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Unraveling Fear: Autonomic and Conscious Responses of Psychopathy Subtypes in Virtual Reality Task

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UNRAVELING FEAR: AUTONOMIC AND CONSCIOUS RESPONSES OF PSYCHOPATHY SUBTYPES IN VIRTUAL REALITY TASK

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Abstract

Psychopathy is a multidimensional construct that defines a personality structure characterized by affective, interpersonal and behavioral deficits. The construct of psychopathy has been classically operationalized into two specific trait sets: Primary Psychopathy and Secondary Psychopathy. A key characteristic to psychopathy, as well as a potential etiological process for its development, is Low-Fear. Low-Fear is consistently associated with Primary Psychopathy traits, but the relationship between low-fear and Secondary Psychopathy remains inconsistent in the literature. The present study aimed to analyze the physiological and behavioral fear responses differ between the psychopathy subtypes in a virtual reality (VR) environment. To this intent, a sample of 73 volunteers was assessed using the Levenson Self-Report Scale (LSRP), the Fearlessness Fear Survey Schedule-III (FFS-III), and the State-trait Inventory for Cognitive and Somatic Anxiety (STICSA). Physiological measures, such as HR and SCL, along with behavioral measures, including total covered distance and mean velocity, were collected during the VR task, consisting of four fear conditions. The results showed no significant relation between psychopathy scores and physiological or behavioral measures. However, the findings show the effectiveness of VR as an emotional induction tool and highlight the need for further research on the complex relationship between psychopathy and fear.

Keywords: Psychopathy, Primary Psychopathy, Secondary Psychopathy, Low-Fear, Virtual Reality (VR), LSRPS, HR, SCL, Movement.

Resumo

A psicopatia é um construto multidimensional que define uma estrutura de personalidade caracterizada por défices afetivos, interpessoais e comportamentais. O construto de psicopatia foi classicamente operacionalizado em dois conjuntos de traços específicos: a Psicopatia Primária e a Psicopatia Secundária. Uma característica que tem sido apontada como crucial da psicopatia assim como um possível processo etiológico no seu desenvolvimento é o baixo-medo (*Low-Fear*). O *baixo-medo* está consistentemente associado aos traços de Psicopatia Primária, mas a sua relação com a Psicopatia Secundária apresenta inconsistente na literatura. O presente estudo presente teve como objetivo analisar se as respostas fisiológicas e comportamentais de medo diferem entre os subtipos de psicopatia num ambiente de realidade virtual (RV). Para este fim, uma amostra de 73 voluntários foi avaliada com o Levenson Self-Report Psychopathy Scale (LSRP), o Fearlessness Fear Survey Schedule-III (FFS-III) e o State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA). Medidas fisiológicas, como batimento cardíaco (HR) e o nível de condutância da pele (SCL), e medidas comportamentais, como distância percorrida e velocidade média, foram recolhidas ao longo da tarefa, que consistiu em quatro condições de medo. Os resultados não revelaram relações significativas entre as pontuações de psicopatia e as medidas fisiológicas ou comportamentais. Contudo, os resultados demonstram a eficácia RV como um instrumento de indução emocional e apontam para a necessidade de desenvolvimento de mais literatura sobre a complexa relação entre psicopatia e medo.

Palavras-Chave: Psicopatia, Psicopatia Primária, Psicopatia Secundária, *Low-Fear*, Realidade Virtual (RV), LSRPS, HR, SCL, Movimento.

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Introduction

For decades researchers have worked to unravel the complex concept of psychopathy, now viewed as a personality structure mainly characterized by emotional coldness and antisocial tendencies (Thomson, 2022).

According to a recent meta-analysis by Gillespie et al. (2023, p. 10), psychopathy is meaningfully related to dangerousness and represents a "risk for future violence or institutional misconduct". Various studies show that a high percentage of incarcerated individuals present antisocial personality disorder (APD), specifically Psychopathy, with percentages ranging from 18% to 47%, across multiple countries (Flórez et al., 2019; Seid et al., 2022; Solomon, 2020; Teimuraz & Rusudan, 2023). Additionally, studies show that the most common personality disorders were related to an increased risk of committing crimes, namely violence and crimes against property (Flórez et al., 2019). Furthermore, higher scores in psychopathy have been correlated with an increased risk of committing violent crimes and of disorderly conduct (Flórez et al., 2019). Lastly, increased general and violent recidivism has been associated with higher scores in psychopathy in adult samples (Asscher et al., 2011; Leung et al., 2019) and in delinquent youth (Asscher et al., 2011).

Brasão and colleagues (2015) assessed the prevalence of personality disorders in a sample of over 290 Portuguese male prisoners that were interviewed with the Structured Clinical Interview for DSM-IV Axis II Personality Disorders. Results showed that a high percentage of inmates, about 80%, presented a diagnostic for personality disorder, and 43% of the participants were diagnosed with antisocial personality disorder, highly associated with psychopathy (Martínez-López et al., 2019) as the main diagnosis (Brasão et al., 2015).

Although individuals with psychopathic personality structure are a minority in the general population, with a prevalence of less than 2%, they are responsible for a significant number of violent crimes and disorderly conducts (Coid & Yang, 2010). Thus, the understanding of psychopathy and its etiology is a concern of public safety.

The earlier conception of psychopathy described by Cleckley (1941/1988) referred to a unidimensional syndrome characterized by deficits in emotional reactivity and interpersonal characteristics. In fact, Cleckley (1941/1988) identifies a constellation of traits associated with psychopathic personality, grouping them into three categories: "mask" features (i.e., superficial charm, absence of delusions, etc.), behavioral deviant features (i.e., antisocial behavior, unreliability, failure to follow a life plan, etc.), and shallow-deceptive features (i.e. insincerity, lack of remorse or shame, poverty in major affective reactions, etc.) (Patrick, 2018).

Cleckley's work on the definition and characterization of a psychopathic personality has served as base to several measures developed to assess psychopathy, namely the Psychopathy Checklist (PCL) that was developed by Hare (1980, 2003). Although originally intended to measure psychopathy as a unidimensional concept, Hare and Neumann (2005) identified four correlated factors underlying the PCL-Revised: interpersonal (i.e., manipulative, grandiose self-worth, etc.), affective (i.e., lack of empathy, callous and unemotional, etc.), lifestyle (i.e., impulsivity, irresponsible, etc.), and antisocial (i.e., behavioral problems, criminal versatility, etc.). Additionally, two superordinate factors were identified as Factor 1, characterized by the interpersonal and affective features of psychopathy that were associated with the concept of primary psychopathy, and Factor 2, characterized by lifestyle and antisocial features of psychopathy associated with a more aggressive and emotionally unregulated personality type (Hicks et al., 2004). Additionally, Levenson and colleagues (1995) developed the Levenson's Self-Report Psychopathy Scale (LSRPS), a scale for the assessment of psychopathy that was designed to produce two factors similar to Hare's PCL (1980), while encompassing a "proto-psychopathic interpersonal philosophy" (Levenson et al., 1995, p. 151). Thus, the LSRPS consists of two scales, one measuring Primary Psychopathy (closely related to PCL Factor 1) with items that assess selfish, uncaring, and manipulative attitudes towards others, while the other subscale measures Secondary Psychopathy (Factor 2), containing items that assess impulsivity and a self-defeating lifestyle (Levenson et al., 1995).

The conceptualization of distinctive types of psychopathy was suggested earlier by Karpman (1941, 1948), who distinguished between idiopathic (primary) psychopathy and symptomatic (secondary) psychopathy and considered primary psychopaths as "true psychopaths". Idiopathic or primary psychopathy was characterized by traits of selfishness, callousness, low anxiety, and lack of empathy, while secondary psychopathy was associated with more neurotic symptoms, preserving the ability of experiencing anxiety (Karpman, 1941,1948).

Nowadays, psychopathy is viewed as a multidimensional construct characterized by specific affective, interpersonal, and behavioral features that are present on a continuum, allowing for the study of psychopathy in the general community, rather than parsing individuals into a psychopath vs. non-psychopath taxonomy (Hare & Neumann, 2008; Jeandarme et al., 2017). The Psychopathy Checklist Revised (PCL-R), alongside its analogous psychopathy measures, is one of the most well established and used instruments to assess psychopathy, both in forensic and community settings (Hare & Neumann, 2008).

More recently, Patrick and colleagues (2014) formulated the triarchic model in order to reconcile differing historical conceptions of psychopathy and alternative approaches to assessing the construct. The triarchic model identifies three underlying dimensions to psychopathic personality that represent distinctive phenotypic identities: disinhibition, boldness, and meanness (Patrick et al., 2009). Disinhibition describes a phenotypic propensity towards impulsivity leading to lack of foresight, deficits in affect and urge regulation, and search for immediate gratification (Patrick et al., 2009). In turn, boldness is used to describe a phenotypic type that is characterized by an ability to stay calm and recover quickly from stressful events, high self-assurance and social efficacy, and tolerance to danger. Lastly, meanness is used to describe phenotypic characteristics including deficits in empathy, lack of close relationships, sensation seeking, and cruelty (Patrick et al., 2009). The lack of inhibitory control, presented as Disinhibition, alongside predatory and manipulative behavior, presented as Meanness, are well emphasized in historic conceptions of psychopathy, being referred to in various literature on criminal psychopathy and externalizing problems (Patrick & Drislane, 2014). Meanwhile, Boldness refers to primary referents of the “mask features” proposed by Cleckley, as well as low fear accounts of psychopathy and relatively weak behavioral inhibition (Cleckey, 1941/1988; Hare, 1965; Lykken, 1957; Fowles, 1980).

Although there is vast investigative work on psychopathy, the etiological processes to psychopathy are yet uncertain, especially considering the distinctions between Factor 1 or Primary Psychopathy and Factor 2 or Secondary Psychopathy (Gao & Raine, 2010). Some authors proposed unitary etiological processes to psychopathy (Lykken, 1957; Newman, 1998; Patrick & Bernat, 2009). However, psychopathic personality does not seem to present one unique origin. Instead, distinct etiological processes seem to underlie different psychopathic traits (Salekin, 2017).

Lykken (1995, cited in Hofmann et al., 2021) proposed that an inherent fearlessness would result in deficits in passive avoidance learning and reduced responsiveness towards aversive stimuli, such as parental punishment and/or emotional distress cues in others, which in turn would underlie the development of primary psychopathy traits, such as selfishness, callousness, manipulativeness, low anxiety (Hofmann et al., 2021; López et al., 2012; Lykken, 1957). However, the “low-fear hypothesis”, proposed by Lykken (1957), does not apply to both dimensions of psychopathy, as secondary psychopaths were assumed to show normal responsiveness to fear and aversive stimuli, while demonstrating high levels of impulsiveness and sensation seeking (Aniskiewicz, 1979; Hofmann et al., 2021).

According to Patrick et al. (2009), following the triarchic model of psychopathy, the three phenotypic structures of traits emerge from two possible pathways that reflect deviations in distinct underlying neurobiological systems: low-fear disposition and externalizing vulnerability (Patrick & Drislane, 2014). Low-fear disposition is theorized to reflect the "under-reactivity of the brain's defensive motivational system", while externalizing vulnerability is presumed to "reflect impairments in frontocortical systems that mediate anticipation, planfulness, and affective/behavioral control" (Patrick & Bernat, 2009, p. 1110). In fact, the Dual Pathway Model of Psychopathy (Patrick & Bernat, 2009) suggests that individuals with affective-interpersonal features, highly related to primary psychopathy, demonstrate hypoarousal to threatening, aversive or punitive conditions, due to the absence of a normal defensive activation when exposed to aversive cues. Contrarily, individuals with lifestyle and antisocial traits, associated with secondary psychopathy, respond with hyperarousal to those same conditions, but rather show impairment in "higher representational systems that interact with primary motivational systems", similar to deficits in high-level processing (Patrick & Bernat, 2009 p. 1114). Some psychophysiological research has supported the Dual Pathway Model of Psychopathy, demonstrating that individuals with high scores in primary psychopathy present hypoarousal, while participants scoring highly on secondary psychopathy demonstrate normal or even hyperarousal in response to intense and sudden stimuli (Fanti et al., 2017; Kyranides et al., 2017; Patrick et al., 1994).

Researchers have relied on the use of physiological data for assessing the reactivity of the autonomic nervous system (ANS) to a threatening or fear inducing stimulus, as an experimental method to measure "fearfulness". The physiological changes accompanying the exposure to affective stimuli are mediated by the relation of two different branches of the ANS: the Sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) (Centifanti et al., 2022). Increases in the SNS are associated with increased heart rate (HR) and increased skin conductance response (SCR) or level (SCL), whereas increases in the PNS are related to lower HR, with no direct effects on skin conductance. Thus, when exposed to threatening or fear-inducing stimuli, there is a surge in sympathetic activation, leading to higher HR and SCL (Bernston et al., 1991 Shaffer & Ginsberg, 2017).

In fact, deficits in autonomic fear responses and emotional recognition are well documented in literature, both in adults (Blair, 2003; Blair et al., 1997; Deming et al., 2023; Díaz-Vázquez et al., 2024; Hare, 1965; Hare et al., 1978; House & Milligan, 1976; Fanti et al., 2017; Marsh & Blair, 2008; Patrick et al., 1994) and in youths with psychopathic tendencies (Blair, 1999; Blair et al., 2004). Earlier studies (Blair et al., 1997; Hare, 1965; Hare et al., 1978;

Lykken, 1957) showed that individuals with higher psychopathy scores presented significantly less SCR to aversive conditioned stimuli or distress cues, when compared to individuals with lower scores or considered non-psychopathic. In addition to electrodermal activity (EDA), heart rate responses to aversive stimuli are also a prominent marker of fear. However, studies have shown no significant effects on heart rate responses (e.g., Hare et al., 1978; Lorber; 2004), presenting contradicting results.

Considering recent perspectives on the concept of psychopathy, literature shows more complex results. A meta-analysis by Lorber (2004) showed that low rest EDA and low task-related EDA were associated with psychopathy, and that EDA reactivity was inversely correlated to psychopathy scores. However, low resting HR and HR reactivity were only associated with aggression and conduct problems, behaviors typically associated with antisocial and lifestyle traits, and subsequently secondary psychopathy (Fusina & Angrilli, 2021; Hicks et al., 2004; Patrick et al., 2009).

Additionally, primary psychopathy, subsequently affective and interpersonal traits, has consistently been associated with low skin response to aversive and fearful stimuli (Benning et al., 2005; Dindo & Fowles, 2011; Fanti et al., 2017), while results relating to secondary psychopathy show contradicting results, such as no significant effect or enhanced response to aversive stimuli (Dindo & Fowles, 2011; Fanti et al., 2017; Kyranides et al., 2017; Thomson, 2022) and lower response to stimuli of various valence (i.e. neutral, aversive, etc.) (Benning et al., 2005; Thomson, 2022). These results may indicate that interpersonal-affective traits are connected to low arousal and fearlessness, while lifestyle-antisocial features are associated with emotional dysregulation and possibly hyperarousal, as suggested by the Dual Pathway Model of Psychopathy (Patrick et al., 2009). Anyhow, the evidence on the relation between deficits on fear responses in psychopathy and physiological measures is still uncertain and this relation must be further investigated.

On a neurobiological level, literature shows that individuals with psychopathic traits show deficits in emotional processing. Emotional and reward processing involves a complex series of interconnected brain regions, with major involvement from the limbic system and the frontal cortex (Blair, 2019). The amygdala and striatum are heavily involved in reinforcement-based learning, while anterior insula and dorsomedial prefrontal cortices are important in the selection of avoidance and inhibition responses, which were found to be affected in individuals with high psychopathy (Blair, 2019). Lower activation of the limbic system and prefrontal cortices during emotional stimuli, such as pain expressions of others, may be associated with reduced learning to avoid actions that harm others, presuming that other individuals' distress cues are aversive to control individuals. Certain areas of the limbic system show a stronger association with specific emotional cues. For example, the amygdala shows higher responsiveness to fearful, happy, and sad emotional expression, with alterations observed in psychopathic individuals indicating a deficit in the recognition of said emotions (Blair, 2019). Existing literature reliably indicates a reduced activation of the limbic system in individuals with psychopathic tendencies and callous-unemotional traits (Blair, 2019). Additionally, the impaired recognition of fearful facial expressions is generalized to vocal tones and body postures (Blair, 2019; Stevens et al., 2001; Verona et al., 2004).

As theorized, the deficits in affective experiences in psychopathy may interfere with socialization and aversive conditioning, including when involves the recognition of fearful and sad facial expressions in others, preventing individuals from pursuing harmful actions (Blair et al., 2001, 2005; Rothemund et al., 2012). Results suggest that the emotional impairments associated with psychopathy surpass the unresponsiveness to facial expressions of emotion and may generalize to fear responses to other stimuli in auditory and visual modalities (Blair et al., 2001, 2005; Marsh & Blair, 2008; Vasconcellosa et al., 2014). Also, a meta-analysis by Dawel and colleagues (2012) suggests that deficits in emotional recognition affected emotions of various valence, as adults with high scores in psychopathy mainly showed deficits in the recognition of happiness and surprise, revealing once again that the relation between impairment in fear response or recognition and psychopathy is still unclear.

Deficits in emotional processing are associated with specific patterns of aggression and avoidance behavior (or lack of) in individuals with high psychopathic traits (Blair, 2019), these individuals to respond to emotional expressions, namely of fear, differently than control subjects. In a study conducted by Hammer and Marsh (2015), participants with lower scores of psychopathy showed primarily approach responses to fearful emotional expressions in both adults and infants. However, the results showed that psychopathy was associated with decreased approach to fearful expressions of fear in adults and infants (Hammer & Marsh, 2015). Studies using the Approach-Avoidance Task, in which participants must respond to facial expressions of emotion with pushing (avoidance) or pulling (approach) a joystick, showed that psychopathic inmates were slower than controls in avoiding angry faces, and even showed tendencies to approach these expressions (Dapprich et al., 2021; Krupic, 2021; von Borries et al., 2012). These results suggest a deficit in social learning and performance, originating from basic mechanisms of automatic responses and action tendencies, and indicating that low threat avoidance tendencies may underlie aggressive behavior (von Borries et al., 2012)

In the last few years, the use of virtual reality (VR) tasks to induce fear responses has been on the rise (Centifanti et al., 2021; Thomson et al., 2018, 2022). Thomson and colleagues (2018, 2022) developed an interactive VR horror video to assess differential autonomous fear responses between different typologies and traits of psychopathy. Results showed significantly less ANS response (both low SNS and PNS reactivity) in participants with high interpersonal traits of psychopathy, as well as lower SNS activation in affective and antisocial facets, the former associated with higher scores in primary psychopathy (Thomson et al., 2018, 2022). On the other hand, Centifanti and colleagues (2021) used a VR roller coaster drop to assess the skin conductance response to a discrete threat in youths with psychopathic tendencies. Results showed that lower anxiety was related to higher callousness and unemotional traits in the youths with psychopathic tendencies, but only in participants with low skin conductance responses to the threat stimuli (Centifanti et al., 2021). In both studies, the use of VR tasks allowed for a realistic and natural presentation of fear inducing stimuli, possibly eliciting natural physiological and emotional responses from the participants.

Additional research (Diemer et al., 2015) shows that fear emotions can be induced through perceptual and conceptual routes, allowing stimuli to be present in the VR setting or to be activated by the mere information about existence of the feared stimulus. Furthermore, the literature shows that emotions evoked through natural and VR settings show no significant differences (Chirico & Gaggioli, 2019), which positions VR as a valuable tool to evoke emotional and physiological responses equivalent to those experienced in a naturalistic, real life context, making it a valuable tool to conduct reliable investigation.

In summary, the relationship between psychopathy and deficits in fear responses has been well developed in the literature, but the evidence regarding distinctive psychophysiological fear responses between individuals with higher Primary Psychopathy or higher Secondary Psychopathy traits is inconsistent across literature (Lorber, 2004; Marsh & Blair, 2008; Thomson, 2022), especially when using HR to measure the responses to fear inducing stimulus (Lorber, 2004); thus, more research is necessary. Moreover, VR turns participants into active elements of the setting, as if they are in the real world, and its use is recommended to establish ecologically relevant results, possibly shedding further light on the previous findings (Centifanti et al., 2021; Chicchi Giglioli et al., 2017; Chirico & Gaggioli, 2019).

Current Study

Considering the literature briefly presented above, this study intends to provide a better understanding of putative psychopathy-related deficits in fear responses, not only through physiological measures, such as heart rate and skin conductance level, but also through conscious measures of fear, such as self-reports of intensity of the emotions felt and exploration of fear inducing stimuli in a VR scenario. More specifically, this study aims to identify the distinctive fear responses between individuals with high scores in Primary Psychopathy and individuals with high scores in Secondary Psychopathy according to the LSRPS scale (Levenson et al., 1995; Portuguese version by Barbosa et al., 2014).

Higher scores in primary psychopathy were expected to be associated with lower skin conductance level (H1) and heart rate (H2) across all fear-inducing conditions in the VR task. Additionally, it was hypothesized that higher scores in primary psychopathy are associated with lower self-reported emotional intensity experienced across all fear-inducing conditions in the VR task (H3). Lastly, higher scores in primary psychopathy, but not secondary psychopathy, were expected to positively and significantly predict total covered distance (m) (H4) and average velocity (m/min) in the virtual reality environment (H5).

Methods

Sample

A power analysis was conducted, following a general linear model based on the meta-analysis of the Fear model (Hoppenbrouwers et al., 2016), to identify an adequate sample size. The analysis revealed that a sample size of 76 participants would be adequate to detect medium effect sizes (Cohen's $f^2 = .15$), with the power of .85 and an α of .05. However, the target sample size was set at 81 participants, to account for possible exclusions.

Participants were recruited from the community between July 2023 and January 2024. All participants were healthy Portuguese nationals, over the age of 18, with normal hearing acuity, as well as normal or corrected-to-normal visual acuity. Participants with reported history of mental or neurological disorders, drug abuse or motor deficits were not considered. Furthermore, patterns of video game playing were taken into account, and individuals reporting a regular use of VR or overly stimulating games (first-person shooter, open world, horror and adventure) were not selected, as this could lead to a lower reactivity in the VR task.

Overall, 81 participants were recruited, of which two participants that did not meet the inclusion criteria (no history of mental or neurological disorders and no experience with virtual reality) were excluded from the study. Additionally, another six participants were incapable of finishing the task, therefore no physiological data was recorded, leading to the exclusion from this study. Thus, the final sample is composed of 73 participants (53% female), with a mean age of 23 years (*SD* = 3.95). In terms of formal education, the mean number of years of study was 15.5 (*SD* = 2.10).

Participants received a 10 Euro voucher as compensation for their time and travelling expenses.

Materials and Instruments

The current study is part of a larger research project, funded by the FCT (EXPL/PSI-GER/1498/2021) hosted at the Laboratory of Neuropsychophysiology, Faculty of Psychology and Educational Sciences. The larger research project is focused on decomposing fear into conscious and automatic responses and examine their relationship with the characteristics that are commonly associated with Primary Psychopathy, as they were expected to reflect low-fear, as well as their possible relation with more premeditated forms of aggression. Specifically, besides measures of psychopathy (Levenson Self-Report Psychopathy Scale; Levenson et al., 1995) and fear (Fear Survey Schedule III), all participants completed an evaluation protocol, prepared in Qualtrics (2022/3), that also provided measures of aggression (Impulsive Premeditated Aggression Scale; Stanford et al., 2003), empathy (Questionnaire of Cognitive and Affective Empathy; Reniers et al., 2010), , anxiety (State-Trait Inventory of Cognitive and Somatic Anxiety; Ree et al., 2008), and immersion in the virtual reality setting (IGroup Presence Questionnaire; Schubert, 2003). In the current study, data from the following instruments were considered:

Self-Report Measures

Sociodemographic Questionnaire. Participants were questioned on their gender, age, nationality, marital status, native language, proficiency in Portuguese, level of education, work status, laterality, visual impairments, hearing impairments, neurological or psychological disorders, medication prescribed, sleep patterns, video game play patterns, as well as drug and alcohol consumption.

Levenson Self-Report Psychopathy Scale (LSRP). The LRSP Scale (Levenson et al., 1995; Portuguese version by Barbosa et al., 2014) is a 26-item scale used to assess psychopathic features with a particular focus on community samples. The scale is composed of two subscales, the Primary Psychopathy (Cronbach's $\alpha = .70$) subscale consisting of 16 items measuring traits such as callousness, lack of remorse, manipulativeness and tendency to lie. The Secondary Psychopathy subscale consisting of the remaining 10 items (Cronbach's $\alpha = .64$) measures impulsiveness, lack of long-term goals, intolerance to frustration and hot-temperedness. All 26 items are scored in a 4-point Likert scale, varying from strongly disagree to strongly agree (Levenson et al., 1995).

State-Trait Inventory of Cognitive and Somatic Anxiety (STICSA). The STICSA is an inventory developed by Ree and colleagues (2008) to provide measures of anxiety. It comprises two scales of 21 items each: a scale that measures state-anxiety regarding how the subject is in the moment, and a scale that measures trait-anxiety concerning how the subject usually feels. Each scale comprises two subscales that analyze cognitive and somatic symptoms of anxiety (10 and 11 items respectively). All items are measured in a frequency scale that varies from "nothing" (1) to "very" (4) (Grös et al., 2007; Mendes, 2018). The inventory demonstrates good internal consistency in the Portuguese population with Cronbach's alphas ranging from .90 to .77 (Mendes, 2018), achieving values that are congruent with previous studies (Grös et al., 2007; Ree et al., 2008).

The Fear Survey Schedule-III (FSS-III). The FSS-III was developed by Wolpe and Lang (1964) to measure phobic anxiety. The survey is composed of five dimensions - social and agoraphobic fears, bodily injury and death fears, fear of sexual and aggressive scenes and harmless animal fears - that add up to 52 items. All items are measured on the degree of anxiety caused on the participant, varying from 0 (not at all disturbed) to 4 (very much disturbed) (Arrindell et al., 2003). The application of the FSS-III to a Portuguese sample showed adequate internal consistency (Cronbach's alpha ranging from .72 to .86), with values consistent with other studies (Arrindell et al., 2003; Dias et al., 2015).

IGroup Presence Questionnaire (IPQ). Participant's post-exposure feelings of presence in the VR environment was recorded through the Portuguese version of the IPQ (Vasconcelos-Raposo et al., 2016) to assess how immersive the experience was. The questionnaire is composed of three subscales: Spatial Presence, Involvement, Experienced Realism. The internal consistency of the IQP showed adequate values when applied to a Portuguese sample, with Cronbach's alpha varying from .53 to .83 (Vasconcelos-Raposo et al., 2016), on par with other versions of IQP (Schubert, 2003).

Short Questionnaire about Perceived Fear. At the end of the VR task, participants were asked to report the emotions they felt from a forced-choice options questionnaire (neutral, fear, happiness, sadness, surprise, disgust, angry), as well as their valence using a 7-point Likert scale ranging from -3 (very negative) to 3 (very positive) and intensity using a 7-point Likert scale ranging from 0 (no intensity at all) to 6 (very intense).

Experimental Set-Up

The virtual reality scenario was displayed on a HTC VIVE Pro VR (HTC corp., 2018) system with 2880*1600 pixel Dual-OLED displays (615 PPI) and high-resolution headphones for 3D spatial audio, using the Unity software (Unity tech., 2023) for VR delivery.

Virtual Reality Task. The VR task consisted of exploring a dark city block, composed of a central hallway and two perpendicular smaller halls (Figure 1.). The alley is surrounded by tall, unsightly buildings. On some of walls there were TV screens broadcasting news, showcasing news anchors with frightened or neutral facial expressions, depending on the experimental conditions. The sounds transmitted through the headphones (e.g., construction site, windows breaking, dog barking, sirens, etc.) also produced neutral or fear-inducing stimuli present in every-day settings.

Figure 1.

Virtual Reality Environment.

The virtual reality task is composed of four conditions that vary in the fear inducing stimuli present. Each condition lasted 90 sec and was separated from the next condition by thunder, to reset the conditions. The first is a neutral environment in which neutral sounds of construction and windows closing could be heard at a distance. The second is meant to evoke fear through fear-inducing sounds (e.g., sirens, dogs barking, glass shattering, doors hitting).

The third condition presents the same sort of fear-inducing auditory stimuli (e.g., door hitting, explosion, gunshot, dumpster closing), but the anchors presenting the news were displaying neutral facial expressions and neutral tones of voice could be heard in the environment. Lastly, the fourth condition starts with an earthquake; soon after the anchors display fearful expressions (see Figure 2.) and fear vocalizations are also presented as stimuli. The stimuli presented in four conditions was previously validated in their ability to produce a fear response and in the intensity of fear response.

Figure 2.

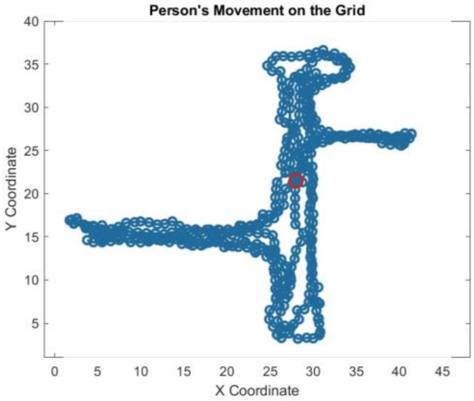
Example of news broadcast with fearful facial expressions.

Behavioral Measures

Throughout the experiment, the position of the participant within the VR environment was continuously recorded. More specifically, the coordinates of the participant's position (see Figure 3.) within the virtual space were documented every second (1 Hz) in order to allow the analysis of the total distance, area of the grid covered, median speed, and freeze time per participant in each condition of the task. These were considered measures of exploration or avoidance behavior in the VR environment.

Figure 3.

Example of coordinates recorded from VR exploration.



Physiological apparatus

The Bitalino (R)evolution BT core was used as the acquisition device for peripheral physiological measures, namely heart rate and electrodermal activity. A proper 2-lead electrode cable connected to the Bitalino amplifier was used for the acquisition of skin conductance, and a 3-lead electrode cable for heart rate. Five disposable pre-gelled Ag/AgCl electrodes model EL507A (BIOPAC, 2023) were used for each participant. The skin conductance was measured through two electrodes, one in the proximal phalanx of the indicator and one in the proximal phalanx of the middle finger of the non-dominant hand, as suggested by the user manual (PLUX, 2020b). The heart rate was measured with a positive electrode placed on the hip bone, a negative electrode will be placed on the right collarbone, and a ground electrode on the participants' hip bone (standard lead II), as suggested by user manual (PLUX, 2020a).

Collected data were transmitted via Bluetooth at a sampling rate of 1000 Hz to the data recording and visualization software OpenSignals (Alpha Build 2020-12-09), installed on a MS Windows laptop. Physiological data, along with time markers, were stored for offline analysis. The initial time marker was recorded at the beginning of a 30 sec baseline recording, right upon entering the VR environment. The subsequent time-marks were inserted at the beginning of each experimental condition.

Procedures

Data Collection

Participants were recruited through multiple methods, namely mailing lists, social networking platforms, posters on campus, and peer-to-peer communication.

The experiment took place at the Laboratory of Neuropsychophysiology of the Faculty of Psychology and Educational Science of U.Porto. Upon arrival at the laboratory, participants were presented with a cover story, informing that the main goal of the experiment was to study participants' behavior in a new VR environment developed by a videogame company. Participants were asked to pay close attention to the VR scenario details and to later share their opinion on the experience. After signing the informed consent and filling out the sociodemographic questionnaire, participants were informed of the physiological data collection procedures and the virtual reality mechanisms. Following the instructions, the necessary equipment and electrodes for physiological data collection were set up on each participant.

The Bitalino amplifier was fastened to the participants' clothes, as to not restrict the participants' movement. Electrodermal activity and heart rate cables were plugged into the Bitalino, and the corresponding electrodes were placed at the non-dominant hand for SCL recording (Fowles et al., 1981; Greco et al., 2016), chest and hip of the participant (Lead II) for HR recording (Francis, 2016; Issa et al., 2023), as previously described. The participants' hands were cleaned with dry cotton to remove excessive sweat.

When signal quality was verified, the participants were positioned in the center of the VR field of movement, and the headset was placed and adjusted to each participant, avoiding the blurring of the visual stimuli. Prior to the beginning of the task, physiological baseline data was collected for a minute. After entering the VR task, participants stood motionless for another 30 seconds and were instructed to familiarize themselves with the virtual environment. After 30 seconds, a bell would ring signaling to participants that they could begin exploring their virtual surroundings for the following 7 min 30 sec. As aforementioned, each condition lasted 90 sec, with 15 sec before the presentation of the first stimulus and 30s before the thunder signaling the transition to the next condition. After completing the experimental task, participants were asked to return to the VR setting, this time with no physiological data collection, in order to recall and answer the questionnaire about their emotional experience during the exposure to the environment. Lastly, participants were asked to fill out the scales concerning personality traits, other variables of interest, and immersion in the VR environment.

Data Analysis

The physiological data collected was analyzed in MATLAB R2022a through dedicated scripts. Firstly, the raw EDA data was converted into micro-Siemens (PLUX, 2020b). In order to measure participants' SNS activity in the fear-inducing conditions, the resting-state SCL (1 minute average skin conductance previous to the VR task) and resting-state HR (1 minute average skin conductance previous to the VR task) was subtracted from the SCL and HR in each of the four fear-inducing conditions. Therefore, EDA and HR were presented as the Δ SCL and Δ HR, which represents its change in relation to resting state for each condition.

Additionally, raw digital electrocardiogram (ECG) data was converted into microvolts (PLUX, 2020a). A 4th order Butterworth bandpass filter with a 0.67-40Hz passband was applied to remove artifacts, for example, derived from muscle activity or electromagnetic interference (Luo & Johnston, 2010; Thompson, 2014; Fedotov, 2016). An automatic peak detection script was then applied to compute HR, using 463ms as minimum peak distance and

20% as minimum peak prominence (Karlsson et al., 2012). Any errors in the peak-finding automation were later corrected through visual inspection.

Due to the nature of the VR task, movement artifacts were common in ECG data. Furthermore, technological difficulties in the data transmission to the visualization software clipping in the signal led to missing physiological data. Thus, a maximum of 5% missing values in physiological data were estimated by using the Expectation Maximization Imputation technique, assuming multivariate normal distribution.

All statistical analyses, including on physiological, behavioral and self-report data, were performed using SPSS statistical software (IBM SPSS Version 29.0). Firstly, behavioral data was computed, and descriptive statistics (means and standard deviations) were calculated for all measures of interest. Furthermore, parametric models were used as confirmatory statistics after the verification of the necessary assumptions. The participants' fear responses, automatic (heart rate and skin conductance level) and conscious (self-reported emotional experience), throughout the VR task were analyzed through Repeated Measures ANCOVA (RM-ANCOVA), with the four conditions as within-subject factors and primary psychopathy as covariate. Partial eta squared values were interpreted as small effect sizes when lower than .01, medium when between .06 and .014, and as large when larger than .14 (Cohen, 1988; Field, 2018). Normality assumption was evaluated with Shapiro-Wilk test and skewness and kurtosis values were also examined whenever the normality assumption was not confirmed. Taking Hair et al. (2010) criteria into account, as skewness values were all < 2, and kurtosis values were all < 7, parametric statistics were always conducted (Corder & Foreman, 2009). The Mauchly's Test was used to analyze sphericity and Greenhouse-Geisser correction was used whenever sphericity assumption was violated, and epsilon (ε) was lower than .75. Post-hoc multiple pairwise comparisons were performed with Sidak correction. Additionally, a multiple linear regression analysis was conducted to examine the psychopathy predictive model in environmental exploration, with primary and secondary psychopathy scores as predictors and mean velocity and total area covered as outcome variables in separate models. The α level for statistical significance was set at .05. Confidence intervals (CI) of 95% were estimated for the standardized beta (β) coefficients, along with p-values for each predictor.

Results

Descriptive Statistics

As presented in Table 1, mean scores, standard deviations, minimum and maximum values were calculated for all self-report measures, namely Primary and Secondary Psychopathy subscales of the LSRP scale, mean total scores of STICSA-Trait scale, mean total scores of FSS-III, and self-reported emotional intensity per fear inducing condition of the VR task.

Table 1.

Descriptive Statistics (mean, standard deviation, minimum and maximum scores) of self-report measures.

	M (SD)	Min - Max
LSRP		
Primary Psychopathy	27.29 (5.51)	17 - 46
Secondary Psychopathy	20.45 (4.29)	13 - 31
STICSA		
STICSA Total	41.66 (10.66)	23 - 68
FSSIII		
FSSIII Total	107.67 (25.33)	58 - 179
Emotional Intensity		
Condition 1	2.95 (1.20)	1 - 6
Condition 2	3.36 (1.18)	0 - 5
Condition 3	3.32 (1.28)	0 - 6
Condition 4	3.68 (1.46)	0 - 6

Notes: LSRP - Levenson Self-Report Psychopathy scale; STICSA - State-Trait Inventory of Cognitive and Somatic Anxiety; FSSIII - Fear Survey Schedule-III; Emotional Intensity)

Descriptive statistics of the Physiological and Behavioral variables are displayed in Table 2.

Table 2.

Descriptive statistics of Physiological and Behavioral variables.

	M (*SD*)	Min - Max
HR (bpm)		
Resting state	89.10 (14.10)	58.68 – 136.59
Condition 1 (Δ HR)	0.35 (7.79)	-14.46 – 31.78
Condition 2 (Δ HR)	-0.40 (8.55)	-14.60 – 42.61
Condition 3 (Δ HR)	0.15 (7.56)	-13.98 – 31.07
Condition 4 (Δ HR)	0.34 (8.36)	-14.33 – 42.94
SCL (μS)		
Resting state	10.95 (5.14)	3.35 – 22.60
Condition 1 (Δ SCL)	1.69 (1.27)	-0.16 – 6.41
Condition 2 (Δ SCL)	2.49 (2.29)	-0.61 – 12.45
Condition 3 (Δ SCL)	3.08 (3.04)	-3.59 – 14.92
Condition 4 (Δ SCL)	3.62 (3.36)	-4.51 – 16.35
VR Movement		
Total Distance (m)	314.72 (56.84)	137.33 - 398.03
Mean Velocity (m/min)	39.94 (7.21)	17.46 - 50.49

Notes: HR = Heart Rate; SCL = Skin Conductance Level, Δ SCL = change in SCL in relation to the resting state; VR = Virtual Reality; bpm = Beats per minute; μS = micro-Siemens; m/min = meters per minute.

Confirmatory Statistics

Initially, separate Repeated Measures ANOVA were performed to ascertain the effects of the experimental manipulation of the VR *fear-inducing conditions* (1, 2, 3, 4) on physiological responses and self-reported emotional intensity.

No main effect of *fear-inducing condition* was observed on Δ HR, $F(1.95, 140.25) = 0.090$, $p = .406$, but a significant effect was found for Δ SCL, $F(1.34, 96.70) = 24.28$, $p < .001$, $\eta^2 = .25$. A post-hoc analysis showed significantly lower levels of skin conductance in condition 1 when compared to condition 2 ($p = .002$), condition 3 ($p < .001$), and condition 4 ($p < .001$). Additionally, condition 2 showed significantly lower levels of skin conductance when compared to condition 3 ($p = .003$) and 4 ($p < .001$), and condition 3 also showed significantly lower levels of skin conductance when compared to condition 4 ($p < .001$).

Finally, a main effect of the *fear-inducing condition* was also observed on the self-reported emotional intensity, $F(3, 216) = 7.08$, $p < .001$, $\eta^2 = .09$. The post-hoc analysis showed significantly lower ratings of emotional intensity in condition 1 when compared to condition 2 ($p = .010$) and condition 4 ($p < .001$), but not when compared to condition 3 ($p = .119$). No other significant differences were found in emotional intensity ratings.

Physiological Responses to Fear Inducing Conditions Accounting for Primary Psychopathy

The hypothesis that higher primary psychopathy scores are associated with lower heart rate and skin conductance across all four conditions in the virtual reality task (H1 and H2). were tested via RM ANCOVA, where the effects of *fear-inducing condition* (1, 2, 3, 4) on the HR and Δ SCL (in separate models) were reexamined when accounting for the primary psychopathy scores as covariate. The same analysis was performed entering secondary psychopathy scores as covariate. Table 3 displays the results of the RM ANCOVA performed. The analyses showed no effects of either Primary or Secondary Psychopathy on HR and SCL variances across all conditions.

Table 3.

Main Effects of the RM ANCOVA conducted for physiological measures.

	F	p	η^2
Δ HR (bpm)			
Primary Psychopathy	2.06	.156	.03
Secondary Psychopathy	0.16	.687	.00
Δ SCL (μS)			
Primary Psychopathy	0.74	.391	.01
Secondary Psychopathy	0.05	.819	.00

Notes*:* HR = Heart Rate, SCL = Skin Conductance Level, bpm = beats per minute, mS = micro-Siemens.

Self-Reported Emotional Responses to Fear Inducing Conditions Accounting for Primary Psychopathy

The hypothesis that higher primary psychopathy scores are associated with lower ratings of emotional intensity (H3) was tested via RM ANCOVA, where the effects of *fear-inducing condition* (Condition 1, 2, 3, 4) on the emotional intensity were reexamined when accounting for the primary psychopathy scores as covariate. The same analysis was performed with secondary psychopathy scores as covariate.

The analyses showed no effects of either Primary or Secondary Psychopathy in ratings of emotional intensity across all conditions (see Table 4).

Table 4.

Main Effects of the RM ANCOVA conducted to test for the covariate effects of Primary and Secondary Psychopathy on self-reported ratings of emotional intensity with fear-inducing condition as within-subject factor.

	F	p	η^2
Primary Psychopathy	0.29	.588	.004
Secondary Psychopathy	0.15	.701	.002

Notes: Table with main and interaction effects of RM ANCOVA of self-reported emotional intensity through four fear inducing conditions, with psychopathy subtypes as covariate.

Psychopathy as predictor of exploration behavior in fear-inducing conditions

A Multiple Linear Regression was performed to test whether Primary Psychopathy scores positively and significantly predict total distance covered in the VR environment, while secondary psychopathy is not a significant predictor of this outcome variable (H4).

The analysis showed that the model does not significantly predict the variance in total distance covered, $F(2, 70) = 0.25$, $p = .779$; Adj. $R^2 = -.021$, nor do any of the psychopathy types (see Table 5).

Table 5.

Multiple Linear Regression coefficients with primary and secondary psychopathy as predictors and total distance covered in the VR scenario as outcome variable.

			95% Confidence Interval				
	t	p	Lower Bound	Upper Bound	B	SE	b
Primary Psychopathy	0.71	.482	-1.64	3.44	0.90	1.27	.087
Secondary Psychopathy	-0.16	.877	-3.52	3.01	-0.25	1.64	-.019

A final Multiple Linear Regression was performed to test whether Primary Psychopathy scores positively and significantly predict mean velocity in the VR environment, while secondary psychopathy is not a significant predictor of the outcome variable (H5).

The analysis showed that the model does not significantly predict the variance in mean velocity, $F(2, 70) = 0.25$, $p = .781$; Adj. $R^2 = -.021$, nor do any of the psychopathy types (see Table 6).

Table 6.

Multiple Linear Regression coefficients primary and secondary psychopathy as predictors and mean velocity in the VR scenario as outcome variable.

			95% Confidence Interval				
	t	*p*	Lower Bound	Upper Bound	*B*	SE	b
Primary Psychopathy	0.70	.484	-0.21	0.44	0.11	0.16	.087
Secondary Psychopathy	-0.15	.881	-0.45	0.38	-0.31	0.21	-.019

Exploratory Statistics

Additional exploratory analyses were performed to have a better understanding of the current results. A bivariate correlations matrix was computed (see supplementary data in Appendix 1.). Although significant correlations were found between behavioral and physiological measures, these results were inconsistent across fear inducing conditions.

Additionally, a Mixed ANCOVA was performed to explore whether variances in HR, SCL, and ratings of emotional intensity across the four fear-inducing conditions (within-subject factor) varied between genders (between-subject factor: male, female), when accounting for the primary psychopathy scores as a covariate. Table 7 shows all effects found in the Mixed ANCOVAS performed.

Table 7.

Main and Interaction Effects of Mixed ANCOVAS

	F	*p*	η^2
HR (bpm)			
Primary Psychopathy	3.49	.067	.05
Sex	4.67	.034	.05
Fear Condition	2.63	.076	.04
Fear Condition*Primary Psychopathy	2.65	.075	.04
Fear Condition*Sex	0.29	.745	.00
SCL (mS)			
Primary Psychopathy	2.86	.095	.04
Sex	12.52	<.001	.04
Fear Condition	0.46	.711	.01
Fear Condition*Primary Psychopathy	2.70	.090	.04
Fear Condition*Sex	6.60	.006	.086
Emotional Intensity			
Primary Psychopathy	0.01	.950	.00
Sex	7,78	.007	.10
Fear Condition	0.33	.801	.01
Fear Condition*Primary Psychopathy	0.40	.756	.01
Fear Condition*Sex	0.77	.512	.01

Notes: Main and interaction effects of Mixed ANCOVAS conducted on HR, SCL and Emotional Intensity across four fear inducing conditions, comparing between genders with primary psychopathy scores as covariate. HR = Heart Rate, SCL = Skin Conductance Level, bpm = beats per minute, mS = micro-Siemens.

The analysis showed a significant main effect of sex on the Δ HR across all conditions with female participants showing a significantly higher HR (*M* = 1.55, *SD* =9.15) compared to male participants (*M* = -1.54, *SD* = 6.32).

Regarding Δ SCL, a significant main effect of sex was also revealed, with female participants (*M* = 3.57, *SD* = 2.65) showing higher levels of skin conductance compared to male participants (*M* = 1.75, *SD* = 1.97).

Lastly, a significant main effect of sex on self-reported emotional intensity was found. Female participants (*M* = 3.62, *SD* = 1.27) reported higher scores of emotional intensity, compared to their male counterparts (*M* = 2.99, *SD* = 1.21).

Discussion

Contemporary conceptions of psychopathy depict the construct as a multidimensional personality structure, characterized by specific affective, interpersonal, and behavioral traits that may be represented on a continuum (Hare & Neumann, 2008). Furthermore, it is now widely accepted that there are distinctive types of psychopathy, based on the prevalent traits of the psychopathic personality structure. Interpersonal (e.g., manipulative, grandiose self-worth, selfishness) and affective (e.g., lack of empathy, callousness, unemotional) traits, which comprise the Factor 1 of a two factor model of Psychopathy, reflect the concept of primary psychopathy. In contrary, lifestyle (e.g., impulsivity, irresponsible) and antisocial (e.g., behavioral problems, impulsivity, criminal conduct) traits, which comprise the Factor 2, are commonly associated with secondary psychopathy (Hare & Neumann, 2005). More recently, the triarchic dimensional model surfaced as a reconcile of various conceptions of psychopathy, that allowed for alternative approaches to the assessment of the construct (Patrick & Drislane, 2014).

Although various unitary and multifactorial etiological processes have been theorized (Lykken, 1957; Newman, 1998; Patrick & Bernat, 2009), "fearlessness" or low-fear disposition has been vastly supported as a crucial factor in the development of traits associated with primary psychopathy (Hofmann et al., 2021). Psychophysiological measures, such as SCL and HR, have been used to demonstrate hypoactivation of the SNS in individuals with psychopathic traits, when exposed to aversive and threatening stimuli (Blair, 2003; Blair et al., 1997; Fanti et al., 2017; Hare, 1965; Hare et al., 1978; Marsh & Blair, 2008; Patrick et al., 1994). However, results are not fully conclusive (Hicks et al., 2004; Lober, 20024; Patrick et al., 2009), namely when a fine-grained look into the relationship between psychopathy subtypes and fear responses, conscious and automatic, is intended.

Considering the relevance of the construct of psychopathy as a concern for public health (Coid & Yang, 2010), the current study aimed to shed further light on the etiological processes of psychopathy, as well as on the relationship of psychopathy with fear. To reach this goal, a virtual reality (VR) environment was developed to ecologically elicit fear responses in the participants, expectedly leading to more reliable results (Marín-Morales et al., 2020). To unravel the relationship between psychopathic subtypes and fear, the virtual reality environment was composed of four different conditions, with increased fear inducing stimuli. Automatic fear responses were measured through HR and SCL alongside with conscious responses, through self-report measures. Exploration-Avoidance of the VR environment were measured through total distance covered and mean velocity in the VR scenario.

As expected, the results concluded that the SCL showed a progressive increase across the conditions, following the increase in fear inducing stimuli in the VR environment. On the other hand, HR showed no significant variance across the fear inducing conditions, recreating the inconsistent relationship between HR responses and threatening or aversive stimuli that has been reported throughout literature (e.g., Hare et al., 1978; Hicks et al., 2004). Additionally, self-reported emotional intensity also showed a gradual increase across the conditions, in line with the increased intensity of the fear-inducing stimuli in the VR environment. Even if reported emotional intensity did not always increased from one condition to the next, the last fear-inducing condition produced more intense and fearful reactions in the participants, as expected according to literature on the use of VR to elicit emotional responses (Chirico & Gaggioli, 2019).

Contrarily to the vast literature on psychopathy and low-fear disposition (Hare, 1965; Hare et al., 1978; Patrick et al., 1994; Blair et al., 1997; Blair, 2003; Marsh & Blair, 2008; Fanti et al., 2017), results show no association between primary psychopathy and physiological responses (measured by HR and SCL) in all four fear-inducing conditions of the VR task. Thus, the relation between psychopathy and fear response deficits remains uncertain (Benning et al., 2005; Dindo & Fowles, 2011; Fanti et al., 2017; Kyranides et al., 2017; Thomson, 2022)

However, present results may be limited by the characteristics of the community sample that was recruited for the study. The present sample shows lower scores both in primary (*M* = 27.29, *SD* = 5.51) and secondary psychopathy (*M* = 20.45, SD = 4.29), than former studies with Portuguese samples. Specifically, a study by Coelho and colleagues (2010) reported a mean score of 31.38 (*SD* = 7.07) for primary psychopathy and 20.48 (*SD* = 5.18) for secondary psychopathy. Authors have theorized that impairments related to etiological neurophysiological processes of psychopathy are only present in individuals with high psychopathic traits (Blair, 2019; Zimak et al., 2014), deeming the present community sample a poor representation of the fear deficits vastly reported in literature.

Additionally, results may be influenced by a lack of better measures of fearlessness traits associated with the construct of psychopathy. The use of the Levenson Self Report Scale (LSRP; Levenson et al., 1995) may have limited the present results, as items taping low-fear are lacking in the scale. Studies have shown that scores of the LSRP scale are strongly correlated with meanness and disinhibition phenotypic traits in psychopathy, but it does not represent boldness, the phenotypic dimension related to low-fear disposition (Patrick & Drislane, 2014). Thus, other scales could discern better between individuals with high psychopathic traits that fall in a low-fear disposition phenotype.

Considering emotional experience and self-reported measures, and in contrast to expectations, results show that primary and secondary psychopathy present no association with variance in self-reported ratings of emotional intensity throughout the fear-inducing conditions in the VR task. Gao and colleagues (2012) noticed psychopathic individuals' inconsistencies in self-reported body sensations and physiological activity (HR), while self-reports of non-psychopathic individuals were significantly correlated with their physiological responses. This somatic aphasia, as addressed by the authors, seems to represent a mind-body disconnection in individuals with higher affective-interpersonal features of psychopathy, suggesting that psychopathic individuals may incorrectly recognize and report their body sensations and associated emotional and experiences.

Lastly, results suggest that psychopathy is not predictive of exploration behavior in the VR environment, measured through total distance covered (m) and mean velocity (m/min). It was hypothesized that individuals with higher scores in primary psychopathy, as associated with fearlessness and hypoarousal to threatening stimuli (Blair, 2003; Blair et al., 1997; Fanti et al., 2017; Hare, 1965; Hare et al., 1978; Marsh & Blair, 2008; Patrick et al., 1994) would show higher exploratory behavior, while individuals with higher scores in secondary psychopathy, commonly associated with higher emotional dysregulation and normal anxiety (Dindo & Fowles, 2011; Fanti et al., 2017; Kyranides et al., 2017; Patrick et al., 2009; Thomson, 2022), would not predict higher exploratory behavior. Indeed, secondary psychopathy does not explain exploratory behavior, but neither does primary psychopathy.

A possible explanatory avenue to be further tested lies on the association between psychopathy and sensation seeking behavior (Hofmann et al., 2021; Portnoy et al., 2014), as well as impulsiveness (Hofmann et al., 2021; Patrick, 2018) and deficits in higher-level processes (Patrick & Drislane, 2014). These may lead to exploratory behavior of the environment despite the fear inducing stimuli, but additional measures would be necessary to adequately explore the links between such variables. Additionally, studies shows that overall psychopathy scores are associated with a total absence of avoidance tendencies towards angry faces (von Borries et al., 2012), showing a lack of recognition in social threat by these individuals. In return, the lack of recognition of threat and the lack of risk-perception (Hosker-Field et al., 2016) could lead to normal exploration in the face of threatening stimuli.

Additional exploratory analyses suggested possible interesting associations between behavioral measures of fear and physiological responses. The HR was positively correlated with self-reported emotional intensity while SCL was negatively correlated with total distance covered in the virtual environment.

The current study aimed to provide a more in-depth look into the relationships between psychopathy subtypes and the automatic and conscious fear responses in a more ecological environment. However, results and conclusions from this study must be interpreted bearing the abovementioned and other limitations in mind. The sample was mostly composed of undergraduate students, young adults with high formal education, preventing the generalization to the population. Additionally, participants were a part of a community sample with low psychopathy, making it possible that deficits typically associated with psychopathy subtypes, namely low responses to fear, are not present.

Technological complications concerning the acquisition of physiological data and the configuration of the VR system also occurred. The VR task was initially prepared to be administered in a CAVE, where participants could actually move and freely explore the environment while using a wireless headset. However, in the final set-up of the task, participants moved in the VR environment through a remote control and using the rotation of their own body only to choose the direction. This arrangement could have led to a less naturalistic way of exploring the environment, and thus to less reliable data.

During data collection, some participants reported feeling motion sickness and vertigo while exploring the VR scenario, a phenomenon that has been reported in literature (Chang et al., 2020). These reports of "cybersickness" (Chang et al., 2020) could have led to less accurate physiological and exploration data.

Lastly, participants frequently reported a sense of novelty when entering the VR task, which as a new and extraneous technology for many participants. This sense of wonder could lead to biased emotional experiences, with participants becoming too enthused with the new experience to properly consider the fear inducing stimuli. Nonetheless, some participants did mention the lack of intensity in some of the fear-inducing stimulus, such as a scream heard in the third condition and the earthquake experienced in the last condition.

As recommendations for future studies, it would be important to refine the use of VR as an instrument in psychophysiological research. Although positive results have been reported, the developed environments still lack in the realism of some stimuli, limiting their potential for producing ecologically accurate responses. Furthermore, future studies should consider different the use of distinct psychopathy measures, such as PCL-R (Hare & Neumann 2005), which allows for the assessment of fear responses in relation to the underlying four facets of psychopathic traits, or the TriPM (Patrick, 2010), a scale that follows the triarchic model of psychopathy and could be valuable in relating dimensions of psychopathy such as boldness with unconscious and conscious fear responses.

In summary, further research should be produced on the complex relationship between psychopathy and fearlessness using multilevel measures (self-reports, behavioral, physiological and neurophysiological responses), focusing on more fine-grained measures of psychopathic traits. The use of VR in future studies simultaneously represents a challenge and an opportunity to obtain reliable evidence in more naturalistic research paradigms.

Conclusion

The present study further tested the evidence that primary psychopathy traits are associated with fearlessness using self-reported, physiological, and behavioral responses of individuals exposed to fear-inducing environments in VR. Deficits in fear responses were proposed as an etiological source of aggressive and antisocial behavior often expressed by individuals with high psychopathy scores. The association between these variables makes it a relevant subject of research for the concern of public health.

Results indicated no association between either primary or secondary psychopathy and low fear responses, measured through HR and SCL, in a VR environment. Additionally, exploratory behavior in the VR environment was not predicted by primary nor secondary psychopathy. However, results support the use of VR was a valuable tool in inducing emotional responses, as SCL and self-reported ratings of emotional intensity presented a gradual increase throughout the fear-inducing conditions.

The complex relations between low-fear disposition, physiological deficits and psychopathy remain uncertain, and further research should be developed. The use of other psychopathy scales and the recruitment of samples with higher psychopathy scores are suggested to suitably evaluate fearlessness in relation to specific traits and features of psychopathy. The development and validation of VR settings is also recommended for future studies, as an efficient tool to conduct more naturalistic research.

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Supplementary Material

Appendix 1.

Bivariate Correlations Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.EI Condition 1																		
2.EI Condition 2	.59**																	
3.EI Condition 3	,41**	.29*																
4.EI Condition 4	.55**	.41**	.34**															
5.Primary Psychopathy	-.02	-.10	-.12	.03														
6.Secondary Psychopathy	-.10	.03	-.09	.01	.27*													
7.FSIII_Total	.14	.26*	.21	.29*	-.11	.29*												
8.STICSA Total	.09	.29*	.02	.24*	.02	.38**	.36**											
9.SCL Condition 1	.06	.12	-.10	.14	.00	.01	.28*	.10										
10.SCL Condition 2	.15	.08	-.03	.18	.09	-.06	.12	-.55	.59**									
11.SCL Condition 3	.14	.11	-.10	.17	.10	-.03	.21	.01	.51**	.91**								
12.SCL Condition 4	.12	.13	-.11	.16	.12	-.02	.20	.02	.49**	.86**	.98**							
13.HR Condition 1	.03	.27*	-.01	.10	.25*	.11	.24*	.21	.06	.00	-.02	-.01						
14.HR Condition 2	.06	.32**	.03	.11	.21	.08	.15	.19	.06	.03	.02	.02	.96**					
15.HR	.06	.36**	.04	.07	.17	.07	.20	.21	.11	.08	.06	.08	.94**	.97**				

Condition 3																	
16.HR Condition 4	.06	.32**	.02	.09	.18	.07	.20	.21	.15	.08	.06	.06	.93**	.98**	.98**		
17.Total Distance	.04	-.19	-.17	-.07	.08	.00	-.10	-.12	-.39**	-.31**	-.20	-.18	-.04	-.13	-.15	-.15	
18.Mean Velocity	.04	-.19	-.17	-.07	.08	.01	-.10	-.12	-.39**	-.31**	-.20	-.18	-.04	-.13	-.15	-.15	.99**

Notes: Bivarite Corrations Matrix, showing Pearson's r. EI = Emotional Intensity, SCL = Skin Conductance Level, HR = Heart Rate. **Correlation is significant p < .001, *Correation is signifant at p <

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