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Effect of psychopathy on emotion recognition in a virtual reality context: Behavioral and eye-tracking data

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EFFECT OF PSYCHOPATHY ON EMOTION RECOGNITION IN VIRTUAL REALITY CONTEXT: BEHAVIORAL AND EYE-TRACKING DATA

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Esta dissertação é apresentada em formato de artigo científico.

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Resumo

Introdução: A psicopatia pode ser definida como um construto multidimensional caracterizado por traços emocionais/afetivos, interpessoais e comportamentais. Alguns aspetos do comportamento social na psicopatia podem ser explicados por défices no reconhecimento de expressões faciais de emoção. Ainda assim, questões importantes permanecem sem resposta no que diz respeito à relação entre psicopatia e reconhecimento das emoções e a natureza dos défices. Uma razão subjacente a esta dificuldade poderá ser uma reduzida atenção para os olhos nestes sujeitos, seguida de uma diminuição da exploração de importantes pistas emocionais presentes na região dos olhos. A dimensão *boldness* do modelo triárquico de psicopatia parece estar associada a este défice.

Objetivos: Estudar o efeito da psicopatia no reconhecimento das expressões faciais e a relação entre os traços de psicopatia e a atenção aos olhos em faces emocionais. Ao utilizar a realidade virtual para a manipulação emocional, pretendeu-se estudar o reconhecimento das emoções em cenários mais realistas e testar se a reduzida atenção para os olhos observada nestes sujeitos é também verificada em cenários mais naturalistas.

Métodos: A amostra incluiu 62 voluntários da comunidade (38 mulheres). Os traços de psicopatia foram medidos com o TriPM e o SRP-SF. Um cenário de realidade virtual semelhante a um café foi utilizado para avaliar a capacidade dos participantes de reconhecer expressões faciais (alegria, neutro, medo e tristeza). Foram recolhidos dados comportamentais e de eye-tracking.

Resultados e Conclusões: Os resultados do nosso estudo não confirmaram a existência de uma relação entre traços de psicopatia e défices no reconhecimento de expressões emocionais, mas corroboram a importância da exploração visual da região dos olhos nas tarefas de reconhecimento emocional. Este estudo também demonstra os benefícios de utilizar cenários de realidade virtual em tarefas de reconhecimento emocional, confirmando a sua eficácia em ambientes experimentais.

Palavras-chave: Psicopatia; Reconhecimento emocional; Eye-tracking; Realidade Virtual

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Abstract

Background: Psychopathy can be defined as a multidimensional construct characterized by emotional/affective, interpersonal, and behavioral features. Certain aspects of social behavior in psychopathy can be explained by deficits in recognizing facial expressions of emotion. Still, important questions remain unanswered regarding the relationship between psychopathy and emotion recognition and the nature of the deficits. One possible reason underneath this deficits is a decreased attention toward the eyes in this subjects, followed by a decreased exploration of important emotional cues present in the eye region. *Boldness* seems to be associated with this deficit.

Objectives: To study the effect of psychopathy on the recognition of facial expressions, and the relationship between psychopathy traits and attention to the eyes of faces expressing emotions. By using virtual reality for emotion manipulation, we intended to study emotion recognition in more realistic scenarios, and test if the reduced attention toward the eyes observed in these subjects is also verified in more naturalistic settings.

Methods: The sample included 62 community-dwelling volunteers (38 women). Psychopathy traits were measured with the TriPM and SRP-SF. A virtual reality scenario resembling a typical coffee-shop was used to assess the participants' ability to recognize emotional facial expressions (happiness, neutral, fear, and sadness). Behavioral and eye-tracking data were collected.

Results and Conclusions: The results of our study do not confirm the existence of a relationship between psychopathy traits and deficits in the recognition of emotional expressions but corroborate the importance of visual exploration of the eye region in emotional recognition tasks. This study also demonstrates the benefits of employing virtual reality scenarios in emotion recognition tasks, confirming its effectiveness in experimental environments.

Keywords: Psychopathy; Emotion Recognition; Eye-tracking; Virtual Reality

Funding: This dissertation was conducted within the research project: RDoC approach to the study of psychopathy: Core features and implications for social decision making, funded by Foundation for Science and Technology (PTDC/PSI-GER/28076/2017).

Resumé

Contexte : La psychopathie peut être définie comme un concept multidimensionnel caractérisé par des caractéristiques émotionnelles/affectives, interpersonnelles et comportementales. Certains aspects du comportement social des psychopathes peuvent être expliqués par des déficits de reconnaissance des expressions faciales des émotions. Cependant, d'importantes questions restent sans réponse concernant la relation entre la psychopathie et la reconnaissance des émotions et la nature des déficits. Une raison possible de ces déficits est une diminution de l'attention portée aux yeux chez ces sujets, suivie d'une diminution de l'exploration des indices émotionnels importants présents dans la région des yeux. L'audace semble être associée à ce déficit.

Objectifs : Étudier l'effet de la psychopathie sur la reconnaissance des expressions faciales, et la relation entre les traits de psychopathie et l'attention aux yeux des visages exprimant des émotions. En utilisant la réalité virtuelle pour la manipulation des émotions, nous avions l'intention d'étudier la reconnaissance des émotions dans des scénarios plus réalistes, et de tester si l'attention réduite vers les yeux observée chez ces sujets se vérifie également dans des contextes plus naturalistes.

Méthodes : L'échantillon comprenait 62 volontaires vivant dans la communauté (38 femmes). Les traits de psychopathie ont été mesurés avec le TriPM et le SRP-SF. Un scénario de réalité virtuelle ressemblant à un café typique a été utilisé pour évaluer la capacité des participants à reconnaître les expressions faciales émotionnelles (bonheur, neutre, peur et tristesse). Des données comportementales et oculométriques ont été recueillies.

Résultats et conclusions : Les résultats de notre étude ne confirment pas l'existence d'une relation entre les traits de psychopathie et les déficits dans la reconnaissance des expressions émotionnelles mais corroborent l'importance de l'exploration visuelle de la région oculaire dans les tâches de reconnaissance émotionnelle. Cette étude démontre également les avantages de l'utilisation de scénarios de réalité virtuelle dans les tâches de reconnaissance des émotions, confirmant son efficacité dans les environnements expérimentaux.

Mots-clés: Psychopathie ; Reconnaissance des émotions ; Suivi des yeux ; Réalité virtuelle

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Introduction

Over the past few years, the concept of psychopathy has become increasingly complex as it has captured the attention of researchers who have sought to understand and clarify this construct. Nowadays, psychopathy is understood as a personality structure, characterized by traits of emotional coldness and antisocial tendencies (Boll & Gamer, 2016). At high levels, this set of personality traits include antisocial behavior, contempt for others, and a fake and manipulative interpersonal style (Hare, 2003), among other features. More precisely, psychopathy can be defined as a multidimensional construct characterized by emotional/affective (e.g., callousness, superficial affect, lack of empathy, lack of remorse or guilt), interpersonal (e.g., manipulation, superficial charm), and behavioral (e.g., recklessness, impulsivity, irresponsibility, disinhibition) features (Gillespie et al., 2019; Hare, 1996; Hare & Neumann, 2008; Patrick et al., 2009).

A growing body of literature (Coid et al., 2009; Gillespie et al., 2017; Gordts et al., 2017; Jeandarme et al., 2017; Lilienfeld, 1994; Lynam, 2002; Pasion et al., 2018) supports the dimensional nature of psychopathy. Several researchers argue that rather than existing as an all or none category, personality traits characterizing psychopathy may actually exist in a continuum on the general population, with less extreme variations of the condition observed across the wider population (Kyriazi et al., 2020; Prado et al., 2015). Dimensional approaches to psychopathy are becoming more informative than taxonomic models (Pasion et al., 2018), allowing researchers to investigate psychopathy in community samples, rather than depend on forensic or institutionalized samples where the prevalence of psychopathy is higher (Burley et al., 2017).

According to Kyriazi and colleagues (2020), contemporary conceptualizations of psychopathy vary, with some emphasising the antisocial tendencies (Hare, 2003), while others highlight the potentially adaptive interpersonal features, such as boldness or fearless dominance (Hall & Benning, 2006; Patrick et al., 2009), in an approximation to the classical descriptions of the psychopathy paradox: individuals showing maladaptive interpersonal behavior, but with no signs of dysfunctional reasoning nor reduced intelligence (Cleckley, 1976).

The Psychopathy Checklist – Revised (PCL-R; Hare 1991, 2003) is one of the most well-established instruments to measure psychopathy (Hare & Neumann, 2008). According to the PCL-R, psychopathy is structured in four facets: affective; interpersonal; lifestyle; and antisocial. These facets compose two factor dimensions of psychopathy, commonly known as Factor 1 (F1; affective and interpersonal facets) and Factor 2 (F2; lifestyle and antisocial behavior facets) (Hare, 2003). This conceptualization of psychopathy also underlies the Self-Report Psychopathy Scale (SRP; Hare, 1980) and its following revisions (Seara-Cardoso et al., 2019).

From another point of view, the Triarchic Model of Psychopathy conceptualises the interpersonal and affective features of psychopathy into two dimensions - *boldness* and *meanness* – while the externalising features (i.e., Factor 2) are reflected in a third dimension - *disinhibition* – together with *meanness* (Patrick & Bernat, 2009). Specifically, the Triarchic Model, proposed by Patrick and colleagues (2009), conceptualizes psychopathy as encompassing three phenotypic dimensions: *disinhibition* (which refers to impulsivity, emotional reactivity, irresponsibility, and impaired regulation of behavior and affect); *meanness* (indexes the callous and uncaring features at the core of the psychopathy construct, reflecting an absence of guilt and lack of empathy, aggressive resource seeking without regard for others and cruelty); and *boldness* (refers to confidence, venturesomeness, fearlessness, and low stress reactivity, interpersonal dominance, emotional resiliency and encompasses quick recovery from stressful or threatening situations). The psychopathic traits defined by the Triarchic Model are theorized to emerge from two etiological neurobiological processes: dispositional fearlessness and externalizing vulnerability (associated with weak inhibitory control) (Paiva et al., 2020a, 2020b; Patrick & Drislane, 2015). Boldness is suggested to be the main phenotypical expression of dispositional fearlessness in psychopathy (Esteller et al., 2016; Fowles & Dindo, 2009; Paiva et al., 2020a), as it will be explained later. The constructs described before can be assessed using the Triarchic Psychopathy Measure (TriPM), a self-report instrument designed to assess psychopathy-related personality traits, based on the Triarchic Psychopathy Model, proposed by Patrick and colleagues, in 2009.

It is theorized that certain aspects of social behavior in psychopathy can be explained by deficits in recognizing facial expressions of emotion, as these serve a critical role in everyday social interactions (Gaizo & Falkenbach, 2008; Marsh & Blair, 2008). Interpersonal relationships and social development are based, in part, on the ability of humans to perceive and discriminate facial expressions of emotion, as important signals that evoke and reinforce specific behaviors from observers (Blair, 1995). Facial expressions convey information of both social and affective relevance (Marsh & Blair, 2008). These elicit rapid responses that serve important adaptive functions, such as interpersonal communication and survival responses (Decety et al., 2014; Levenson, 1999). Therefore, the correct recognition and processing of facial expressions of emotion are key factors for social adjustment.

According to literature, individuals who exhibit more pronounced psychopathy traits show deficits in the ability to experience and perceive affect, being unable to process others' emotional cues (i.e., facial expressions of emotion) and, essentially, understand others' emotions (Gaizo & Falkenbach, 2008; Marsh & Blair, 2008). This, in turn, might impair the normative development of empathy and social cognition, increasing the likelihood of developing antisocial behaviors (Blair, 2005; Decety et al., 2014). According to a meta-analysis conducted by Marsh and Blair (2008), signs related to the suffering of others (such as expressions of fear) represent key cues for inhibiting antisocial and/or inappropriate behavior. Thus, aggressive and other antisocial behaviors may result from a failure in integrating information conveyed by others' social cues (Blair, 2003; Montagne et al., 2005).

Literature on facial emotion processing is one of the largest regarding emotional processing in psychopathy (Kosson et al., 2019), but the research in this field has yielded mixed results. Findings from individual studies and meta-analyses provide inconsistent responses regarding the relationship between psychopathic traits and facial emotion recognition, in both community and forensic samples, regardless of the psychopathy measures used. Even though many studies suggest that individuals high in psychopathic traits display (general or specific) emotion recognition deficits (Blair & Coles, 2000; Blair et al., 2001, 2002, 2004, 2005; Brook et al., 2013; Cigna et al., 2017; Dadds et al., 2006; Dargis et al., 2018; Dawel et al., 2012; Dolan & Fullam, 2006; Fairchild et al., 2009; Hansen et al., 2008; Hastings et al., 2008; Igoumenou et al., 2017; Iria & Barbosa, 2009; Kosson et al., 2002; Mitchell et al., 2006; Montagne et al., 2005; Pera-Guardiola et al., 2016; Prado et al., 2015; Stevens et al., 2001; Vasconcellos et al., 2014; Wilson et al., 2011), there are several examples within the literature in which psychopathy was not associated with impairments in emotional recognition (Beussink et al., 2020; Book et al., 2007; Deming et al., 2022; Gaizo & Falkenbach, 2008; Gillespie et al., 2015, 2021; Glass & Newman, 2006; Kranefeld & Blickle, 2022; Mowle et al., 2017; Pajer et al., 2010; Pham & Philippot, 2010; Seara-Cardoso et al., 2011). In fact, superior performance of psychopathic individuals in emotion recognition tasks when compared to non-psychopathic individuals has also been empirically supported by a few studies (Cigna et al., 2017; Copestake et al., 2013; Gaizo & Falkenbach, 2008). Therefore, important questions remain unanswered regarding the relationship between psychopathy and facial emotion recognition.

In Psychopathy-related literature, the most often studied emotions are anger, fear, sadness, and happiness (Kimonis et al., 2020; Kosson et al., 2016). Whereas there are studies suggesting that psychopathy is associated with global impairments in facial emotion recognition (Dawel et al., 2012; Herpertz et al., 2001; Vasconcellos et al., 2014; Wilson et al., 2011), most suggest specific impairments in the recognition of facial expressions with negative valence, such as disgust (Hansen et al., 2008; Igoumenou et al., 2017; Kosson et al., 2002), sadness (Cigna et al., 2017; Eisenbarth et al., 2008; Hastings et al., 2008), and/or fear (Blair & Coles, 2000; Blair et al., 2001, 2002, 2004, 2005; Dadds et al., 2006; Dargis et al., 2018; Dolan & Fullam, 2006; Fairchild et al., 2009; Iria & Barbosa, 2009; Mitchell et al., 2006; Prado et al., 2015). Even if less often noticed, impairments in the recognition of faces with a positive emotional valence (e.g., happiness) have also been reported in relation to psychopathy (Dolan & Fullam, 2006; Hastings et al., 2008; Pham & Philippot, 2010).

The relationship between psychopathy and recognition of facial expressions of fear has been the most extensively explored in the literature (Dargis et al., 2018; Iria & Barbosa, 2009). The main reason for this is that low fear models of psychopathy have hypothesised that the inability to experience fear might be due to deficits in recognizing fear in others, which may make the individual more prone to manifest psychopathic-related behaviors through development (Patrick et al., 2009; Marsh & Blair, 2008). Still, the bewilderment of whether there is a general impairment in the recognition of facial expressions of emotion, a specific deficit in the recognition of emotions of negative valence, or even a specific deficit in fear recognition has not yet been resolved.

One common critique present in the literature rests on the argument that by measuring psychopathy as a global trait (e.g., total psychopathy scores), research might miss important interactions between specific psychopathy dimensions (e.g., dispositional fearlessness) and facial emotion recognition (Campos et al., 2022; Fowles & Dindo, 2009; Paiva et al., 2020a). Also, different samples might have distinct distributions of psychopathic traits (e.g., it is expected that forensic samples have a higher prevalence of antisocial behaviors than community samples) making it fundamental to analyse the associations between specific psychopathic dimensions and facial emotion recognition.

Regarding the dimensions of psychopathy, the interpersonal-affective traits have been related to deficits in the recognition of neutral expressions, (Hansen et al., 2008), as well as facial expressions of fear and disgust (Igoumenou et al., 2017), and associated with increased sadness recognition (Cigna et al., 2017). Meanwhile, the lifestyle-antisocial traits of psychopathy have been linked to impairments in the recognition of fear (Igoumenou et al., 2017), sadness (Cigna et al., 2017; Dolan & Fullam, 2006), and happiness (Hastings et al., 2008), and associated with increased disgust recognition (Hansen et al., 2008). Finally, Gillespie and colleagues (2021) found an association between the boldness dimension of TriPM and reduced recognition of sad faces. Boldness is suggested to be the main phenotypical expression of dispositional fearlessness in psychopathy, associated with reduced sensitivity of the brain to threat and punishment cues (Fowles & Dindo, 2009; Paiva et al., 2020a), which might explain a not yet uncovered impairment in fear recognition in subjects with high scores of boldness. According to Esteller and colleagues (2016), it is important to note an increasing evidence suggesting that boldness has been related to manipulative and arrogant tendencies (Poy et al., 2014; Strickland et al., 2013), callous affect, dishonesty, and guiltlessness (Drislane et al., 2014), as well as self-reported delinquency (Almeida et al., 2014), despite the apparently positive and "healthy adjusted functioning" descriptions of the boldness dimension. The personality traits embodied in the boldness dimension seem to be particularly significant in the expression of fear deficits — as evidenced, for example, by a blunted aversive-potentiated startle response (Esteller et al., 2016). One specific structure involved in these rapid and automatic neuronal responses is the amygdala, a structure located in the medial temporal lobe that is known to be involved in many aspects of emotional processing. The amygdala plays an essential role in the recognition of fear, as shown by neuroimaging findings (Adolphs, 2006; Vasconcellos et al., 2014). In line with the research in this field, it was found that higher levels of psychopathy are associated with a reduced autonomic nervous system response to emotional stimuli (Benning et al., 2005; Blair et al., 2014; Fanti, 2018; Gillespie et al., 2019; Kyranides et al., 2019).

Despite the abovementioned findings, results are inconsistent regarding the nature of the deficits in the recognition of facial expressions of emotion in psychopathy. Research has suggested that the affective dimension of psychopathy seems to be associated with difficulties in recognizing the suffering of others from emotional expressions (Brislin et al, 2018; Dargis et al., 2018; Gillespie et al., 2015; Igoumenou et al., 2017), and with the hypoactivity of the amygdala to facial expressions of fear (Jones et al., 2009; Viding et al., 2012; White et al., 2012). In turn, the interpersonal dimension of psychopathy appears to be associated with a reduced attention to the eyes upon facial exploration (Dargis et al., 2018; Gillespie et al., 2015, 2017, 2019). Thus, difficulties directing attention to the eye area while exploring facial expressions of emotion, along with a possible malfunctioning of the amygdala circuits, may underly the poor recognition of emotions in psychopathy (Boll & Gamer, 2016; Moul et al., 2012). Indeed, the processing of facial expressions depends on a network of structures that includes the occipitotemporal cortex (particularly the fusiform gyrus and superior temporal gyrus), anterior cingulate cortex, ventromedial prefrontal cortex, and amygdala (Adolphs, 2006; Hansen et al., 2008). According to the meta-analysis conducted by Marsh and Blair (2008), dysfunction in one or more structures of this network may be associated with antisocial behavior, and models of amygdala dysfunction are central to the understanding of the development of psychopathy (Patrick et al., 1994; Vasconcellos et al., 2014). Several studies have reported the existence of structural abnormalities in the amygdala in individuals with high psychopathy traits, as well as a reduction in amygdala activation during the presentation of fear faces, fear conditioning, and other tasks involving emotional processing (Boll & Gamer, 2016).

The amygdala is involved not only in the emotional response to faces, but also provides the necessary prerequisites for this perception by directing gaze and attention to the emotionally salient regions of the face (Adolphs, 2006). Thus, the amygdala appears to play a key role in registering and directing attention to emotionally salient stimuli, being highly responsive to ocular stimuli (Dadds et al., 2008). Consequently, dysfunctions in the amygdala may affect the exploration of facial expressions, impairing the recognition of emotional states. The literature has supported the idea that difficulties in recognizing expressions of emotion, both in individuals with high psychopathy and with amygdala disfunctions, may be reduced if they are instructed to direct their attention to the eye region during emotion recognition tasks (Adolphs et al., 2005; Dadds et al., 2006, 2008). For example, a study conducted by Dadds and colleagues (2008) showed that the deficit in fear recognition was alleviated in patients with amygdala lesions when they were explicitly instructed to look into the other people's eyes. Adolphs and colleagues (2005) also showed a patient with a bilateral amygdala lesion was inattentive to information present in the eye area relative to healthy participants, but when she was instructed to direct her attention to the eye region, her performance improved considerably (Adolphs et al., 2005). Similar problems were detected in children exhibiting disruptive behavior disorders and CU traits; again, this effect of temporarily correcting deficits in emotion recognition was observed (Adolphs et al., 2005; Dadds et al., 2006).

A possible explanation for these results is that emotions are communicated through different configurations of facial muscles in such a way that specific regions of the face, such as the eyes, are particularly relevant for decoding emotional states (Eisenbarth & Alpers, 2011). Facial elements present in the eye region (like the eyebrows) deliver essential information about the others emotional state (Itier & Batty, 2009; Gehrer et al., 2019). Indeed, the literature has documented the importance of paying attention to the eyes compared to other regions while scanning facial stimuli (Eisenbarth & Alpers, 2011; Wells et al., 2016). Besides the eyes, particularly the mouth and nose regions tend to also attract the attention of the viewer (Gehrer et al., 2019). While information from the eyes seems to be more useful for recognizing fearful, anger, and sad expressions, disgust and happy faces seem to be associated with increased attention to the mouth region (Dadds et al., 2008; Eisenbarth & Alpers, 2011; Scheller et al., 2012; Schurgin et al., 2014; Smith et al., 2005; Wells et al., 2016). For this reason, directing attention to critical facial features (such as the eyes and mouth) is associated with better performance in emotion recognition tasks than other facial regions (such as the chin or ears), which do not provide as much information relevant for emotion recognition (Adolphs, 2006; Wells et al., 2016). The lack of attention to these critical regions may generate difficulties in recognizing the expressed emotion (Gillespie et al., 2017; Martin-Key et al., 2018).

Several of the studies conducted in order to evaluate the relationship between psychopathy traits and ocular exploration in the recognition of facial expressions of emotion have concluded that high psychopathic traits predict reduced eye gaze and reduced attention orienting toward the eyes during emotion recognition tasks (Boll & Gamer, 2016; Dadds et al., 2008; Gehrer et al., 2019; Gillespie et al., 2015, 2017; Martin-Key et al., 2018). Contrary to the studies mentioned above, Kyranides and colleagues (2019) did not achieve the same results, with individuals with CU traits showing similar number fixations in the eye region compared to the control group.

Regarding the psychopathy dimensions, Dargis and colleagues (2018) concluded that the affective-interpersonal traits of psychopathy are significantly related to a reduction in the number of fixations in the eyes of faces expressing fear. This association was driven particularly by interpersonal psychopathic traits (e.g., egocentrism, falseness), whereas fear recognition accuracy was inversely related to affective psychopathic traits (e.g., callousness, lack of empathy). There is also evidence that boldness psychopathic traits are associated with reduced attention to the eyes, namely with reduced dwell time and fixation counts, and slower first fixation latencies in the eyes compared to the mouth (Gillespie et al., 2017). These effects suggest that boldness is associated with difficulties in directing attention to emotionally salient aspects of the face. At last, disinhibition was associated with greater attention toward the eyes of fearful faces, but not happy or sad faces (Gillespie et al., 2021).

Taking into consideration the aforementioned findings, deficits in the recognition of facial expressions of emotions in psychopathy, notably fear, appear to be secondary to less exploration of the eye region (Gillespie et al., 2015). However, the literature is still unclear as to whether the relationship between psychopathy traits and reduced fixations on the eyes is general (independent of the facial expression) or specific to emotional expressions of fear. Dadds and colleagues (2008) and, more recently, Dargis and colleagues (2018) investigated this relationship and found an association between reduced fixations to the eyes of particularly fearful faces, supporting the assumption of an emotion-specific impairment in attention orienting, but further investigation is needed to explore this phenomenon. In fact, not only is there a lack of consensus regarding the effect of high psychopathy traits on the recognition of facial expressions, but research is also unclear regarding the factors that may underlie this deficit or its specificity (general impairment or specific to emotional expressions of fear). The inconsistent findings observed across different studies might result from differences in the nature of the sample (e.g., criminal, non-criminal), differences in discriminating power and methodological factors, such as the psychopathy measures and the method selected for emotion elicitation - ability to elicit affective states reliably and ethically (Marín-Morales et al., 2020) - in laboratory environments (Kosson et al., in 2019).

One classical problem of research in classical controlled laboratory settings for social cognition is that experiments are conducted in an environment that is much apart from the natural environments where social interaction occurs, thus critically limiting the generalization of findings. For example, questions are raised as to whether the reduced attention to the eyes in photos of faces that was found in individuals with high psychopathic traits can be generalized to less artificial settings (Gehrer et al., 2019). As so, there is a clear need to investigate emotion recognition abilities in psychopathy in more naturalistic contexts.

Current research on recognition of facial expressions of emotion in individuals with high psychopathy traits shows that the stimuli used to portray emotions have little ecological validity and several authors recommend the use of more ecological and naturalistic paradigms (Adolphs, 2006; Cigna et al., 2017). The traditional emotion elicitation methods are non-immersive (two-dimensional stimuli). Thus, characteristics such as the feeling of presence and interaction with the environment are important aspects that are not considered in the mentioned methods (Monteiro et al., 2011). This means that they do not have the ability to incite high levels of presence - understood as the subjective feeling of "being-there" - in the subjects (Baños et al., 2004; Marín-Morales et al., 2020). A high sense of presence creates in the user the sensation of interacting and reacting as if s/he was in the real world (Marín-Morales et al., 2020). This justifies the pursuit for alternative methods that provide greater subject involvement in experimental tasks and bring laboratory stimulation closer to real-life contingencies.

Given the sense of presence that Virtual Reality (VR) provokes in its users, it has been proposed as a more effective way of eliciting emotions in experimental environments than traditional laboratory paradigms (Centifanti et al., 2022; Dores et al., 2014; Felnhofer et al., 2015; Geraets et al., 2021; Giglioli et al., 2017; Marín-Morales et al., 2020; McLachlan et al., 2021; Monteiro et al., 2011; Reichenberger et al., 2020; Riva et al., 2007). In VR, users become active participants in the virtual environment, sensing the scenarios as if they were in the real world (Giglioli et al., 2017). Thanks to its ability to allow researchers to simulate environments with high levels of accuracy, sense of presence, and interactivity, VR is becoming more popular in emotion research (Benbouriche et al., 2014; Dores et al., 2014). Briefly, VR involves the simulation of real-world experiences using computer graphics in which the users are immersed into and interact with the virtual environment (McLachlan et al., 2021). The stimuli developed in VR possess properties that bring them closer to reality (Reichenberger et al., 2020), without losing the capacity to manipulate, control, and experimentally replicate them (Dores et al., 2014). This method can lead to an increase in the intensity of the emotional response, bringing it closer to real-life contingencies, as supported by several studies (e.g., Benbouriche et al., 2014; Dores et al., 2014; Monteiro et al., 2011; Slater et al., 2009). As suggested by Riva and colleagues (2007), three-dimensional stimuli can induce emotions more effectively than two-dimensional stimuli in experimental settings. Indeed, there is neuroimaging (fMRI) evidence that 3D visual stimuli can induce increased emotional arousal, suggesting that the augmented realism positively regulates the amygdala response (Dores et al., 2014).

Essentially, technological advances in VR posit several advantages to its use in the experimental study of facial emotion recognition: (1) it is very simple to record eye movements within VR, thus allowing to analyse the association between attention to critical action units of the face and facial emotion recognition; (2) its applicability has been proven in studies involving the recognition of facial expressions of emotion; and (3) its naturalistic and immersive properties increase the ecological validity of the findings and thus its generalization to the natural environments.

Despite the need of more research to validate direct comparisons between VR scenarios and real environments (Marín-Morales et al., 2020), there are additional benefits of using VR scenarios, like the opportunity to develop complex environments that would be hard or impossible to recreate with the traditional research methods (Dores et al., 2012; McLachlan et al., 2021), offering researchers the opportunity to better investigate affective processes in controlled laboratory conditions.

Current study

Considering the abovementioned research, the present study intended to address the gaps in the literature concerning the (a) effect of psychopathy dimensions on the recognition of emotions in facial expressions, and (b) the relationship between psychopathy traits and attention to the eyes of faces expressing emotions. By using virtual reality for emotion manipulation, we intended to study emotion recognition in more realistic scenarios, and test if the reduced attention toward the eyes observed in these subjects is also verified in more naturalistic settings.

Based on theory and on the mixed evidence reported here, we hypothesized that (H1) less attention orienting toward the eyes is associated with deficits in the identification of emotional expressions. We expected that high psychopathy scores are associated with reduced attention orienting toward the eyes and deficits in emotion recognition - more precisely, we predicted that psychopathy is associated with less attention orienting toward the eyes (H2) and with poorer recognition of facial emotional expressions (H3). We also predicted that high boldness scores are related to less attention orienting toward the eyes (H4) and associated with increased deficits in fear recognition (H5).

Method

1. Participants

Sixty-two community-dwelling volunteers (38 women) without self-reported history of neurological or psychiatric conditions were recruited. We relied on a convenience sample recruited through advertisements, social media, and email. All participants reported to have normal or corrected-to-normal visual and auditory acuity. The participants had Portuguese as their native language and their age ranged from 18 to 54 years (*M*=26.58; *SD*=8.73). Participation was voluntary upon informed consent.

2. Materials

2.1. Self-report measures

Participants filled out the self-report questionnaires on the Qualtrics online platform (version 07.2022, Qualtrics, Provo, UT). Psychopathy traits were measured via self-report questionnaires, specifically two instruments based on two distinct models of psychopathy: (a) the Triarchic Psychopathy Measure (TriPM; Patrick, 2010; Portuguese version by Paiva et al., 2020b) based on the triarchic psychopathy model; and (b) the Self-Report Psychopathy Scale - Short-Form (SRP-SF; Neumann & Pardini, 2014; Paulhus et al., 2016; Portuguese version by Seara-Cardoso et al., 2019) based on the Psychopathy Checklist–Revised model (PCL-R; Hare, 2003).

Sociodemographic Questionnaire. Participants self-reported their age, sex, nationality, first language, education level, handedness, daily medication, alcohol and drugs consumption, quality of sleep (the night before) and whether they had a diagnosis of sensory, mental, or neurological problems. This information was essential for the sample characterization.

The Triarchic Psychopathy Measure. The TriPM is a 58-item self-report measure that has been widely used in this field to operationalize the three phenotypical constructs described in the Triarchic Model of Psychopathy: Boldness; Meanness; and Disinhibition (Patrick et al., 2009). Each item is scored on a 4-point Likert scale, ranging from 0 (*false*) to 3 (*true*), with reverse scoring for items reflecting a lower degree of psychopathic traits. The TriPM was designed to better capture the adaptive features of psychopathy which are likely to be more prevalent in community samples, as in this study (Kimonis et al., 2020; Patrick et al., 2009).

Each dimension of the TriPM shows high correlations with the main psychopathy assessment instruments, good temporal stability and construct validity, and high predictive power (Paiva et al., 2020b; Patrick, 2010). In the present study, the European Portuguese version of the TriPM was used (Paiva et al., 2020b). As stated by Paiva and colleagues (2020b), this version presents good internal consistency (Cronbach's alpha values for the total scale was .88 and ranged from .80 to .87 for the subscales). Regarding reliability, test-retest revealed high correlation coefficients between the two administrations (corelation (*r*) scores for the total scale was .875 and ranged from .762 to 852 for the subscales, with all $p < .001$).

Self-Report Psychopathy Scale - Short-Form. The SRP-SF is a 29-item scale designed to assess four facets of psychopathy – interpersonal, affective, lifestyle, and antisocial - in line with the PCL–R (Hare, 2003). The response to each item ranges from 1 (*disagree strongly*) to 5 (*agree strongly*), with higher scores corresponding to higher levels of psychopathy. Scores of each facet are obtained by summing up the corresponding individual item scores. The antisocial subscale includes eight items, but the items "committed a crime" and "gang activity" are omitted in offender and community samples, respectively, given their low variability in these samples. The remaining subscales are composed of seven items (Neumann et al., 2015; Seara-Cardoso et al., 2019).

The SRP–SF demonstrates good internal consistency and assesses the same constructs as the PCL–R and the other versions of SRP, representing an effective method to assess psychopathic traits in community samples (Gordts et al., 2017; Neumann & Pardini, 2014; Neumann et al., 2015; Seara-Cardoso et al., 2019). In the present study, the Portuguese version of the SRP-SF was used (Seara-Cardoso et al., 2019), which reproduces the factors proposed by the original version and presents good internal consistency (Cronbach's alpha values ranged from .71 to .84 for the subscales and was .87 for the total scale) (Seara-Cardoso et al., 2019).

2.2 Experimental setup

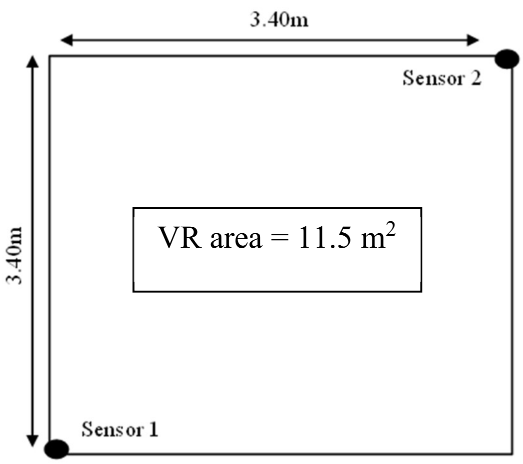
The immersive virtual scenario was displayed on a VR system, incorporated with an eye-tracking sensor. This VR system is composed by (1) the software for VR delivery (Unity) and (2) a headset consisted of a VR HTC Vive system with double AMOLED 3,6" diagonal lens, 1080*1200 pixels, 90 Hz refresh rate and a 110 degrees visual field.

The data collection and the VR scenario ran on a Dell computer, with Intel(R) Core(TM) i7-7700 Processor with 3.60 GHz, a graphic card NVIDIA GeForce RTX 3060 and Windows 11 Pro Home operating system, and the task was initiated with the *Viveport* application. The eye-tracking data was collected using the VIVE Pro-Eye System incorporated in the VR headset.

Data collection took place in a room with VR sensors placed 1.80 meters from the ground (according to Figure 1), creating a VR area of 11.5m2. A table was placed in the middle of the VR area in order to simulate a coffee table, which was presented in the VR scenario (see below).

Figure 1.

VR area dimensions.



2.3 Virtual reality task – "Coffee Without Words" design

The VR task consisted in a social interaction between the participant and an NPC/ avatar of the same sex. The scenario resembled a typical coffee-shop, with elements like chairs, tables, windows, costumers, a waitress, and a bar stand. In this coffee-shop, participants were sitting on a bench, with a table with some dishware and, on the other side, a chair for the other person (avatar/NPC). The coffee-shop was decorated with shelves (with books and other room decoration), lamps, and plants. During the task, the participants were free to visually explore the scenario in a 360º range. The sounds presented through the headphones were consistent with the presented environment (for example, people talking and traffic sounds on the street).

As illustrated in Figure 2, the task was composed of eight trials, randomly presented, and each lasting 90 seconds. In a between-trial design, two variables were manipulated: the NPC's eye contact direction (20% of the time directing gaze at the participant vs 80% of the time directing gaze at the participant) and the NPC's facial expression (happiness, neutral, fear, sadness).

Figure 2.

A. *Manipulation of the NPC's facial emotion and eye conact.* ***B.*** *Timeline of each trial.*

A.

	Emotion	NPC Eye Contact
Condition	Neutral Fear Sadness Happiness	Low direct eye contact (20%)
	Neutral Fear Sadness Happiness	High direct eye contact (80%)

B.

	Trial timeline		
Low direct eye contact condition (20%)	No Eye Contact Random [20-50]s	Eye Contact 20 s	No Eye Contact Remaining time
High direct eye contact condition (80%)	Eye Contact Random [20-50]s	No Eye Contact 20 s	Eye Contact Remaining time

In each trial, the avatar was expressing one of the four emotions mentioned above, and the intensity of the emotion was randomly switching between low and high during the 90 seconds. Besides fear, we included sadness and happiness states in the task since sadness has a negative valence, as well as fear, which allowed us to assess whether the effect is more specific for fear or if it is related only to the fact of being a negative valence emotion. Happiness, having positive valence, allowed us (along with sadness) to discriminate the valence effect. Finally, neutral facial expressions were the control condition. The facial expressions of emotion designed for this task were adapted from the ones proposed by Oliver and Alcover (2020) and are represented in Figure 3.

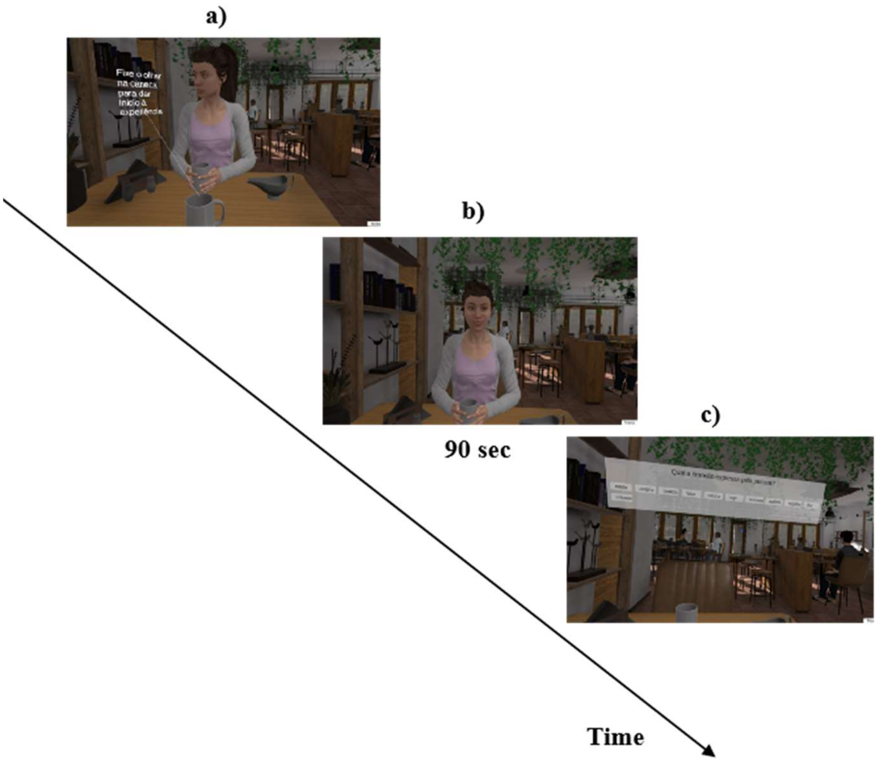
Figure 3.

Examples of NPC's facial expressions (happiness, neutral, fear, sadness).

As presented in Figure 4, after completing one trial, participants had to direct their gaze to the mug closest to them to start a new trial and continue the task. Only then, a new condition was presented. After the stimuli exposure (i.e., at the end of each trial) participants answered the following questions: (1) "What emotion did the person express?" (multiple-choice question with the following options: "*fear*", *"happiness*", "*sadness*", "*anger*", "*neutral*", "*disgust*", "*surprise*", "*euphoria*", "*pride*", "*pain*", and "*embarrassment*"); (2) "What was the person's level of arousal?" (seven-point Likert scale ranging from "*1 - very low*" to "*7 - very high*"); (3) "How positive or negative was the person's emotion?" (seven-point Likert scale ranging from "*1 – very negative*" to "*7 – very positive*"); (4) "What percentage of time was the person looking at you?" (multiple-choice question with the following options: "*10%*", "*20%*", "*30%", "40%", "50%",* "*60%", "70%", "80%", "90%", "100%*"); (5) "How comfortable were you in the previous scenario?" (seven-point Likert scale ranging from "*1 – very uncomfortable*" to "*7 – very comfortable*"; (6) "Did you feel the emotion was directed at you?" (seven-point Likert scale ranging from "*1 - not at all*" to "*7 – a lot*") and (7) "How long do you estimate the previous scenario lasted? (in seconds)" (multiple-choice question with the following options "*71-80", "81-90", "91-100", "101-110", "111-120", "121-130*"). Questions were displayed and responded inside the VR scenario by moving their head to select the response.

Figure 4.

Trial design: (a) Start; (b) interaction phase; and (c) response phase.



3. Procedure

The study took place at the Laboratory of Neuropsychophysiology of the University of Porto. All the tasks, measures, and procedures were approved by the local ethics committee.

Upon arrival at the Laboratory facilities, participants were told that the main goal of the study was the exploration of VR scenarios for research. After signing the written informed consent, participants filled out the online questionnaire with the sociodemographic data and self-report measures. Besides the psychopathy measures, participants filled out other self-report instruments, which were part of a larger study. Responses were kept anonymous by replacing participants' names with an identification code. Then, participants performed the VR task while their oculomotor/eye activity was being tracked and collected through the eye-tracking sensor embodied in the VR headset.

Before initiating the task, the headset was placed and adjusted for each participant such that their eyes were in the centre of the screen, to avoid blurring of the presented stimuli. After placing the headset, the experimenter ensured that participants were comfortable and perceiving a well-focused display. The eye tracker was calibrated to each participant before initiating the task, using a 5-point calibration screen. The headset's audio output was also adjusted for each participant.

It was explained to the participants that during the experiment they would find themselves in a virtual environment resembling a coffee shop and that in front of them there would be a person who could be expressing different emotional states. Participants were told to observe the scenario presented and, at the end of each trial, respond to some questions. The participants were requested to try their best to focus on the VR scenario and detach from the surrounding laboratory environment, given that the greater the immersiveness in the virtual reality the higher the quality of the data collected.

After the instructions, participants were given a 1-minute period of habituation to the scenario without the NPC and a 1-minute period of habituation to the scenario with the NPC present, which allowed participants to become familiar with their surroundings. The participants' seat was adjusted to the height and distance of the NPC, as well as to the table in front of them to make the experience as realistic as possible. After checking that the eye-tracking was functioning correctly and ensuring the comfort and well-being of the participants, the experiment began.

Eye-tracking data was collected with a 45 Hz sampling rate (in 22ms intervals) and at each timepoint participants eye gaze was classified according to the NPCs' element they were looking at (eyes, mouth, face, nose or body). Then, the number of fixations was computed for each body part in each scenario. In order to be considered a *fixation*, participants had to be looking to *that* bodypart for at least 150ms (Reichenberger et al., 2020). Besides the number of fixations, the total time looking at each body part and the mean duration of fixations to each body part were computed for each scenario. All computations were performed using MATLAB.

At the end of the task, the VR headset was removed, and participants received a 10€ voucher as a reward for taking part in this study. The total data collection session lasted approximately 1 hour.

4. Data analyses

Statistical analyses were performed using IBM SPSS 26 (IBM Corporation, Armonk, NY, USA). Firstly, descriptive statistics (means and standard deviations) were computed for all measures of interest. Then, separate RM-ANOVAs with *eye contact* (20%, 80%) and *emotion* (Happiness, Neutral, Fear, Sadness) as within-subjects factors, and *accuracy, arousal, valence, directed gaze time estimation* (*DGTE*), *and trial time estimation* (TTE) as dependent variables, were performed to check if the behavioral and eye-tracking measures were successfully manipulated. Based on the partial eta squared values (η^2_p), we interpreted effect sizes lower than .01 as small effects, effects between .06 and 0.14as medium effects, and effects larger than .14 as large effects (Field, 2018).

After manipulation check, RM-ANOVAs with *eye contact* (20%, 80%) and *emotion* (Happiness, Neutral, Fear, Sadness) as within-subjects factors, and *accuracy* as dependent variable, were performed to assess accuracy rates among emotions and eye contact, and main mistakes made. The eye-tracking data were analysed with RM-ANOVAs with *emotion* (Happiness, Neutral, Fear, Sadness), *bodypart* (Face, Mouth, Eyes) and *eye contact* (80%, 20%) as repeated measures. Normality was evaluated with the Shapiro-Wilks test (no severe violations were observed) and Mauchly's Test was used to analyse sphericity. Since estimated epsilon (ε) were greater than 0.75 in all analyses, when the sphericity assumption was violated, the Huynd-Feldt Correction was used. Post-hoc pairwise comparisons were Bonferroni corrected.

In order to test our hypotheses, bivariate correlational analyses were formerly conducted between TriPM (boldness, meanness, and disinhibition) and SRP-SF (total) scores, and behavioral (emotion recognition accuracy) and eye-tracking responses (dwell time, number of fixations, and mean fixation time). Based on Cohen's (1988) recommendations, we interpreted effect sizes lower than .5 as small effects, effects between .5 and .8 as moderate effects, and effects larger than .8 as large effects. The correlations between dwell time and number of fixations revealed a multicollinearity effect (r = .915)[1]. For this reason, we included only one of the variables (dwell time) (Field, 2018).

Finally, in order to test predictive models of eye-tracking responses in emotion accuracy (1), and of psychopathic traits in emotion accuracy (2) and eye-tracking responses (3), we performed linear regression analyses with (1) eye-tracking responses as predictors (dwell time and mean fixation time) and emotion accuracy as dependent variables, and TriPM (boldness, meanness, and disinhibition) and SRP-SF (total) scores as predictors, and emotion accuracy (2) and eye-tracking responses (3) as dependent variables. The alpha threshold for statistical significance was set at .05. Confidence intervals (CI) at 95% for the standardized beta (β) coefficients were calculated, along with p values for each predictor. No multicollinearity effects were found in these models. Regarding the outliers' analyses, it is important to mention that in the models including psychopathy dimensions as predictors of the eye-tracking measures, the maximum value of standardized residuals ranged between 3.40 and 4.60 (higher than 3). However, these outliers were not removed from the models since Cook's distance was always lower than 1, revealing no significant influential cases (Field, 2005).

[1] In all regression models including these variables as predictors, VIF was higher than 10.

Results

1. Part A – VR scenario: manipulation checking

1.1. Descriptive statistics

Means (and standard deviations) per emotion (happiness, neutral, fear, and sadness) and eye contact (20% and 80%) were calculated for (1) behavioral measures (emotion recognition accuracy, self-reported perceived arousal, self-reported perceived valence, NPC directed gaze time estimation - DGTE, trial time estimation - TTE) and (2) eye-tracking measures (dwell time - DT and mean fixation time - MFT) (see Table 1). Emotion recognition accuracy rates (hits and misses) are detailed in a confusion matrix (Table 2).

Table 1.

Means (and standard deviations) of behavioral and eye-tracking responses per condition (20% versus 80%).

	Happiness		Neutral		Fear		Sadness	
	20%	80%	20%	80%	20%	80%	20%	80%
Accuracy	.71(.46)	.82(.39)	.65(.48)	.85(.36)	.32(.47)	.24(.43)	.89(.32)	.95(.22)
Arousal	4.6(1.5)	4.7(1.4)	3.2(1.9)	2.9(1.6)	4.0(1.7)	4.0(1.6)	3.8(1.7)	4.3(1.6)
Valence	5.4(1.4)	5.7(.9)	3.7(1.0)	4.1(.8)	2.5(.9)	2.9(1.2)	2.4(1.2)	2.1(.7)
DGTE	3.5(2.1)	7.3(1.7)	2.9(2.1)	6.6(1.9)	2.6(1.4)	6.9(1.9)	2.7(1.6)	6.9(1.9)
TTE	2.6(1.3)	2.8(1.4)	2.5(1.4)	2.8(1.5)	2.6(1.2)	2.6(1.2)	2.7(1.4)	2.9(1.4)
DT_Body	4.2(13.4)	6.2(21.7)	12.5(44.1)	7.4(41.6)	2.9(11.3)	3.4(14)	6.2(20)	10.3(24.4)
DT_Face	997.3(559.8)	835.0(418.0)	935.5(428.5)	833.7(483.7)	903.9(501.6)	788.1(381.7)	968.3(535.4)	874.3(511.7)
DT_Eyes	578.4(374.7)	625.4(406.5)	678.3(457.5)	678.3(428.4)	632.9(399.3)	695.7(463.8)	662.4(458.2)	644.7(440.1)
DT_Mouth	496.1(407.3)	552.8(354.0)	484.8(379.4)	493.1(365.6)	525.9(287.1)	599.0(346.3)	444.8(338.6)	525.2(371.8)
DT_Nose	477.3(414.7)	535.7(465.9)	502.1(481.2)	515.1(413.7)	450.7(420.1)	494.0(457)	474.0(377.7)	530.8(430.7)
NF_Body	.2(.7)	.3(1).	.4(1)	.2(.8)	.1(.5)	.2(.6)	.2(.5)	.4(.1)
NF_Face	62.2(16.9)	57.6(16.4)	60.9(17.8)	55.3(17.9)	59.4(18.6)	54.4(15.8)	59.6(15.6)	58.1(20.1)
NF_Eyes	39.5(19.8)	41.7(23.0)	42.1(24.1)	44.0(26.8)	41.7(22.6)	45.1(26.4)	42.6(24.1)	42.1(23.9)
NF_Mouth	28.5(17.5)	30.8(17.1)	28.0(18.1)	28.3(18.1)	31.2(16.4)	32.9(16.0)	26.1(16.0)	28.9(15.9)
NF_Nose	31.3(18.9)	33.9(21.0)	32.0(19.6)	33.1(19.3)	29.4(17.4)	31.9(21.0)	30.1(18)	33.2(19.3)

MFT_Body	2.5(6.6)	3.2(9.8)	5.9(20.9)	2.3(9.4)	2.5(10.5)	1.6(6.1)	4.3(13.5)	5.7(12.4)
MFT_Face	16.2(5.7)	14.6(4.6)	15.6(4.5)	14.7(4.0)	15.0(4.2)	14.4(3.8)	16.1(5.3)	14.8(4.8)
MFT_Eyes	13.7(4.4)	13.9(4.1)	14.1(4.9)	13.7(4.8)	14.4(5.7)	14.9(3.6)	14.4(4.8)	14.2.7)
MFT_Mouth	16.7(4.6)	18.1(5.3)	16.8(4.1)	16.9(4.8)	17.2(4.6)	17.9(4.1)	16.5(4.8)	17.7(4.9)
MFT_Nose	14.4(4.9)	15.1(5)	14.8(5.4)	14.9(4.9)	14.5(5)	14.4(5.5)	15.3(6.1)	15(4.5)

Notes: Table with means (and standard deviations) of behavioral (accuracy, arousal, valence, directed gaze time estimation - DGTE, and trial time estimation - TTE) and eye-tracking responses (dwell time - DT, number of fixations - NF and mean fixation time - MFT) for the different bodyparts (body, face, eyes, mouth and nose) per eye contact condition (20% versus 80%).

Table 2.

Correct and incorrect responses (in percentage) for each eye contact condition.

Emotion selected	Eye contact	Emotional expression selected			
		Happiness	Neutral	Fear	Sadness
Fear	80%	0.00	3.23	24.19	1.61
	20%	3.23	0.00	32.26	3.23
Happiness	80%	82.26	0.00	0.00	0.00
	20%	71.00	1.61	0.00	0.00
Sadness	80%	0.00	1.61	11.29	95.16
	20%	1.61	6.45	14.52	88.71
Anger	80%	0.00	3.23	8.06	0.00
	20%	1.61	0.00	3.23	0.00
Neutral	80%	1.61	85.48	16.13	0.00
	20%	6.45	64.52	9.68	1.61
Disgust	80%	1.61	0.00	9.68	0.00
	20%	0.00	3.23	11.29	0.00
Surprise	80%	1.61	0.00	9.68	0.00
	20%	1.61	3.23	0.00	0.00
Euphoria	80%	3.23	0.00	0.00	0.00
	20%	3.23	0.00	0.00	0.00
Pride	80%	8.06	1.61	0.00	0.00

	20%	9.68	1.61	0.00	0.00
Pain	80%	0.00	0.00	8.06	1.61
	20%	0.00	0.00	0.00	3.23
Embarrassment	80%	1.61	4.84	12.90	1.61
	20%	1.61	19.35	29.03	3.23

Notes: Confusion matrix of emotional expressions indicating the impact of eye contact (80% versus 20%). Values express the average proportion of identification of the specific emotional expression. Hits are shown with grey background.

1.2. Tests on behavioral measures

Regarding the effects of the experimental manipulations (emotion and eye contact) on the behavioral measures, Table 3 summarizes the main effects and interactions of the Repeated Measures ANOVA conducted for each behavioral measure.

Table 3.

Main effects and interactions of the Repeated Measures ANOVA conducted for each behavioral measure.

		F	*p*-value	η^2_p
Emotion recognition accuracy				
	Emotion	$F_{(3,183)} = 61.81$	< .001	.503
	Eye contact	$F_{(1,61)} = 4.60$	.036	.070
	Emotion*Eye contact	$F_{(3,183)} = 2.79$	.042	.044
Perceived arousal				
	Emotion	$F_{(3,183)} = 24.47$	< .001	.286
	Eye contact	$F_{(1,61)} = 0.45$	.507	.007
	Emotion*Eye contact	$F_{(3,183)} = 2.33$	.076	.037
Perceived valence				
	Emotion	$F_{(3,183)} = 243.51$	< .001	.802
	Eye contact	$F_{(1,61)} = 6.85$	.011	.102
	Emotion*Eye contact	$F_{(3,183)} = 4.02$	.008	.063
DGTE				
	Emotion	$F_{(3,183)} = 5.60$	.002	.084
	Eye contact	$F_{(1,61)} = 484.75$	< .001	.888

Emotion*Eye contact	$F_{(3,183)} = 0.63$	.596	.010
Trial time estimation			
Emotion	$F_{(3,183)} = 0.63$	.623	.009
Eye contact	$F_{(1,61)} = 5.26$	.025	.076
Emotion*Eye contact	$F_{(3,183)} = 0.53$	.662	.009

Notes: Table with the main effects of emotion and eye contact, and interactions between emotion and eye contact of the Repeated Measures ANOVA conducted for each behavioral measure (emotion recognition accuracy, perceived arousal, perceived valence, NPC directed gaze time estimation – DGTE, and trial time estimation - TTE).

Regarding emotion recognition accuracy, Bonferroni multiple comparisons on the main effect of emotion shows higher accuracy rates for sadness when compared with happiness, neutral, and fear (all $p \leq .001$), and lower accuracy rates for fear when compared with neutral and happiness (both $p < .001$) expressions. On the main effect of eye contact, 80% elicited higher accuracy rates than the 20% ($p = .036$). Finally, in the emotion*eye contact interaction (see Figure 5a), fear shows lower accuracy rates in the 80% condition when compared with happiness, neutral, and sadness expressions (all $p < .001$). In the 20% eye contact condition, fear shows lower accuracy rates when compared with happiness, neutral, and sadness expressions (all $p <.007$), and sadness shows higher accuracy rates when compared with neutral ($p=.008$).

Concerning the arousal of the facial expressions, Bonferroni multiple comparisons on the main effect of emotion shows higher perceived arousal for happiness when compared with neutral, fear, and sadness expressions (all $p < .001$), and lower perceived arousal for neutral when compared with fear and sadness expressions (both $p < .001$). No significant eye contact nor emotion*eye contact interaction were found.

In relation to the valence of the facial expressions, Bonferroni multiple comparisons on the main effect of emotion shows higher perceived valence for happiness when compared with neutral, fear, and sadness (all $p < .001$), for neutral when compared with fear and sadness (both $p < .001$) and for fear when compared with sadness expressions ($p = .001$). On the main effect of eye contact, 80% elicited higher perceived valence than the 20% ($p = .011$). Finally, in the emotion*eye contact interaction (see Figure 5b), happiness shows higher perceived valence in the 80% condition when compared with neutral, fear, and sadness expressions (all $p < .001$), for neutral when compared with fear and sadness (both $p < .001$), and for fear when compared with sadness expressions ($p < .001$). The same effects occur in the 20% eye contact condition (all $p <$

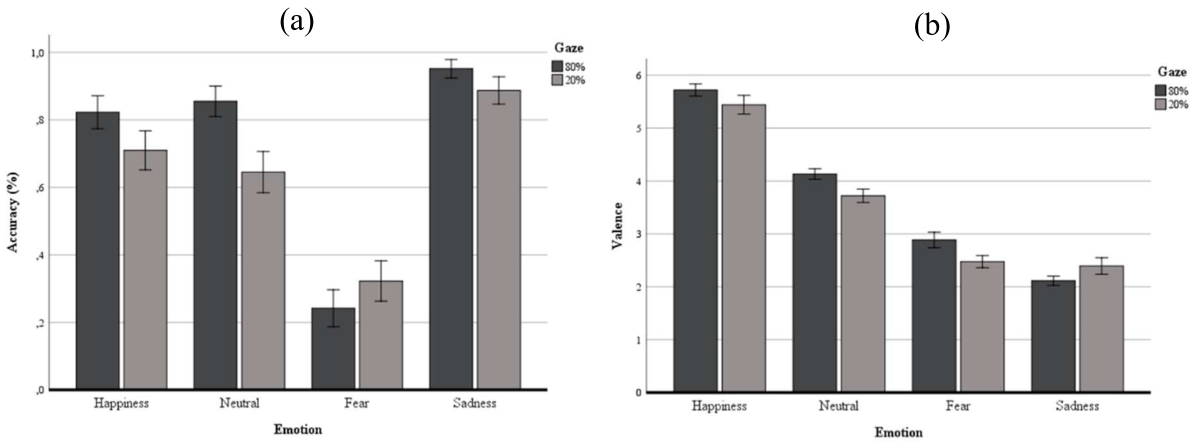
.001), except for fear and sadness, in which perceived valence was not significantly different.

Regarding the NPC directed eye contact time estimation (DGTE), Bonferroni multiple comparisons on the main effect of emotion shows higher DGTE for happiness when compared with neutral, fear, and sadness (all $p < 0.049$). On the main effect of Eye contact, 80% elicited higher DGTE than the 20% condition ($p < .001$). No significant emotion*eye contact interaction was found.

Lastly, related to trial time estimation, Bonferroni multiple comparisons on the main effect of eye contact shows that 80% condition elicited higher estimated trial time than the 20% ($p = .025$). No significant emotion or interaction effect was found.

Figure 5.

Bar charts for the significant interactions between emotion and eye contact, regarding the behavioral measures: (a) accuracy, (b) valence.



1.3. Tests on eye-tracking measures

Regarding the effects of the experimental manipulations (bodypart, emotion, and eye contact) on the eye-tracking measures, Table 4 summarizes the main effects and interactions of the Repeated Measures ANOVA conducted for each eye-tracking measure. See Table 2 for descriptive statistics on eye-tracking data *per* emotion and eye contact condition.

Table 4.

Main effects and interactions of the Repeated Measures ANOVA conducted for each eye-tracking measure.

		F	*p*-value	η_p^2
Dwell time				
	Bodypart	$F_{(2, 122)} = 15.397$	< .001	.202
	Emotion	$F_{(3, 183)} = 0.208$	.891	.003
	Eye contact	$F_{(1, 61)} = 0.436$	.512	.007
	Bodypart*Emotion	$F_{(6, 366)} = 3.815$	.001	.059
	Bodypart* Eye contact	$F_{(2, 122)} = 15.007$	< .001	.197
	Emotion* Eye contact	$F_{(3, 183)} = 0.250$	.861	.004
	Bodypart*Emotion* Eye contact	$F_{(6, 366)} = 0.858$	.526	.014
Mean fixation time				
	Bodypart	$F_{(2, 122)} = 18.138$	< .001	.229
	Emotion	$F_{(3, 183)} = 0.798$	.496	.013
	Eye contact	$F_{(1, 61)} = 0.145$	.705	.002
	Bodypart*Emotion	$F_{(6, 366)} = 2.053$	.058	.033
	Bodypart* Eye contact	$F_{(2, 122)} = 11.249$	< .001	.156
	Emotion* Eye contact	$F_{(3, 183)} = 0.494$	.687	.008
	Bodypart*Emotion* Eye contact	$F_{(6, 366)} = 0.795$	.574	.013

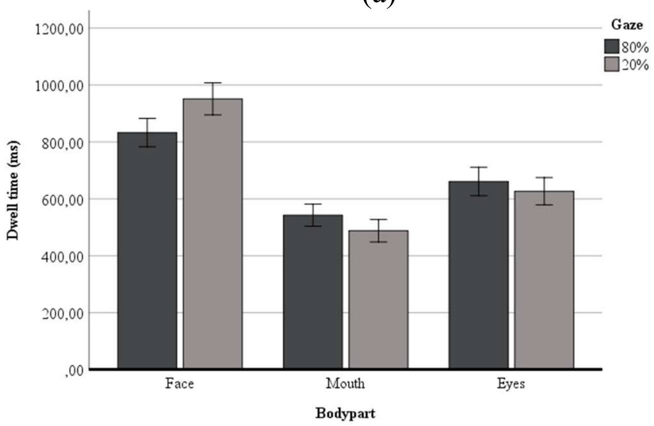
Notes: Table with the main effects of bodypart, emotion and eye contact, and interactions between bodypart and emotion, bodypart and eye contact, emotion and eye contact, and bodypart, emotion and eye contact of the Repeated Measures ANOVA conducted for each eye-tracking measure (dwell time and mean fixation time).

Concerning the dwell time (DT), Bonferroni multiple comparisons on the main effect of bodypart showed that the face had significantly higher total DT than the eyes and mouth (both $p < .002$). A significant interaction between bodypart and eye contact (see Figure 6a) showed that in 80% eye contact DT was higher for the face when compared with eyes and mouth (both $p < .041$). In the 20% eye contact DT was also higher for the face when compared with eyes and mouth (both $p<.001$). A significant interaction between bodypart and emotion (see Figure 6b) showed that DT was higher for the face when compared with the eyes and mouth in the happiness (both $p < .001$), neutral, fear and sadness expressions (all p < .032). No other main or interaction effect was found.

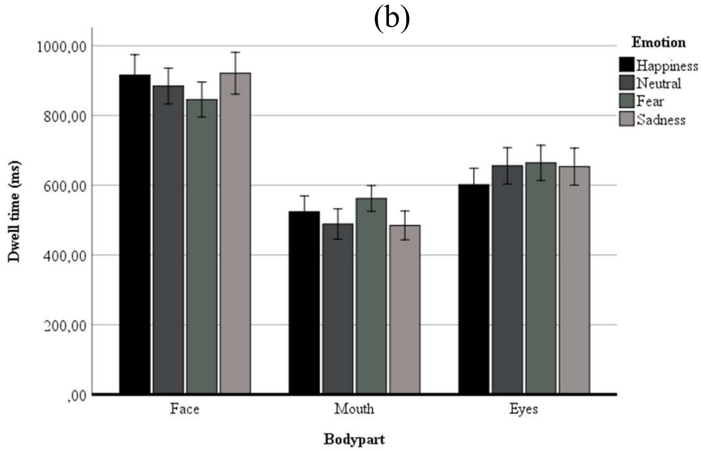
Figure 6.

Bar charts for the significant interactions between (a) bodypart and emotion and (b) bodypart and eye contact, for the dwell time.

(a)



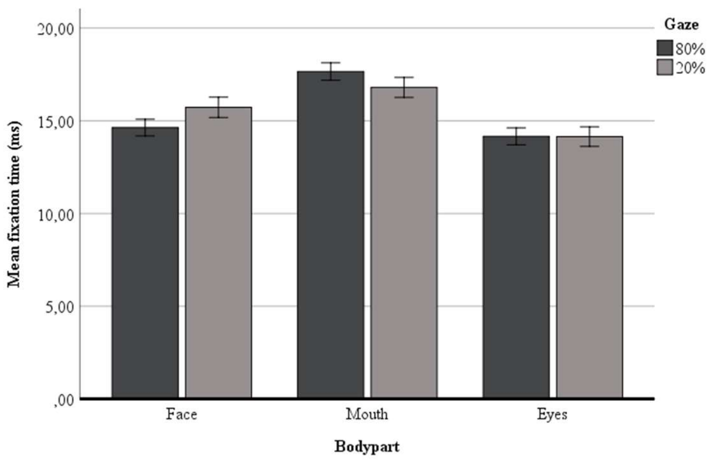
(b)



Related to the mean fixation time (MFT), Bonferroni multiple comparisons on the main effect of bodypart showed that the mouth had a significantly higher MFT than face and eyes (all $p<.002$). A significant interaction between bodypart and eye contact was also found (see Figure 7). In the 80% eye contact MFT was higher for the mouth when compared with face and eyes (all $p<.001$). In the 20% eye contact, MFT was lower for the eyes when compared with mouth and face (all $p<.039$). No other main or interaction effect was found.

Figure 7.

Bar chart for the significant interactions between bodypart and eye contact, for the mean fixation time.



2. **Part B - Hypothesis testing**

Means for SRP-SF total scores, boldness, disinhibition, and meanness are displayed in table 5.

Table 5.

Descriptive statistics (means and standard deviations, SD) for SRP-SF total score, and boldness, meanness, and disinhibition scores of TriPM.

	Mean	*Sd*	Min-Max	Cronbach's A
SRP-SF total score	47.2	13.9	28-85	0.895
TriPM Boldness	28.9	9.2	11-54	0.862
TriPM Meanness	9.8	8.5	1-37	0.894
TriPM Disinhibition	14.4	7.5	2-32	0.813

Notes: descriptive statistics (means, standard deviations - SD) for SRP-SF total score, and boldness, meanness, and disinhibition scores of TriPM.

To test whether focusing attention to the eyes influences recognition accuracy (H1), separate linear regression models with dwell time and mean fixation time in the eyes as predictors of emotion recognition accuracy (happiness, neutral, fear, and sadness) were conducted.

The statistics of the models and the standardized coefficients for each predictor are displayed in Table 6. Dwell time was significantly associated with the fear accuracy, with high dwell time to the eyes being associated with higher recognition of fear emotional expressions. No other significant associations were found.

To better investigate these associations, we conducted bivariate correlations between recognition accuracy of fear (by eye contact) and dwell time.

We found a positive association between fear recognition accuracy at 20% eye contact and dwell time (r = .329, p = .010). For the 80% eye contact condition no significant association was found.

Table 6.

Linear regression models with dwell time (DT) and mean fixation time (MFT) in the eyes as predictors of happiness, neutral, fear, and sadness recognition accuracy.

Emotion	*t*	*p*	β	*F*	*df*	*p*	adj. R^2
Happiness							
Overall Model				0.262	2, 61	.770	-.025
Dwell Time	0.677	.501	0.102				
Mean Fixation Time	-0.564	.575	-0.085				
Neutral							
Overall Model				0.948	2, 61	.393	-.002
Dwell Time	-0.592	.556	-0.088				
Mean Fixation Time	1.372	.175	0.204				
Fear							
Overall model				3.559	2, 61	.035	.077
Dwell Time	2.666	.01	0.380				
Mean Fixation Time	-1.263	.212	-0.180				
Sadness							
Overall Model				0.283	2, 61	.754	-.024
Dwell Time	-.184	.855	-0.028				
Mean Fixation Time	.723	.473	0.108				

Note: Table with linear regression models with dwell time (DT) and mean fixation time (MFT) in the eyes as predictors of happiness, neutral, fear, and sadness recognition accuracy.

In order to explore the relationship between psychopathy scores and attention orienting toward the eyes (H2), separate linear regression models were conducted with SRP-SF total score as predictor for dwell time and mean fixation time in the eyes.

The statistics of the models and the standardized coefficients for each predictor are displayed in Table 7. No significant associations between SRP-SF total scores and dwell time or mean fixation time on the eyes were found.

Regarding the association between psychopathy scores and emotion recognition accuracy (H3), separate linear regression models were conducted with SRP-SF total score as predictor for happiness, neutral, fear and sadness recognition accuracy.

The statistics of the models and the standardized coefficients for each predictor are displayed in Table 7. No significant associations between SRP-SF total scores and recognition accuracy were found.

Table 7.

Linear regression models with SRP-SF total score as predictor of dwell time (DT), mean fixation time (MFT), and happiness, neutral, fear, and sadness recognition accuracy.

Emotion	*t*	*p*	β	*F*	*df*	*p*	adj. R^2
DT							
Overall Model				0.293	1, 60	.590	-.012
SRP-SF	-0.541	.590	-0.070				
MFT							
Overall Model				0.150	1, 60	.700	-.014
SRP-SF	0.387	.700	0.050				
Happiness							
Overall Model				0.000	1, 60	.996	-.017
SRP-SF	.0006	.996	0.001				
Neutral							
Overall Model				0.015	1, 60	.903	-.016
SRP-SF	-0.123	.903	-0.016				
Fear							
Overall Model				0.631	1, 60	.430	-.006
SRP-SF	0.794	.430	0.102				
Sadness							
Overall Model				0.032	1, 60	.859	-.016
SRP-SF	0.178	.859	0.023				

Note: Table with linear regression models with SRP-SF total score as predictor of dwell time (DT) and mean fixation time (MFT) in the eyes, and happiness, neutral, fear, and sadness recognition accuracy.

To test the relationship between psychopathic traits and attention orienting toward the eyes (H4), separate linear regression models were conducted with boldness, meanness, disinhibition as predictors for dwell time and mean fixation time in the eyes.

The statistics of the models and the standardized coefficients for each predictor are displayed in Table 8. No association was found between the boldness scores and the attention given to the eyes.

Table 8.

Linear regression models with boldness, meanness and disinhibition scores as predictors of dwell time and mean fixation time in the eyes.

Eye-tracking Measure	*t*	*p*	β	*F*	*df*	*p*	adj. R^2
Dwell time							
Overall Model				1.167	3, 58	.195	.029
Boldness	0.573	.569	.085				
Meanness	.0378	.707	.063				
Disinhibition	-1.773	.082	-.267				
Mean Fixation Time							
Overall Model				0.829	3, 58	.483	-.008
Boldness	1.454	.151	.221				
Meanness	-0.249	.804	-.042				
Disinhibition	0.349	.728	.054				

Note: Table with linear regression models with boldness, meanness, disinhibition as predictors of dwell time and mean fixation time in the eyes.

Separate linear regression models were also tested with boldness, meanness, and disinhibition as predictors of happiness, neutral, fear and sadness accuracy, to test whether boldness scores are associated with fear recognition (H5).

The statistics of the models and the standardized coefficients for each predictor are displayed in Table 9. No significant associations were found.

Table 9.

Linear regression models with boldness, meanness and disinhibition scores as predictors for happiness, neutral, fear and sadness accuracy.

Emotion		*t*	*p*	β	*F*	*df*	*p*	adj. R^2
Happiness								
	Overall model				0.209	3, 58	.890	-.040
	Boldness	-0.676	.502	-0.104				
	Meanness	0.395	.694	0.068				
	Disinhibition	0.079	.937	0.012				
Neutral								
	Overall model				0.021	3, 58	.996	-.051
	Boldness	0.109	.914	0.017				
	Meanness	0.038	.970	0.007				
	Disinhibition	-0.173	.864	-.027				
Fear								
	Overall model				0.445	3, 58	.722	-.028
	Boldness	1.097	.277	0.168				
	Meanness	-0.516	.608	-0.088				
	Disinhibition	0.664	.510	0.103				
Sadness								
	Overall model				0.564	3, 58	.641	-.022
	Boldness	-0.733	.467	-0.112				
	Meanness	-0.300	.765	-0.051				
	Disinhibition	-0.666	.508	0.103				

Note: Table with linear regression models with boldness, meanness, disinhibition score as predictors for happiness, neutral, fear and sadness accuracy.

Discussion

Psychopathy is a personality structure that can be defined as a multidimensional construct characterized by emotional/affective, interpersonal, and behavioral features (Gillespie et al., 2019; Hare, 1996; Hare & Neumann, 2008; Patrick et al., 2009). It is theorized that certain aspects of social behavior in psychopathy can be explained by deficits in recognizing facial expressions of emotion (Gaizo & Falkenbach, 2008; Marsh & Blair, 2008). Still, important questions remain unanswered regarding the relationship between psychopathy and facial emotion recognition and the nature of the deficits. One possible reason that appear to be underneath this deficits is a decreased attention toward the eyes in this subjects, followed by a decreased exploration of important emotional clues present in the eye region (Gillespie et al., 2015).

The aim of the current study was to explore the effect of psychopathy dimensions on the recognition of emotions in facial expressions by using virtual reality (VR). We also intended to study the importance of orienting attention to the eyes in emotion recognition tasks, as well as the relationship between psychopathy traits and attention to the eyes of faces expressing emotions. Through VR, we intended to study emotion recognition in more realistic scenarios, and test if the deficits previously observed in psychopathic subjects are confirmed in such scenarios.

In recent years, virtual reality has been proving to be a useful tool in psychology, both in research and clinical practice (Dores et al., 2012; Riva et al., 2007). A real social interaction like the one depicted in this study would be exceedingly difficult to create in real circumstances. Given its ability to induce a high sense of interaction and immersiveness (Baños et al., 2004; Marín-Morales et al., 2020; Riva et al., 2007), VR enables the development of scenarios that are close to real-life contingencies, and yet, highly controlled. These scenarios provide the opportunity to study the effects of psychopathy traits on behavioral and eye tracking responses under a new and more realistic paradigm than the traditional methods (2D pictures and videos), increasing the ecological validity of the findings (Dores et al., 2014; Reichenberger et al., 2020). Notwithstanding, to ensure ecological validity, it is necessary to guarantee that the scenario and the emotional stimuli created can induce the intended effects. For that, manipulation check analyses were conducted.

As expected, the results allow to conclude that participants perceived happiness as the most positive expression, followed by neutral, fear, and sadness. Also, participants reported lower levels of activation (arousal) for neutral expressions when compared with facial expressions of emotions (happiness, fear, and sadness). These results show that the facial expressions developed for the VR scenario were generally well designed and representative of the target emotions. Likewise, regarding the eye contact manipulation, the 80% eye contact condition elicited higher accuracy rates, perceived arousal, estimated trial duration, and directed gaze time estimation than the 20% condition. This suggests that the eye contact manipulation was also appropriate.

Regarding the participants ability to recognize emotional expressions, sadness had the highest accuracy rate. In contrast, fear was the hardest emotion to recognize. The low recognition levels observed in fear occurred both in 20% and 80% eye contact conditions and are consistent with the difficulty in recognizing fear expressions, which have been mentioned in literature (Calvo & Nummenmaa, 2016; Geraets et al., 2021). Additionally, recognition of facial expressions of emotion is highly facilitated by congruent contextual information (Theurel et al., 2016). While happiness, neutral, and sad facial expressions of emotion might occur in a typical social interaction, fear might be more difficult to recognize in a context where it is uncommon and unexpected, like in a coffee-shop. In fact, fear was commonly mistaken for embarrass which is a marked social emotion, more typical in social-interactive contexts. However, questions can still be raised regarding the quality of the developed facial expression of fear.

Regarding the eye contact effects on accuracy, in the 80% eye contact condition the NPCs spent most of the time staring directly at the person sitting in front of them, which gave the participants more opportunities to perceive, integrate, and analyse the emotional clues present in the NPC's facial expression. In contrast, in the 20% eye contact conditions, the NPC was constantly avoiding the participant, which decreased the number of emotional clues available. Indeed, emotion recognition was significantly higher in the high direct eye contact conditions (80%), which supports the idea that the number of emotional clues available contribute to increase emotional recognition.

It is well stablished in literature that certain elements of the face, such as the eyes and the mouth, play an important role in emotion recognition (Eisenbarth & Alpers, 2011;

Wells et al., 2016). The importance of focusing attention to the eye region has been highly documented in the literature, since it contains features that are extremely informative of others emotional state (Eisenbarth & Alpers, 2011; Gehrera et al., 2019; Itier & Batty, 2009; Wells et al., 2016). Indeed, and consistent with previous studies (Adolphs, 2006; Adolphs et al., 2005; Dadds et al., 2006, 2008; Gillespie et al., 2017; Martin-Key et al., 2018), the results of this study suggest that the visual exploration of critical facial elements - specifically the eyes - is highly associated with emotion recognition accuracy, with the eyes being the region where the participants spent most of the time looking at (dwell time), regardless of the eye contact condition. The time spent exploring the eye region seems to have increased the participants' ability to recognize the emotional expressions presented, which may justify the high accuracy rates observed when the attention toward the eyes was higher, confirming our first hypothesis. However, and remarkably, the mouth had higher mean fixation time scores than the eyes, which means that participants spent more time looking at the eyes, but each fixation was, on average, brief.

It was also observed a meaningful relationship between the attention given to the eyes and the recognition of emotional expressions of fear. An association between reduced fixations to the eyes of fearful faces has already been mentioned in the literature (Dadds et al., 2008; Dargis et al., 2018; Gillespie et al., 2015, 2017), supporting the assumption of an emotion-specific impairment in orienting attention. Interestingly, this pattern of eye region exploration was found only in low direct eye contact conditions (20%), where the number of emotional clues was lower. This supports the idea that orienting our attention toward the eyes may increase the amount of available emotional clues, facilitating the recognition of emotions in faces. These results suggest that the need to look at the eyes of others may increase in ambiguous situations, i.e., in situations when recognising the emotion being expressed becomes more difficult. That being said, looking to the eye region may, indeed, facilitate the recognition of unclear or ambiguous fear expressions. Still, further investigation is needed in order to explore this phenomenon.

Studies have reported that psychopathy traits seem to be related with a decreased visual exploration of the eye region in emotion recognition tasks (Boll & Gamer, 2016; Dadds et al., 2008; Gehrera et al., 2019; Gillespie et al., 2015, 2017; Martin-Key et al., 2018). Thus, a relationship between psychopathy and the attention orienting toward the eyes was expected. However, contrary to what was hypothesised, no association was found between psychopathy scores (SRP-SF) and the attention towards the eyes. Same results were reported by Kyranides and colleagues (2019).

Given the literature, it was also expected an association between high psychopathy scores and deficits in emotion recognition accuracy. However, this effect was not observed in this study. Similar to other studies (Beussink et al., 2020; Book et al., 2007; Deming et al., 2022; Gaizo & Falkenbach, 2008; Gillespie et al., 2015, 2021; Glass & Newman, 2006; Kranefeld & Blickle, 2022; Mowle et al., 2017; Pajer et al., 2010; Pham & Philippot, 2010; Seara-Cardoso et al., 2011), psychopathy traits were not associated with increased difficulties in emotional recognition. Likewise, contrary to what was predicted, no effect of boldness was found on the attention to the eyes, nor on the fear recognition accuracy. Still, it is important to mention that this study relied on a community sample, in which psychopathy scores are usually lower. It should be taken into consideration the possible presence of significant effects in more heterogeneous samples, including individuals recruited from forensic settings, thereby capturing the full spectrum of psychopathy traits. Moreover, it is important to note that the deficits previously found were reported in studies that used more traditional stimuli (photos and, in some cases, videos), which are less ecological than the ones provided by the VR system. Having said that, it is possible that the emotion recognition deficits previously observed in psychopathic subjects are not present in more naturalistic interactions as the one provided by immersive VR. Nevertheless, more studies are needed in order to further validate this hypothesis.

Study limitations and future directions

The current study provides more knowledge regarding the relationship between psychopathy, emotion recognition, and eye tracking responses, in more realistic scenarios. However, the results and conclusions drawn from this study should be interpreted with caution, considering its limitations. Firstly, all variables were measured via self-report questionnaires, which may be subject to social desirability and prone to response biases. Additionally, certain psychopathic deficits may only become manifest at elevated levels of psychopathy, therefore being harder to find in community samples (Zimak et al., 2014). Therefore, as previously mentioned, it is possible that high psychopathy scores are not well represented in the community sample of this study. Also, given the size of the sample, it is possible that some of the statistical analyses may be underpowered, reducing the probability of detecting existing effects.

Some observations have to be made regarding the presented emotional expressions. Concerning the NPC's mouth, his/her teeth and gums were perceived by the participants as less than realistic and natural. This effect was especially reported in fearful faces and might have moderated the results achieved in recognition accuracy and eye-tracking responses, as it may have hindered emotional recognition accuracy and elicited a greater attentional focus to the mouth region (see Table 1). Therefore, it is important to interpret the results regarding fear with particular caution. Nevertheless, participants often described the VR scenario as generally realistic and immersive. In fact, because VR scenarios are more naturalistic, they have more distracting elements than static or dynamic images, which can affect the surroundings exploration and, for that reason, the eye tracking responses.

It is important to note that, despite its benefits, the methodology used in this study is recent and therefore, still needs further research and exploration. Future studies may consider the creation and validation of more 3D facial expressions of emotions and the development of a repository of 3D avatars (NPCs), which would contribute to the elaboration and establishment of a standardized protocols, reducing biases that may derive from the quality of the developed stimuli.

It would also be interesting to create scenarios in which the NPC interacts more actively with the participant (e.g., physically or vocally), or to consider the presentation of emotional sounds (e.g., crying, laughing) simultaneously with facial expressions. Finally, the creation of emotion-inducing scenarios that do not necessarily need to include NPCs would be equally noteworthy.

In summary, the results of our study do not confirm the existence of a relationship between psychopathy traits and deficits in the recognition of emotional expressions but corroborate the importance of visual exploration of the eye region in emotional recognition tasks. This study also demonstrates the benefits of employing virtual reality scenarios in emotion recognition tasks, confirming its effectiveness in experimental environments.

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