time estimation, stimulus-related ERPs do not provide information about neurophysiological correlates of time estimation itself; they are simply the brain's response to pleasant, unpleasant, and neutral images (at the moment the stimulus is "released" and the brain response captured, the participant does not even know how long the stimulus, i.e., the image, will be exposed). As explained above, we only analyzed stimuli-related ERPs, because we were unable to extract enough segments from the EEG recordings to obtain response-related potentials of acceptable quality.

In future studies, it would be important to provide a response box with more options, as well as to analyze response-related ERPs and increase the sample size. Given the scarcity of studies conducted to date, future research should consider a dissociation of P3 components to better discriminate the neural correlates of impulsive behavior and, specifically, of psychopathy. It would also be relevant to examine whether a reduction in LPP limited to negative stimuli could discriminate psychopathy or, at least, individuals with more pronounced disinhibition traits compared to other traits. Thus, it would be possible to consider LPP as a potential neuromarker to characterize different phenotypic manifestations of psychopathy.

In summary, in the time estimation task, there was no major effect of the emotional condition. There were also no significant effects of boldness and meanness, nor of the interaction of these facets with the emotional conditions, on the values of θ. However, there was an almost significant effect of disinhibition on the values of θ, with higher values on this variable associated with greater values of θ in the unpleasant emotional condition. In the intertemporal decision-making task, there were no significant effects of any psychopathy measure (boldness, disinhibition, and meanness) on the values of the gains and losses ratios. There were also no significant effects of any psychopathy measure on the response times observed in each type of choice. In addition, the analysis of the neurophysiological correlates of the intertemporal decision-making task did not reveal a main effect of the *decision-making condition* (gains now-week, gains now-month, losses now-week, losses now-month), nor effects of any psychopathy measure on the N1 and P3 amplitudes. The interactions of each psychopathy measure (boldness, disinhibition, and meanness) with the decision-making condition did not show significant effects on the amplitude of N1 and P3, in any case. The analysis of the neurophysiological correlates of the time estimation task revealed that higher meanness values are associated with smaller N1 amplitude in the pleasant emotional condition, whereas higher disinhibition values are associated with greater N1 amplitude in the pleasant emotional condition. Still in this task, higher disinhibition values were associated with a smaller LPP amplitude in the unpleasant emotional condition.

In sum, the increase in the distribution of attention resources towards time and/or the increase in activation states, including those originated by responses to emotional stimuli, may be the main factor that alters the way impulsive individuals and, presumably, individuals with high psychopathy, consider time when making decisions. According to the cognitive models of time perception, the over-estimation of a certain time duration may be a consequence of a greater focus on time and increasing activation. On many occasions, impulsive individuals, especially when they are distracted, do not over-estimated time, which is an argument against a fundamental dysfunction of the "internal clock". Conversely, these individuals are more likely to experience a slowing of time during situations in which they are unable to express their impulsive urges, for example, when an individual must wait for a delayed reward and is faced with the passage of time. However, more research is needed to determine the causal relationships between decision-making, emotional response, and time perception. Studies with different populations of individuals provide evidence that the notion of time is an important factor in understanding altered decision-making.

5. Author note

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Declarations

Author contribution statement

Diana Moreira: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Andreia Azeredo: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Susana Barros: Contributed reagents, materials, analysis tools or data.

Fernando Barbosa: Analyzed and interpreted the data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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