LONELINESS EFFECTS ON SOCIAL COGNITION AND AFFECTIVE PROCESSES

Ph.D. Student

Adriana Patrizia González Pizzio

Tutor: Anna Pecchinenda

PhD Program in Behavioral Neuroscience. Neuropsychology and Cognitive Neuroscience curriculum. XXXVI Cycle - Department of Psychology – Sapienza University of Rome

«Not a very sensible thing to do […], fall for someone who is not of your kind, some who will only complicate your life, disrupt your routine and mess with your sense of stability and rootedness. But, then again, anyone who expects love to be sensible has perhaps never loved»

— “The island of missing trees”, Elif Shafak

ACKOWLEDGMENTS

This work could have not been possible without the support and guidance of Prof. Anna Pecchinenda. Thank you for your trust, for allowing me to fail so that I could learn, for striving me to succeed.

Special thanks to Prof. Luis Carretié, who guided me throughout my research period abroad, I also extend my gratitude to all the laboratory members: Uxía, Fátima and Estrella who welcomed me and made me feel as a part of their group from the very beginning.

Thank you Prof. Alla Yankouskaya and Prof. Guido Alessandri for your time, for the help and the uppermost motivation to do better. Particular thanks to the volunteers that took part in the Experiments, as the studies were only made possible by your participation.

Family and friends. Words fall short to express the depth of gratitude, appreciation, and love I hold for each one of you. All of this work would not have been possible without your support, encouragement, but most of all, without your love. Mama, papa, me habéis enseñado muchas cosas, la mayoría de ellas me ha convertido en la persona que soy y me brindan la posibilidad de encaminarme a quién quiero llegar a ser. Sin embargo, aquella que guardo más cerca es la perseverancia, vosotros sois el mejor ejemplo de empeño, de voluntad y de amor. Amigos, no podría haber llegado hasta aquí sin vuestro apoyo, en lo bueno y en lo malo, sin vuestra confianza, sois fundamento, base y pilar de este trabajo, pero sobre todo de mi vida. To all, "*Thank you*" is not strong enough but it will have to do.

Martina, you have been such a blessing, life was special because of you. We all have loved you very much. Time has passed but there has been no day where you were not missed, nor it will ever be one. I love you, always.

ABSTRACT

Loneliness, an aversive state often associated with depression or anxiety, differs from being physically alone and is characterized by the perception of being socially isolated and dissatisfied with current social relationships. It can range from transient sensations to chronic conditions, with the latter linked to various mental and physical health problems including anxiety or depression, cardiometabolic disease and increased mortality rates. Theoretical models of loneliness propose that lonely individuals are prone to negative thinking, expect rejection, and perceive their social environment as threatening. Evidence from studies using emotional stimuli, in particular emotional faces, have showed that socially excluded participants are more likely to give priority to social relevant positive stimuli. Studies have also evidenced that socially excluded individuals tend to avoid negative relevant social stimuli, in line with the hypothesis that social exclusion motivates toward affiliative related cues and away from negative social stimuli. The present research aims to comprehensively explore the impact of loneliness on memory for faces, orienting attention to social cues, selective attention to faces, and inhibition for social stimuli. The first study aimed to investigate whether loneliness and social contacts modulated the Own Age Memory Bias, i.e., the enhanced recognition for faces pertaining to the individuals own age group. Results indicated that individuals reporting lower levels of loneliness were more likely to exhibit an Own Age Bias for novel signs of affiliation, specifically novel happy faces. Conversely, this bias was not observed in individuals with higher levels of loneliness. The second study examined the modulation effect of loneliness on attentional shift towards emotional faces. Although gaze cueing effects were observed, no group differences between lonely and non-lonely participants emerged. The third study aimed to assess the modulation effect of loneliness on selective attention for emotional faces. Results showed interference from emotional distractors when the valence of targets word did not match the valence of the

distractor’s facial expression, but no effect of loneliness. The forth study explored the impact of loneliness on later processes of cognition, specifically whether loneliness influenced response inhibition to emotional stimuli. Result evidenced a modulation effect of emotion in response inhibition; however, this was independent of loneliness. Understanding the effects of loneliness on different aspects of social cognition is crucial, but it has become more urgent recently as especially young individuals have suffered from the lack of social contacts with their peers during the Covid-19 lockdown. Future research on the effects of loneliness on social cognition may be beneficial to comprehend if the mechanisms contributing to prolonged loneliness involve reduced bias towards negative stimuli or hypervigilance towards social threat signals.

INDEX

INDEX OF TABLES

INDEX OF FIGURES

CHAPTER 1

THEORIES AND EMPIRICAL EVIDENCE ON LONELINESS

Introduction

Loneliness has been defined as an aversive state without offsetting characteristics barely undistinguishable from other psychological disorders such as depression or from individual differences in personality traits such introversion or neuroticism (Cacioppo & Cacioppo, 2018a). Different from being physically alone, loneliness or perceived social isolation is related to the perception of being socially isolated and to the dissatisfaction with current social relationships (Cacioppo & Cacioppo, 2014). In this respect, loneliness represents a distressing emotional state that either motivates to seek new relations and/or to repair current social contacts or either drives to a feeling of hopelessness and/or apathy (Perlman & Peplau, 1981).

Loneliness has usually been conceptualized as a mismatch between one's expectations about their social relationships and the reality of those relationships (Peplau & Perlman, 1982; American Psychiatric Association, 2023). Objective social isolation and perceived social isolation may appear to be similar albeit they are two different phenomena. The first refers to the low frequency of contact between a person and the others, the latter refers to the subjective perception of the person ideals and needs of social relationships (Cacioppo, Hawkley, Norman & Berntson, 2012). Typically, research on loneliness uses objective indicators such as social network size, the frequency of social contact or social involvement in activities, and subjective indicators of loneliness, which reflect the individual's perceived discrepancy between desired and actual social relationships (Perlman & Peplau, 1981; Cornwell & Waite, 2009).

Perceived social isolation (PSI) is usually associated to a momentary feeling, (i.e., state-loneliness), that fluctuates depending on social contexts and company (Qualter et al., 2015), and being related to individuals' intrinsic changes in belonging need and to idiosyncratic responses to loneliness triggering situations (e.g., being physically alone; Parkhurst & Hopmeyer, 1999). This has been characterised as differential reactivity hypothesis for which lonely individuals respond differently to triggers in the environment, particularly lonely adolescents report higher loneliness levels when physically alone compared to non-lonely pears, and that intimate social situations (e.g., being with close friends) act as protective factors (van Roekel, Scholte, Engels, Goossens & Verhagen, 2015; van Roekel, Verhagen, Engels, Scholte, Cacioppo & Cacioppo, 2018). Social isolation however can be also understood as a chronic condition not tied to contextual features, (i.e., trait or chronic-loneliness; Shiovitz-Ezra & Ayalon, 2009), which represents a major risk for morbidity and premature mortality, independent of objective social isolation and health behaviours (see review by Leigh-Hunt, Bagguley, Bash, Turner, Turnbull, Valtorta & Caan, 2017).

Independently of the temporal aspect in which one can feel lonely, Cacioppo, Cacioppo, Cole, Capitanio, Goossens, and Boomsma (2015), described loneliness as a condition that unfolds in three different although related facets: a) intimate loneliness –subjective perception of missing a significant other (Weiss, 1973 in Cacioppo et al., 2015; Maes, Vanhalst, Van den Noortgate & Goossens, 2017.)–, b) relational loneliness – subjective perception of lacking quality social connections (i.e., sympathy group, usually includes between 15 and 50 people, Buys & Larson, 1979, Dunbar, 2014, and Weiss, 1973 in Cacioppo et al., 2015)–, and c) collective loneliness –person's perception of their active network (i.e., where an individual has the possibility to connect even at distance with others, Dunbar, 2014 in Cacioppo et al., 2015)–. A vast number of studies have suggested that lacking an intimate partner significantly increases the chances of feeling lonely (e.g., Hughes et al., 2021; Schmitz, Mauritz & Wagner, 2021)

Regardless of the distinction between momentary and chronic loneliness both have been related to negative outcomes and are negatively related to happiness (Martín-María, Caballero, Miret, Tyrovolas, Haro, Ayuso-Mateos & Chatterji, 2019). In fact, population-based longitudinal research suggests that perceived social isolation is a major risk for morbidity and mortality, independently of objective social isolation and health behaviours (Cacioppo et al, 2015) and it is a common experience with increasing prevalence in industrialized countries (Cacioppo et al., 2015). Many systematic reviews and meta-analyses focusing on mental health outcomes have evidenced associations between loneliness, anxiety, depression, hopelessness, and uselessness (Aartsen & Jylhä, 2011; Gum, Shiovitz-Ezra & Ayalon, 2011; Courtin & Knapp, 2017; Böger & Huxhold, 2018; Barreto, Victor, Hammond, Eccles, Richins & Qualter, 2021; for a review see Dahlberg, McKee, Frank & Naserr, 2022). In addition, the association between loneliness and physical health suggests increased risk for cardiometabolic disease, poorer sleep quality and overall higher mortality rate (Park et al., 2020; Holt-Lunstad, Smith, Baker, Harris & Stephenson, 2015; see Maes, Qualter, Vanhalst, Van den Noorgate & Goossens, 2019 for a metanalysis). Evidence from a cross-cultural study aimed to explore the prevalence of loneliness across the 25 European nations found that elderly people are more prone to suffer from loneliness than younger adults, and that residents in Northern European countries were less likely to report feeling lonely compared to Southern European nations (Yang & Victor, 2011). More recent population-based studies have provided further evidence that loneliness affects prevalently the elderly (Margrett et al., 2011; Nyqvist, Nygård & Scharf, 2019).

Further to the association between loneliness and physical and mental health, there is also evidence that loneliness affects cognition (Cacioppo & Hawkey, 2009). In depth analysis on the relationship between loneliness and cognitive function will be address in the next section.

Theoretical models on loneliness

Physical and Social Pain Overlap Model

Eisenberg and Lieberman (2004) posed that threats to social connections are processed in an ancient ontogenetic system, given that they represent a higher risk to the survival of the individual and that the system must act as an alert signal to point out the danger. The Physical and Social Pain Overlap model suggests that processing social pain relies on the same mechanisms as processing physical pain and that the overlay between processing occurs because the physical pain detection system was already developed when animals evolved to respond to social exclusion (Eisenberg & Lieberman, 2004). Additionally, the model suggests that given the interconnection between systems, the factors that enhance the sensitivity to one may also affect the other, and vice versa. Namely, endogenous, and exogenous factors that attenuate the sensitivity of the physical pain system may downregulate the social pain system too. Based on the Social and Physical Pain Overlap model, MacDonal and Leary (2005) proposed that painful feelings triggered by social exclusion function as an alarm signal to effectively avoid exclusion. That is, the painful emotions serve as a signal to alert an individual to stay away from rejection and to approach acceptance.

Conflict-Monitor Model on Ostracism

Evidence from lesion and neuro-stimulation studies have found that the anterior cingulate cortex –mainly the dorsal part– and the periaqueductal grey area, underlying processing physical pain play an important role in social pain (e.g., separation distress in children, romantic rejection from peers and grief; Tchalova & Eisenberg, 2015). The activation of the anterior cingulate cortex however is not only related to pain processing, but it also reflects conflict monitoring (e.g., Bolling, Pitskel, Deen, Crowley, McPartland, Mayes & Pelphery, 2011; Le, Zhornitsky, Wang & Li, 2020). Accordingly, the Conflict-Monitor Model on Ostracism (Eisenberg, Lieberman & Williams, 2003) suggests that being ostracised constitutes a violations of expectations and yields a conflict-based reaction (Sleegers, Proulx & Van Beest, 2017). Evidence from electrophysiological studies show enhanced N2 and P3b amplitude related to conflict-monitoring system and to context-updating in socially excluded participants (Weschke & Niedeggen, 2015; Hudac 2018). As with the Social and Physical Overlap model, this model focuses on transient situations of social exclusion, and thus, lacks explanation on the underlying mechanisms of loneliness chronification.

Temporal Need-Threat Model

The temporal Need-Threat Model (Williams, 2007) is based on two premises, the first is that belonginess is a need, and that without that connection with others, individuals suffer physical and psychologically (Baumeister & Leary, 1995). The second premise is that the act of ostracism is an evolutionarily adaptive group behaviour, which appears to happen across a wide range of animal species, and which has occurred across human history. The model describes three stages in processing ostracism and social exclusion at 1) reflexive; 2) reflective and 3) resignation stages. Williams (2007), suggests that correctly detecting ostracism and adequately responding to it allows the individual to increase survival opportunities. Given that exclusion has severe negative consequences for the ostracised individual, it has been posed a detection bias, which allows to quickly detect ostracisms signals, even when they are false alarms. Subsequently after detecting ostracism signals an initial reflexive stage is deployed, through which pain (i.e., high distress, threatened fundamental needs, reduced positive affect, and increased negative affect) acts as a warning signal to orient the individual’s attention to the given event. At the reflective stage, the excluded individuals appraise the importance of the ostracism event to effectively restore the threatened needs. The model suggests that during this phase, individual differences in self-esteem, anxiety, self-regulation ability or rejection sensitivity, play a key role in the speed of recovery. The last stage, resignation, occurs when ostracised individuals remain excluded for long periods of time, either by the same group/individual or by others, and the main feature is that they become affectively numb and cognitively deconstructed. In the long-term, ostracised individuals display a passive attitude towards life, suggesting that if perceived ostracism continues over time it can lead to negative psychological outcomes.

Rational Emotive Behaviour Therapy Theory

The Rational Emotive Behaviour Therapy Theory, (David & Szentagotai, 2006), which assesses negative evaluations of one’s representation of the world, assumes the existence of four features-demandingness, catastrophising, low frustration tolerance, and depreciation beliefs- related to specific negative cognitions (i.e., irrational beliefs) as well as four attributes -preference, non-catastrophising, high frustration tolerance and acceptance beliefs- related to specific positive cognitions (i.e., rational beliefs). Irrational beliefs, referred to both internal and external life-events, are central to the development of emotional, behavioural, and psychophysiological responses that are detrimental to health (physical and mental, i.e., psychopathology account). In contrast, specific positive cognitions of internal and external live-events are related to the development of emotional, psychophysiological, and behavioural responses that are protective of well-being (i.e., psychological health account). This means that whereas the psychopathology account suggests that the bias toward negative and threatening stimuli that characterizes lonely individuals perpetuates and reinforces both perceived and objective isolation, the psychological health perspective suggests that higher frustration tolerance and a non-catastrophising narrative may be protective factors against loneliness. Hyland, McGinty, Karatzias, Murphy, Vallièrs & Power (2018), provided evidence in support of the Rational Emotive Behaviour Therapy Theory by showing that even if both psychopathology and psychological health accounts explain differences in loneliness, the irrational beliefs accounted for greater effect. Other similar models on loneliness are the Theory of Mental Incongruity (Münch, 1972) suggests that lower self-esteem and social support are the main features of long-lasting loneliness whereas the Theory of Relational Loneliness (van Baarsen, 2002), attributes it solely to lower social support (Münch, 1972; van Baarsen, 2002).

Social Information Processing Model

The Social Information Processing Model, (Dodge & Crick, 1990), developed to explain the divergences on social cognitions between maladjusted and socially adjusted children, posits that social experiences provide children with feedback about their social relations, but also about themselves and the others. The model assumes that differences in social cognition along with differences in attributional styles (internal or external) play a key role in loneliness. More specifically they pose six non-linear stages of cognitive processing that result in a given behaviour: (1) cue encoding, (2) cues interpretation, (3) goals clarification, (4) response access and subsequent decision, (5) enhancement of the selected response and (6) memory. It is argued that people attend to both situational and internal cues, which are encoded and interpreted, yet such interpretation is influenced by cognitions about the self and the situation, by past experience as well as by attention allocation. As previously mentioned, this model was developed as an attempt to explain aggressive behaviour deployed by social maladjusted children, in this light, it has been evidenced that aggressive children tend to rely more on previous experience (i.e., schemata) and pay more attention to aggressive cues, but also they pursue goals that are unfit for social relations (e.g., show aggressive behaviour toward the others but also try too hard to get others to like them), and show a narrow repertoire of responses (Crick & Dodge, 1994). Accordingly, the model poses that lonely individuals display the same cognitive-behavioural pattern as socially maladjusted children: selective attention toward social negative stimuli and a tendency to rely on schemata. As for aggression, goal clarifications and past experiences (i.e., memory) would make lonely people more prone to select and display nonoptimal responses, resulting in further isolation. In other words: negative misconceptions about the environment and the others lead lonely people to deploy cognitive and behavioural processes that reaffirm not only that the others and the social context are threatening, but that he/she is not capable of enact adequate responses in order to fulfil salutary relationships (Crick & Dodge, 1994).

Evolutionary Theory of Loneliness

The Evolutionary Theory of Loneliness, (Cacioppo et al., 2018b) describes loneliness as an aversive emotional state with a biological signal that motivates the repair or replacement of non-salutary relationships. Accordingly, humans are innately social beings as relationships with others have increased the likelihood of reproduction and survival through sharing and collaborating. Establishing beneficial and reliable social relations increases the evolutionary fitness, that is the probability that the line of descent from an individual will hover and/or increase in the population. Since survival depends also on the capability of the individual to correctly distinguish foe from friend and that establishing and maintaining salutary social relationships increases evolutionary fitness, correctly identify social cues is needed to satisfy both conditions and the brain has evolved to do so. The Evolutionary Theory of Loneliness

(Cacioppo et al., 2018b) posits that loneliness results from individuals assessing their need to belong as unfulfilled and their social relationships as lacking, which is experienced as aversive and motivates attempts at resolving the situation. Therefore, loneliness motivates individuals to seek and establish social relationships to eliminate the negative feeling of loneliness but also to experience rewarding social relationships. In this view, loneliness has a signal value, which automatically triggers a set of genetic, neural, hormonal, behavioural and psychological interrelated functions including: (1) increased sleep fragmentation; (2) stress due to the increased activation of the hypothalamic-pituitary-adrenocortical (HPA) axis; (3) selective sympathetic immunity; (4) altered transcriptome dynamics; (5) decreased viral immunity; (6) increased inflammatory substrate; (7) increased prepotent responding, and (8) increased depressive symptomatology (Cacioppo et al., 2018b; Cacioppo & Cacioppo 2016; Cacioppo, Cacioppo, Cole, Capitanio, Goosens & Boomsma, 2015). The deployment of such response might be innocuous in the short term, but in the long run may lead to premature mortality (Cacioppo et al., 2018).

Multimotive Model of Rejection

The model proposed by Richman and Leary (2009) describes how people react to threats to social inclusion and belonginess by taking into account different relational, contextual, and dispositional factors. Those three aspects influence people's responses –seek acceptance, harming others, and withdrawal– to negative interpersonal events such as social exclusion, ostracism, stigmatisation, rejection, or neglect, and their short- and long-term consequences. The model suggests that all threats to acceptance and belonginess are related to an immediate response of higher negative affect and lowered self-esteem. After the immediate response, there are six construal that determine people's response to the social negative situation. The first construal refers to the cost of rejection, according to which rejections with higher costs are stronger motivators for the individual to behave in a way to restore social relations. The second construal refers to the possibility to reconnect, according to which if the alternatives to establish connections with others are high, then the person will avoid the current negative relation. The third construal refers to the possibility to repair, according to which if the individual thinks that the current relation can be repaired, he/she will adopt a more prosocial or approach-related behaviour. The value of the relationship construal assumes that if the relation is highly valued then the person would be more motivated to repair it. The chronicity construal assumes that if the rejection situation has a pervasive nature, it will predict avoidant or withdraw behaviours. Lastly, if the individual perceives that the rejection has been fair, he/she will be more prone to restore the connection. If the responses of the individual lead to a restored sense of acceptance, then the rejection situation would not exert any long-term negative consequences on mental and physical health. In contrast, if the person responds so that the sense of acceptance is not restored, then the rejection would have a negative long-term impact on mental and physical health.

Integrative Model of Loneliness

Finally, considering that the changes in cognition engendered by loneliness are similar to those shown by children with social maladjustment (i.e., Spithoven, Bijttebier & Goossens, 2017), it has been proposed that better predictions would be possible by combining the Evolutionary Theory of Loneliness (Cacioppo et al. 2018) with the Social Information Processing model developed (Crick & Dodge, 1994). Established that loneliness motivates all people to resolve the negative feelings that result from the unfulfilled need to belong, Spithoven et al., (2017) argue that loneliness causes both an initial social withdrawal, which allows an effective analysis of social cues by physical distancing themselves from others, and a bias cognition to guarantee preferential processing of social stimuli. Combining both models results in the conceptualizing lonely people as characterised by a predominantly focus on negative or threatening social stimuli and by a negative bias for social cues. The negative cognitive biases include a hypervigilance toward negative and threat-related social stimuli, a negative attributional style towards themselves and others, and a predisposition to view the situations as unchangeable. As suggested by the Social Information Processing model (Dodge & Crick, 1990), these processing stages do occur in parallel and influence each other.

The various theories emphasize different components of loneliness, but they share two common features. First, they assume that lonely people tend to hold negative attributions, expect rejection, and evaluate themselves and others negatively (Spithoven et al., 2017). Second, they hypothesize that feeling lonely affects attention, interpretation, and memory for negative social stimuli (Cacioppo & Hawkley, 2009) and elicit an implicit hypervigilance for social threats, which negatively bias further processing (Cacioppo & Hawkley., 2009; Cacioppo, Weiss, Runesha & Cacioppo, 2014). Accordingly, lonely individuals tend to see their social world as threatening, hold more negative social expectations, and show a memory bias for negative social events.

Neural correlates of loneliness

The benefits resulting from loneliness signalling the need to repair or replace salutary relations (Cacioppo et al., 2014) go beyond social preservation, as social interactions play a key role for brain development and function across all ages (Blakemore, 2010; Beadleston et al., 2019). To assess to what extent loneliness is associated to stable changes in the brain activity a growing body of studies has used neuroimaging techniques. Findings have evidenced that perceived social isolation is associated with decreased regional grey matter volume in the posterior Superior Temporal Sulcus (pSTS), an area implicated in basic social perception (Kanai, Bahrami, Duchaine, Janik, Banissy & Rees, 2012; Zovetti, Rossetti, Perlini, Brambilla & Bellani, 2021 for a review), and increased regional grey matter in the left dorsolateral Prefrontal Cortex, related to executive function and emotion regulation (Kong, Wei, Li, Cun, Xue, Zangh & Qiu, 2014; Zovetti et al., 2021 for a review). In addition, loneliness is associated to reduced fractional anisotropy among areas of the ventral attention network, which may explain in attention shifting between endogenous and exogenous attention (Tian, Liang, Yuan, Chen, Xu & Yao; 2014; Tian et al., 2017; Zovetti et al., 2021 for a review).

Loneliness is also associated to smaller volume of the left anterior amygdala, hippocampus and cerebellum which are involved in social and emotional processes (Düzel et al., 2019), to increased activation of the inferior temporal gyrus, (IGT), involved in processing social information from faces (Yi, Li, Xiao, Ma, Fan & Dai, 2018), to increased functional connectivity within the right central operculum network and the right supramarginal gyrus involved in task set maintenance, tonic alertness and salience encoding, and to decreased functional connectivity between the cingulo-opercular and the fronto-parietal network indexing executive control processes (Layden et al., 2017).

Indeed, fMRI studies have found that lonely individuals show increased activation of areas of the visual cortex and altered activation patterns of the temporoparietal junction (TPJ) in response to unpleasant and threatening social stimuli, this pattern would be indicative of heightened attention towards negative social stimuli and impaired mentalization abilities (Cacioppo et al., 2015). Moreover, lonely individuals also show decreased activation of the ventral striatum in response to positive social stimuli, suggesting that pleasant social stimuli are experienced as less rewarding (Cacioppo et al., 2009). However, findings relative to the role of ventral striatum are mixed, as Inagaki et al., (2015) showed that loneliness was related to increase activity of the ventral striatum in response to pictures of close social circle in contrast to strangers. Recent evidence by D’Agostino, Kattan & Canli (2018) shows no association between loneliness and activity of the ventral striatum in response to social pictures. Importantly, these differences may be due to sample size as the sample in Cacioppo et al., (2009) consisted of 23 female university students whereas the sample in D’Agostino et al., (2018) consisted of 49 older adults and 50 younger adults. A recent metanalysis on the neural substrates of social exclusion (Vijayakumar, Cheng & Pfeifer, 2017) concludes that social exclusion and loneliness are associated to larger bilateral activation of ventromedial prefrontal cortex and medial orbitofrontal cortex and to increased activation of a small cluster in the left lateral prefrontal cortex, which included the ventrolateral prefrontal cortex and lateral orbitofrontal prefrontal cortex. This pattern of activation would suggest that compensatory brain activity of areas involved in cognitive control and self-regulation is recruited to compensate for the effects of social isolation on cognition. Further, loneliness has also been linked to increased functional connectivity between areas of the cingulo-opercular network, which could explain not only the hypervigilance towards negative stimuli (Qualter et al., 2013), and reduced executive control, (Hawkley & Capitanio, 2015) but also sleep fragmentation and elevated basal levels of vascular resistance (Layden et al., 2017, for a review see Lam et al., 2021) that have been observed in lonely individuals.

A recent metanalysis on the neural substrates of social exclusion (Vijayakumar, Cheng & Pfeifer, 2017) concludes that social exclusion and loneliness are associated to larger bilateral activation of ventromedial prefrontal cortex and medial orbitofrontal cortex and to increased activation of a small cluster in the left lateral PFC, which included the ventrolateral PFC and lateral OFC. This pattern of activation would suggest that compensatory brain activity of areas involved in cognitive control and self-regulation is recruited to compensate for the effects of social isolation on cognition. Further, loneliness has also been linked to increased functional connectivity between areas of the cingulo-opercular network, which could explain not only the hypervigilance towards negative stimuli (Qualter et al., 2013) and reduced executive control (Hawkley & Capitanio, 2015), but also sleep fragmentation and elevated basal levels of vascular resistance (Layden et al., 2017, for a review see Lam et al., 2021) that have been observed in lonely individuals.

Effects of loneliness on cognition

The drive to form social relationships has been associated to evolutionary benefits that include increased access to food and resources, higher safety from threats and predators, and enhanced opportunities for reproduction (Lamblin, Murawski, Whittle & Fornito, 2017). Perceived social isolation and the feeling of loneliness that it engenders are linked to biological warning mechanisms developed to guarantee that the individual acts in a way that restores social connections, enhancing survival. Accordingly, different theories on loneliness predict that the feeling of loneliness affects cognition at various levels, from early to late-stages of cognitive processing (e.g., Kyaw & Levine, 2023; see Boss, Kang & Branson, 2015 for a review; see Park et al., 2020 for a metanalysis).

Research on the effects of loneliness on cognition has often been conducted using tasks in which participants are induced to feel socially included or ostracised, or using instructions leading people to believe that they will face a future of social isolation. Importantly, the effects on cognitive functions occur not only when the person reports feeling lonely, but also when the person is led to believe that he/she will be lonely in the future, which has been interpret as showing that it is the perception of being lonely that impacts cognitive processing (e.g., Baumeister, Twenge & Nuss, 2002). Research on loneliness has also used different questionnaires that assess feeling lonely over time (Van Roekel et al., 2018).

Regardless of how perceived loneliness is induced and measured, the mechanism underlying the link between loneliness and cognitive processing rests on the assumption that as a negative state, loneliness motivates to reconnect with others to fulfil the innate need to belong but to do so lonely individuals first withdraw from social relationships (e.g., Cacioppo et al., 2018a), as this physical distancing allows to adequately observe and evaluate social situations (e.g., Williams, 2007; Qualter et al., 2015). Taking a step back modulates a series of cognitive processes aimed at prioritizing processing social over non-social information to increase the opportunity to reconnect with others (Spithoven et al., 2017). Yet, as social stimuli can represent the possibility to reconnect but also the possibility to be further excluded and isolated, lonely individuals who focus only on the latter often exhibit biases towards negative stimuli, typical of self-protective behaviour (Cacioppo & Hawkley, 2009). In the next sections, this evidence will be presented and discussed.

Research on the effects of social exclusion and loneliness on attention and empathy to social stimuli

Evidence on the effects of perceived social isolation on attention comes from studies that have manipulated ostracism to induce social exclusion and loneliness, being the Cyberball task (Williams, Cheung & Choi, 2000) the most used. It consists in a virtual ball-tossing game involving three characters. Participants are told that they are playing with other two-individuals who are connected via Internet. The participant controls one of the three characters whereas the other characters are controlled by the computer. In the social exclusion condition, the participant receives one toss from each character at the start of the game and then never again, whereas in the social inclusion condition, participants receive one-third of all tosses (i.e., 10 tosses). A control condition in which the characters are bins and participants toss the ball 10 times is not always included (Williams et al., 2000; Williams, 2007).

Various tasks have been used to assess the presence of attentional biases in lonely individuals. These tasks range from assessing how gaze directions of other individuals is interpreted by using the “cone of gaze” which refers to the range of gaze-angles interpreted as direct (Syrjämaki, Lyrra & Hietanen, 2020), to assess response to emotional faces signalling approach or avoidance (González, Yankouskaya, Alessandri, Loreto & Pecchinenda, 2022). This is because these tasks allow to investigate whether lonely individuals exhibit attentional biases towards specific types of stimuli, such as negative or socially relevant information, which therefore aids to understand how loneliness influences attentional processes and emotional processing.

It has been proposed that ostracised individuals show a tendency to misinterpret others cues as affiliative. Importantly, in social interactions humans rely upon information from other faces and especially, from the eyes, as gaze can communicate subtle but crucial signals about intentions and interests of other individuals (Baron-Cohen & Cross, 1992; Baron-Cohen, 1999; Preckel, Kanske & Singer, 2018). Processing eye gaze was likely developed because being aware of the focus of attention of others provides crucial information for assessing potential sources of threats or rewards, and conveys valuable information for social interactions (Haxby, Hoffman & Gobbini, 2002; Lang & Bradley, 2010).

Findings on the effects of social exclusion using the cone of gaze task has been mixed (Lyrra, Wirth & Hietanen, 2017; Syrjämaki, Lyrra, Wirth & Hietanen, 2020a). In both studies, using the Cyberball task, participants were assigned to the social exclusion or inclusion conditions, following which, they completed the Need Threat Scale (van Beest & Williams, 2006) and performed a cone of gaze judgment task. They were presented faces with slightly friendly expressions and either straight gaze (0 degrees) or gaze deviated of 2, 4, 6 or 8 degrees to the left or to the right. Participants judged whether the face was looking at the participant and rate how strongly or not they felt the gaze. Whereas Lyyra, Wirth and Hietanten (2017) found that ostracised participants showed a wider cone of gaze, that is they considered a wider range of angles as directed at them, Syrjämaky, Lyyra, Wirth and Hietanen (2020a) showed that ostracised participants not only judged a narrower range of gaze directions (i.e., smaller cone of gaze) as being directed at them, but also reported weaker impressions of being looked at. These latter findings were interpreted as showing that ostracised individuals who respond by seeking solitude might start to view others as unapproachable. However, it is unclear whether these different findings between studies are due to sample differences (college students vs adults).

Observed direct gaze, that is the gaze of another individual directed at the observer, and adverted gaze, that is the gaze of another person directed away from the observer, have different signal values. In fact, establishing eye contact and engaging in mutual attention has been often related to approach-oriented motivation. However, approach-oriented emotions can be positive when signalling affiliation in the case of happiness or negative as when signalling aggression in the case of anger (i.e., Shared Signal Hypothesis see Adams & Kleck, 2005). Research on direct-gaze has used this ambiguity as it can signal affiliation or aggression depending on the emotional facial expression portrayed to investigate whether lonely individuals show a negative attentional bias.

Research has used the attention disengagement task to assess whether direct-gaze holds the attention of lonely individuals. In the study of Syrjämaki and Hietanen (2018), using the Cyberball task, 62 participants were assigned to the social exclusion, inclusion, or control conditions after which they completed the Need Threat Questionnaire (van Beest & Williams, 2006) and performed an attentional disengagement task. Cue stimuli, which were randomly presented for 200ms or 500ms in the centre of the screen, were faces with direct or downward gaze. Target stimuli where horizontal and vertical lines that were displayed on the left or the right of the face. Participants were instructed to correctly identify if the target was a horizontal or a vertical line. Results showed longer RTs on trials with direct gaze compared to trials with downward gaze for the social inclusion group. In contrast, there were no differences in RTs in trials with direct and downward gaze for the social exclusion group. Therefore, socially excluded participants seem to avoid direct gaze probably because it would not reduce the distress elicited by social exclusion.

The gaze-cueing task has been used to examine whether lonely individual’s attention is automatically drawn to the same location of the gaze-cue or not. Capellini, Riva, Ricciardelli and Sacchi, (2019), allocated participants to a social exclusion or inclusion conditions of the Cyberball. After completing the Need Threat Scale (Williams, 2009) and the Rejection-related Emotion Scale (Buckley, Winkel & Leary, 2004) participants performed a gaze-cueing task. For Experiment 1 the gaze-cueing task consisted in the presentation of neutral faces looking straight ahead (900ms), after which the face could look left or right (200ms). Participants responded to targets “L” and “T” presented left or right of the fixation point. Experiment 2 used the same procedure but this time, instead of the face looking straight ahead, symbolic cues were used (i.e., an oval with a black segment; 900ms) with two X at the extremes. The directional cue was a black arrow pointing toward the left or toward the right (200ms). In both cases, results showed gaze cueing effects (i.e., faster RTs on congruent than incongruent trials), but no group differences.

Other studies have assessed attentional biases by using the dot-probe task which allows to investigate how lonely individuals allocate their attention to different stimuli. For example, across 3 experiments Xu, Li, Zhang, Sun, Fan, Zeng and Yang, (2015) investigated whether social exclusion promotes attentional biases toward social acceptance cues (i.e., smiling faces) or toward social exclusion cues (i.e., angry faces). In experiment 1, 40 students were randomly allocated to a social inclusion or exclusion conditions of the Cyberball. Participants then completed the Need Threat Scale (van Beest & Williams, 2006), the Positive and Negative Affect Schedule (Watson et al., 1988), and performed the dot-probe task. In this task a target was presented at one of the spatial locations previously occupied by a pair of faces (500ms), one emotional (angry or happy) and the other neutral. Half of the time the dot appeared at the same location as the emotional face (congruent trial), and half at the same location as the neutral expression (incongruent trial). Results showed longer RTs to targets that appeared at the location of neutral faces compared to targets that appeared at the same location as the emotional faces, indicating that emotional faces attracted attention. Importantly, participants in the exclusion group showed slower RTs to targets presented at the location of smiling faces, whereas there were no group differences for target presented at the location of angry faces. In experiment 2, 42 students underwent the same social induction and performed the same task, the only difference was that stimulus onset asynchrony was reduced to 200ms, to assess attentional orientation instead of attentional hold. Findings again showed longer RTs to probes presented at the location of neutral faces. However, this time two groups showed a different pattern: the exclusion group showed an attentional bias toward happy faces (i.e., short RTs to targets following happy faces compared to neutral faces) whereas the inclusion group showed an attentional bias to threat (i.e., shorter RTs to targets following angry faces than neutral faces). Finally, experiment 3 used the same procedure and task, with the only exception that 42 participants completed the dot-probe task with angry and smiling facial expressions paired together, rather than with a neutral face (presentation time of face pair was 200ms). Findings showed faster RTs to targets presented at the location of happy faces compared to targets presented at the location of angry faces for the exclusion group. Altogether these results indicate that momentary social exclusion results in an attentional bias toward affiliative cues which may signal the possibility for social reconnection.

DeWall, Maner and Rouby, (2009) in 4 experiments investigated whether social exclusion, manipulated by task instructions, increased attentional biases toward smiling faces. For all experiments undergraduate students first completed a brief demographic questionnaire and the Eysenck Personality Questionnaire (Eysenk & Eysenk, 1975), then they were assigned to one of three social conditions. In the future alone condition participants were told that probably they would end up being alone later in life, in the future belonging control condition participants were told that they would have stable and rewarding relations through live, while participants in the misfortune control condition were informed that they would become more prone to suffer accidents and injuries. Participants then completed the Brief Mood Introspection Scale (in Experiment 1; Mayer & Gaschke, 1988), or the Positive and Negative Affect Schedule (for Experiments 2, 3 and 4; Watson et al., 1988), and performed either one of three tasks. In experiment 1, 69 students performed a face in the crowd task, in which they were asked to find a target-face in a crowd of other faces (distractors). The facial expression of the target could be angry, sad, or smiling, (50% were male), presented among neutral distractor-faces of the same gender as the target. Participants completed 3 blocks (of 48 trials), consisting of a 3x3 matrix of faces in which the target was presented among 8 distractors. Findings showed that the future alone group detected smiling faces faster than the other two groups. In experiment 2, 46 participants performed a free viewing eye-tracking task in which 4 arrays of 4 angry, sad, neutral, and smiling faces to directly report eye-moments (i.e., more ecological measure of visual attention). Results show that future alone participants spent less time on sad faces compared to the other two groups. Similar to Experiment 2, Experiment 3 investigated whether social excluded participants deployed more attentional resources to positive social stimuli therefore, the task included two additional images per array (neutral and positive non-social pictures). Results from 85 participants showed that future alone group fixated more on smiling faces than the other groups, and that there were no differences for positive non-social images. Lastly, in experiment 4, 66 participants were told that they would send video messages to another participant (confederate), but half were told that their partner had to leave unexpectedly (irrelevant departure condition), and the others were told that their partner refused to work with them (social exclusion condition), and performed a dot-probe task, in which a smiling, angry or disgust face was paired with a neutral face. Trials began with a fixation cross (1000ms), replaced by the face pairs(1000ms), and then by a small dot that could appear at the same location as the emotional face or at the same location as the neutral picture. Participants' task was to respond to the dot based on location. Results showed slower RTs to targets presented at the location of smiling faces for participant in the personal exclusion group compared to irrelevant departure group. Taken together, these finding were interpreted as suggesting that social excluded participants attend more to affiliative cues (i.e., smiling faces).

Evidence on the effects of long-lasting form of social exclusion comes from studies that have measure self-reported feelings and perceived loneliness using questionnaires and evaluation scales (e.g., UCLA Loneliness Scale, Russell, 1996).

In an eye-tracking study Saito, Motoki, Nouchi, Kawashima and Sugiura (2020) investigated whether loneliness –assessed via the UCLA Loneliness Scale (Russell, 1996)– affects automatic attention to faces. They recorded eye movement of 44 college students performing a face-house task, consisting of 10 pictures of houses that contained a house, a yard, and the sky (i.e., targets) and 10 pairs of pictures of faces varying on warm/cold and competent/incompetent content (i.e., distractors). Participants responded based on whether the pictures were identical. Findings showed that lonely participants paid more attention to warm faces (i.e., made more fixations to warm faces) whereas competent faces capture the automatic attention of non-lonely participants (i.e., non-lonely-participants made more fixations to competent faces). However, the effect of distractors type on automatic attention was similar among groups such that both lonely and non-lonely individuals made a similar number of fixations to distractor faces, with the only difference being on the face content: warm for lonely and competent for non-lonely participants.

Ypsilanti, Robson, Lazarus, Powell and Overton, (2020) used a free-viewing task while eye movements were recorded to assess whether loneliness (assessed by the UCLA Loneliness Scale, Russell, 1996) is linked to self-disgust (measured by the Self-Disgust Scale, SDS; Overton et al., 2008). Eighty older adults performed a free-viewing task while eye moments were recorded during the presentation of 9 pictures of faces portraying neutral expressions (8 faces were taken from the IAPS database while 1 was a picture of the participant taken prior to the task). There were no differences between groups, although lonely participants had shorter fixation duration during the presentation of their own picture compared to the photo of the others.

Other studies have assessed whether loneliness affects Theory of Mind, which refers to the ability to understand other’s internal states (motivations, desires, beliefs, and emotions) and that those affect people’s actions and behaviours (Premack and Woodruff in Baron-Cohen, Leslie & Frith, 1985). Floyd and Woo (2019) investigated whether loneliness affect Theory of Mind abilities. Participants (N=1035) aged between 18 to 74 were randomly assigned to a non-social or social framing conditions. Participants were told that people who perform well on the task are more likely to succeed on every-day problem-solving situations, excel in school and attain good jobs (academic framing). Alternatively, participants were informed that people who performed well tend to also do well in every-day social situations, are more likely to form strong and long-lasting relations (social framing). Participants performed the Reading the Mind in the Eyes test (Baron-Cohen, 2001), in which they were presented with 36 images of the upper part of faces, only the eyes and the lower part of the forehead is visible, and they were asked to choose the emotional expression from one of four emotions. Findings showed a negative relation between loneliness and the accuracy in attributing emotions based on the eyes' expression.

Finally, some studies have explored the effects of ostracism on the ability to empathise. Empathy is at the core of social attention, and it has been conceptualised as the ability to share and understand the emotions of others while being aware of the distinction between the self and others (Decety & Jackson, 2004). Empathy provides with information about the others, but also about the environment, making it possible to detect potential threats based on body postures or the expression shown by others (Frith & Frith, 2006a, 2006b; Klein, Shepherd & Platt, 2009).

Fan, Jie, Luo, Pang, Xu, Yu and Zheng, (2021) in an ERP study investigated how social exclusion affects the ability to show empathy to the pain of others. Forty-five students were randomly allocated to either a social inclusion or exclusion conditions of the Cyberball. Participants then completed the Need Threat Scale (Zadro, Williams & Richardson 2004), Positive and Negative Affect Schedule (Watson, Clark & Tellegen, 1988), Rejection Sensitivity Questionnaire (Feldman & Downey, 1994) and the Interpersonal Reactivity Index (Davis, 1983), and performed a pain-empathy task. This task consisted of 60 coloured pictures of hands, 30 of which showed hands in a painful situation and 30 showed hands in neutral situations. Participants were asked to rate the content of each picture as pain or neutral. Behavioural evidence showed an overall increase on response times for painful pictures, but no group effects. ERPs evidence showed larger early N2 amplitude for pain stimuli but no group differences. In contrast, social excluded participants showed smaller P3 and larger LPP amplitude in response to pain pictures, interpreted as due to decreased attention towards pain stimuli and reduced top-down control in processing pain.

In addition, Hu, Zheng and Huang (2020), across 2 experiments investigated the extent to which lonely participants empathise with others who are experiencing positive emotions. Participants completed the UCLA Loneliness Scale (Russell, Peplau & Cutrona, 1980), NASA Task Load Index (Hart & Staveland, 1988) and performed an empathy-selection-task (Cameron et al., 2019), consisting of 30 trials, in which an image of a person is displayed. Participants choose between describing objective characteristics of the image or trying to feel what the person on the picture is feeling (in Experiment 1 only positive pictures were used while in Experiment 2 positive and negative pictures were included). After the task, participants had to complete the Multidimensional Scale of Perceived Social Support (Chou, 2000). Results showed that lonely individuals selected more the empathy decks and were more likely to avoid negative empathy trials compared to non-lonely individuals, and perceived higher social support from the people in the decks they chose to empathize with. Importantly, whereas after performing the positive empathy lonely individuals reported less loneliness, such that differences was not present after performing the negative empathy. Therefore, these findings suggest that loneliness does not affect empathy in general but negative empathy specifically as engaging oneself in positive empathy would help lonely people to decrease their loneliness effectively, whereas negative empathy fails to play a part in the loneliness intervention.

In summary, even though lonely people seem more prone to empathise with others, there is no accordance on the ulterior motive that guides prosocial behaviour of lonely people, results suggest that the motive of prosocial behaviour could be based on a more egoistic motivation: the interpretation of the interaction as a social reconnection might reduce the original distress of exclusion (Baston & Powell, 2003). This has led researchers to propose that loneliness and social exclusion mainly affect processing of socially relevant stimuli. In this context, evidence from studies using social stimuli such as faces show that lonely individuals prioritize social relevant positive stimuli: they detect faster and spend more time fixating smiling faces and they interpret a wider range of face-stimuli as directed to them (e.g., Lyrra, Wirth & Hietanen, 2017). In fact, results from cone-of-gaze judgments show that lonely individuals have wider range amplitude of direct-gaze (e.g., Syrjämaky, Lyrra, Wirth & Hietanen, 2020a). Finally, there is some evidence that lonely individuals avoid negative relevant social stimuli, in line with the hypothesis that loneliness motivates toward affiliative related cues and away from negative social stimuli (e.g., Xu, Li, Zhang, Sun, Fan, Zeng & Yang, 2015; DeWall, Maner & Rouby, 2009). Importantly, given that the majority of studies reported here have explored induced social isolation, it is not clear whether the effects of momentary social exclusion and loneliness are similar. However, if the underlying mechanisms are the same for momentary as well as for lasting social exclusion when loneliness is experienced over a longer period of times, some detrimental outcomes will appear, but the extent to which trait loneliness impairs attention is not understood, neither the implications of long-term feelings of loneliness on late stages of cognition such as memory, executive function, or emotional regulation.

Research on the effects of social exclusion and loneliness on different cognitive functions

Other studies have assessed the effect of social exclusion on the so-called executive functions (Altabácker et al., 2016), which refers to high-level cognitions such as planning, organizing, monitoring, encompassing response inhibition, working memory, task-switching, problem-solving and decision making (Cudo & Zabielska-Mendyk, 2019; Borai, Aly & Ibrahim, 2020). There is good evidence on the effects of ostracism on working memory reports impairments on different tasks, especially when task require more cognitive resources (e.g., Buelow et al., 2015; Xu et al., 2018; Fuhrmann, Casy, Speekenbrink & Blakemore, 2019; Paolini, Giacomantonio, van Beest, Baiocco & Salvati, 2019). These studies have focused on the effects of long-lasting forms of social exclusion among younger adults, as findings indicate that young individuals aged between 16 to 25 years frequently report feelings of loneliness (Surkalim et al., 2022).

More specifically, Buelow, Okdie, Brunell & and Trost (2015), investigated the effects of ostracisms by the Cyberball task on working memory and decision making. Seventy-four university completed the Positive and Negative Affect Schedule (Watson, Clarck & Tellegen, 1988), and the Need Threat Questionnaire (Van Beest & Williams, 2006) and performed the Digit Span subtest (Wechsler, 2008), in which participants are asked to recall a series of numbers in a forward, backward, and sequential manner, and the Iowa Gambling Task (Bechara, Damasio, Damasio & Anderson, 1994), in which participants choose cards from four decks of cards and depending on from which deck they choose, they win or lose money. Findings showed that participants in the social exclusion condition performed worst on the sequencing test and selected more cards from disadvantageous decks (i.e., decks A and B) on the Iowa Gambling Task.

Fuhrmann, Casy, Speekenbrink and Blakemore (2019) investigated the effects of social exclusion (by the Cyberball) on working memory. Participants [98 females aged between 10 and 38, of which 36 young adolescents (aged between 10 and 14); 35 mid-adolescents (aged between 14 and 17), and 27 adults (from 18 to 38 years old)], completed the Need Threat Questionnaire (Williams et al., 2000), performed two versions of the *n*-back task (i.e., 0-back, and 2-back) and the dot-matrix task. In the n-back task, participants view a sequence of numbers and are asked to indicate whether a given stimulus matches the one from *n* steps back. Larger *n*-back increases cognitive load. In the dot-matrix task, participants have to correctly recall the sequence in which a series of dots appeared in a matrix. Excluded young adolescents showed greater performance impairment on the 2-back condition than for the 0-back and there were no group differences on dot-matrix task. These findings were attributed to young adolescents having lower inhibitory control and executive function ability rather than to the effects of social exclusion situation. It is possible that differences due to social exclusion may emerge between groups when more demanding tasks are used.

Paolini, Giacomantonio, van Beest, Baiocco & Salvati (2019), investigated whether social exclusion affects working memory capacity in 88 male participants of which 44 considered themselves homosexuals and 44 considered themselves as heterosexual. Participants were randomly allocated to a social exclusion or inclusion conditions of the Cyberball after which they performed a computerized version of the operation span task. Participants had to solve a series of math problems while retaining a letter in memory as they would have to correctly recall it at a latter moment (after 3, 4, 5, 6 or 7 math problems). Results show that socially excluded homosexual participants had lower working memory capacity compared to socially excluded heterosexual participants, indicating that social exclusion in stigmatized groups impairs working memory ability more than in non-stigmatized groups.

Xu, Qiao, Qi, Li, Diao, Fan & Yang, (2017) investigated how social exclusion affects working memory performance in two experiments. Thirty-eight female students, randomly assigned to social exclusion or inclusion conditions of the Cyberball, completed the Need Threat Scale (van Beest & Williams, 2006), the Positive and Negative Affect Schedule (PANAS: Watson, Clarck & Tellegen, 1988) and performed a lateralised change detection task (Vogel, McCollough & Machizawa, 2005) while EEG was recorded. The task consisted of a brief bilateral array presentation of coloured rectangles (red and green) of multiple orientations, and participants' task was to memorise the orientation of the red rectangles presented in either one of the two arrays. An arrow pointing to the left or right indicated the rectangles to be remembered, after which the array was displayed (100ms). Following a 900ms retention interval, the test array was presented. There were four task conditions with varying difficulty: one target-one distractor, two targets no distractors, two targets-two distractors and four targets no distractors. From the EEG data, the contralateral delay activity (CDA) component –associated to working memory storage capacity– was extracted. Behavioural results show that excluded participants had lower retrieval rates but there were no differences on storage capacity with the socially included participants. Importantly, included participants showed a progressive amplitude enlargement of the contralateral delay activity (CDA) with increasing task difficulty, whereas socially excluded participants did not. In Experiment 2 the same procedure was used, and 36 participants were asked to remember one to five coloured squares and to indicate whether or not the to-be-remembered items changed colour. Behavioural data revealed no group differences, but ERP results showed that socially excluded individuals exhibit reduced amplitude of the CDA component with increasing task complexity. Therefore, the present findings indicate working memory impairments in lonely people.

On cognitive control Cacioppo, Balogh and Cacioppo (2015) investigated whether loneliness (measured with the UCLA Loneliness Scale; Russel, 1996) affects interference from negative social stimuli while EEG recording. Young adults with high (N=38) or low (N= 32) loneliness performed a social Stroop (30 emotional, of which 15 positive and 15 negative, and 30 social, of which 15 positive and 15 negative words), and a colour-word Stroop tasks with words presented in four different colours. Participants' task was to press one of the four buttons of a key-pad that corresponded to the colour of the ink of each word presented. EEG findings showed that lonely participants were faster to respond to negative social words compared to non-lonely individuals (i.e., lonely participants responded approximately 200ms faster compared to non-lonely participants). Interestingly, whereas negative social and non-social stimuli did not elicit different early microstates (i.e., specific brain-activity patterns that occur shortly after a stimulus), positive social and positive non-social stimuli elicited different early microstates which might indicate that even if negative stimuli elicit attention faster this processing is not as sensitive to social characteristics compared to positive stimuli. Similarly, Gardner, Pickett, Jefferis and Knowles (2005, Study 2) asked 74 university students to complete a vocal-emotional Stroop task with 32 words' voice recordings, half of which semantically positive and half semantically negative. Voice tone was also manipulated (positive or negative) such that half of the time it was congruent with the valence of the spoken word, and the other half was incongruent. Participants identified the valence of the word while ignoring the emotional tone of the speaker. Results failed to show greater interference from negative social tone in lonely participants. In contrast, Shin and Kim, (2019), using a similar vocal Stroop-task with socially related positive and negative words (e.g., friends and foes, respectively), showed that lonely participants had slower responses on trials with negative vocal tone, especially when the content was social related.

Xu and collaborators (2020) evidence that ostracised participants demonstrated weakened proactive control and enhanced reactive control. In the first study, 43 female students were randomly allocated to either a social inclusion or to a social exclusion condition of the Cyberball, after which they completed the Need Threat Scale (van Beest & Williams, 2006), the Positive and Negative Affect Schedule (PANAS: Watson, Clark & Tellegen, 1988), and performed the AX-Continuous Performance Task (Chaillou, Giersch, Hoonakker, Capa, Doignon-Camus, Pham & Bonnefond, 2018). The task consisted in presenting one of two letters (A or B) as cues, followed by a probe (X or Y). Participants were asked to respond as accurately and quickly as possible based on whether X followed A. Trials started with a fixation cross (presentation time varied randomly between 1000 and 1400ms), followed by the cue (300ms), followed by another fixation cross, which after 1400ms was substituted by the probe. For the ERPs data, the P3b and the contingent negative variation (CNV) components related to stimuli attentional processing and response preparation, respectively, and the N2 and P3a components, related to conflict monitoring and conflict resolution, were analysed. Smaller P3b and CNV amplitudes are related to weakened proactive control, whereas larger P3a and N2 amplitudes are associated with enhanced reactive control. Behavioural results showed that socially excluded individuals made more commission errors as they exhibited lower accuracy on the BX trials and they had smaller amplitudes for the d P3b and CNV indicative of a weakened proactive control, as well as smaller P3a amplitude and more negative N2 component, indicative of enhanced reactive control. In study 2 a similar procedure was used, and 43 female performed a cued-Flanker task while EEG was recoded. The task consisted in a presentation of a centred arrow flanked by two distractors arrows pointing either in the same direction (congruent) or different direction (incongruent trial) as the central one. Additionally, the colour of the cue could be informative or uninformative: red and green indicated a left-right identification, blue and purple indicated an up-down, whereas yellow was uninformative. P3b and CNV components related to stimuli attentional processing and response preparation were analysed. Behavioural results showed no performance differences between socially included and excluded participants. In contrast, ERPs findings showed smaller P3b and CNV amplitudes in excluded participants suggesting overall diminished cognitive control in perceived social isolation.

Zhu and Wang (2017) in two experiments used a gambling task to explore the effects of perceived social isolation, assessed by the R-UCLA Loneliness Scale (Russell, Peplau & Curtrona, 1980). The task was divided into a gain and a loss scenario, containing each 28 trials. On each trial participants had to decide between a safe choice –winning or losing money with certainty– and a risky choice –winning or losing money with a 50% probability–. Experiment 1 included 93 university students, and results showed that on the gain condition individuals with higher loneliness scores showed a tendency to avoid risk comparted to participants with lower loneliness scores, while no difference was found on the loss scenario. Experiment 2 included 133 university students that were randomly allocated into gain condition and loss condition, each group was then assign to either gain scenario –hypothetical possibilities to win money–or loss scenario –hypothetical possibilities to lose money– of the gambling task, and after each decision participants were asked to score the difficulty of the made decision. Participants then had to complete the Perceived Loss of Control Scale (Newcomb & Harlow, 1986). Results showed that on gain scenario high-loneliness individuals avoid risky choices compared to low-loneliness participants

If lonely individuals are characterised not only by misinterpreting painful expressions as aggressive, it is possible that this effect is also present in other processes such as emotional recognition and memory. Smith, Norman and Decety (2020) investigated whether changes in loneliness affected emotion recognition in 112 medical students. Participants performed an emotion-recognition task at the beginning and at the end of each academic year for the first three years. The emotion recognition task consisted of 64 videos of actors portraying different facial expressions: happy, sad, angry or pain, 16 videos were displayed for each emotion. Findings showed reduced ability to discriminate sad and angry faces, but no difference for painful or happy faces. Importantly, higher loneliness was associated an increased bias to mislabel emotions as painful and angry. Lonely students also required less time to correctly label sad faces. This evidence is in line with the suggestion that loneliness is maintained by a positive feedback, according to which lonely participants are more efficient in recognizing negative emotions.

Pearce and collaborators (2020) asked participants (2632 participants, age from 16 to 99 years), to read some extracts of an individual's diary and, after a delay, to list as many events as they could from the diary. Results showed a positive relation between loneliness and recall for negative events, but not with recall accuracy. In a second experiment 22.054 participants, age from 16 to 99 years, were randomly assigned to a non-social or a social framing conditions, participants were asked to choose the emotion that best characterises the expression portrayed by a set of 24 faces from four options: happy, fearful, angry, or sad. Results again showed a positive relation between loneliness and recall for negative events, yet effects were small. These findings highlight that lonely individuals are more prone to remember negative events, but it is unclear whether this is due to a mood congruency effect according to which information that is affectively congruent with the current mood is better remembered or it reflects impaired performance for positive information.

Other studies have assessed whether loneliness affects trusting others which is another aspect of social cognition. In a fMRI study, Lieberz et al., (2021) asked 40 lonely young adults and 42 non-lonely young adults (assess with UCLA-L, Russell et al., 1980), to perform 2 tasks. An adapted version of a trust-game, in which the investor, chooses whether he/she wants to invest in an unknown trustee, who can keep all the money for him/herself or share the money with the investor was used. Participants always played as investors and were to think that they were playing against another player (trustees' responses were pre-recorder). Participants also performed a risk-task, in which they invested money, the computer would randomly decide whether the money would be share or not. Additionally, they completed questionnaires assessing personal trust and an interpersonal distance to strangers' task in which they were to tell the ideal distance to a stranger as well as the distance where they felt slightly uncomfortable. Lonely participants reported less interpersonal trust compared to non-lonely individuals as well as greater preferred interpersonal distance to strangers. Behavioural result showed overall lower investments for the high loneliness participants. Neuroimaging analysis revealed enhanced activity on the trust-related brain areas during the trust game compared to the risk game (i.e., insula, medial prefrontal cortex, hippocampus, amygdala, and temporo-parietal junction). However, lonely participants showed lesser activation in the left anterior insula, right nucleus accumbens and left amygdala compared to non-lonely individuals during the trust game (i.e., brain areas related to rewards, e.g., Weinstein, 2023).

In an EEG study, Cacioppo, Bangee, Balogh, Cardenas-Igniguez, Qualter and Cacioppo, (2016), asked 19 young adults –10 high in loneliness and 9 low in loneliness– to perform an evaluative task, consisting of 28 images that varied in social/non-social and threat/not-threat content presented for 1s, after which participants judged the valence of the picture. Results indicated that lonely participants showed fewer microstates toward social threats and different activation patterns in regions including the visual cortex, the inferior and superior temporal gyrus, and the dorsolateral prefrontal cortex compared to non-lonely individuals. Altogether, these findings are indicative that lonely individuals may have trouble integrating trust-related information and that this could interfere in risky decision-making processes.

In summary, findings described the research assessing the effects of temporal social exclusion on cognition suggest that this momentary feeling of isolation is related to diminished performance on decision-making and working-memory (Buelow et al., 2015; Fuhrmann et al., 2019; Xu et al., 2017; Paolini, 2019), as well as poorer cognitive control (Cacioppo et al., 2015; Gardner et al., 2005 Exp. 2; Xu et al., 2020). Similarly, research on chronic feelings of loneliness on decision making evidence that lonely individuals make are more conservative in their choices (i.e., they make less risky choices under loss expectations). Findings from research conducted with neutral stimuli have been inconclusive with regard to whether social exclusion yield decreased performance at tasks assessing executive functions. Another important aspect of cognition is emotional regulation which refers to the ability of the person accurately perceiving and identifying emotions in oneself and others. Research has suggested that lonely individuals show altered patterns of emotional recognition for which they easily recognise angry or painful faces but have troubles recognising happy faces (Smith et al., 2020). Other studies have also found that long-term loneliness is related to memory bias to negative emotions, that is, lonely individuals are more prone to remember negative past events (Pearce et al., 2020). Studies assessing social cognition suggests that lonely individuals are characterised by altered social evaluations of others compared to non-lonely individuals when lonely participants experience negative social interactions, they judge others as not-trust worthies (e.g., Lieberz et al., 2021; Cacioppo et al., 2016).

Conclusions

In this chapter, after providing a definition of loneliness, the different theories on loneliness have been described, followed by evidence from the available empirical studies conducted on young individuals. The current definition of loneliness sees it as resulting from the perception of being socially isolated and is characterised by the dissatisfaction with current social relationships. Loneliness can either be a momentary feeling (i.e., state-loneliness) or a more chronic state (i.e., trait-loneliness). According to most theories, a central aspect of loneliness is its adaptive functions, at least in the short run, as it acts as a warning signal to encourage to repair the unsatisfactory social relations or replace them with more satisfactory ones.

The different theories differ on the individuals' response to this initial alarm signal is depending on whether models have a more cognitive, cognitive-behavioural, or integrative perspective. Importantly, regardless of the theoretical approach, the effects of loneliness on cognitive functions occur not only when the person reports feeling lonely, but also when the person believes that he/she will be lonely in the future. This aspect nicely illustrates that, it is the perception of being lonely that impacts cognitive processing. Indeed, the research described in this chapter suggests that in the short run, loneliness is characterised by an initial attentional bias towards affiliative cues (Capellini et al., 2019; Xu et al., 2015; DeWall et al., 2009), which supports evidence that loneliness initially motivates to build and maintain social relations. However, if these negative outcomes persist over time, lonely people exhibit more avoidant-behaviour compared to non-lonely counterparts (Cacioppo et al., 2025).

This is in line with theoretical models on loneliness that postulate that lonely people tend to hold negative attributions, expect rejection, and evaluate themselves and others negatively and that feeling lonely affects a wide range of cognitive processes from attention to memory for negative social stimuli and elicit an implicit hypervigilance for social threats, which negatively bias further processing.

The neuroimaging evidence also shows associations between loneliness and brain areas related to social perception as well as executive function and emotional regulation (Superior Temporal Sulcus and dorsolateral Prefrontal Cortex; Kanai et al., 2012). In addition, loneliness is associated changes in brain activation that may explain difficulties on the successful attention shift between endogenous and exogenous attention (Tian et al., 2014). Importantly, loneliness is not only linked to changes in brain activity and brain structure, it also has been proved to affect performance at behavioural task assessing attention and executive function and especially when task difficulties increase (Zhu & Wang, 2017, Smith et al., 2020, Pearce et al., 2020).

In conclusion, research on loneliness has resolved some question as it has been related to negative physical health outcomes (i.e., increase risk of cardiovascular disease), whereas many others remain unanswered (e.g., how lonely individuals behave in a social setting). Understanding the effects of loneliness on social cognition has become critical not only to fill the gap in literature but also to enable interventions aimed to mitigate its negative outcomes.

CHAPTER 2

THE EFFECTS OF LONELINESS ON THE OWN AGE MEMORY BIAS FOR EMOTIONAL FACES

Introduction

It has been found that when individuals experience chronic feelings of loneliness, it can influence their perception and interpretation of social cues (for a review see Spithoven, Bijttebier & Goossens, 2017). This bias can lead to heightened sensitivity to social threats and increased vigilance for signs of rejection or exclusion (Cacioppo et al., 2018). Moreover, loneliness has been associated with negative self-perception and a tendency to interpret ambiguous social situations negatively (Zhu, Zhu, Gao & Luo, 2018; Ypsilantis et al., 2020). These cognitive biases can perpetuate a cycle of loneliness, as individuals may withdraw from social interactions or struggle to form meaningful connections.

This study focuses on the memory bias for social stimuli among lonely young adults. Although previous research has highlighted the influence of loneliness on various cognitive processes, including memory, there is still a significant gap in understanding the specific memory biases related to social stimuli in lonely individuals.

The own group memory bias

Human faces convey a wide spectrum of information, ranging from situational and transient information such as mood and intention, to categorical and less changeable information as race, gender, or age (Bruce & Young, 1986, Haxby, Hoffman & Gobbini, 2000). This information is important for social interactions. Importantly, attention to faces can be affected by an individual’s characteristics (Garner, Mogg & Bradley, 2006; Marini, Marzi & Viggiano, 2011) which in turn can affect memory encoding and recall (Burgees & Weaver, 2003). Accordingly, a well-known effect in face recognition is the so called own-group memory bias (Howard & Rothbart, 1980; Hugenberg, Young, Bernstein & Sacco, 2010; Fuller, Majolo, Flack & Ritchie, 2021) as people are better at remembering faces of their group.

Traditionally, there are two accounts for the Own-Group Bias. The social-cognitive evaluation account attributes the bias to differences in judgements for members of the own and other-group. More salient or positive evaluations of in-group members lead to preferential processing of own-group faces compared to out-group ones (for a meta-analysis see, Meissner & Brigham, 2001). For the perceptual expertise account, the bias is due to the greater contact and familiarity (experience) with individuals of the same group (Wiese, 2012). Most likely both accounts play a role in engendering the advantage for own-group faces (see the categorization-individuation model; Hugenberg et al., 2010). One the most studied features that allows in- and out-group biases is race, and results have robustly determined that individuals recognise more accurately faces of their own race than faces from other races (Meissner & Brigham, 2001; Valentine & Endo, 1992). Similar to the own-race bias, the own-age bias refers to the tendency to recognise those of similar age range as oneself more accurately than individuals of other ages (Wiese, Schweinberger & Hansen, 2008).

The own age memory bias

The own-age bias effect refers to the phenomenon where individuals demonstrate better recognition and memory for faces belonging to their own age group compared to faces from other age groups (Wiese, Schweinberger & Hansen, 2008). In a meta-analysis, Rhodes and Anastasi (2012) concluded that the Own Age Bias is a robust effect for correct recognitions (i.e., higher hit-rates for same-age), false alarms (i.e., higher for other-age faces), and discriminability (i.e., higher for same-age faces), but not for response criterion (i.e., no clear tendency for conservative or liberal responses for facial age).

In line with the perceptual expertise account, previous studies have point out that children, young and older adults show an own age bias, albeit the effect is greater in younger adults compared to the other age groups (Anastasi & Rhodes, 2005; Rhodes & Anastasi, 2012; Neuman, End, Luttmann, Schwinberger & Wiese, 2015). Recently, Cronin, Craig, and Lipp (2020b) have provided some evidence in support of the perceptual expertise account of the own age bias. On the first experiment, 182 participants were allocated to a middle-age and young adults' condition (N=90) or to a middle-age and older adults' condition (N=92). Participants performed a face task, which was subdivided into an encoding and a test phase. During the encoding participants were sequentially presented 24 male faces (12 young and 12 middle-aged adults or 12 older and 12 middle-aged adults) for 1000s or 1500ms and they were instructed to try and memorise them. In order to ensure participants paid attention to the faces hey were asked to press the spacebar as soon as the face disappeared. In between phases, a filler task was performed and lasted for 5 minutes. The test phase consisted in the presentation of 48 identities, 24 previously seen and 24 new faces, participants were instructed to respond "seen" if faces had already been viewed or "not seen" if faces were not previously seen. Results did not show differences in accuracy between conditions. On Experiment 2, 272 participants were equally distributed to a young-middle aged, to a middle-aged and older adult and to a young-older adults' condition. Procedure did not vary, with the exception that in the young and old condition, stimuli consisted of faces of young and older adults. Results evidence the presence of an Own-Age Bias in the young-old condition, and no performance difference between middle-aged/older and middle-aged/young adults. Finally, on experiment 3, 85 participants performed the same face task, with the exception that stimuli consisted on faces from middle-aged and younger adults. After completion of the face task, participants were directly instructed to categorise per age (for each of the faces presented participants had to decide whether the face was young or older). Results of the recognition task did not show differences in performance for middle-aged and younger faces, moreover, results from the categorisation task further fail to prove an Own-Age Bias. Even though findings suggest that Own-Age Bias can occur because of younger adults have more contact with peers that they have with older population, since no older adults were included, it cannot be concluded that Own-Age Bias is age specific to younger populations.

Evidence in support of the social-cognitive account also comes from studies demonstrating an Own Age Bias when using a mixed-list of own- and other-age faces, but not when using a pure-list of only own- or other-age faces (Bryce & Dodson, 2013). This finding has been attributed to the fact that the Own Age Bias only emerges when age is made salient in the mixed-list condition. However, Cronin, Craig, and Lipp (2020a) have recently shown evidence of Own Age Bias with mixed as well as with pure lists. More specifically, they conducted 3 experiments to explore the extent to which pure and mixed lists of young and older adults play a role on Own Age Bias. On experiment 1, 168 participants were randomly assigned to a mixed-list, a pure young list or a pure old list condition, (56 subjects for each condition). Participants on each condition performed a face task which was divided into an encoding and a test phase. Stimuli included 96 male identities, 48 young and 48 older adults. During the encoding phase 24 identities were displayed [mixed list (12 young and 12 older adults), pure young (24 young adults) and pure old (24 older adults)], one at a time for either 1000s or 1500s and to ensure participants paid attention to the faces, they were asked to press the spacebar as soon as the face disappeared. Participants completed a non-related filler task which lasted for approximately 5 minutes. During the test phase, participants completed the recognition test consisting of the 24 faces seen during encoding presented intermixed with a new set of 24 identities for each condition. Images were presented one at a time for up to 10s and participants were instructed to respond “Seen” or “Not Seen”, if they respond “Seen” they were prompted with an additional remember/know/ guess question asking if they “remember the face, think they know it, or are making a guess”. Results showed an overall Own-Age Bias, such as that independently of the condition in which participants were included, they were more accurate to recognise younger faces (own-age). On experiment 2, 177 participants underwent the same procedure and performed the same task, the only difference was that stimuli included 96 female identities (48 young and 48 older adults). Results showed an overall tendency to recognise better young faces, participants had fewer false alarms and made more conservative responses to young faces compared to older ones. Lastly, on experiment 3, 156 participants underwent the same procedure and performed the same task, the only difference was that during encoding phase faces were presented against 3 different backgrounds: a hospital, a basketball court, and a white rectangle, whereas during test phase background was a grey rectangle, this modification was set to test if age-stereotypical backgrounds influence categorization processes. Results, however, showed an overall own-age bias: participants committed overall fewer false alarms and made more conservative responses to young compared to older adult faces. Findings suggest that social categorization does not drive the Own Age Bias, as participants do show this effect for both pure and mixed lists.

Studies have shown that individuals, including young adults, tend to have superior recognition and memory for faces of their peers or individuals within their own age range. This bias can have implications for social interactions, as it may influence how individuals perceive and remember faces, potentially affecting their ability to form accurate impressions and maintain meaningful connections with individuals from different age groups. Even if evidence clearly shows that an Own Age Bias occurs with neutral faces, it remains unclear whether this effect also occurs with emotional faces.

Emotion modulation of the own age memory bias

Studies focused on the emotion modulation of this effect have found an Own Age Bias (i.e., faster, and more accurate recognition) for emotional faces of young individuals (Riediger, Voelkle, Ebner & Lindenberger, 2011; Ebner et al., 2013; Ziaei, Persson, Bonyadi, Reutens & Ebner, 2019). Denkinger and Kinn (2018) observed the Own Age Bias for emotional and neutral faces in young as well as in old individuals. They asked participants (68 young and 19 older adults) first to rate the likeability of a set of 50 young and old faces with neutral, positive, or negative expressions (emotion category not specified). After a filler task, participants performed a face recognition task (seen/not seen). Findings showed an Own Age Bias regardless of the facial expression, albeit the Own Age Bias was smaller for positive faces.

Ebner and Johnson (2009), failed to observe an Own Age Bias in young and old participants when using emotional and neutral faces. In their study, participants (32 young and 24 older adults) categorised old and young happy, angry, and neutral faces based on emotion, following which they completed a face recognition task (seen/not seen). In contrast, Cronin et al. (2019), have recently showed that emotional faces eliminate the Own Age Bias. They conducted 3 experiments using an intentional learning task at encoding (i.e., memorize faces) followed by a face recognition task (seen/not seen), separated by a 5-minute filler task. In experiment 1, neutral faces of young and old individuals were used, and findings showed an Own Age Bias (i.e., higher sensitivity to younger faces). In experiment 2 (72 participants) the same procedure was used with neutral and angry faces. Findings showed an Own Age Bias for neutral but not for angry faces. Finally, in experiment 3, neutral and sad faces (experiment 3a with 90 participants), or neutral and happy faces (experiment 3b with 90 participants) were used. Findings again showed an Own Age Bias, due to more accurate recognition for young neutral faces but not for young emotional faces.

The present study: the effect of loneliness and the own age memory bias for emotional faces

As previously mentioned, there is strong evidence that supports the Own Age Bias, however the effects of emotional expressions are not consistent. We hypothesise that Own Age Bias should occur and even be enhanced for emotional faces when the need for social contacts and social affiliation with one's peers is high. This assumption is based on recent work demonstrating that the need for social affiliation affects the neurobiology of emotional processing by activating effective and reward-related brain areas (Elsinger et al., 2021; Grennan et al., 2021). Moreover, it was suggested that the absence of positive social interaction may create a want, or 'craving', that directs behaviour to repair what is lacking by triggering emotional and motivation processes (Tomovva et al., 2022). However, this has not been investigated yet in relation to the own-age bias in faces processing and the present study intends to fill this gap (see Appendix 1 for the published article, Gonzalez et al., 2022).

The research question stems from evidence that loneliness, that is the social pain engendered by perceived social isolation, motivates people toward signals of possible reconnection (DeWall, Maner & Rouby, 2009). This is because lonely individuals show an acute need to re-establish social connections and prioritise affiliative signals (Xu et al., 2015; Syrjämaki & Hietanen, 2018). However, lonely individuals are also sensitive to signals of social rejection and prioritise social threats (Cacioppo et al., 2009; Cacioppo, Balogh & Cacioppo, 2015; Cacioppo et al., 2016). Consequently, as happy, and angry faces signal possible social affiliation and possible social threat respectively, they should be especially salient stimuli for lonely individuals. In addition, considering that the mechanisms underlying the Own Age Bias rely on expertise in social interactions with own-age individuals (Wiese et al., 2008; Hugenberg, Wilson, See & Young 2013; Wiese, Wolff, Steffens & Schweinberger, 2013) and/or on the salience of own-age individuals (Hugenberg et al., 2010) , it is well possible that lonely individuals, who have fewer and less satisfying interactions with their peers (Mund, Freuding, Möbius, Horn & Neyer, 2019) show a reduced Own Age Bias.

Method

All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Psychology Department Ethic Committee, Sapienza University of Rome. Informed consent was obtained from the study participants.

Participants

Two-hundred and thirty-five university students aged between 18 and 30 years old (age M= 21.23 SD= 2.08; Males= 42, Females= 193) took part in the study. Sample size was a priori calculated using G*Power software (Faul, Erdfelder, Buchner& Lang, 2009). We used the Own Age Bias effect size (d= .70, $\alpha = .05$; $\beta - 1 = .95$) reported by Cronin, Craig and Lipp (2019), which in turn is based on the Own Race Bias effect ($\eta_p^2 = .11$) reported by Gwinn, Barden and Judd (2015). This established that with d = 0.70, $\alpha = 0.05$, power = 0.951, 130 participants were sufficient to detect a moderate-large effect. In addition, calculations based on the effect size (t_{63}= 4.14, p<.001, d_{av} = 0.64) reported in exp. 1 by Cronin et al. (2019), established that with d=.64, a=.05, power=.951, a sample size of 108 participants was sufficient. However, as the experiment was conducted online, we oversampled to 235 participants.

Stimuli

Forty-eight identities (24 young adults: 12 males/12 females and 24 older adults: 12 males/12 females) were selected from the FACES database (Enber, Riediger, & Lindenberger, 2010). For each identity, neutral, angry, and happy expressions were selected for a total of 144 stimuli (72 young and 72 old). Young adult faces were between 22 and 33 years, older adult faces were between 61 and 80 years old. Images were in colour and 335 by 418 pixels in size. Based on available validation data (Ebner et al., 2010), the selected stimuli were balanced for distinctiveness, and expression accuracy. The 144 selected faces were divided in two equal sets of 72 faces (12 young faces and 12 older faces, all balanced for gender, with each of the 3 expressions), each set used for the encoding and test phases. As the FACES datasets has 2 versions of each face (version A and version B), each set of 72 faces was presented in both versions (if version A was presented at encoding, version B was presented at test phase as the “seen faces” together with the set of “new faces”). Which set of faces was used for encoding and test were counterbalanced across participants with two versions of the task (i.e., the 72 faces used for the encoding phase in one version of the experiment were used as “new faces” for the test phase in the other version of the experiment).

For male-faces, the selected young and old faces differed for age, $t_{(22)}= 26.471$, $p<.001$ but were matched for expression accuracy $t_{(22)}=.417$, $p=.171$ and distinctiveness, $t_{(22)}= 2.185$, $p=.74$. For female-faces, the selected young and old faces did differ for age $t_{(22)}= 23.573$, $p<.001$, but were matched for expression accuracy $t_{(22)}= 1.368$, $p=.185$ and distinctiveness $t_{(22)}= 1.261$ $p=.221$ (see Table 1).

	Male			Female		
Rating	Young	Old	*p*	Young	Old	*P*
Age	28.30 (3.44)	68.36 (3.95)	<.001	26.54 (3.08)	68.34 (5.31)	<.001
Expression (accuracy)	92.42 (4.83)	88.92 (7.06)	.171	88.42 (10.67)	82.08 (8.27)	.185
Distinctiveness	34.98 (23.62)	35.76 (22.41)	.74	38.8 (23.73)	35.88 (23.02)	.221

Table 1. Mean ratings (SD) for young and older selected faces

Questionnaires

The Italian version of the UCLA Loneliness Scale (Boffo, Mannarini & Munari, 2012) was used to assess loneliness. In addition, and for purposes not related to the hypotheses of the present study, two other questionnaires were used as a filler task. As in Cronin et al., (2019) participants were also presented with four questions aimed at assessing the frequency of social contacts with people of their own age group and with older people. Participants responded using an 8-point scale ranging from 1 (daily) to 8 (less than once a year). More specifically, the questions were: 1) How often do you have personal (i.e., face-to-face) contacts with young adults (approx. between 18 to 30 years of age)?; 2) How often do you have personal (i.e., face-to-face) contacts with older adults (approx. 65 years of age and older)?; 3) How often do you have other types of contact (e.g., phone, e-mail, letter) with young adults (approx. between 18 to 30 years of age)?; 4) How often do you have other types of contact (e.g., phone, e-mail, letter) with older adults (approx. 65 years of age and older)?

Tasks

Face Task (encoding phase): There were 144 trials, consisting of 72 young (36 females and 36 males, each with neutral, happy, and angry expression) and 72 old faces (36 females and 36 males, each displaying neutral, happy, and angry expressions. Pictures were displayed one at a time for 1500ms. To make the encoding task less predictable, the intertrial interval randomly varied between 1000ms and 1500ms. Participants were instructed to categorise each face based on age and responded by pressing “G” for GIOVANE (young) of “A” for ANZIANO (old). For each trial, the instruction “memorise the face” appeared below the face and remained onscreen the same as the face. Faces were displayed in a new random order for each participant.

Memory Task (test phase): There were 144 trials, consisting of 72 previously seen faces (36 young and 36 older faces) showing neutral, happy, or angry expressions intermixed with a new set of 72 faces (36 young and 36 old faces) showing neutral, happy, or angry expressions. Faces were presented on screen one at a time for 10s and participants responded whether they had seen or not seen the face previously by pressing “V” for VISTA (seen) and “N” for NON VISTA (novel). Faces were displayed in a new random order for each participant. As participants used their own keyboard to respond, to prevent labelling the keys, keys were chosen to be intuitive for each categorization task.

Experimental Design

The experimental design is a 2 (Face Age: young, old) × 3 (Face Emotion: neutral, happy, and angry) repeated measure design.

Procedure

The experiment was conducted online, using Testable (www.testable.org). The study was advertised using Moodle: students could read the study description on Moodle and sign up to complete the task online during the booked timeslots. On the day of the appointment, both participant and experimenter were connected via video-call (using Google Meet). After sending the link of the experiment, both participant and experimenter remained connected to the video-call via Google Meet.

Participants first read the description of the study and the experimenter answered eventual questions. Then, participants completed the informed consent, following which the questions of the UCLA Loneliness Scale (Boffo et al., 2012) and the 4 questions on social contact appeared onscreen. Participants completed the questionnaire before the Face Task to allow them to think about their social interactions. Upon completion of the questionnaire, the task instructions were presented onscreen. Participants were instructed to memorize a series of faces presented on screen as they would be asked to recognize them later. These intentional learning instructions are in line with other Own Age Bias studies (Rodhes & Anastasi, 2012). To further facilitate encoding, participants were also asked to categorise each face as young or old as soon as the faces disappeared from the screen. Following the encoding phase, participants completed a filler task (i.e., questionnaires unrelated to loneliness) for approximately 5 mins. Next, the instructions for the face recognition task appeared onscreen. Participants were informed that they were going to see some faces, some of which they had already seen during the previous task, and some were novel. Their task was to indicate for each face whether they had already seen it or not seen it. For both tasks, participants were asked to respond as quickly and accurately as they could. Finally, participants were thanked for the participation, were asked if they had questions, and were dismissed from the Google Meet video-call.

Data Analyses

Task Performance Measures: Two performance measures were used: response time (RTs) and accuracy for the Face Task (i.e., encoding phase) and the Memory Task (i.e., test phase). Data were analysed separately for each phase. Means RTs for correct responses were computed for each experimental condition. Accuracy, computed as corrected recognition (Pr), was calculated by subtracting the false alarm rate from the hit rate. For seen faces, false alarm rates represented the proportion of test trials in which the participant incorrectly responded ‘seen’ to a face that had not been seen before. Hit rates were computed as the proportion of test trials in which the participant correctly responded ‘seen’ to a face that was seen before. For novel faces, hit rates represented the proportion of novel faces that were correctly recognised as ‘novel’, whereas false alarm rates represented the proportion of previously seen faces that were recognised as ‘novel’.

Loneliness and social contacts: For the Italian adaptation of the UCLA, (Biffo etl., 2012), a total score was computed after reverse scoring five items: higher scores indicate more loneliness. To assess whether number of social contacts can predict loneliness scores, we carried out a multiple regression analysis with number of social contacts with young and older people as independent variables and UCLA scores as dependent variable. We used backward as the method of data entry and tested two models where one model included both independent variables, the second model contained only one independent variable. To test whether Own Age Biases could predict loneliness we used multiple regression analysis. We calculated the biases as difference in recognition scores between (i) Seen Angry Young faces and Seen Angry Old faces; (ii) Seen Happy Young faces and Seen Happy Old faces; (iii) Novel Happy Young faces and Novel Happy Old faces; (iv) Novel Angry Young and Novel Angry Old faces. These three biases were entered as predictors and UCLA score as dependent variable.

Reliability analysis: Recent work demonstrated that high measurement error for response time and accuracy could be detrimental to the analysis and the inferences drawn from it (Cooper, Gonthier, Barch & braver, 2017; Rouder, Kumar & Haaf, 2019). Therefore, prior to data analysis, we assessed the reliability of our measurements by estimating the internal consistency of accuracy and response times for the test phase. We used a permutation-based split-half approach with 5000 random splits (Parsons, Krujit & Fox, 2018, Parsons, 2020). In the split-half method, the data for a measure is split into two halves. The Pearson correlation between these halves with subsequently applied the Spearman-Brown (prophecy) correction for the underestimations resulting from splitting the number of observations in half is then calculated as an estimate of the measure's internal reliability.

Linear Mixed Modelling: To test the hypothesis that there is Own Age Bias for neutral but not for emotional faces, we applied a linear mixed modelling approach (LMM) (Bater, Kliegl, Vasishth & Baayen, 2015; Bates, Mächler, Bolker & Walker, 2014). The advantage of using this approach here is twofold. First, compared to a classical analysis of variance (ANOVA), LMM suffers less loss of statistical power if there are missing data (Quené & Van den Bergh, 2008) and in the test phase there is a small proportion of missing RT data. Second, LMMs allow us to estimate fixed effects and their interaction and simultaneously, parameters of the variance and covariance components of random effects due to subjects (Baayen, Davidson & Bates, 2008). The random effect of subjects, which is the subjects' deviations from the grand mean accuracy, and RT and subjects' deviations from the fixed-effect parameters is also of substantive theoretical interest here as it can provide future research with an important heuristic for identifying the sources of experimental effects. The contribution of the random effect of subjects was estimated using the Likelihood Ratio Test (LRT) (Judd, Westfall & Kenny, 2012). The likelihood ratio statistic is equal to two times the difference of the log-likelihoods of two models, where one model includes a parameter of interest (fitted model), and the second model (null-model) does not contain the parameter of interest. Normality in the distribution of the residuals of final models was assessed using quantile-quantile plots.

Each LMM model in the Faces Task included three fixed terms (Age (Old, Young), Emotion (Angry, Happy, Neutral), interaction between Age and Emotion (Age*Emotion)) and a random effect of Subjects to account for idiosyncratic variation that is due to individual differences. To incorporate categorical effects from factors with discrete levels into the LMMs, we based our analyses on contrasts, which allow us to code factors as independent variables in linear regression models. We used a simple coding scheme to contrast levels of the Age factor ([Old – Young]) and Helmert coding scheme to contrast levels of the Emotion factor ([Neutral – (Angry, Happy)] and [Angry – Happy]). All LMM models were estimated using Jamovi version 2.2 (The jamovi project (2020). [Computer Software]. https://www.jamovi.org).

Face Task (encoding phase): To test the effects of Age of faces (Old, Young) and Emotion (Angry, Happy, Neutral) on categorisation performance, we modelled accuracy and response time using two separate LMM models. A fitted model included accuracy or response time as a dependent variable, three fixed effects (Age of faces, Emotion, and interaction term Age*Emotion) and one random effect term (Subject).

Memory Task (test phase): First, to get an overall understanding of the performance and the central tendency of responses in the Face Task we used a bootstrapping procedure (Sui, He & Humphreys, 2012). For each condition, we paired RT (x) and accuracy (y) for each participant. The data sets were then resampled with a replacement but kept the sample size as the number of participants. This procedure was repeated 2000 times, and each resampled set was plotted as a single data point. This procedure allowed us to visualise both the mean and variance of the data for each condition and their overlap indicating potential bias effects. The bootstrapping procedure was performed separately for seen and novel faces. Second, four separate LMMs were used to estimate the effects of Age of faces (Old, Young) and Emotion (Angry, Happy, Neutral) on accuracy and response time for seen and novel faces.

Results

Face Task (Encoding Phase)

Accuracy (Pr): Overall, participants were accurate in categorising the age of faces (M_{old}=0.97, SD=0.05; M_{young}=0.98, SD=0.04). A LMM on Pr indicated that including a random effect of Subject benefited the model (LRT=190.01, df=1, *p* < .001). The results of fixed effects showed no effect of Age (F(1,1170) =1.94, *p*=.16) and Emotion (F(2,1170)=2.12, *p* =.1). The interaction between Age and Emotion was also non-significant F(2,1170) = 0.34, p=.71). A random effect of Subject explained 29% of the overall variation in accuracy responses.

Response Times (RTs): A LMM on RTs revealed no significant fixed effect of Age (F(1,1170)=0.21, *p*= .87, Emotion (F(2,170)=1.0, *p*=.34 and Age by Emotion interaction (F(2,1170)=0.56 *p*=.61). A contribution of a random effect of Subject was significant (LRT=1712.16, df=1, *p*<.001) and explained 83% of the overall variation in response time. Therefore, findings for the encoding phase do not show any effects for Emotion or Age of faces.

Memory Task (Test Phase)

Reliability analysis: Using 5000 random splits, the Spearman-Brown corrected RT reliability estimates for seen and novel faces were 0.76, 95% CI [0.71, 0.8] and 0.79, 95% CI [0.76, 0.83] respectively. The corrected accuracy reliability estimates for seen and novel faces were 0.22, 95% CI [0.03, 0.39] and 0.33, 95% CI [0.19, 0.43] respectively (see

Supplementary Materials, Fig. S1 and Fig. S2 for details). Overall, these results indicated a good reliability (Koo & li, 2016) for RT and moderate reliability for the Pr measures.

Bootstrapping analysis: The bootstrapping procedure for Seen faces indicated that RT distribution-clouds largely overlap between old and young faces for emotional (Angry, Happy) and neutral faces (Figure 1A). This suggests that the Own-Age Bias for faces is unlikely to be driven by differences in speed of responding. In contrast, the distribution-clouds for recognition accuracy (Pr) for emotional faces (Angry, Happy) do not overlap, indicating that participants were more accurate in recognising own-age faces. For Novel faces, RT distribution-clouds for Happy and Neutral faces do not overlap (Figure 1B). Moreover, the RT distribution-clouds for younger faces are located on the left, suggesting that participants recognised younger faces faster than old ones. The Own-Age Bias for Happy faces is also evident in recognition accuracy (Pr), where the distribution-clouds for young and old faces shows a non-overlapping pattern. In contrast, distribution-clouds for Angry faces are largely overlapping for RT and recognition accuracy (Pr) suggesting no Own-Age Bias.

Linear Mixed Modelling: We tested these effects using four separate LMMs (two on recognition accuracy and two on response time) for seen and novel faces.

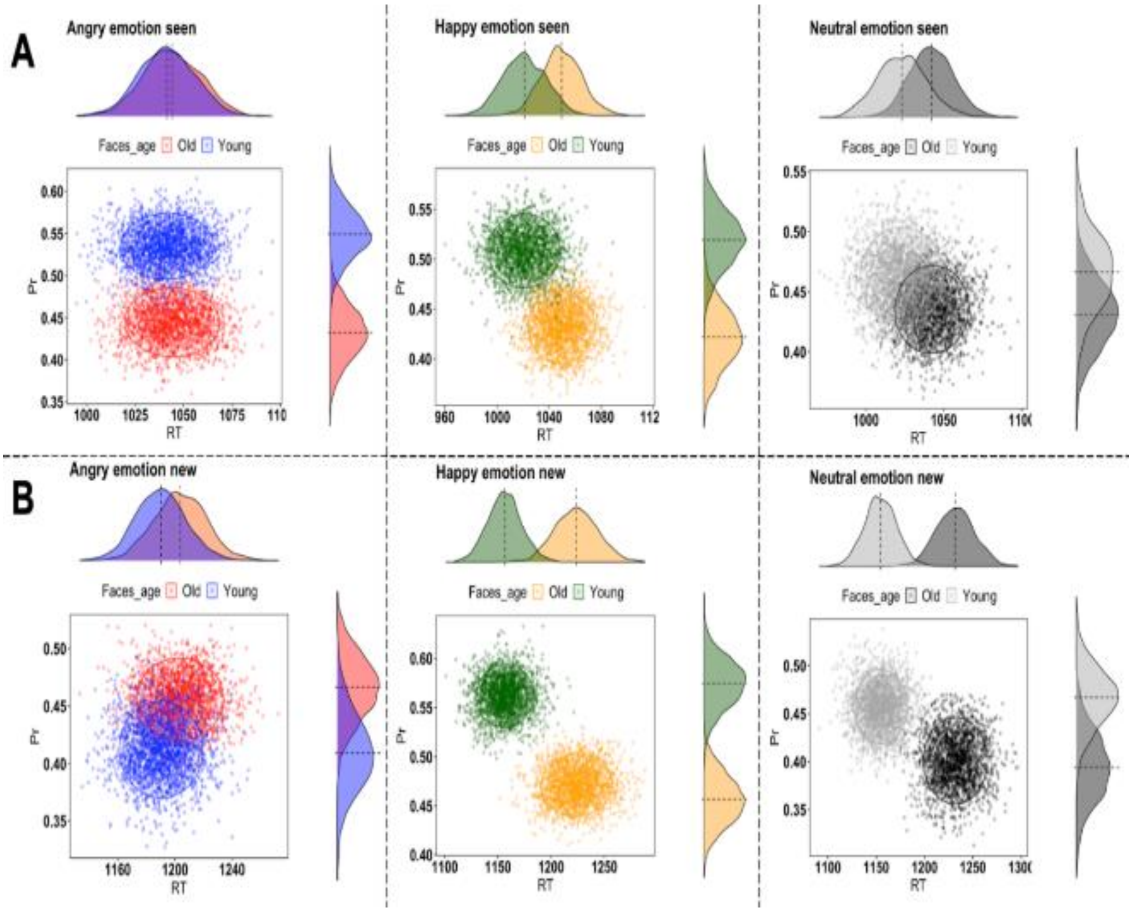

Figure 1. Bootstrapped means of RT (X-axis) and accuracy (Y-axis) for seen (A) and novel faces (B) in the test phase for Angry (left column), Happy (middle column) and Neutral faces of old and young individuals. Corresponding density plots visualise the distributional overlap of the effects for RT (top plots) and accuracy.

Performance Accuracy (Pr) for seen faces: A LMM on Pr for Seen Faces showed a main effect of Age of faces (F(1,1170)=20.06, *p*<.001): participants were more accurate in recognising younger, seen faces compared to old, seen faces [Young-(Old)], B=0.06, 95% CI [0.03, 0.09), SE=0.01, t(1170)=4.48, p_{holm} <.001). The Emotion term was also significant (F(2,1170)=3.35, *p*=.035) indicating that participants were more accurate in recognising emotional faces compared to neutral faces, [Neutral-(Angry, Happy)], (B=0.03, 95% CI [0.00, 0.06], SE=0.01, t(1170)=2.28, *p*=.023) (Figure 2A). There were no differences between

Angry and Happy faces; [Angry-(Happy)], (B=0.02, 95% CI [-0.01, 0.05], SE=0.02, t(1170)=1.23, *p*=.22). The interaction term (Age by Emotion) was non-significant (F(2,1170)=2.14, *p*=.12). A random effect of Subjects (LRT=537.41, df=1, *p*<.001) contributed 51% to the overall variation in accuracy.

Response Times (RTs) for seen faces: A LMM on RTs for Seen Faces revealed no significant fixed terms (F(2,1170)=0.47, p=.62; F(1,1170)=3.48, *p*=.06; F(2)=1.04, *p*=.35 for Emotion, Age of faces and Age by Emotion respectively). A random effect of Subjects (LRT=604.79, df=1, *p*<.001) explained 54% of the overall variation in response time. Therefore, although for Seen Faces, recognition accuracy is greater for emotional faces of all ages, the typical Own Age Bias with greater recognition accuracy for young faces is present.

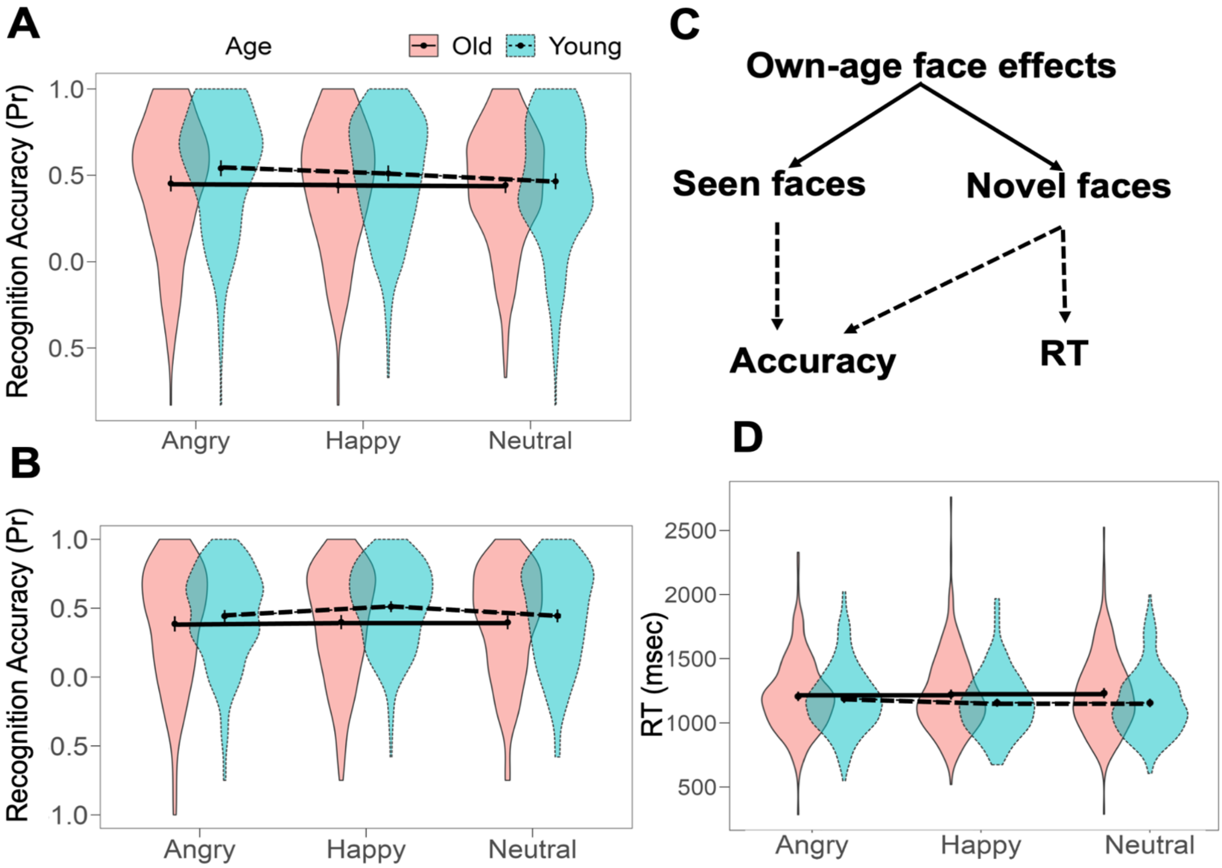

Figure 2. Violin plots depicting the Own Age Bias in recognition accuracy for Seen (A) and Novel faces (B), and response time for Novel faces (D). The black dots represent means of the estimates with 95% confidence intervals. Panel (C) represents a schematic summary of the measurements showing the own-age biases in faces.

Performance Accuracy (Pr) for novel faces: All three fixed terms in a LMM on Pr for Novel Faces were significant (Age: F(1,1170)=84.91, *p*<.001; Emotion: F(2,1170)=10.45, *p*<.001; Age by Emotion interaction: F(2,1170)=6.86, p=.001(Figure 2B). The main effect of Age of faces was due to greater recognition accuracy for own-age faces, [Young-(Old)], B=0.07, 95% CI [0.06, 0.09], SE=0.01, t(1170)=9.21, *p*<.001). The main effect of Emotion showed no differences in recognition accuracy between neutral and emotional faces, [Neutral-(Angry, Happy)], B= -0.01, 95% CI [-0.03, 0.00], t(1170)=1.70, p=.09). However, recognition accuracy was greater for happy compared to angry faces, [Angry-(Happy)], B= -0.04, 95% CI

[-0.06, -0.02], SE=0.01, t(1170)= -4.27, *p*<.001). The interaction term was driven by greater recognition accuracy for younger emotional faces, [Neutral –(Angry, Happy)*Old-Young], B=0.04, 95%CI [0.00, 0.07], SE=0.02, t(1170)=2.26, *p*=.02). Moreover, recognition accuracy was greater for happy, young faces compared to angry, young faces, [Angry-(Happy)*Old-Young], B=0.06, 95% CI [0.02, 0.09], SE=0.02, t(1170)=2.94, *p*=.003). An additional analysis of simple effects of Emotion for old faces showed no effects of emotion on recognition accuracy for old faces, [Neutral-(Angry, Happy)], B=0.00, 95% CI [-0.02, 0.03] and [Angry-(Happy)], B= -0.01, 95% CI [-0.04, 0.01]). A random effect of Subjects (LRT=1820, df=1, *p*<.001) contributed to 85% of the overall variation in accuracy for novel faces.

Response Times (RTs) for novel faces: A LMM on RTs revealed no effect of Emotion (F(2,1167)=0.25, *p*=.078). There was an effect of Age of faces (F(1,1167)=27.43, *p*<.001): participant were faster in responding to young faces, [Old-(Young)], B=52.39, 95% CI [32.78, 72.00], SE=10.0, t(1167)=5.24, *p*<.001) (Figure 2D). A fixed effect omnibus F-test showed a significant Age by Emotion interaction (F(2,1164)=3.14, *p*=.04). However, estimates for two contrasts ([Neutral-(Angry, Neutral)*Old-Young] and [Angry-(Happy)*Old-Young] were not reliable (B=35.34, 95% CI [6.26, -76.94], SE=21.22, t(1167)=1.67, *p*=.09; B=42.92, 95% CI [-2.11, 93.95, t(1167)=1.87, *p*=.06). In sum, findings show that Own-Age Bias is evident for both recognition accuracy and response time (Figure 1, Figure 2C).

Loneliness and number of contacts

The mean of loneliness scores across the sample was 24.12 (SD=6.12). Participants reported significantly less contacts with young people compared to number of contact with old people (MD=5.5, SE=0.22, 95%CI [5.04, 5.92], t(235)=24.51, *p*<.001, Cohen’s d = 1.59, 95% CI [1.40, 1.79]. Multiple linear regression using backward data entry indicated that only number of contacts with young people could predict loneliness scores (B=0.63, 95%CI [0.23, 1.04], t=3.06, *p*=.002) and the model yielded better fit after removing number of contacts with older people as a predictor (B=0.19, 95%CI [-0.05, 0.44], t=1.61, *p*=.11) (see Supplementary Materials, Fig. S3 and Fig. S4, Table S1 and S2 for details).

Loneliness and own-age bias for faces

A multiple regression model showed that Own-Age Biases in recognition accuracy for Seen Angry and Happy faces were not reliable predictors of loneliness (B=1.53, SE=1.13, 95% CI [-0.71, 3.76], t=1.35, *p*=.18; B=-1.92, SE=1.13, 95% CI [-4.15, 0.32], t=-1.69, *p*=.09 respectively). There was a small effect of Own-Age Biases in recognition accuracy for Novel Happy faces on UCLA scores (B=-4.44, SE=2.04, 95%CI [-8.46, -0.43], t=2.18, *p*=.03) indicating that stronger Own-Age Biases are associated with less loneliness (see Supplementary Materials, Fig. S5, Table S3 for details).

Discussion

We investigated whether the Own Age Bias – that is the better recognition for faces of individuals of one's own age – that has been consistently observed with neutral faces, also occurs with emotional faces. In addition, we assessed to what extent self-reported loneliness and number of social contacts modulate the Own Age Bias for neutral and emotional faces. To this aim, young individuals completed a two-phase experiment, in which they categorised faces of old and young individuals showing neutral, happy, and angry expressions based on age (young vs old). In the test phase, participants were presented with already seen and novel faces. Their task was to assess for each face whether they had previously seen it.

Findings for the whole sample show an Own Age Bias for both, seen faces (i.e., greater accuracy for young faces) and for novel faces (i.e., greater accuracy and faster responses for young faces). Importantly, albeit recognition accuracy was better for emotional faces, the Own Age Bias occurred for neutral as well as for emotional faces. In addition, when looking at whether loneliness affects the Own Age Bias, findings showed that individuals who reported less loneliness were more likely to show an Own Age Bias for novel happy faces, expressing social affiliation. Although the effect is small, this is an interesting finding considering that induced social exclusion (via the Cyberball task) has been linked to increased attention to signals of possible social reconnection (Xu et al., 2015), and loneliness has been linked to increased attention toward signals of social threat (e.g., Cacioppo et al., 2016). Therefore, the implications of the present findings are twofold. Firstly, we observed an Own Age Bias with neutral and emotional faces, whereas Ebner and Johnson (2009) and Cronin et al., (2019) did not. We believe that this could be due to differences in the task used at encoding. In fact, although in their meta-analysis Rhodes and Anastasi (2012) concluded that task requirements were not predictive of the magnitude of the Own Age Bias, this conclusion may well apply to studies using neutral faces only. This is because with neutral faces there is only one salient dimension (i.e., age) whereas with emotional faces of young and old individuals there are two salient dimensions (i.e., age and emotion). We used an age categorization task at encoding based on evidence, (Hugenberg et al., 2010) that this task, by emphasizing the salient age-dimension, enhances the own-age memory bias. In contrast, Ebner and Johnson (2009) used an emotion categorization task and Cronin et al., (2019) used a passive viewing task and the instructions to memorize the face and press a key as soon as the face disappeared from screen. This would point to the importance – when assessing the Own Age Bias – of using task instructions that emphasise the salience of the age dimension especially when there is a competing salient dimension (i.e., emotion). However, our study differed from past studies also about the stimuli used and how performance was assessed. In fact, our stimuli were balanced for distinctiveness as this can affect memory performance (e.g., Valentin & Endo, 1992) and we opted for assessing performance by using the discrimination index (i.e., Pr) separately for seen and novel faces. This is as in Denkinger and Kinn (2018), whereas Ebner and Johnson (2009) and Cronin et al. (2019) used d’ as a combined-overall performance for seen and new faces. However, it has been pointed out that d’ can produce extremely biased predictions for recognition performance (Snodgrass & Corwin, 1998).

Given that we observed an Own Age Bias for neutral as well as for emotional faces, the second research question is whether loneliness affects the Own Age Bias. Our findings show that for young individuals, it is the number of social contacts with their peers that is associated with loneliness and that lower loneliness is characterized by a larger Own Age Bias for novel signals of social affiliation (i.e., novel happy faces). The other side of the coin being that this bias is not present with higher levels of loneliness, suggesting that what loneliness does is to reduce the natural tendency toward new signals of social connections from one’s peers, which may contribute to maintaining the causes of loneliness. This is an important and novel finding considering that evidence indicates a bias toward signals of social connection in response to momentary social exclusion (e.g., Xu et al., 2015; Syrjämäki & Hietanen, 2018) but that loneliness is linked to a bias is toward social threat signals (e.g., Cacioppo et al., 2009, Cacioppo et al., 2015, Cacioppo et al., 2016). Although past findings refer to attentional biases whereas the present study expands the effect to the Own Age Bias, it is quite possible that loneliness affects a wide range of social cognition processes. In fact, recent evidence shows that high levels of loneliness in young individuals is associated with changes in brain areas (i.e., stronger functional connectivity between the inferior frontal gyrus and the supplementary motor area, the precentral gyrus, the superior parietal lobule) involved in social attention (Brilliant et al., 2022).

To conclude, the present findings indicate that the Own Age Bias occurs for neutral as well as emotional faces in young individuals, provided the age of faces is salient for the task at hand. In addition, for young individuals the number of social contacts with their age peers is important as it predicts loneliness. Finally, only young individuals with less loneliness show an Own Age Bias for novel, happy faces. This points to a typical bias toward new signals of social affiliation that is lacking or reduced in individuals with more self-reported loneliness.

Despite the strengths of the present study, we should also acknowledge some limitations, that may be addressed by future research. Our participants reported moderate levels of loneliness and future research should address whether our findings generalize to high levels of loneliness. Alternatively, higher loneliness could be linked to an Own Age Bias for social threat signals. In addition, our study was conducted using an online platform (as was the study by Cronin et al., 2019), during the lockdown due to Covid-19 pandemic. Albeit we used video-calls via Google Meet to ensure that participants completed the task under relatively controlled conditions (i.e., being alone in the room, being in quiet environment, etc.) a certain variability between conditions could still be present. In addition, loneliness was assessed with the UCLA due to its validity and reliability. However, this questionnaire assesses overall loneliness whereas loneliness may have multiple subcomponents. Moreover, self-report measures may be prone to social desirability (see Richman, Kieser, Weisband & Drasgow, 1999) although, using standardized questionnaires allows to counteract these issues. Importantly, that the study was conducted during the lockdown due to the Covid-19 pandemic and that participants completed the study remotely, may have made more socially acceptable for students to report their feelings of loneliness as they could be attributed to the objective and extreme conditions. Indeed, for a separate study in our laboratory we have recently experienced that it is particularly challenging to motivate individuals with high levels of loneliness to take part in laboratory-based studies as we tried to select participants based on their results to the questionnaire completed online, but we had to change our strategy as there was a very low response-rate.

Understanding the effects of loneliness on different aspects of social cognition is important, but it has become more urgent recently as especially young individuals have suffered from the lack of social contacts with their peers during the lockdown due to Covid-19 pandemic. Future research on the effects of loneliness on social cognition could help understanding whether the mechanisms that contribute to maintaining loneliness are characterized first by reduced bias toward novel social affiliation signals, followed by hypervigilance for novel social threat signals.

CHAPTER 3

THE EFFECTS OF LONELINESS ON ORIENTING ATTENTION TO THE GAZE-DIRECTION OF EMOTIONAL FACES

Introduction

Loneliness has been related to the evolutionary benefits of re-establishing social connections (Cacioppo & Cacioppo, 2018). Accordingly, lonely individuals would deploy larger attentional resources to social signals of possible affiliative cues that may facilitate reconnecting with others (Lamblin, Murawski, Whittle & Fornito, 2017). However, loneliness has also been found to have a profound impact on the perception and interpretation of social cues (for a review see Spithoven, Bijttebier & Goossens, 2017). Indeed, research suggests that individuals who experience chronic loneliness tend to exhibit a negative bias towards social cues, such as assuming others' intentions as more negative or perceiving ambiguous social situations as more hostile, becoming maladaptive and triggering distress and hypervigilance for social threats (Cacioppo & Cacioppo, 2014). This bias further perpetuates a cycle of perceived social isolation, as these individuals may withdraw from social interactions, leading to increased loneliness.

The primary objective of this study was to investigate the impact of loneliness on attentional shift to social stimuli, specifically focusing on emotional faces. By examining the effects of loneliness on attention to emotional faces that social signal affiliation or threat, this study aims to contribute to the existing body of knowledge on the complex interplay between loneliness and social attention.

Orienting attention based on social cues

During social interaction, humans gather information from social signals like gestures, facial expressions, and/or gaze direction in order to make inferences about other's state of mind, intentions, and motivations (Baron-Cohen, 1995). The direction of the eye-gaze of another individual is an important social signal as it can indicate the focus of attention and the object of interest of others, as humans understand that people tend to look at what they are interested in (Baron-Cohen, 1995; Driver et al., 1999; Gallagher & Frith, 2003). Not surprisingly, individuals shift their attention toward the spatial location looked at by another individual. Typically, this is assessed using the gaze cueing paradigm (Friesen & Kingstone, 1998; Driver et al., 1999; Frischen, Bayliss, & Tipper, 2007; Friesen, Halvorson & Graham, 2011), in which the central cue is represented by a face looking left or right. A target is then presented either at the same location looked at by the central cue (i.e., valid, or congruent trial) or at the opposite location (i.e., invalid, or incongruent trial; Driver et al., 1999), cue is not predictive of target location (50% probability that target appears on the cued location). Typical findings can vary depending on the specific study and experimental conditions (see McKay, Grainger, Coundouris, Skorich, Phillips & Henry, 2022 for a metanalysis). However, findings consist of faster reaction times to validly cued targets compared to invalidly cued targets. This effect is also known as the Gaze Cueing Effect. Gaze cues can also influence accuracy as participants tend to be more accurate when the gaze cue and target are congruent compared to when they are incongruent (e.g., Lasalle & Itier, 2015; Hietanen, 1999, see Frischen et al., 2007 for a review, see McKay et al., 2021 for a metanalysis).

Emotion modulation of gaze cueing effects

Even if gaze cueing effect appears to be robust, it is not clear whether emotional expressions influence this effect, for so, the gaze cueing paradigm has also been used to assess whether orienting based on gaze-cues is affected by the emotional expression shown by the others (see Dalmaso et al., 2020, McKay et al., 2021). When looking into faces, humans tend to explore and fixate more the eye region, for such, Bayliss and colleagues (2010) throughout 3 experiments young adults performed a gaze cueing task with dynamic neutral, happy, angry, surprised, and fearful expressions, presented first with straight gaze and then with adverted gaze or crossed eyes (only Exp.1). Findings showed enhanced gaze cueing effects for fearful and surprised faces in comparison to happy, angry, and neutral ones. Importantly, there was a direct correlation between the size of the sclera and the gaze-cueing effect that the emotion modulation is due to the perceptual characteristics of the fearful eyes.

It has been suggested that the attentional shift elicited by the observed direction of eye gaze of an emotional face may be of evolutionary advantage as it facilitates the detection of potential dangers and rewards, and thus, enhances survival opportunities (Öhman & Mineka 2001 in McKay et al., 2022). However, obtaining evidence in support of this hypothesis has proved challenging as some studies failed to observe emotion modulation of gaze cueing effects (e.g., Hietanen & Leppänen, 2003; Yu, Ishibashi & Iwanaga, 2023) whereas other studies have but only under certain conditions (e.g., Pecchinenda, Pes, Ferlazzo, & Zoccolotti, 2008; Bayliss, Schuch, & Tipper, 2010; Friesen, Halvorson, & Graham, 2011; Kuhn & Tipples, 2011; see also Dalmaso, Castelli, & Galfano, 2020 for a review).

More specifically, Hietanen and Leppänen (2003) conducted 6 experiments in which university students performed a gaze cueing task with neutral, happy, and angry expressions, presented first with straight gaze and then with adverted gaze. They failed to observe emotion enhanced gaze cueing effects. This was regardless of if the task (i.e., detection task), SOA (Exp. 1: 150ms or 200ms; Exp. 2: 200ms or 600ms; Exp. 3 75ms or 200ms: Exp. 4: 14, 40 or 67ms; Exp. 5: 50ms or 300ms; and Exp. 6: 100ms or 600ms) and face stimulus properties

(Exp. 1, Exp.2, Exp. 5, and Exp. 6: face photographs, Exp. 3, Exp.4: schematic face drawings). Overall, findings showed that nonpredictive gaze cues trigger an attentional shift in the direction of the observed gaze, albeit the emotional expression of the face does not have any effect on this attention orienting.

More recently, Yu, Ishibashi & Iwanaga (2023) recorded eye-movement during a gaze-cueing task with fearful and neutral expressions with 12 university students. Trials started with a fixation cross (900-1000ms), followed by a neutral face with straight-gaze (500ms). After each neutral face with straight gaze, eye-gaze shifted (left-right or remained straight; 100ms), expression either changed to fearful or remained neutral (presentation was either 100, 200 or 400ms). Targets were presented either on the left or on the right of fixation and participants were instructed to respond based on target location. Results showed a cue validity effect, with faster response times to targets presented at cued locations compared to uncued locations, however there was no effect of face expression or of presentation time.

Bayliss, Schuch and Tipper (2010) explored whether affective context of the looked-at object could modulate gaze-cueing of happy, disgusted, or neutral faces. In Experiment 1, 20 university students performed a gaze-cueing task. Cue was a neutral female face with straight-gaze, flanked by 2 placeholders, after 1500ms the eyes moved to either the right or the left and after 250ms facial expression changed to happy or disgust (250ms), followed by the target. Participants had to respond to target location (right or left to the face). Results showed a cue validity effect with faster responses on valid trials compared to invalid trials, but no difference between facial expression. In Experiment 2, 40 university students performed the same gaze-cueing task, with the exception that half of them were assigned either a positive context –targets were always pleasant stimuli– and half were assigned to a negative context –targets were always unpleasant stimuli–. Again, results showed a cue validity effect with faster responses to cued locations (valid trials) compared to uncued location (invalid trials). A larger gaze effect was found for happy faces compared to disgusted ones. In addition, there were congruency effects for which pleasant targets elicited stronger cueing effects for happy faces and negative context elicited grater cueing effects for fearful faces, indicative that cueing-effect may depend on deeper processing of the target.

Similarly, in an eye tracking study Kuhn and Tipples (2011) examined whether cueing-effects varied as a function of emotional expression and target valence. Twenty-two university students were presented centrally neutral faces with straight-gaze (1500ms), which changed gaze direction to the left, right, up, or down, and expression changed from neutral to fearful or happy (300ms). The targets were four images of animals (two neutral, one threatening and one pleasant), participants were asked to find the most pleasant/threatening one and respond as fast as possible when they found it. Results showed that fearful faces enhanced gaze-following when participants searched for a threatening animal, and that saccade latencies were more rapidly executed toward the cued location compared to the uncued locations.

Lastly, Pecchinenda, Pes, Ferlazzo and Zoccolotti (2008) investigated whether an evaluative judgement could modulate the gaze cueing effect with happy, fearful, disgusted, and neutral faces. Evidence showed larger cueing effects for disgusted and fearful compared to happy or neutral expressions, only when and evaluative task was used and not when a perceptual task was used. This findings suggest that the emotion modulation of the gaze-cueing effect may depend on top-down factors. This account is in keep with studies showing that stable characteristics of a person, modulate gaze cueing effects by emotional faces.

Taken together, these findings suggest that gaze-cueing effects for emotional faces can be modulated using an emotional task (Pecchinenda et al., 2008), by using and emotional context (Bayliss et al., 2010; Kuhn & Tipples, 2011). Moreover, findings are consistent with prior studies in which it is posed that threat-related information exerts efficient and automatic attentional processed because it is evolutionary beneficious.

The effect of individual characteristics on attention to emotional faces

The way in which people deploy attentional resources is affected by intrinsic individual's characteristics (e.g., Garner, Mogg & Bradley, 2006, Marini, Marzi & Viggiano, 2011), which in turn can affect memory encoding and recall (e.g., Burgess & Weaver, 2003; Pezdek, Abed & Cormia, 2021). Previous research examining the effects of perceived loneliness on processing social information has provided a mixed picture with lonely individuals having more difficulties with social stimuli (i.e., decreased ability to recognize emotions, Knowles, Lucas, Baumeister & Gardner, 2015), while others suggesting that loneliness leads to better memory for emotional faces (Du, Tiang, Jian & Tian, 2022; see study reported in Chapter 2). In addition, the direction of emotion-specific effects on social attention are unclear, as some studies show that loneliness is associated with better recognition of angry and sad faces (e.g., Smith, Norman & Decety, 2019), other showing better recognition for angry but not fearful, sad, or happy faces (e.g., Lodder, Scholte, Goossens, Engels & Verhagen, 2015; see Chapter 2), and yet others that loneliness is associated to better recognition of faces showing sadness and fear, but not anger (e.g., Vanhalst, Gibb & Prinstein, 2017). Taken together, this evidence points to perceived loneliness being linked to a bias toward social threat signals (e.g., Cacioppo, Norris, Decety, Monteleone & Nusbaum, 2009).

Moreover, the gaze cueing paradigm with emotional faces has also been used to investigate the role of individual differences in the emotion modulation of cueing effects. Namely, Tipples (2006) investigated whether trait fearfulness affects the gaze-cueing effect observed with happy or fearful faces. In this task a centrally neutral face (750ms) was followed by either a happy or a fearful face with averted gaze (either to the left or to the right; 300 or 700ms), which was followed by the target (a “L” or a “T”) to which participants responded based on target identification. Results showed larger gaze-cueing effect for fearful emotional faces. Importantly, correlation analysis showed a positive correlation between participants’ trait fearfulness and gaze-cueing for fearful faces.

In addition, Putman, Hermans and van Honk (2006) asked 30 undergraduate students to complete the State-Trait Anxiety Inventory (Spierlberger, Gorusch & Lushene, 1970) and perform a gaze-cueing task. Trials started with a fixation cross (1000ms), followed by face display –consisting of six gradually morphing pictures to either a happy or a fearful expression (200ms)–, on some trials a target was presented on other there was no target (catch trials). Participants were instructed to respond to the target and withhold response if no target appeared. Results showed cueing effects with shorter responses to cued locations compared to uncued locations. There were also enhanced cueing effects for fearful faces compared to happy faces, for individuals with higher anxiety levels. In Experiment 2, 20 undergraduate students completed the State-Trait Anxiety Inventory (Spierlberger, Gorusch & Lushene, 1970) and performed a gaze-cueing task. Trials started with a fixation cross (1000ms), followed by face display –consisting in six gradually morphing pictures to either a happy or a fearful expression (200ms)–, and substituted by the target (in contrast to Exp. 1, in Exp. 2 there was no catch condition, target was always presented). Participants again responded to target location. Results showed enhanced cueing effects for fearful expressions compared to happy faces and a positive correlation between trait anxiety and cueing effects for fearful faces.

Similarly, Holmes, Richards and Green (2006) in 3 studies investigated how individual differences in anxiety assessed by the State-Trait Anxiety Inventory (Spilberger, Gorusch, Lushene, Vagg & Jacobs, 1983) modulated gaze-cueing effects for emotional faces. In Experiment 1, 36 young and middle-aged adults performed a gaze cueing task. After fixating a central point (775ms), emotional faces (fearful, happy, and neutral) were presented left or right of fixation, with gaze looking towards a target appearing in the opposite location or the face could straight forward (away of the target location, 225ms), participants had to respond based on target identification. Findings showed a cue validity effect (faster response times for valid trials compared to invalid ones). Importantly, high-state anxiety participants showed larger gaze-cueing effect with fearful faces compared to neutral and happy ones. In Experiment 2, 36 university students performed the same gaze-cueing task, this time with angry faces instead of fearful faces (happy and neutral faces were also used). Again, there were cue validity effects with faster responses to valid compared to invalid trials, however, this time there were no differences between low in anxiety and high in anxiety participants. In Experiment 3, 36 participants performed the same gaze cueing task as Experiment 2, with the exception that cue-stimuli were presented centrally on the screen. Results showed an overall cue validity effect, and there were slower responses for high-state anxiety participants on angry faces compared to neutral faces. Findings support the hypothesis that gaze direction in negative emotional faces attracts attention, compared to either positive emotional or neutral faces.

Altogether, these findings suggest that the gaze direction of others, elicits shifts in attention and that attention can be influenced by the emotional expression shown by others but also by individual characteristics. More specifically, individual differences in trait fearfulness and anxiety can impact gaze cueing effects for fearful faces compared to neutral and happy faces. (e.g., Tipples, 2006; Fox, Mathews, Calder, & Yiend, 2007; Putman, Hermans, & van Honk, 2006; Holmes, Richards, & Green, 2006). This entails that not only transitory task characteristics (e.g., task instructions, contextual information) but also stable characteristic of the individual enhances the salience of emotional stimuli that are more relevant for the individual and in doing so, modulates attention. This heightened salience can lead to a bias in attention, where individuals are more likely to prioritize and attend to threatening or fearful stimuli.

The question is whether this modulation is specific to threat and threat-related information or whether it is more general and it applies also to other individuals' characteristics and stimuli. More specifically, whether there is a relationship between loneliness and attention to social information of affiliation or threat. To our knowledge, whether perceived loneliness modulates orienting by observed gaze direction of emotional faces has not been investigated before, although there are few studies on the effects of transient social exclusion on gaze cueing effects.

Namely, Capellini, Riva, Ricciardelli and Sacchi (2019), used the Cyberball task to temporarily manipulate social exclusion. In Experiment 1, 81, participants completed the Need Threat Scale (Williams, 2009) and the Rejection-related Emotion Scale (Buckley, Winkel & Leary, 2004) and performed a gaze-cueing task. Stimuli consisted of neutral faces looking straight ahead, rightward, or leftward, while targets consisted of two capital letters "L" and "T". Gaze-direction was non-predictive of target location. Trials started with a fixation cross (900ms), followed by a face with direct gaze (900ms), subsequently gaze changed to averted to the left (leftward gaze) or to the right (rightward gaze), and after 200ms the target appeared at the looked at location (valid trial) or at the opposite side (invalid trial). Participants responded based on target identity. Results showed gaze cueing effects (i.e, faster RTs on valid than invalid trials), but no group differences. Experiment 2 used the same procedure but this time, instead of the face looking straight ahead, a schematic face of an oval with a black segment with two X at the extremes was used. Results again showed cueing effects (i.e., longer RTs on incongruent than congruent trials) and no group differences.

The present study: the effect of loneliness on gaze cueing for emotional faces

The present study investigated whether perceived loneliness enhances gaze-cueing effect for emotional faces signalling affiliation or threat compared to neutral faces. According to the avoidance motivation approach of loneliness (e.g., Nikitin & Schoch, 2021), loneliness should yield greater cueing effects for angry faces (i.e., hypervigilance to negative social stimuli). In contrast, according to the approach motivation (e.g., Nikitin & Schoch, 2021), loneliness should enhance cueing effects for happy faces as they signal affiliation. To this aim, we used a non-predictive gaze-cueing task with happy, angry, and neutral faces. In addition, we used an incidental face memory task to assess to what extent loneliness also affects incidental memory for attended emotional faces. By investigating the specific patterns of attention and implicit memory to emotional social signals, the study aims to shed light on the complex interplay between loneliness and the effects on social cognition.

Method

All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Psychology Department Ethic Committee, Sapienza University of Rome: Institutional Review Board Approval Prot. n. 0000867. Informed consent was obtained from the study participants.

Participants

One hundred-thirty-five university students took part in the experiment, however, due to technical issues the data of one participant was discarded because incomplete. The final sample comprised 134 university students [females= 108; males= 26; age= 22.04 (sd=2.35)].

Sensitivity analysis conducted using G*Power software (Faul et al., 2007) showed that with the current sample size we would have 80% power to detect effect sizes of $n^2{}_p$=.02, or a small-medium effect size.

We started pre-screening participants based on scores at the UCLA Loneliness Scale (Boffo et al., 2012) but it proved difficult to get high in-loneliness individuals to come to the laboratory following the completion of the online questionnaire so that we decided to recruit independently from the UCLA scores. Therefore, participants were *a posteriori* divided into two groups based on the loneliness scores.

Stimuli

Twenty-four identities (12 males and 12 females) were selected from the Radboud Face Database (Langner, Dotsch, Bijlstra, Wigboldus, Hawk & Van Knippenberg, 2010), each portraying angry, happy, or neutral facial expressions (see Table 2 for face identities).

Female	Male
RAFD01, RAFD14, RAFD16, RAFD19,	RAFD09, RAFD15, RAFD20, RAFD23,
RAFD22, RAFD26, RAFD27, RAFD32,	RAFD24, RAFD25, RAFD30, RAFD33,
RAFD56, RAFD57, RAFD58, RAFD61	RAFD36, RAFD38, RAFD46, RAFD71

Table 2. Selected Faces Identities from the Radboud Face Database.

For each identity there were 2 different gaze directions: averted left and averted right. Based on available validation data (Langner et al., 2010), the selected stimuli were balanced on agreement on emotional categorization t(18)= .08, p=.921; mean intensity rating for facial expression t(18)= .26 p=.694; clarity t(18)= .74, p=.411; mean genuineness rating for facial expression t(18)= .16, p=.847; mean valence rating for facial expression t(18)= 1.32, p=.169 and attractiveness t(18)= .37, p=.713 (see Table 3).

	Male	Female	*p*
Agreement on emotional categorization	94.3 (10.26)	94.00 (5.48)	.921
Intensity of facial expression	3.63 (.37)	3.60 (.18)	.694
Clarity of facial expression	3.92 (.30)	3.84 (.20)	.411
Genuineness of facial expression	4.04 (.25)	4.03 (.23)	.847
Valence of facial expression	3.22 (.26)	3.09 (0.19)	.169
Attractiveness of facial expression	2.45 (.38)	2.387(.56)	.713

Table 3. Mean ratings (SD) for male and female selected faces.

Target stimuli consisted of two letters (i.e., “L” and “T”) presented either on the left or the right side of fixation. Cues were non predictive of target-location, such that there were equal probability of targets appearing on the same location looked by the cue (i.e., congruent trial), or on the other side of the cued location (i.e., incongruent trial).

Face assignment to novel or seen condition was counterbalanced with different versions of the task. To this aim, 16 identities were then selected for the gaze-task (half male and half female), the remaining 8 identities served as the novel faces for the incidental memory task. Face identities were randomly divided in three sets, the combination of identities that served for seen and novel faces resulted into six different versions of the experiment. Participants were randomly assigned to one of the versions: each version has a similar number of participants (around 21 participants for each version).

Questionnaires

The Italian version of the UCLA Loneliness Scale (Boffo, Mannarini & Munari, 2012) consisting of a 10 items scale was used to assess perceived loneliness. The Italian version of the Interpersonal Acceptance–Rejection Loneliness Scale (IPARLS; Senese, Nasti, Mottola, Sergi, Massaro & Gnisci, 2021) consisting of 15 items was used to assess perceived loneliness. We decided to use both questionnaires as they measure slightly different constructs. The UCLA questionnaire measures general loneliness whereas the IPARLS measures subjective feelings of distress by loneliness (i.e., emotional component).

In addition, we used the Italian version of the Depression Anxiety Stress Scale-21 (DASS-21) (Bottessi, Ghisi; Altoè, Conforti, Melli & Sica, 2015) which is a 21 items scale to assess depression (7 items), anxiety (7 items) and stress (7 items) on a 4-point Likert scale format ranging from 0 (it has never happened to me) to 4 (it has happened usually).

Tasks

Gaze-Cueing Task (encoding phase): Participants completed 384 trials divided in 4 blocks of 96 trials each with equally probable factorial combination of facial expression (3: angry, happy, and neutral), gaze direction (2; left and right), and target position (2: left and right). Target stimuli consisted of two letters “L” and “T” presented either on the left or the right side of the screen. Gaze cues were not predictive of target location (cue predictive validity was 50%).

Incidental Memory Task (test phase): The incidental memory task consisted of 48 trials of which 24 faces used during the gaze-cueing task and 24 new faces presented with straight-gaze and neutral, happy, and angry expressions. Images were presented one at a time for up to 10s in a new random order for each participant. In order to counterbalance seen/not seen faces, six different versions of the task were generated in which faces presented as seen and novel faces varied accordingly.

Apparatus

The gaze-cueing task was presented using E-Prime Version 2.0 Professional software for Windows 7, which also recorded participants' responses. Stimuli were presented on a Pentium IV computer via a 17" CRT monitor (1024 x 768 pixels, 60 Hz). Participants sat comfortably in front of a computer screen at a viewing distance of approximately 60cm and in order to prevent head movements a chin rest was used.

Procedure

Once participants gave their consent, they were asked to complete an online version of the UCLA loneliness scale (Boffo & Municcio, 2012) -administered via Testable (www.Testable.org), before coming to the laboratory. Once in the laboratory, participants again provided their written informed consent and they were presented with the 15 items of the IPARLS (Senese et al., 2021). We opted for asking participants to complete these items before the Gaze-Cueing Task to allow participants to think about their social interactions. Upon completion of the questionnaires, the task instructions were presented on screen. Participants were asked to respond as accurate and quickly as possible based on whether the letter was an "L" or a "T" by pressing two keys appropriately labelled ("U" and "B" were chosen to be perpendicular to left and right location). Participants completed a total of 384 trials (4 blocks of 96 trials) resulting from the factorial combination of the 48 faces (8 male faces portraying happy, angry, or neutral facial expressions as well as 8 female faces portraying happy, angry, or neutral facial expressions) with the eye-gaze direction (leftwarded and right-warded), and target position (either right or left side of the screen) and target ("L" and "T").

Each trial started with a centrally presented fixation cross for 750ms, then a face-cue appeared (250ms), followed by the target, which appeared either on the left or on the right of the screen (in a spatially congruent or spatially incongruent position with respect to the eye-gaze direction) until a response was made or 3000ms elapsed (see Figure 3). As gaze direction was non-predictive of the target location, in 50% of the trials, the target appeared in the gazed-at location (valid condition), and in the other 50% of trials, the target appeared in the opposite location (invalid condition).

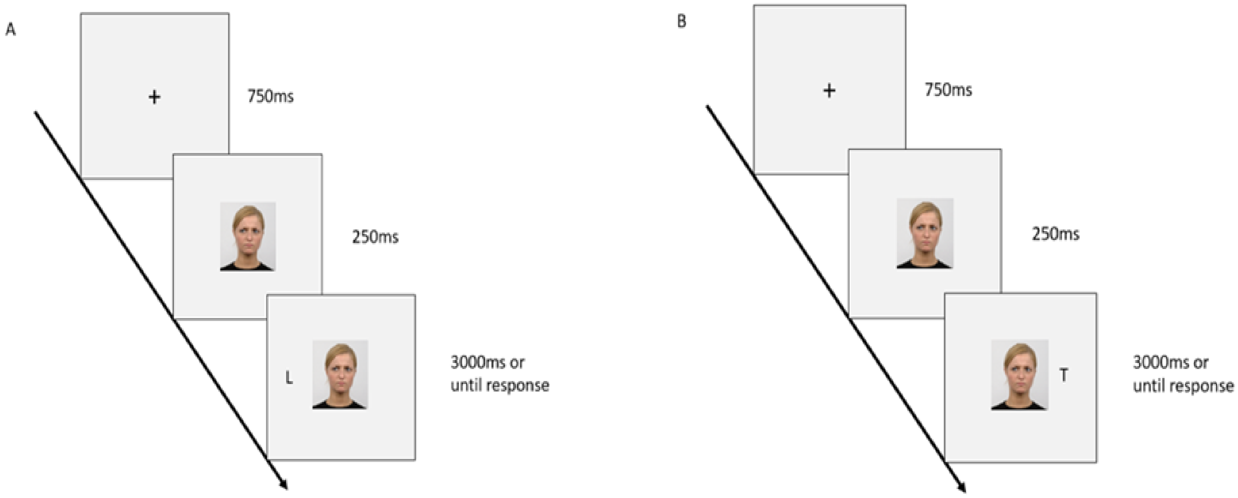

Figure 3. Time course of events in the gaze-cueing task. Examples above shows a congruent trial with valid neutral cue (**A**) and an incongruent trial with invalid neutral cue (**B**). The intertrial interval randomly varied between 500ms and 1500ms.

Following the gaze cueing task (encoding phase), participants completed a filler task (i.e., the DASS questionnaire) for approximately 5 mins. This was followed by an incidental memory task, in which participants were informed that they would see some faces, some had already been presented in the previous task and others where new. Participants' task was to respond as quickly and accurately as possible by pressing one of the keys for "Seen" or "Not Seen" using the keys 'V' and 'N' accordingly labelled (see Figure 4). Upon completion, participants were debriefed, thanked for their participation, and dismissed.

Figure 4. Example of a typical trial in the incidental memory recognition task.

Experimental Design

The experimental design was a 2 (group: high lonely vs low loneliness) by 3 (face expression: angry, happy vs neutral) by 2 (cue validity: valid vs invalid) mixed-factorial with the first factor between-subjects.

Data Analysis

Loneliness. For the Italian adaptation of the UCLA a total score was computed after reverse scoring five items: scores typically range from a minimum of 10 to a maximum of 50 and higher scores indicate more loneliness. In the present sample, the UCLA lower score was 12 and the higher score was 47. For the Italian adaptation of the IPARLS a total score was computed: scores typically range from a minimum of 15 to a maximum of 75 with higher scores indicating higher levels of loneliness. In the present sample, the IPARLS lower score was 15 and the higher score was 65. Participants who scored below the median (<28.0) were considered as low in loneliness (N=65; females= 54; males= 11), whereas participants who scored above (>28.0) were considered as high in loneliness (N=69; females= 53; males=16).

The same procedure was conducted also for the IPARLS scores: participants who scored below the median (<32.0) were considered as low loneliness (N=63; females= 53; males= 10), while participants who scored above the median (>32.0) were considered as high loneliness (N=71; females= 55; males= 16).

Behavioural data. All data processing and analysis were conducted in SPSS v.27. Trials in which an error was made (6.22%) and trials with RTs not within 120ms and 2.5 SD from the mean (9.4% of the remaining trials) were excluded from analyses. Mean RTs for correct responses were computed for each condition. Accuracy was computed as the proportion of correct responses (hit rates). This procedure was also carried out for seen and novel faces: hit rates were computed as the proportion of test trials in which participants correctly responded “seen” to a face that was seen before and correctly responded “not seen” to a face that was new, respectively.

As the UCLA and IPARLS assess different aspects of loneliness, data were analysed with group based on the general measure of loneliness (UCLA) as well as with group based on the social isolation and rejection measure of loneliness (IPARLS).

Gaze performance (encoding phase). To test the effects of loneliness on gaze cueing a 2 × 3 × 2 mixed factorial ANOVA was performed with Group (2: high and low loneliness), Expression (3: anger, happiness, and neutral) and Cue (2: valid and invalid) with the first factor between subjects.

Incidental memory task (test phase). To test the effects of loneliness on implicit memory a 2 × 3 × 2 mixed factorial ANOVA was performed with Group (2: high and low loneliness), Expression (3: anger, happiness, and neutral) and Face (2: seen and novel) with the first factor between subjects.

Loneliness and other psychological disorders. To test whether loneliness was related to other psychological disorders we performed a Pearsons' correlation between the two loneliness questionnaires and the DASS.

Results

Correlations

There was a positive relation between UCLA and IPARLS questionnaires (r=.454 *p*<.01). Whereas the UCLA was positively correlated to Depression (r=.314 *p*<.01) and Stress (r=.170 *p*<.05), the IPARLS was positively correlated to Depression (r=.519 *p*<.01), Anxiety (r=.357 *p*<.01) and Stress (r=.600 *p*<.01).

	UCLA	IPARLS	DDEP	DANX	DSSS
UCLA	--				
IPARLS	,454**	--			
DDEP	,314**	,519**	--		
DANX	,155	,357**	,600**	--	
DSSS	,170*	,433**	,725**	,673**	--

Table 4. Correlation table between loneliness [assessed by the UCLA and the IPARLS] and other psychological features [assessed by the DASS-21]. ***p*<.001 *p<.05.

Gaze Cueing Task (encoding phase).

Reaction Times (RTs).

ANOVA results conducted with Group based on the UCLA scores showed that the main effect of Group was not statistically significant ($F_{1,132}$= 3.29, *p*= .072). There was a significant main effect of Cue ($F_{1,132}$=14.54, *p*<.001, n^2_p=.098), with shorter RT on trials with valid cues (M=535, SE=5.2) compared to trials with invalid cues (M=539, SE=5.3). The main effect of Expression was significant ($F_{2,131}$=27.13, *p*<.001, n^2_p=.293), Bonferroni corrected pairwise comparison showed overall longer RTs on trials with happy faces (M=542, SE=5.3) than on trials with neutral faces (M=534, SE=5.2), *p*<.001, and with trials with angry faces (M=535, SE=5.3), *p*<.001.

The 2-way interactions Group × Cue ($F_{1,131}$=.534, *p*=.466), Group × Expression ($F_{2,131}$=.946, *p*=.391), and Cue × Expression ($F_{2,131}$=.683, *p*=.507), as well as the 3-way interaction Cue x Expression x Group ($F_{2,131}$=.193, *p*=.825) were not statistically significant (see Figure 5 and Table 5).

ANOVA results conducted with Group based on the IPARLS showed that the main effect of Group was not statistically significant ($F_{1,131}$=.680, *p*=.441). There was a significant main effect of Cue ($F_{1,131}$=15.280, *p*<.001, n^2_p=.104), with shorter RT on trials with valid cues (M=523, SE=4.7) compared to trials with invalid cues (M=527, SE=4.8), *p*<.001. The main effect of Expression was significant ($F_{2,131}$=26.389, *p*<.001, n^2_p=.289), Bonferroni corrected pairwise comparison showed overall longer RTs on trials with happy faces (M=530, SE=4.8) than on trials with neutral faces (M=523, SE=4.8), *p*<.001, and with trials with angry faces (M=522, SE=4.8), *p*<.001.

The 2-way interactions Group × Cue ($F_{1,131}$=.641, *p*=.425), Group × Expression ($F_{2,131}$=.037, *p*=.964), and Cue × Expression ($F_{2,130}$=.706, *p*=.495), as well as the 3-way interaction Cue x Expression x Group ($F_{2,130}$=.193, *p*=.195) were not statistically significant (see Figure 5).

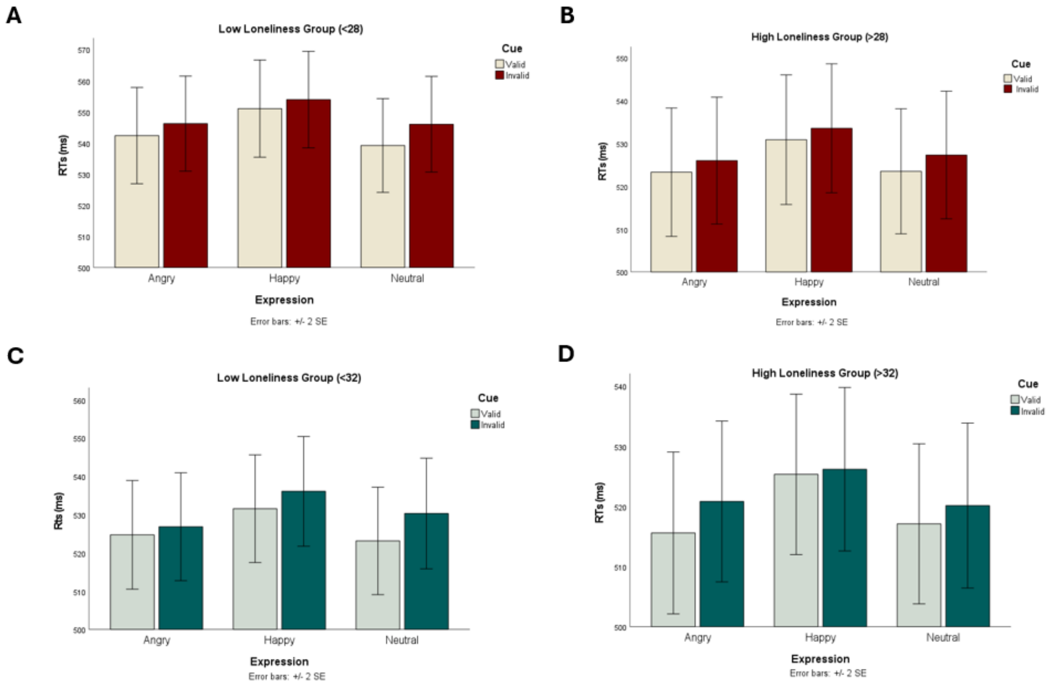

Figure 5. Reaction Times on trials with Valid and Invalid Cues for Angry, Happy, and Neutral faces for the UCLA questionnaire [low loneliness (**A**) and high loneliness (**B**) groups] and for the IPARLS questionnaire [low loneliness (**C**) and high loneliness (**D**) groups]. Error bars represent SE of the means.

	Valid Condition				Invalid Condition			
	Geneal Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	542 *(8)*	523 *(8)*	525 *(7)*	516 *(7)*	546 *(8)*	526 *(7)*	527 *(7)*	521 *(7)*
Happy	551 *(8)*	531 *(8)*	532 *(7)*	525 *(7)*	554 *(8)*	534 *(8)*	536 *(7)*	526 *(7)*
Neutral	539 *(8)*	524 *(7)*	523 *(7)*	517 *(7)*	546 *(8)*	527 *(7)*	530 *(7)*	520 *(6)*

Table 5. Mean (and SE) Reaction Times at the gaze cueing task.

Response Accuracy.

ANOVA results conducted with Group based on the UCLA scores showed a significant main effect of Group ($F_{1,132}$=4.83, p<.03, n^2_p=.035) due to greater overall response accuracy for the low loneliness group (M=.94, SE= .004) than for the high loneliness group (M=.93, SE= .004), p=.03. There was a marginally significant main effect of Cue ($F_{1,132}$=3.898, p=.05, n^2_p=.03), with higher response accuracy on trials with valid cues (M=.94, SE=.003) compared to trials with invalid cues (M=.94, SE=.003). The main effect of Expression was significant ($F_{2,131}$=381.319, p<.001, n^2_p=.853), Bonferroni corrected pairwise comparison showed overall lower response accuracy on trials with neutral faces (M=.92, SE=.003) than on trials with angry faces (M=.96, SE=.003), p<.001, and with trials with happy faces (M=.96, SE=.003), p<.001.

The 2-way interactions Group × Cue ($F_{1,132}$=.005, p=.942), Group × Expression ($F_{2,131}$=.223, p=.801), and Cue × Expression ($F_{2,131}$=.1.515, p=.224), as well as the 3-way interaction Cue x Expression x Group ($F_{2,131}$=.873, p=.420) were not statistically significant (see Figure 6 and Table 6).

ANOVA results conducted with Group based on the IPARLS scores showed that the effect of Group was not significant ($F_{1,131}$=.433, p=.433). There was a significant main effect of Cue ($F_{1,132}$=4.71, p=.032, n^2_p=.035), with higher response accuracy on trials with valid cues

(M=.939, SE=.003) compared to trials with invalid cues (M=.94, SE=.003) $p<.05$. The main effect of Expression was significant ($F_{2,130}=330.72$, $p<.001$, $n^2_p=.836$), Bonferroni corrected pairwise comparison showed overall lower response accuracy on trials with neutral faces (M=.90, SE=.003) than on trials with angry faces (M=.96, SE=.003), $p<.001$, and with trials with happy faces (M=.95, SE=.003), $p<.001$.

The 2-way interactions Group × Cue ($F_{1,131}=.635$, $p=.427$), Group × Expression ($F_{2,130}=.537$, $p=.586$), and Cue × Expression ($F_{2,130}=1.32$, $p=.271$), as well as the 3-way interaction Cue x Expression x Group ($F_{2,130}=1.98$, $p=.142$) were not statistically significant (see Figure 6 and Table 6).

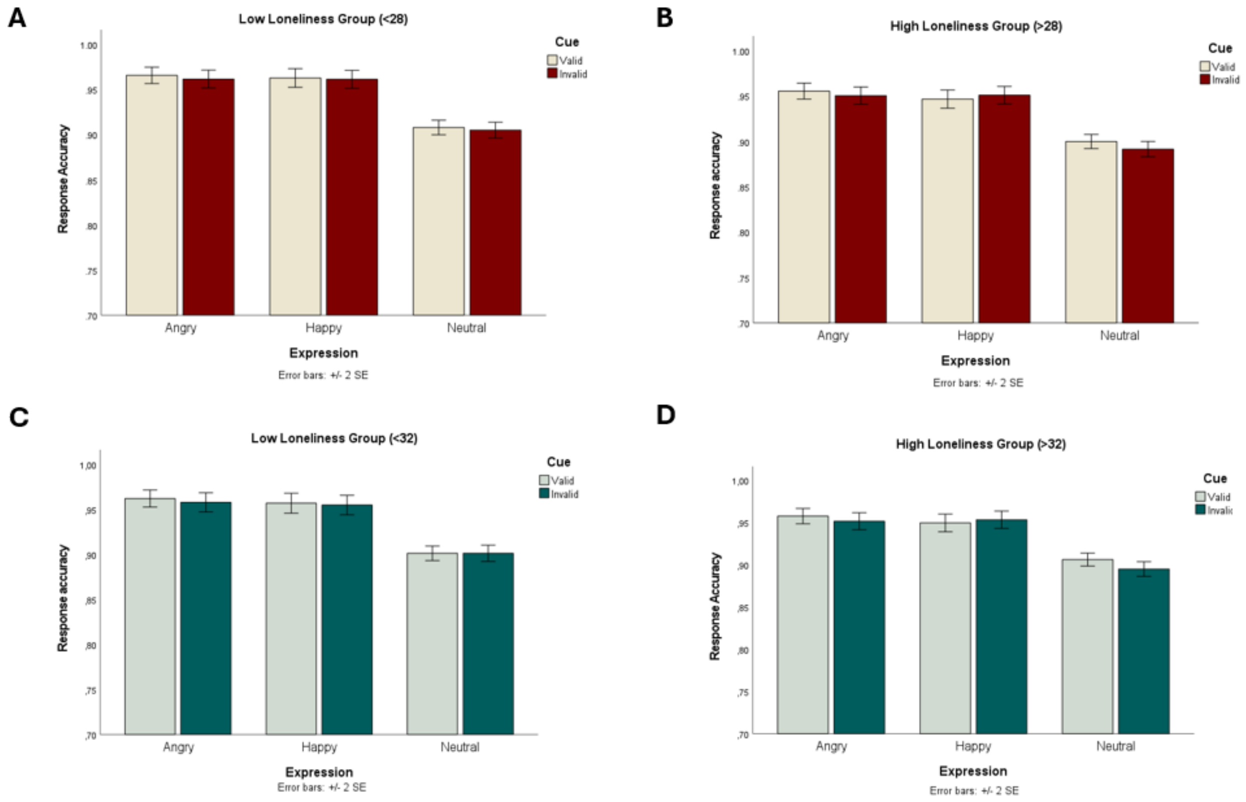

Figure 6. Response accuracy on trials with Valid and Invalid Cues for Angry, Happy, and Neutral faces for the UCLA questionnaire [low loneliness (**A**) and high loneliness (**B**) groups] and for the IPARLS questionnaire [low loneliness (**C**) and high loneliness (**D**) groups]. Error bars represent SE of the means.

	Valid Condition				Invalid Condition			
	Geneal Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	.965	.955	.962	.957	.961	.950	.958	.951
	(.005)	*(.004)*	*(.005)*	*(.004)*	*(.005)*	*(.005)*	*(.005)*	*(.005)*
Happy	.962	.946	.957	.947	.961	.951	.955	.953
	(.005)	*(.005)*	*(.006)*	*(.005)*	*(.005)*	*(.005)*	*(.005)*	*(.005)*
Neutral	.908	.900	.901	.906	.905	.891	.901	.895
	(.004)	*(.004)*	*(.004)*	*(.004)*	*(.004)*	*(.004)*	*(.005)*	*(.004)*

Table 6. Mean (and SE) Response Accuracy at the gaze cueing task.

Incidental Memory Task (test phase).

Reaction Times (RTs).

ANOVA results conducted with Group based on the UCLA scores showed that the main effect of Group was statistically significant, ($F_{1,130}$= 4.13, p= .044, n^2_p=.031) due to overall longer RTs for the low loneliness group (M= 1053, SE= 20) than for the high loneliness group (M= 997; SE= 19). There was a significant main effect of Face ($F_{1,130}$=7.30, p<.008, n^2_p=.053), with shorter RT on trials with seen faces (M=1003, SE=14) than on trials with novel faces (M=1048, SE=18). The main effect of Expression was also significant ($F_{2,260}$=3.10, p<.05, n^2_p=.023). Bonferroni-corrected pairwise comparisons showed overall longer RTs on trials with angry faces (M=1045, SE= 16.6) than on trials with neutral (M=1009, SE= 15.3), p<.05 but no difference with happy faces (M=1021, SE= 16.5), p=.31.

The 2-way interactions Group × Face ($F_{1,130}$= 1.58, p=.21), Group × Expression, ($F_{2,129}$=.81, p=.45), and Face × Expression ($F_{2,129}$=.60, p=.55) as well as the 3-way interaction ($F_{2,129}$=.30, p=.74), were not statistically significant (see Figure 7 and Table 7).

ANOVA results conducted with Group based on the IPARLS showed that the main effect of Group was not statistically significant, ($F_{1,128}$=.002, p=.960). There was a significant main effect of Face ($F_{1,128}$=67.51, p=.012, n^2_p=.048), with shorter RT on trials with seen faces (M=966, SE=12.9) than on trials with novel faces (M=1000, SE=13.3). Whereas the main effect of Expression failed to reach statistical significance ($F_{2,127}$=2.24, p=.110).

The 2-way interaction Group × Face was significant ($F_{1,60}$=10.66, p=.002 n^2_p=.151). Follow up analysis on low loneliness group revealed longer RTs for angry novel faces compared to angry seen faces (t_{60}= -2.64, p=.011 d=-.338), longer RT for happy novel faces compared to happy seen faces (t_{61}=-2.45, p=.017 d=-.312), and longer RT for neutral novel faces compared to neutral seen faces (t_{60}=-2.22, *p*=.030 *d*=-.282). Whereas contrasts for the high loneliness group failed to evidence significant differences between angry novel and angry seen faces (t_{69}=.894, *p*=.374), between happy novel and happy seen faces (t_{69}=-.846, *p*=.400), and between neutral novel and neutral seen faces (t_{69}=-1.11, *p*=.269).

Group × Expression, ($F_{2,127}$=2.244, *p*=.224), and Face × Expression ($F_{2,127}$=.340, *p*=.712) as well as the 3-way interaction ($F_{2,127}$=1.373, *p*=.257), were not statistically significant (see Figure 7 and Table 7).

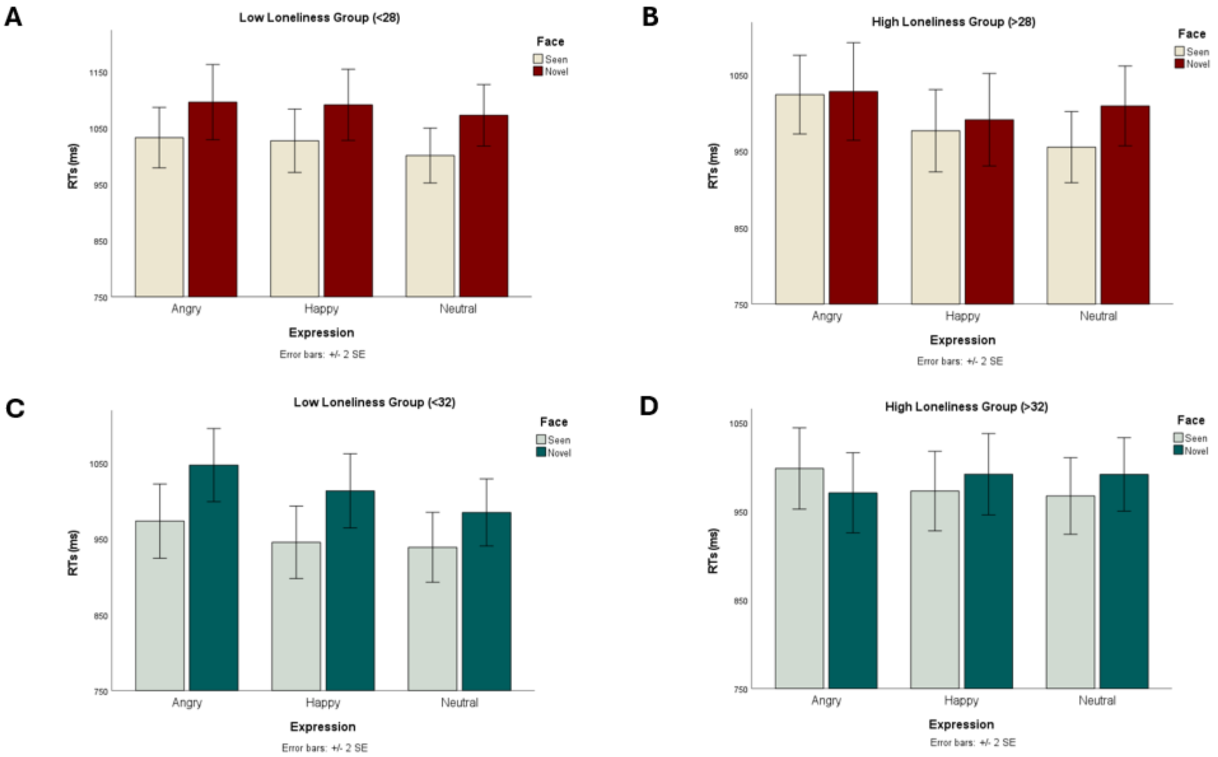

Figure 7. Reaction Times on trials with Seen and Novel Faces for Angry, Happy, and Neutral faces for the UCLA questionnaire [low loneliness (**A**) and high loneliness (**B**) groups] and for the IPARLS questionnaire [low loneliness (**C**) and high loneliness (**D**) groups]. Error bars represent SE of the means.

	Seen Faces				Novel Faces			
	General Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	1032 *(29)*	1024 *(26)*	972 *(24)*	1046 *(24)*	1096 *(33)*	1028 (*32*)	998 *(23)*	970 *(22)*
Happy	1027 *(28)*	977 *(27)*	945 *(24)*	1013 *(24)*	1091 *(32)*	991 *(30)*	972 *(22)*	991 *(23)*
Neutral	1001 *(24)*	955 *(23)*	938 *(23)*	984 *(22)*	1072 *(27)*	1009 *(26)*	967 *(21)*	991 *(21)*

Table 7. Mean (and SE) Reaction Times at the incidental memory task.

Response Accuracy.

ANOVA results conducted with Group based on the UCLA showed that the main effect of Group was not statistically significant, ($F_{1,132}$= 1.49, p= .22). There was a significant main effect of Face ($F_{1,132}$=61.79, p<.001, n^2_p=.32), with lower accuracy on trials with seen faces (M= .73, SE= .01) than on trials with novel faces (M=.85, SE= .01). The main effect of Expression was not significant ($F_{2,264}$=.12, p=.89).

The 2-way interactions Group × Face ($F_{1,132}$= 3,66, p=.058), Group × Expression, ($F_{2,129}$=1.14, p=.32), as well as the 3-way interaction ($F_{2,129}$=.89, p=.41), were not statistically significant (see Figure 7). In contrast, the Face × Expression interaction reached statistical significance ($F_{2,129}$=7.11, p< .001, n^2_p=.05). Bonferroni-corrected pairwise comparisons showed that for seen faces, recognition accuracy was greater for angry (M=.75, SE=.02) than for neutral (M=.71, SE=.02) faces, p=.009. In contrast, for novel faces, recognition accuracy was lower for angry faces (M=.83, SE=.02) than for neutral (M=.87, SE=.01) faces, p=.035. No other comparison reached statistical significance (see Figure 8 and Table 8 for means and SE).

ANOVA results conducted with Group based on the IPARLS showed that the main effect of Group was not statistically significant, ($F_{1,131}$=.101, p=.751). There was a significant main effect of Face ($F_{1,131}$=58.722, p<.001, n^2_p=.31), with lower accuracy on trials with seen faces (M=.73, SE=.01) than on trials with novel faces (M=.85, SE=.01). The main effect of Expression was not significant ($F_{2,130}$=.457, p=.634). In contrast, the Face × Expression interaction reached statistical significance ($F_{2,130}$=5.424, p=.005, n^2_p=.077). Bonferroni-corrected pairwise comparisons showed that for seen faces, recognition accuracy was greater for angry (M=.75, SE=.01) than for neutral (M=.704, SE= .02) faces, p=.014. In contrast, for novel faces, recognition accuracy was lower for angry faces (M=.83, SE=.01) than for neutral (M=.86, SE=.01) faces, p=.014.

The 2-way interactions Group × Face ($F_{1,131}$=.981, p=.324), Group × Expression, ($F_{2,130}$=.457, p=.634), as well as the 3-way interaction Group ($F_{2,130}$=1.367, p=.259), were not statistically significant (see Figure 8 and Table 8 for means and SE).

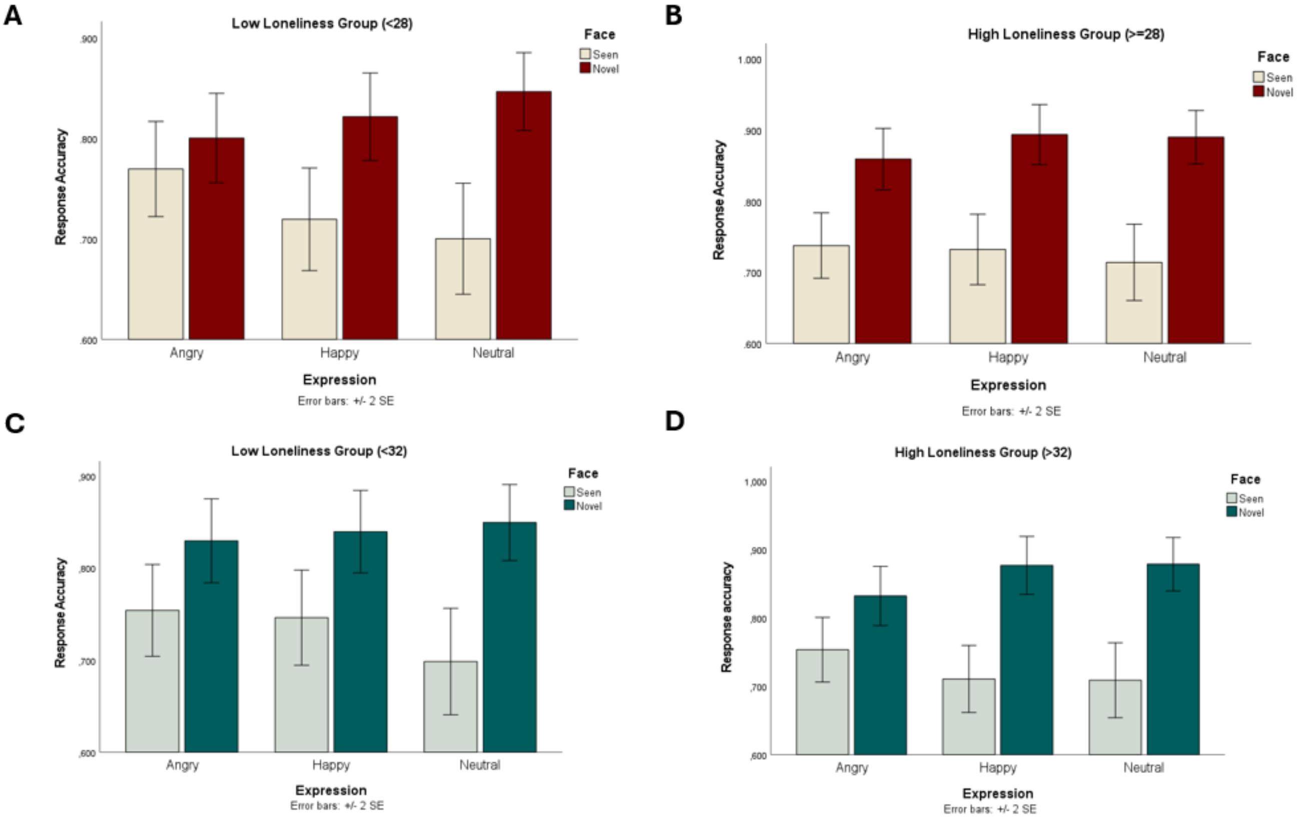

Figure 8. Response accuracy on trials with Seen and Novel Faces for Angry, Happy, and Neutral faces for the UCLA questionnaire [low loneliness (**A**) and high loneliness (**B**) groups] and for the IPARLS questionnaire [low loneliness (**C**) and high loneliness (**D**) groups]. Error bars represent SE of the means.

	Seen Faces				Novel Faces			
	Geneal Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	.769	.737	.754	.754	.800	.859	.829	.832
	(.024)	*(.023)*	*(.025)*	*(.024)*	*(.022)*	*(.022)*	*(.023)*	*(.022)*
Happy	.719	.732	.746	.711	.821	.893	.839	.877
	(.028)	*(.025)*	*(.026)*	*(.025)*	*(.022)*	*(.021)*	*(.022)*	*(.021)*
Neutral	.700	.714	.698	.709	.846	.889	.849	.879
	(.025)	*(.027)*	*(.029)*	*(.027)*	*(.019)*	*(.019)*	*(.021)*	*(.020)*

Table 8. Mean (and SE) Response Accuracy at the incidental memory task.

Discussion

We investigated whether loneliness – assessed as general loneliness by the UCLA scale or as emotions related to social rejection assessed by the IPARLS scale – affects the attentional shift elicited by the direction of another person's gaze. Therefore, young individuals completed a gaze-cueing task, in which participants were presented angry, happy, and neutral faces looking either to the left or to the right of the screen (cue), followed by a target to which participants responded. In addition, to build upon the findings reported in Chapter 2, showing that only low loneliness participants exhibit a memory bias for faces of individuals with happy expressions (just seen or novel faces), we also used an incidental face recognition task at the end of the gaze-cueing task. This allows to assess whether the memory bias relies on the explicit encoding of faces of different ages.

Findings showed the typical cueing effects with faster responses on trials with valid cues compared to invalid cues. Importantly, this effect was not modulated by the expression of the face-cue or by the loneliness level of the individuals – regardless of how loneliness was assessed. That the gaze cueing effect did not vary as a function of the facial expression of the face-cue aligns with previous gaze-cueing studies, (see for a review and McKay et al., 2021). Similarly, to previous studies our results also evidence a main face emotion effect, for which participants took more time to respond on trials with happy expressions (e.g., Mogg, Holmes, Garner & Bradlye, 2008). Happy expressions are generally associated with affiliative emotions and are perceived as less compared to angry expressions and participants may take more time to process and respond to happy expressions (e.g., Feldmann-Wüstefeld, Schmidt-Daffy & Schubö, 2011).

Moreover, whereas it is surprising that gaze cueing effects for the different expressions did not vary between the two groups, this finding is in keep with that of Capellini and collaborators (2019) who used the Cyberball to induce temporary social exclusion. Although a central difference between the two studies is that here, different emotional expressions (angry, happy, and neutral) were used, whereas Capellini and colleagues used either neutral faces or non-naturalistic representations of a face (Exp. 1 and Exp. 2, respectively).

One implication of the present findings is that loneliness does not affect the gaze cueing effect by emotional faces the way trait fearfulness does (Tipples, 2006). This may be due to differences in function between anxiety and loneliness. In fact, whereas fearfulness has the function to detect potential threats, even social threats, loneliness has the function to re-establish social connections. Accordingly, the information provided by gaze direction is important to establish social connections as many social interactions rely on this signal. It has been found that lonely individuals are more prone to interpret a wider range of gaze-angles as direct (i.e., wider "cone of gaze"; Lyrra et al., 2017), and to hold gaze longer (Lodder, Scholte, Goossens, Engels & Verhagen, 2016).

Interestingly, the influence of loneliness on gaze cueing fails to reveal a discernible impact, thereby implying that the subjective experience of loneliness (as assessed by UCLA) or the emotional distress associated with social isolation (IPARLS) do not significantly influence the deployment of attention in response to gaze cues.

Findings from the incidental face recognition task indicated that response times were shorter for already seen faces compared to novel faces. In addition, response times for angry faces tended to be longer compared to happy faces and neutral faces. In contrast to findings reported in Chapter 2, the current study showed a possible recognition bias to threat signals. This different finding could be due to encoding, as participants in the own-age memory bias study were instructed to remember the face as they would have to recognise it later and to judge the faces based on their age. In contrast, in the current study participants were not informed about the later recognition phase and they were informed that the gaze direction of the face was not informative to performing the gaze cueing task. It is possible that the memory bias relies on more explicit processing of emotional faces, future studies should address whether context or instructions influence recognition biases towards emotional stimuli in lonely individuals.

Overall, participants were better for novel faces compared to familiar ones and this effect may be due to allocating more time and cognitive resources to a task can lead to increased accuracy, as it allows for more careful and deliberate processing. Conversely, allocating less time and resources to a task can result in faster performance but at the cost of reduced accuracy (Zimmerman, 2011).

The present findings are indicative that emotional facial expressions influence participants' ability to accurately recognize and remember the faces. Whereas angry familiar faces were related to increase recognition accuracy, compared to happy and compared to neutral, an opposite pattern appears for novel faces, where neutral faces were related to better recognition compared to happy but specially to angry faces. In addition, it is also possible that both avoidance and approach motivations are at play (Elliot, Gable & Mapes, 2006). When individuals encounter angry faces, it triggers an innate response to avoid potential threats or negative situations (e.g., Becker & Detweiller-Bedell, 2008). As a result, individuals tend to pay more attention to familiar angry faces, leading to better recognition and enhanced memory for these faces (e.g., Ohman, Lundqvist & Esteves, 2001). This heightened recognition serves as a defence mechanism, allowing individuals to quickly identify potential threats and take appropriate action to avoid harm. On the other hand, when individuals encounter novel faces heightens approach motivation, as a results it facilitates better recognition and memory, as individuals are motivated to explore and engage with new social stimuli (Chapter 2). These findings highlight the complex interplay between motivational systems and facial recognition processes, shedding light on the underlying mechanisms involved in social perception and behaviour.

In summary, the present study examined the potential influence of loneliness on attention to and implicit memory for social signals. Contrarily to our hypothesis, there were no effects of loneliness on both measures. Low-loneliness individuals were more accurate in recognizing novel faces, regardless of the emotional valence, compared to faces they had previously seen. That individuals with low-loneliness are better at recognizing faces in general suggests that loneliness is linked to a reduced ability to distinguish known faces from unknown faces of unfamiliar individuals.

Although the present study provides valuable insights into the complex interplay between cue validity, face emotion, loneliness, and memory performance, some limitations must be acknowledged. First, we tried to include in the study participants with higher scores on loneliness, but very-lonely participants were reluctant to take part, therefore the sample included in the present study is more representative of moderate levels of loneliness and not high loneliness. Second, it is important to note that even if psychometrical properties of self-reported questionnaires like the UCLA and IPARLS are well known, participants may still be reluctant to respond to some questions (e.g., Richman, Kieser, Weisband & Drasgow, 1999), which may lead to underestimating loneliness.

Finally, in line with the study of Senese and collaborators (2021) the present findings show that the emotional distress related to social rejection (assessed by the IPARLS) was related to the general measure of social isolation (assessed by the UCLA), although neither influenced attention orientation to gaze cues or memory recognition. Moreover, the present study further shows that loneliness is related to depression (see Erzen & Çikrikci, 2018 for a metanalysis), anxiety (see Park et al., 2020 for a review) and stress (e.g., Campagne, 2019).

CHAPTER 4

THE EFFECTS OF LONELINESS ON SELECTIVE ATTENTION TO EMOTIONAL FACES

Introduction

The study described in the previous chapter found that loneliness does not affect orienting attention based on social stimuli when using the gaze cueing task. The study described in this chapter addresses whether loneliness affects selective attention, that is the ability to prioritize information that is task relevant and ignore other that is task irrelevant. This research question stems from theoretical models that posit that when individuals feel isolated from their peers, and they are unsatisfied by their social relations, their attention tends to become more focused on self-preservation (e.g., Nezlek, Wesselmann, Wheeler & Williams, 2015) and exhibit heightened sensitivity to social threats (e.g., Cacioppo, Cacioppo & Boomsma, 2014). This bias may be an adaptive response to protect oneself from further social harm and it is thought to be a result of a hypervigilance mechanism to avoid other rejections and being ostracised. Indeed, there is some evidence showing that loneliness is characterized by an attentional bias toward threat (Cacioppo & Hawkey, 2009, see Spithoven et al., 2021 for a review). However, loneliness also motivates to re-establish social contact and attention may be directed towards signals of potential social interactions and opportunities for connection (e.g., Cacioppo, Cacioppo & Boosmsa, 2014). Consequently, lonely individuals may display increased attention social stimuli, signalling social threat or ambiguous social cues but they may also show increased attention to social stimuli signalling affiliation (e.g., Du, Tang, Jian & Tian, 2022), as lonely individuals are motivated to seek social connection and validation.

Selective attention involves prioritizing specific information that is relevant for the task at hand and for our goals, while ignoring or inhibiting irrelevant ones. Prioritization can be based on bottom-up mechanisms (i.e., stimulus-driven attention), that allows allocation of attention based on stimuli salience (Corbetta, Patel, & Shulman, 2008; Theeuwes, 1994) or on top-down (i.e., voluntary, goal-driven) mechanisms (Desimone & Duncan, 1995; Egeth & Yantis, 1997), which requires cognitive control to actively maintain processing priorities in working memory and provide biasing signals in favour of goal-relevant stimuli (e.g., Corbetta & Shulman, 2002; Desimone & Duncan, 1995). Additionally, emotional salience also prioritizes attention through mechanisms that share characteristics of bottom-up and top-down mechanisms (see Pourtois, Schettino & Vuilleumier, 2013).

One of the most frequently used tasks to assess selective attention is the Stroop Task (Stroop, 1935) and its variants. In the typical Stroop task, participants are presented with words that are printed in different colours and they are required to name the colour of the ink while ignoring the word itself. Typical findings show that when the ink colour and colour-name do not match (i.e., incongruent trials), participants show increased response times and decreased response accuracy (i.e., Stroop effect).

In the next section the evidence collected with emotional variants of the Stroop Task are discussed.

Selective attention to emotional faces

Salient stimuli –physical and affective– capture attention in a bottom-up manner (Yantis & Jonides, 1990), disrupting other ongoing voluntary processing, even when they are not relevant to the current task at hand (LeDoux, 2000). Therefore, to selectively attend some information while ignoring other requires enhancing goal-relevant emotional target and/or inhibit the goal-irrelevant emotional distractor (Etkin et al., 2006; Egner et al., 2007).

Underlying mechanisms of emotional attention are supported by neural circuitry centred on the amygdala, which trough feedback to sensory processing areas biases the neural representation of emotional stimuli over competing neutral ones (i.e., Pessoa, 2009; Pourtois et al., 2013). When emotional stimuli are competing for selective attention, the focus is on the factors affecting what is prioritized (i.e., which emotional category or valence). In fact, previous research indicates that stimuli associated with threats take precedence over other information due to the evolutionary advantage of rapidly detecting potential harm (Öhman & Mineka, 2001).

Researchers have developed different variants of the Stroop task to assess emotional modulation of selective attention (e.g., the emotional Stroop task, face-word interference task, Flanker task) in which a target and a distractor are presented as a compound stimulus, with one to be attended and the other to be ignored. The congruence between the two stimuli is manipulated and typical findings include increases in response times and decreases in response for the incongruent condition. In the emotional Stroop Task (see Williams, Mathews & MacLeod, 1996 for a review), participants are presented with words or images that are emotionally valenced (e.g., positive, or negative), printed in different ink-colour, and are asked to name the colour of the stimuli while ignoring the emotional content. Typical findings consist in slower response times and lower accuracy on emotionally charged stimuli compared to neutral stimuli (see Song et al., 2017 for a meta-analysis).

Other studies have presented two separate stimuli, one to be attended and the other to be ignored. The two stimuli can be physically separated (i.e., Flanker Task) or presented as a unique, compound stimulus (i.e., face-word interference task). In the emotional Flanker Task (Eriksen & Schultz, 1979) participants are presented a central target stimulus (e.g., a word or an image) surrounded by distractor stimuli (flankers) that can be emotionally congruent or incongruent with the target. Typical findings show that emotional distractors can lead to slower responses and decreased accuracy compared to neutral distractors suggesting that emotional stimuli can interfere in selective attention, leading to slower and less efficient processing. In the Face-Word Interference Task (Beall & Herbert, 2008), positive and negative words (e.g., happy and despair) are superimposed to faces portraying different emotional expression (e.g., happy, angry, and neutral), hence targets –words– and distractors –faces– can be either affectively congruent or incongruent. Participants are asked to correctly categorise words as positive or negative as quickly and accurately as possible, whilst ignoring the emotionally-charged faces. Typical results show longer response times and lower accuracy on incongruent trials (i.e., interference effect, Beall & Herbert, 2008).

More specifically, Beall and Herbert, (2008) presented emotional distractors consisting of different face expression (happy, sad, and blurred in Exp. 1 and happy, angry, and blurred in Exp. 2) and target-words consisting of prototypical adjectives of the emotional distractor-face (e.g., bliss, grieve). Participants performed two versions of the task, expression, and word conditions. In the expression condition participants responded to the facial expression (positive or negative) while ignoring the word, whereas in the word condition, participants responded to word targets based on valence (i.e., positive/negative) while ignoring the distractor-faces. Findings showed greater interference from distractor-faces compared to distractor-words. Moreover, results showed that interference was greater from happy compared to sad and blurred distractor faces (Exp. 1), but that interference effects were similar between happy and angry distractor-faces compared to blurred distractor faces (Exp. 2).

Considering that what is prioritized for attention may depend on personal goals and individuals' concerns (e.g., Krug & Carter, 2012), much research has focused on understanding the individual differences that contribute to interference from emotional distractors. In particular Krug and Carter (2012) explored whether differences in trait anxiety would increase interference from threat-related distractors. In an fMRI study, 21 high-trait anxiety participants along with 21 low-trait anxiety participants (assess with the trait scale of the STAI, Spielberg 1983) completed two versions of a face-word interference task, in which two words – "neutral" and "fearful"– were presented over neutral or fearful faces. Congruency was manipulated such that proportion of congruent-incongruent conditions between tasks varied (Task 1: high expectancy 65% of incongruent trials; Task 2: low expectancy 35% of incongruent trials). Overall, results showed that higher anxiety was related to increase RTs and decreased accuracy.

Other studies have investigated age differences in prioritizing positive information as old individuals often show a positivity bias (e.g., Mather & Carstensen, 2003, Isaacowitz, Wadlinger, Goren, & Wilson, 2006), as an attempt to boost their emotional well-being (i.e., positivity effect, Kennedy, Mather & Cartensen, 2004). To assess whether ageing is linked to increased interference from positive stimuli, Viviani and colleagues (2021) used a face-word interference task with young and old individuals. They presented positive and negative words overlayed to happy, angry, and neutral-scrambled faces. Findings showed no differences between old and young individuals as interference from angry faces on positive words was greater than that from happy faces on negative words for old as well as young adults. Finally, Ros and collaborators (2021) used a face-word interference task to examine the role of depression on interference from emotional distractors. Twenty-six depressed old adults (assess by the ICD-10 criteria) and 26 healthy matched-controls performed a face-word interference task in which the words "happy or sad" were presented overlayed to an emotional face "happy or sad". In the face block participants were instructed to respond based on the emotion portrayed by the face, whereas in the word block participants were had to respond based on word valence. Results showed that depressed older patients responded slower and less accurate compared to healthy older adults, and this pattern was consistent on both word-task and face-task. Results also showed that during the face-task depressed older adults obtained lower correct responses on the positive trials and on the negative trials, independently on whether there were congruent or incongruent.

In conclusion, there is evidence that emotional distractors interfere with target processing, although it is unclear whether negative distractors create greater interference than positive ones. In addition, research assessing whether individual characteristics are linked to greater interference from specific emotional distractors is mixed.

The effect of social exclusion and loneliness on selective attention to emotional faces

Based on the assumption that the desire for positive and lasting social relationships represents a fundamental need for human beings (Williams, Cheung & Choi, 2000), it has been suggested that the motivation to establish social relationships (DeWall, Maner & Rouby, 2009), as well as differences on social context or social roles (Ma & Zhang, 2021), may influence the information that is prioritise over other.

For instance, DeWall and colleagues (2009) in 4 experiments investigated whether social exclusion could influence attention allocation. Participants' social condition was manipulated by task instructions in which some were told that they probably would end up being alone later in life (i.e., future alone condition), others were led to belief that they would have long, stable and rewarding relations (i.e., future belonging condition), and others were informed that they would be more prone to suffer accidents or injuries (i.e., future misfortune; Exp. 1, Exp. 2, and Exp. 3). In Experiment 1, 79 undergraduate students performed a face in the crowd task where they were asked to find as quickly and accurate as possible an emotional face (angry, sad, or happy) within a crowd of other neutral faces. In Experiment 2 and

Experiment 3 undergraduate students (N=45 and N=85, respectively) performed a free viewing eye-tracking task in which they were presented arrays of faces (Exp. 2: 4 arrays of 4 angry, sad, neutral, and happy faces; Exp. 3: 6 arrays of 4 angry, sad, neutral, and happy faces). In Experiment 4, social condition was induced by task instruction where they were told that they would send video messages with another participant (confederate), but half were told that their partner had to leave unexpectedly (irrelevant departure condition), and the others were told that their partner refused to work with them (social exclusion condition). Sixty-six undergraduate students then completed a dot-probe task, in which a smiling, angry or disgust face was paired with a neutral face. In this task two faces were presented on the left and the right side of the computer screen (1000ms) followed by a dot that could appear either on the left or on the right side. Participants were asked to indicate as quickly and accurate as possible the location of the dot. Results showed that social excluded participants were faster to detect happy faces (Exp.1) and that happy faces did capture more attention in comparison to angry or sad faces. Results also evidenced that socially excluded individuals are more likely to avoid negative social stimuli (i.e., lesser number of fixations and decreased duration of fixations; Exp. 2 and Exp. 3). Altogether, findings suggest that threats to social inclusion function as an intrinsic signal that motivates and guides the individuals’ attention to positive social stimuli (i.e., affiliative cues) that could restore their sense of belonginess.

Fernandes and collaborators (2019) assessed whether the mere presence of others (in the same space) affects interference from emotional distractors. Sixty-two undergraduate students were randomly assigned to either the presence condition (placed in a room with other participants without engaging interactions) or the alone condition (isolated in another room), following which they performed a face-word interference task. Participants were simultaneous presented a word –target– overlayed to a face–distractor–. Sixteen words (8 positive and 8 negative) and sixteen faces (half portraying happiness and the other half displaying anger) were used. Half of the participants were asked to categorise the word as happy or angry, as accurate and quickly as possible (i.e., word-face task), while disregarding the face, while the other half were instructed to evaluate the facial expression displayed (i.e., face-word task) while ignoring the distractor-word. Overall RTs were longer on incongruent trials. Importantly, happy faces interfered more with processing of an emotional word compared to angry faces, and this interference was greater for individuals in the alone condition.

In an EEG study, Ma and Zhang (2021) investigated the extent to which social power influences selective attention to emotional stimuli. Thirty-eight college students were randomly assigned to a high-power or to a low-power condition. In the high-power condition, they were asked to recall a past event in which they had power over another individual, meanwhile, in the latter, they were instructed to recall a past event in which somebody else had power over them. After the social power manipulation, participants completed the face-word interference task, in which 2 emotional words (happy and fear) were overlayed to 32 emotional faces (16 happy and 16 fear), and participants were asked to judge, as quickly and accurate as possible, whether the face was portraying a happy or fear emotion, while disregarding the emotional distractor-word. Trials started with a fixation cross (400ms), followed by a black screen (400-600ms), followed by the presentation of the word-face pair for 1000ms. Throughout the task, congruent and incongruent trials had the same proportion (50-50). Findings showed that participants were less accurate for happy faces compared to fearful ones and they were slower for fearful faces compared to happy faces. Importantly, there were no groups differences on behavioural interference measures. EEG analysis for fearful faces revealed larger P1 amplitude in the incongruent trials and a more negative N170 component in the congruent condition for individuals in the low-power group compared to participants in the high-power group. In contrast, happy faces elicited larger P1 amplitudes in incongruent condition for the participants in the high-power group compared to the low-power group. Therefore, individuals in the high-power group allocate more attentional resources in the early stages of processing (P1) whereas participants in the low-power condition allocate more resources to processing of the emotional stimulus (N170), independently of the emotion type. Importantly, participants in the low-power condition allocate more attention to threat stimuli (i.e., fearful faces), than individuals in the high-power condition.

Unfortunately, even if these studies show that social context exerts an influence in the individual's ability to selectively attend some information and ignore emotional distractors, these findings may not directly apply to loneliness as being in the presence of others or having low power does not necessarily entail feeling lonely. To our knowledge the only study that assesses the effects of loneliness on selective attention to emotional stimuli is the study of Shin and Kim (2019). In their study, 95 university students were enrolled and after completing the UCLA loneliness scale (Russell, 1996) they performed an auditory Stroop Task. In this task, participants listened to 80 words of which 40 were social and 40 non-social, additionally, both social and non-social words could be positive (20 words per category, 40 in total) and negative (20 words per category, 40 in total). Vocal tone was manipulated such that half the times it matched the word content (i.e., congruent) and for half did not (i.e., incongruent). Participants were asked to respond to the word, thus, indicating whether it was positive or negative and ignore the vocal tone in which was spoken. Findings showed only a marginal effect of lonely participants deploying more attention to negative vocal tone than to positive vocal tone (i.e., slower responses were observed for trials with negative vocal tone compared to positive). These findings suggest greater interference from negative vocal tone in lonely individuals, however not only results have to be taken with caution as the effects were marginal, but also it is unclear whether this could apply to other sensory modalities such as the visual domain.

The present study: the effect of loneliness on selective attention to emotional faces

The reviewed studies described so far show that distractor-faces in the word-face interference task emotional engender conflict and yield interference when they are affectively incongruent with target-words. However, it is not clear which stimulus valence engenders greater interference effects. For instance, angry distractor-faces sometimes elicit less interference than happy distractor-faces and this has been attributed to threat-related distractors being processed faster and (e.g., Beall & Herbert, 2008). That is, threat-related stimuli (fearful but also angry faces) may engender facilitation effects when target and distractors are affectively congruent and less interference when they are affectively incongruent, as individuals respond promptly to potentially threatening situations (Pessoa, 2009).

The present study aimed at investigating whether individual differences in self-reported loneliness affects selective attention to emotional distractor-faces. We used emotional - happy and angry - and neutral scrambled distractor faces presented with positive and negative target-words. The research question stems from evidence showing that individuals goals and concerns may affect which information is prioritized for processing over other. It has been suggested that since the drive to form social relationships is related to evolutionary benefits in conditions of perceived loneliness people deploy larger attentional resources to affiliative happy faces that may indicate a possible reconnection (Lamblin, Murawski, Whittle & Fornito, 2017; Chen, Nummenmaa & Hietanen, 2017). We hypothesize that if loneliness motivates to approach happy faces (e.g., Nikitin & Schoch, 2021), individuals experiencing loneliness will exhibit greater interference for happy faces, reflecting a bias towards positive stimuli. In contrast, if loneliness motivates to detect social threat, (e.g., Nikitin & Schoch, 2021), then we expect greater interference for angry faces, indicating a bias towards negative stimuli.

Method

All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Psychology Department Ethic Committee, Sapienza University of Rome: Institutional Review Board Approval Prot. n. 0000867. Informed consent was obtained from the study participants.

Participants

Ninety-eight university students took part in the experiment, however, due to technical issues the data of one participant was discarded because incomplete. Behavioural data of one participants was missing. Of the 97 participants, UCLA data were missing for 1 participant, therefore group analyses were based on 96 participants [females= 82; males= 15; age = 21.36 (*sd*=3.57)]. Of the 97 participants, IPARLS data were missing for 5 participants, therefore group analyses were based on 92 participants [females= 72; males= 15; age = 21.37 (*sd*=3.64)].

Sensitivity analysis conducted using G*Power software (Faul et al., 2007) showed that with the current sample size we would have 80% power to detect effect sizes of n^2_p=.02, or a small-medium effect size.

We started pre-screening participants based on scores at the UCLA Loneliness Scale (Boffo et al., 2012) but it proved difficult to get high in-loneliness individuals to come to the laboratory following the completion of the online questionnaire so that we decided to recruit independently from the UCLA scores. Therefore, participants were *a posteriori* divided into two groups based on the loneliness scores.

Word-Face Interference Task

Forty-eight middle-aged adult faces (24 males and 24 females) were selected from the FACES database (Ebner, Riediger, & Linden-Berger, 2010, see Table 9) as distractors. For each identity, neutral, angry, and happy expressions were selected for a total of 144 stimuli (48 happy, 48 angry and 48 neutral faces). All pictures were edited, adjusted to the centre, and balanced for brightness using Adobe Photoshop 6.0 with an average brightness value of 106.5 cd/m2. When presented on screen, faces measured 14.8 x 12.4 cm. Words were presented in uppercase, lime green, bold, 45-point Arial font (Baggott, Palermo & Fox, 2011) pre-tested for readability. Each of the 48 words was presented superimposed onto each type of distractor-face (happy, angry, scrambled) at the height of the nose. Stimuli were displayed on a 19-inch LCD monitor (resolution 1920 × 1080, refresh rate 60 Hz), subtending 13° of visual angle when presented at 60 cm of distance. E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA, 2012) for Windows 7 was used for stimulus presentation and data collection. Responses were entered using a standard USB-keyboard with timing error less than 1ms.

Targets were 48 words (24 positive, 24 negative) selected from the Italian translation and validation of the Affective Norms for English Words (ANEW; Montefinese et al., 2014). Positive and negative words differed for valence (positive M= 7.53; SD=.12; negative M=2.78; SD=1.5, t_{46}=24.80 p<.001), but not for arousal (positive M= 5.44; SD=.16; negative M=5.60; SD=.21, t_{46}=.6 p=.55), and word length (positive M= 7.08; SD=.22; negative M=7.00; SD=.18, t t_{46}= 2.53 p=.100). Neutral faces, edited in scrambled images of 50 pixels using MATLAB, were used as controls. Additionally, another 12 words (6 positive and 6 negative) were used as targets in the practice session, along with another 12 faces (4 angry, 4 happy, and 4 neutral).

The task had an equally probable factorial combination of Target Valence (positive, negative) and Face Distractor (angry, happy, scrambled) so that target and distractor could be congruent (i.e., positive word/happy face or negative word/angry face), incongruent (i.e., positive word/angry face or negative word/happy face) or control (i.e., positive, or negative word/scrambled face).

Female		**Male**	
011_m_f_a_a.jpg	073_m_f_h_b.jpg	026_m_m_a_a.jpg	077_m_m_h_b.jpg
052_m_f_a_b.jpg	097_m_f_h_a.jpg	051_m_m_a_b.jpg	126_m_m_h_b.jpg
093_m_f_a_a.jpg	122_m_f_h_b.jpg	056_m_m_a_b.jpg	165_m_m_h_a.jpg
111_m_f_a_b.jpg	138_m_f_h_b.jpg	092_m_m_a_b.jpg	179_m_m_h_a.jpg
113_m_f_a_a.jpg	006_m_f_n_a.jpg	094_m_m_a_b.jpg	058_m_m_n_a.jpg
117_m_f_a_b.jpg	019_m_f_n_b.jpg	104_m_m_a_b.jpg	068_m_m_n_a.jpg
157_m_f_a_b.jpg	029_m_f_n_a.jpg	108_m_m_a_a.jpg	082_m_m_n_a.jpg
168_m_f_a_b.jpg	050_m_f_n_a.jpg	116_m_m_a_a.jpg	136_m_m_n_b.jpg
035_m_f_h_a.jpg	084_m_f_n_a.jpg	007_m_m_h_b.jpg	149_m_m_n_b.jpg
043_m_f_h_a.jpg	128_m_f_n_a.jpg	014_m_m_h_a.jpg	155_m_m_n_b.jpg
061_m_f_h_b.jpg	156_m_f_n_a.jpg	032_m_m_h_a.jpg	159_m_m_n_b.jpg
064_m_f_h_a.jpg	180_m_f_n_a.jpg	045_m_m_h_b.jpg	169_m_m_n_a.jpg

Table 9. Selected Faces Identities from the Ebner FACES Database.

Questionnaires

The Italian version of the UCLA Loneliness Scale (Boffo, Mannarini & Munari, 2012) consisting of a 10 items scale was used to assess perceived loneliness. The Italian version of the Interpersonal Acceptance–Rejection Loneliness Scale (IPARLS; Senese, Nasti, Mottola, Sergi, Massaro & Gnisci, 2021) consisting of 15 items was used to assess perceived loneliness. We decided to use both questionnaires as they measure slightly different constructs. The UCLA questionnaire measures general loneliness whereas the IPARLS measures subjective feelings of distress by loneliness (i.e., emotional component).

Apparatus

The face-word interference task was presented using E-Prime Version 2.0 Professional software for Windows 7, which also recorded participants' responses. Stimuli were presented on a Pentium IV computer via a 17" CRT monitor (1024 x 768 pixels, 60 Hz). Participants seated comfortably in front of a computer screen at a viewing distance of approximately 60cm.

Procedure

Participants were asked to complete an online version of the UCLA loneliness scale (Boffo & Municcio, 2012) -administered via Testable- before coming to the laboratory. Once in the laboratory, participants provided their informed consent and they were presented with the 15 items of the IPARLS (Senese et al., 2021). We opted for asking participants to complete these items before the face-word task to allow participants to think about their social interactions. Upon completion of the questionnaires, the task instructions were presented onscreen. Participants were instructed to respond, as accurate and quickly as possible, based on whether the word denoted something positive or negative while ignoring the distractor-faces. Participants performed 12 practice trials, after which they completed a total of 288 trials (6 blocks of 48 trials each), resulting from the combination of the 72 faces (24 male faces portraying either happy, angry, or neutral facial expressions as well as 24 female faces portraying either happy, angry, or neutral facial expressions) with the positive or negative valanced words.

Trials started with a central fixation point (250ms), followed by the face-word pair that remained on screen until response, once response was recorded the feedback was displayed onscreen (500ms). The intertrial-interval (ITI), varied randomly between 500 and 1500ms (see Figure 10). Participants responded to target-words by pressing the keys "1" or "2" labelled as “Positive” and “Negative”, using their index and middle finger of the right hand. Responses were made on a USB keyboard with timing error less than 1ms and keys assignment to “Positive” and “Negative” was counterbalanced between participants.

The task had an equally probable factorial combination of Target Valence (positive, negative) and Face Distractor (angry, happy, scrambled) so that target and distractor could be congruent (i.e., positive word/happy face or negative word/angry face), incongruent (i.e., positive word/angry face or negative word/happy face) or control (i.e., positive, or negative word/scrambled face).

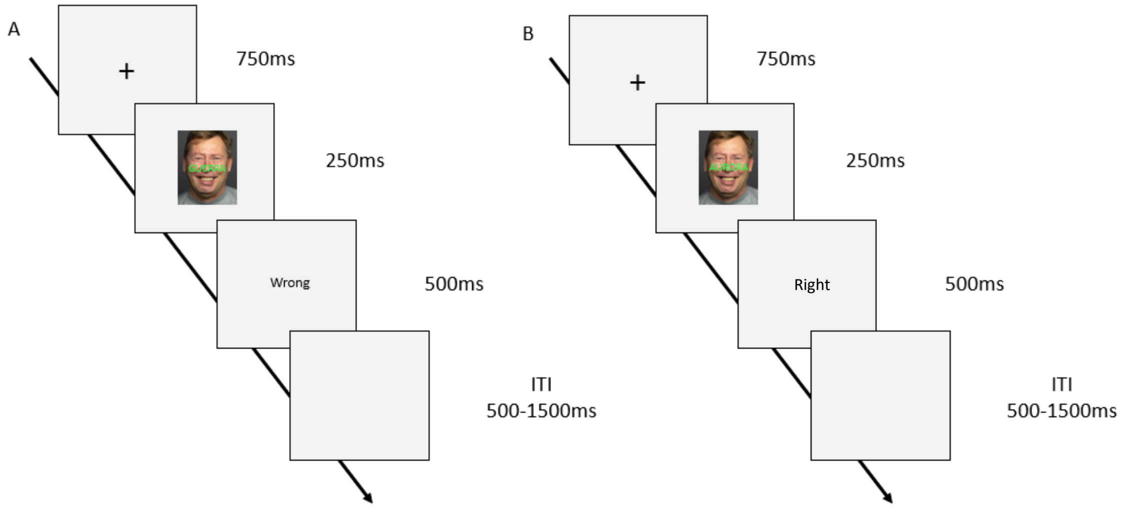

Figure 9. Schematic time course of displays presented in the face-word interference task, for incongruent (**A**) and congruent trials (**B**). To make the encoding task less predictable, the intertrial interval randomly varied between 500ms and 1500ms.

Experimental Design

The experimental design was a 2 (Group: high lonely, low loneliness) by 2 (Word Valence: positive, negative) by 3 (Face Distractor: angry, happy, neutral) mixed-factorial with the first factor between-subjects.

Data Analysis

Loneliness. For the Italian adaptation of the UCLA a total score was computed after reverse scoring five items: scores typically range from a minimum of 10 to a maximum of 50 and higher scores indicate more loneliness. In the present sample, the UCLA lower score was 12 and the higher score was 47. For the Italian adaptation of the IPARLS a total score was computed: scores typically range from a minimum of 15 to a maximum of 75 with higher scores indicating higher levels of loneliness. In the present sample, the IPARLS lower score was 15 and the higher score was 65.

As the UCLA and IPARLS assess different aspects of loneliness, data were analysed with group based on the general measure of loneliness (UCLA) as well as with group based on the social isolation and rejection measure of loneliness (IPARLS).

For the UCLA scores, participants who scored below the median (<24.0) were considered as low in loneliness (N=51; females=43; males= 8), whereas participants who scored above (>24.0) were considered as high in loneliness (N=46; females=39; males=7). The same procedure was conducted also for the IPARLS scores: participants who scored below the median (<32.0) were considered as low loneliness (N=49; females=42; males=7), while participants who scored above the median (>32.0) were considered as high loneliness (N=44; females=36; males=8).

Behavioural data. All data processing and analysis were conducted in SPSS v.27. Trials in which an error was made (6.22%) and trials with RTs not within 120ms and 2.5 SD from the mean (9.4% of the remaining trials) were excluded from analyses. Mean RTs for correct responses were computed for each condition. Accuracy was computed as the proportion of correct responses (hit rates). This procedure was also carried out for seen and novel faces: hit rates were computed as the proportion of test trials in which participants correctly responded "seen" to a face that was seen before and correctly responded "not seen" to a face that was new, respectively.

As the UCLA and IPARLS assess different aspects of loneliness, data were analysed with group based on the general measure of loneliness (UCLA) as well as with group based on the social isolation and rejection measure of loneliness (IPARLS). One participant's UCLA data was missing, analysis were carried out on 96 participants. Five participant's IPARLS data were missing, analysis were carried out on a sample of 92 participants.

Face Word Interference Task. All data processing and analysis were conducted in SPSS v.27. Trials in which an error was made (4.48%) and trials with RTs not within 120ms and 2.5 SD from the mean (2.96% of the remaining trials) were excluded from analyses. Mean RTs and correct responses (i.e., accuracy) were computed for each condition. RTs and response accuracy data were analysed with a 2 x 2 x 3 mixed-factorial ANOVA with Group (2: low loneliness, high loneliness) by Word Valence (2: positive, negative) by Face Distractor (3: angry, happy, neutral) with the first factor between-subjects.

In addition, when the interactions were statistically significant for RTs, interference was computed as {[(RTs Incongruent - RTs Control)/[(RTs Incongruent + RTs Control)]/2} * 100 whereas Facilitation was computed as {[(RTs Congruent - RTs Control)/[(RTs Congruent +

RTs Control)]/2} * 100 (Petrucci & Pecchinenda, 2016). Interference is indicated by positive scores whereas facilitation by negative scores.

Results

Reaction Times (RTs).

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,94}$=.608, *p*=.44). There was a significant main effect of Word Valence, ($F_{1,94}$=12.91, *p*<.001, $n^2{}_p$=.121) due to fast RTs on trials with positive words (M=668, SE=5.7) than on trials with negative words (M=677, SE=5.6) *p*<.001. The main effect of Face Distractor failed to reach statistical significance ($F_{2,93}$=2.11, *p*=.127).

The 2-way interaction Word Valence × Face Distractor ($F_{2,93}$=71.22, *p*<.001, $n^2{}_p$=.605), was significant. Bonferroni-corrected pairwise comparisons showed that for angry faces, slower RTs were obtained for positive target words (M=679, SE=5.7) compared to negative target words (M=667, SE=5.9) *p*<.001. In contrast, for happy faces, RTs were faster for positive target words (M=657, SE=6) than for negative target words (M=684, SE=5.6) *p*<.001. Similarly, for scrambled neutral faces, faster RTs were found for positive target words (M=668, SE=5.9) than for negative target words (M=681, SE=5.6) *p*<.001.

The 2-way interactions Group × Face Distractor ($F_{2,93}$=.11, *p*=.89), Group × Word Valence ($F_{1,94}$=.96, *p*=.33), as well as the 3-way interaction ($F_{2,93}$=.11, *p*=.89) did not reach statistical significance (see Figure 10 and Table 10).

ANOVA results conducted with Group based on the IPARLS mirrored the results obtained with the UCLA as they showed that the Group main effect was not statistically significant ($F_{1,90}$=.432, *p*=.51). There was a significant main effect of Word Valence, ($F_{1,90}$=10.99 *p*=.001, $n^2{}_p$=.109) due to faster RTs on trials with positive words (M=669, SE=5.8) than on trials with negative words (M=678, SE=5.7) $p<.001$. The main effect of Face Distractor was not significant ($F_{2,89}=2.98$ $p=.056$). The 2-way interaction Word Valence × Face Distractor ($F_{2,89}=68.26$, $p<.001$, $n^2{}_p=.605$), was significant. Bonferroni-corrected pairwise comparisons showed that when presented with angry distractor-faces, RTs were slower for positive target words (M=680, SE=5.8) compared to negative target words (M=668, SE=6) $p<.001$. In contrast, when presented with happy distractor-faces, RTs were faster for positive target words (M=658, SE=6) than for negative target words (M=685, SE=5.7) $p<.001$. Finally, when presented with scrambled neutral faces, RTs were faster for positive target words (M=670, SE=5.9) than for negative target words (M=682, SE=5.8) $p<.001$.

The 2-way interactions Group × Face Distractor ($F_{2,89}=.06$ $p=.94$), Group × Word Valence ($F_{1,90}=.681$ $p=.41$), as well as the 3-way interaction ($F_{2,89}=.59$, $p=.56$) did not reach statistical significance (see Figure 10).

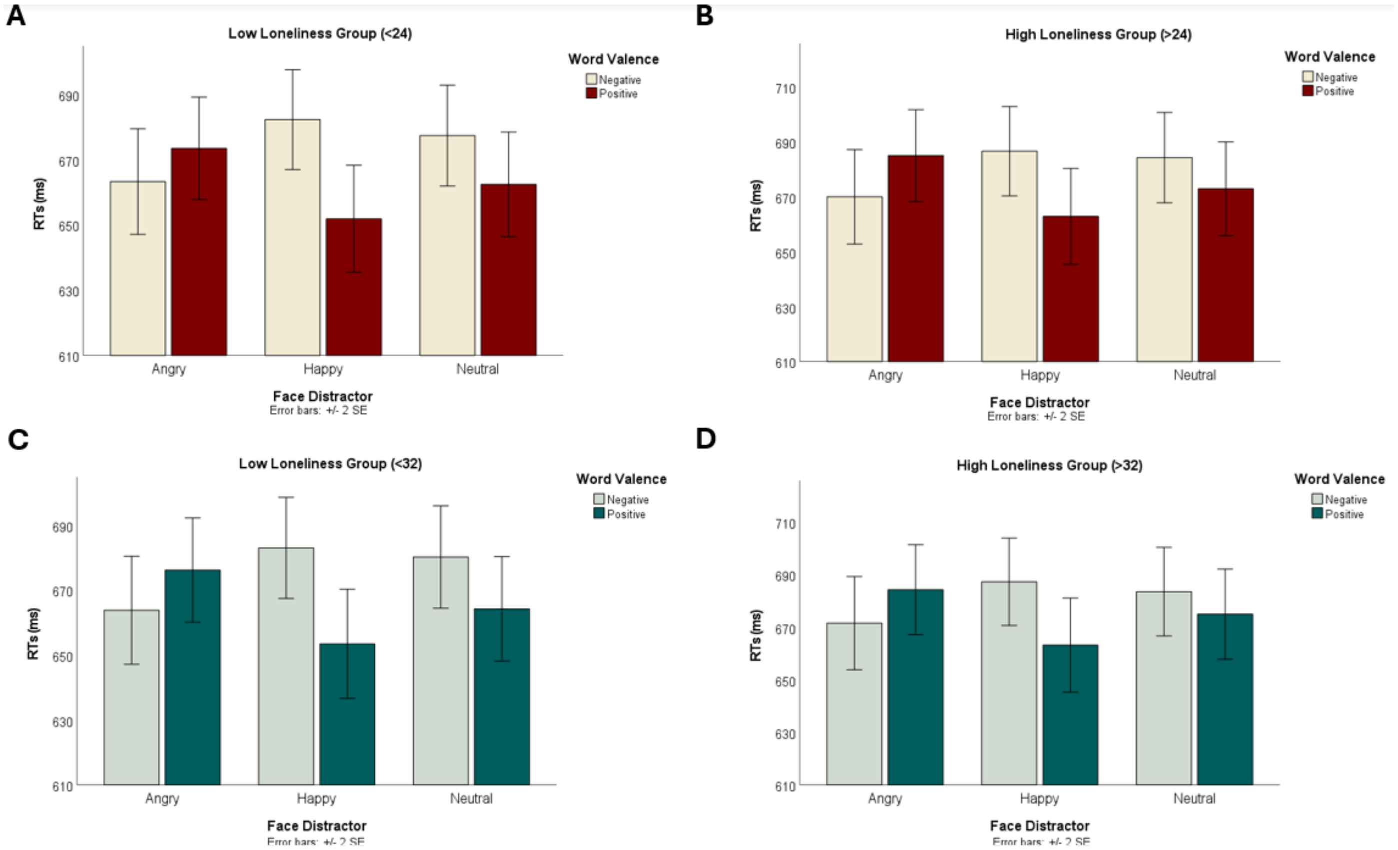

Figure 10. Reaction Times (RTs) on trials with positive and negative target words for Congruent, Control, and Incongruent Conditions for the UCLA questionnaire [low loneliness (**A**) and high loneliness (**B**) groups] and for the IPARLS questionnaire [low loneliness (**C**) and high loneliness (**D**) groups]. Error bars represent SE of the means.

	Negative Words				Positive Words			
	Geneal Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	663	670	664	672	673	685	676	684
	(8.1)	*(8.6)*	*(8.3)*	*(8.9)*	*(7.8)*	*(8.3)*	*(8.0)*	*(8.6)*
Happy	682	687	683	687	651	663	653	663
	(7.6)	*(8.1)*	*(7.8)*	*(8.3)*	*(8.2)*	*(8.7)*	*(8.4)*	*(9.0)*
Neutral	651	684	680	684	662	673	664	675
	(7.7)	*(8.2)*	*(7.8)*	*(8.4)*	*(8.0)*	*(8.5)*	*(8.0)*	*(8.6)*

Table 10. Mean (and SE) Reaction Times at the face-word interference task.

Interference.

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,94}$=.11, *p*=.75). The main effect of Face Distractor ($F_{1,94}$=5.95, *p*=.02, n^2_p=.06) was significant, with greater interference of angry faces (M=.44 SE=.08) compared to happy faces (M=.14 SE=.09) *p*=.017. The 2-way interaction Group × Face Distractor ($F_{1,94}$=.200, *p*=.66) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,94}$=.06, *p*=.81). The main effect of Face Distractor ($F_{1,94}$=4.88, *p*=.03, n^2_p=.05) was significant, with greater interference of angry faces (M=.40 SE=.08) compared to happy faces (M=.12 SE=.09) *p*=.03. The 2-way interaction Group × Face Distractor ($F_{1,94}$=.353, *p*=.55) failed to reach statistical significance.

Facilitation.

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,94}$=.014, *p*=.91). The main effect of Face Distractor ($F_{1,94}$=1.50, *p*=.22) and the Group × Face Distractor ($F_{1,94}$=.00, *p*=.99) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,94}$=.412, *p*=.52). The main effect of Face Distractor ($F_{1,94}$=.750, *p*=.39) and the Group × Face Distractor ($F_{1,94}$=.74, *p*=.39) failed to reach statistical significance.

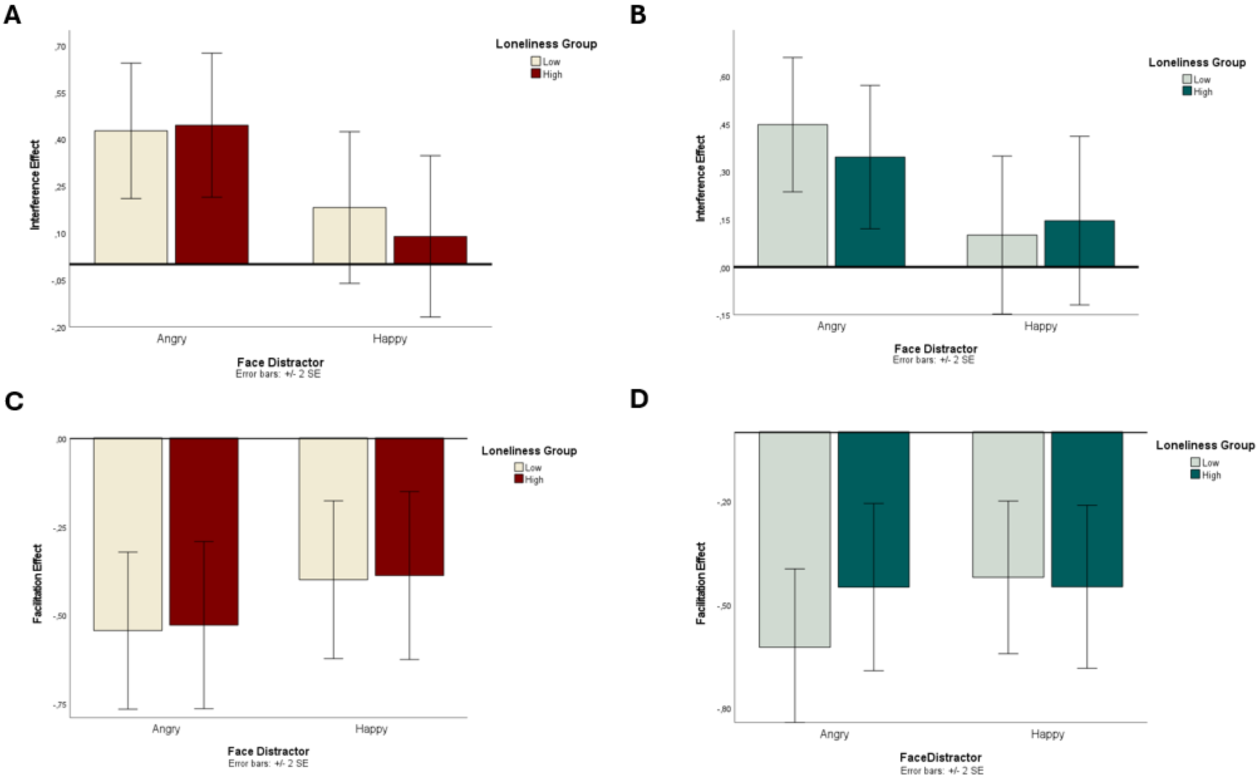

Figure 11. Group effect for Interference Effect [UCLA questionnaire (**A**) and IPARLS questionnaire (**B**)] and Group effect for Facilitation effect [UCLA questionnaire (**C**) and IPARLS questionnaire (**D**)]. Error bars represent SE of the means.

Response Accuracy.

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,95}$=.563, *p*=.46). The main effect of Face Distractor as well as the main effect of Word Valence, ($F_{1,95}$=2.92, *p*=.091), failed to reach statistical significance ($F_{2,94}$=2.28, *p*=.107, n^2_p=.307). However, the 2-way interaction Word Valence × Face Distractor was significant ($F_{2,94}$=20.72, *p*<.001, n^2_p=.306). Bonferroni-corrected pairwise comparisons showed that when presented with angry distractor-faces, accuracy was higher for negative target words (M=.96, SE=.004) compared to positive target words (M=.95, SE=.006) *p*<.001. In contrast, when presented with happy distractor-faces, accuracy was lower for negative target words (M=.95, SE=.004) than for positive target words (M=.97, SE=.004) *p*<.001. Finally, when presented with scrambled neutral distractor-faces, accuracy was higher for positive target words (M=.97, SE=.004) than for negative target words (M=.95, SE=.005) *p*=.019. The 2-way interactions Group × Face Distractor ($F_{2,94}$=.09 *p*=.92), Group × Word Valence ($F_{1,95}$=.36, *p*=.55), and as well as the 3-way interaction ($F_{2,94}$=.19, *p*=.82) did not reach statistical significance (see Figure 12 and Table 11). The 2-way interactions Group × Face Distractor ($F_{2,94}$=.09 *p*=.92), Group × Word Valence ($F_{1,95}$=.36, *p*=.55), and as well as the 3-way interaction ($F_{2,94}$=.19, *p*=.82) did not reach statistical significance (see Figure 12 and Table 11).

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,91}$=1.88, *p*=.17). The main effect of Face Distractor was statistically significant ($F_{2,94}$=3.27, *p*=.04, n^2_p=.068), due higher accuracy on trials with neutral faces (M=.96, SE=.004), than on trials with angry faces (M=.95, SE=.004). Whereas the main effect of Word Valence, ($F_{1,91}$=3.45, *p*=.07), did not reach statistical significance (see Figure 12 and Table 11). The Word Valence × Face Distractor was significant ($F_{2,90}$=18.93, *p*<.001, n^2_p=.296). Bonferroni-corrected pairwise comparisons showed that for angry faces, accuracy scores were higher for negative target words (M=.96, SE=.004) compared to positive target words (M=.95, SE=.006) *p*<=001. In contrast, for happy faces, accuracy was lower for negative target words (M=.95, SE=.004) than for positive target words (M=.97, SE=.004) *p*<.001. Similarly, for scrambled neutral faces, higher accuracy scores were found for positive target words (M=.97, SE=.004) than for negative target words (M=.95, SE=.005) *p*=.019.

Additionally, the 2-way Group × Word Valence interaction was significant ($F_{1,91}$=4.95, *p*=.029, n^2_p=.30). Pairwise comparisons showed that the low loneliness group had higher accuracy for positive target words (M= .96, SE= .005) than for negative target words (M= .95, SE= .005), *p*= .03. In contrast, there was no difference in accuracy for the high loneliness group, *p*= .71. Lastly, the 2-way interactions Group × Face Distractor ($F_{2,90}$=1.17, *p*=.32), and the 3-way interaction Group × Word Valence × Face Distractor ($F_{2,90}$=2.51, *p*=.087) did not reach significance.

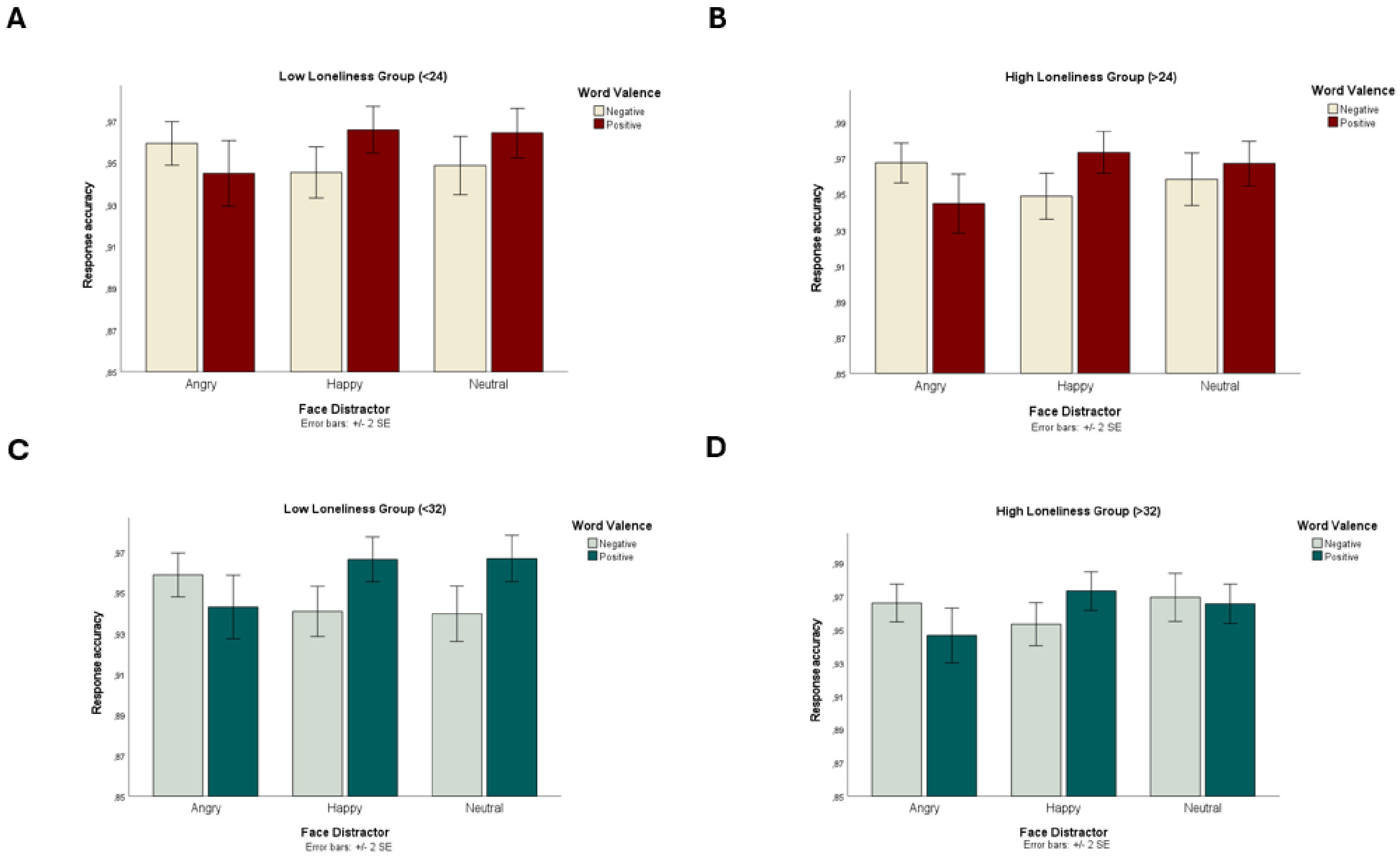

Figure 12. Response accuracy on trials with positive and negative target words for Congruent, Control, and Incongruent Conditions for the UCLA questionnaire [low loneliness (**A**) and high loneliness (**B**) groups] and for the IPARLS questionnaire [low loneliness (**C**) and high loneliness (**D**) groups]. Error bars represent SE of the means.

	Negative Words				Positive Words			
	Geneal Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	.96	.97	.96	.97	.95	.95	.95	.95
	(.005)	*(.006)*	*(.005)*	*(.006)*	*(.008)*	(.008)	*(.008)*	(.008)
Happy	.95	.96	.94	.95	.95	.97	.97	.97
	(.006)	*(.007)*	*(.006)*	*(.006)*	*(.006)*	*(.006)*	*(.005)*	*(.006)*
Neutral	.95	.95	.94	.97	.96	.98	.96	.97
	(.007)	*(.006)*	*(.007)*	*(.007)*	*(.007)*	*(.006)*	*(.006)*	*(.006)*

Table 11. Mean (and SE) Response accuracy at the face-word interference task.

Discussion

It has been suggested that lonely individuals have an attentional bias either toward affiliative signals (e.g., Lamblin, Murawski, Whittle & Fornito, 2017) or toward threat signals (e.g., Cacioppo & Hawkley, 2009). Here, we investigated whether self-reported loneliness – assessed as general loneliness by the UCLA scale or as emotions related to social rejection assessed by the IPARLS scale – affects the emotional modulation of selective attention, that is the process of focusing on specific emotional stimuli while ignoring others. To this aim, young individuals completed a face-word interference task, in which participants were presented angry, happy, and neutral-scrambled distractor-faces with positive or negative target-words. Both target words and distractor faces were presented simultaneously, therefore participants had to ignore the distractor faces to prevent any effects (interference or facilitation) on processing the target words. Importantly, using scrambled distractors allows to have a control condition against which to assess interference and facilitation effects from failing to ignore emotional distractors that are affectively congruent or incongruent with the target-words.

Findings are consistent with previous studies demonstrating interference from emotional distractors with slower and less accurate responses when the valence of targets word did not match the valence of the distractor's facial expression (e.g., Beall & Herbert, 2008) and facilitation from emotional distractors with faster and more accurate responses when the valence of targets word matched the valence of the distractor's facial expression. Overall, responses to positive-valenced words were faster than to negative-valenced words, which again is consistent with previous research (e.g., Liu, Xin, Jin, Hu & Li, 2010). Importantly, findings from interference and facilitation scores showed an overall greater interference from angry distractor-faces which again is in line with past evidence (e.g., Öhman & Mineka, 2021) stating that threatening stimuli as angry faces take precedence over other information as it is evolutionary beneficial to detect it promptly. However, self-reported loneliness – regardless of how loneliness was assessed – did not affect this bias to threat-distractors. In contrast, facilitation scores showed no differences between the different distractors, suggesting that this task elicits interference more than facilitation effects when the target and distractors vary on valence rather than identity (e.g., Beall & Herbert, 2008).

Theoretical conceptualisations of loneliness have posed that since the drive to form social relationships is related to evolutionary benefits in conditions of social exclusion people deploy larger attentional resources to social cues aiming to detect faster possible affiliative cues that may indicate a possible reconnection (Lamblin, Murawski, Whittle & Fornito, 2017; Chen, Nummenmaa & Hietanen, 2017). Accordingly, we had reasoned that if loneliness is driven by approach motivation toward affiliative social signals (e.g., Nikitin & Schoch, 2021), individuals experiencing loneliness will exhibit greater interference from happy distractor-faces, reflecting a bias towards positive stimuli. In contrast, if lonely individuals prioritize social threats and signals of social rejection (Cacioppo, Norris, Decety, Monteleone & Nusbaum, 2009; Nikitin & Schoch, 2021), then they should show greater interference for angry faces, indicating a bias towards negative stimuli. The present findings show that loneliness does not affect selective attention to task-irrelevant emotional distractors.

To our knowledge only the study of Shin and Kim (2019) assess the effect of loneliness on selective attention, specifically on the auditory modality. Results of their study failed to provide consistent evidence for which lonely individuals exhibit a negativity bias towards negative social stimuli. Other studies that have aimed to explore the effects of social power (Ma & Zhang, 2021) on selective attention found that when exposed to threat stimuli (i.e., fearful faces), participants in the low-power condition allocate more attention to those than the individuals in the high-power condition, indicating a negativity bias. Studies that explore the effects of social contexts (DeWall et al., 2008, Fernandes et al., 2019) found greater interference effects of happy faces, but that such effect was lessened for participants in the alone condition. Mixed evidence on the effects of social contexts could therefore suggest that threats to social inclusion function as an intrinsic signal that motivates and guides the individual to search for positive social stimuli (i.e., affiliative cues) that could restore their sense of belonginess.

In addition, findings are consistent with past evidence on accuracy performance interference effects of incongruent stimuli on accuracy scores, as increased errors were committed when target's word valence did not match the facial expression portrayed (e.g., Beall & Herbert, 2008). Interestingly, results derived from both the UCLA and IPARLS provide different conclusions on the effects of loneliness on selective attention to emotional stimuli. Results failed to report an effect of general loneliness –as assessed by the UCLA scale– on response accuracy. However, when analysing social rejection –as assess by the IPARLS scale– results evidence that non-lonely participants were more accurate for positive-target than for negative-target words, whereas no difference between target's valence was to be found for the high loneliness group. These outcomes could imply that the influence of loneliness on selective attention may be context-dependent, this is, that the emotional distress associated with social isolation (IPARLS) may influence attention in emotional contexts.

Altogether, our results failed to provide evidence that word-valence impaired response accuracy, which is in line with past studies that used valenced-target words (e.g., Ma & Zhang, 2021.)

In summary, the present study examined the potential influence of loneliness on selective attention to emotional distractor-faces and in contrast to our hypotheses, there were no effects of loneliness. To this aim, it is important to acknowledge some limitations of the present study. Firstly, we attempted to include individuals with extreme loneliness scores in our study, but while non-lonely participants readily volunteered to take part in the study, very-lonely participants were hesitant to come to the laboratory. As a result, the sample included in our study is more representative of moderate levels of loneliness rather than high levels. Secondly, it is worth noting even if psychometrical properties of self-reported questionnaires such as the UCLA and IPARLS have been evaluated, individuals may be resistant to report high levels of loneliness (e.g., Richman, Kiesler, Weisband & Drasgow, 1999), potentially leading participants to underestimate their feelings of loneliness. Lastly, considering that loneliness has been associated with higher levels of anxiety and depression, future studies should consider incorporating a fearful or sad condition to further investigate this phenomenon and to shed light on in the underlying mechanisms on selective attention processes among lonely individuals.

CHAPTER 5

THE EFFECTS OF LONELINESS ON RESPONSE INHIBITION TO SOCIAL STIMULI

Introduction

As seen in Chapter 1, loneliness is considered as an adaptive response that has evolved to signal a lack of social connection or support (Cacioppo & Cacioppo, 2018) and that it should motivate to re-establish social connections and possibly prevent further social isolation. Accordingly, loneliness should also affect the information prioritized for processing by lonely individuals. Past research suggests that individuals experiencing loneliness exhibit heightened sensitivity towards social cues, particularly those indicative of potential threat (i.e., fearful, or angry faces; see Spithoven et al., 2017 for a review). However, evidence is mixed as other studies have failed to report attentional biases differences between non-lonely and lonely individuals (e.g., Lodder et al., 2015).

The studies described in the previous chapters showed that only individuals low in loneliness are better are recognising affiliative signals from strangers that they have only just met (Chapter 2), whereas the study on attention to social signals reported in Chapter 3 showed that loneliness does not affect attentional shifts to the gaze direction of others showing affiliative or threat-related expressions nor it affects participants implicit recognition of these faces. Similarly, the study reported in Chapter 4 showed no differences in selective attention to affiliative or threat distractors between low and high loneliness participants. This final study assesses whether lonely individuals find more difficult to inhibit responses to emotional social stimuli. Response inhibition refers to the ability to suppress or control impulsive behaviours and inhibit inappropriate responses.

This research question stems from the literature showing that when individuals feel socially disconnected or lonely, they may be more inclined to engage in impulsive behaviours to cope with their emotional distress or seek immediate gratification (Fujisawa, Nishitani, Ishi & Shinohara, 2011). In fact, it has been proposed that the feeling of loneliness can lead to a heightened state of vigilance, which can disrupt cognitive processes involved in response inhibition (Cacioppo & Cacioppo, 2018ab). This can result in difficulties in delaying gratification, making thoughtful decisions, or inhibiting impulsive reactions. In fact, loneliness has been shown to impair behavioural inhibition, making it more difficult for individuals to regulate their behaviour effectively (Verhagen, Derks, Roelofs & Maciejewski, 2023).

Response inhibition to emotional faces

Response inhibition, fundamental to purposeful behaviour, involves the ability to suppress an initially planned prepotent response (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999) or choose between multiple response alternatives (Barch, Braver, Sabb, & Noll, 2000). Traditionally it has been conceptualised as a competition between a go and a stop process, in which the response executed is whichever reaches the threshold first (i.e., Race Model, Logan & Cowan, 1984). Yet more recent models have posited that go and stop processes are not completely dissociated, as the go process can be decelerated by the detection of the stop signal (i.e., Cancellable-Rise-To-Threshold, Salinas & Standford, 2013). It is posed that response inhibition is not a unitary construct but that it relies on broader processes, including signal detection, response preparation and interference control. The Go/NoGo task has been used to inhibitory response, here participants respond to a Go signal and withhold response during the NoGo trials.

Emotional information plays a crucial role in daily life, and it is prioritized for processing as it potentially signals valuable information for individuals, hence affecting both cognition and behaviour (Lu, Jaquess, Hatfield, Zhou & Li, 2017; Lu, Wang, Long & Cheng, 2021). Valence differences between emotional information engenders different attentional responses: research on visual attention has demonstrated that threatening stimuli attract more attention compared to positive or neutral stimuli (e.g., Öhman, Flykt & Esteves, 2001). Similarly, processing of angry faces requires a great deal of attentional resources (i.e., anger superiority effect, ASE; Hansen & Hansen, 1988) compared to happy and neutral faces. Yet, evidence is not consistent as other studies reported that happy faces compared to angry were longer attended (i.e., happiness superiority effect, HSE; Becker et al., 2011). It has been suggested that attentional demands of a task may modulate the emergence of such effects: anger superiority effect when tasks are demanding while happiness superiority effect when tasks require fewer attentional resources (Gong & Smart, 2021; Gong & Li, 2022). In addition to emotional information prioritizing attentional resources, emotions may also affect behaviour by facilitating or inhibiting certain responses depending on whether they entail approach or withdrawal tendencies (e.g., Sandler, 2013). Indeed, a bulk of literature on emotional information has evidence that both positive and negative stimuli affect inhibitory control (e.g., Verbruggen & De Houwer, 2007). However, when using more complex emotional stimuli such as faces, there is no strong evidence on the direction of such effect (e.g., Pessoa, Padma, Kenzer & Bauer, 2012; Rebetez, Rochat, Billieux, Gay & Van der Linden, 2014).

More specifically, Schulz, Fan, Magidina, Marks, Hahn and Halpering (2007) compared performance on both the traditional and emotional versions of the Go/NoGo task in college students (N=85). Both tasks consisted of 4 blocks of 96 trials each of which 75% Go and 25% NoGo trials. Stimuli used were green and red circles for the non-emotional Go/NoGo, whereas for the emotional task, stimuli were happy and sad faces from 24 identities that were randomly alternate as Go and NoGo cues across blocks. In both tasks, trials started with a fixation cross (1250-1750ms), after which the stimuli were presented (500ms). In general, participants had higher inhibitory rates (i.e., fewer commissions and faster responses) on the non-emotional version compared to the emotional Go/NoGo task. Moreover, on the latter, results showed an emotion effect, for which participants were more likely to respond (i.e., lower response times and greater commissions to happy faces) to happy faces compared to sad ones. Even if this study provides evidence in support of inhibition impairments for happy faces, it is not clear in which condition happy faces interfere greatly with inhibitory response, as results do not clarify the effects of emotional faces separately for Go and NoGo conditions.

Further, Pandey and Gupta (2022a) investigated whether emotional information impaired response inhibition using an implicit emotional Stop-Signal Task. Fifty-six individuals were instructed to press a button based on gender judgments (left arrow for male, right arrow for female). Trials began with a fixation point (500ms) and in the go-trials, a face appeared (neutral, angry, or happy) for 1000ms followed by a blank screen (ITI variable from 500 to 1500ms). In the stop-trials, after the go-signal (a neutral, angry, or happy face), another face appeared on the top of the go-signal for 250ms, and this informed participants not to press any button. There were 6 blocks of 180 trials each, of this 126 were Go (equally distributed between emotions) and 54 were Stop trials (equally distributed between emotions). Results showed that participants committed more omission, discrimination, and commission errors (i.e., not responding when required, wrongly responding, and responding when not required respectively) and took longer to respond to angry faces compared to happy and neutral ones.

This was also explored in a second study (Pandey & Gupta, 2022b) using a double-step saccade task. In Experiment 1, 19 participants performed an implicit double step emotional stop-signal task for which emotional faces (neutral, angry, and happy) were used as step-signals. Trials started with the presentation of a grey dot for a random duration between 300 and 800ms. In the no-step (grey square that could appear in eight different locations with angular separation of 45º) participants were instructed to make a saccade. Then a blank screen appeared (ITI varied from 1000ms to 2000ms). On 40% of the trials (i.e., step-signal trials) the first target was followed by a second target (neutral, angry, or happy face) with a short (50ms) or a long (150ms) delay: participants had to make a saccade to that second target and to cancel the saccade to the first target. Results showed impairments in inhibition processes for trials with longer delays, as the ability to correctly inhibit pre-planned responses decreases with the longer delay. Moreover, inhibition was impaired for angry faces compared to neutral and happy faces. This finding was interpreted as further evidence that angry facial expressions capture additional attentional resources which results in greatly interference with ongoing activities (i.e., lower successful response adaptation). Experiment 2 with 15 participants, was similar to Experiment 1 with the exception that faces were used as first targets whereas grey squares were used as the step-signal. Lastly, in Experiment 3 (N=12), for both steps geometrical shapes were used –grey circle and grey square as first and second target, respectively. Results of both Experiment 2 and Experiment 3 did not find any effect of emotion or condition, but revealed an effect of target delay, thus increasing difficulty to inhibit responses at longer delays.

Lastly, Saylik, Castiello and Murphy (2021) explored the effects of emotional interference on learning. Ninety-seven university students performed a probabilistic Go/NoGo task. The task consisted of 5 conditions –4 emotional (angry, fearful, happy, and sad) and 1 non-emotional (neutral), with 2 epochs each –acquisition and reversal. Epochs consisted in 50 trials of which 50% were Go and the other 50% were NoGo trials. As a probabilistic task, on 75% of the go stimuli feedback was correctly associated, whereas 25% of target stimuli were associated with no-go. Trials started with a fixation cross (1000ms) followed by the face (500ms), and the feedback (1000ms), for the go condition participants were instructed to press the spacebar as quickly as possible whereas they were told to withhold responses during the no-go trials. Overall findings showed an effect of condition, with lower inhibition rates in the reverse condition compared to the acquisition one. Interestingly, happy faces engendered greater accuracy rates (i.e., lower error rates), while results further showed that angry facial expressions capture additional attentional resources which results in greatly interference with ongoing activities (i.e., increased error rates) compared to other emotional expressions (angry, sad, and fearful) and neutral.

In conclusion, the abovementioned studies suggest that emotional stimuli, particularly those conveying happiness or anger, can impact response inhibition processes. Schulz et al., (2007) highlighted the differential effects of emotional stimuli on inhibitory rates, with participants demonstrating higher inhibition performance in response to non-emotional cues compared to emotional ones. Pandey and Gupta (2022a, 2022b) further clarify the distinct inhibitory impairments triggered by emotional expressions, particularly anger. Lastly, Saylik, Castiello, and Murphy's (2021) findings emphasize the relationship between emotional interference and cognitive performance, revealing that emotional stimuli, and in particular angry faces, greatly interfere with response inhibition.

The effects of individuals differences on response inhibition

Extensive research has investigated the relationship between individual characteristics and the ability to suppress impulsive or automatic responses. Past literature has revealed that personality traits, such as impulsivity, play a crucial role in response inhibition, with individuals scoring higher on impulsivity exhibiting diminished inhibition (e.g., Horn, Dolan, Elliott, Deaking & Woodruff, 2003). Furthermore, emotional states, such as anxiety (e.g., Pessoa, Padmala, Kenzer & Bauer, Waters & Valvoi, 2009) or depression (e.g., Yu et al., 2017; Liang et al., 2021) have been shown to affect response inhibition, with heightened emotional arousal impairing inhibitory control. Additionally, studies have also assessed age influences on response inhibition (e.g., Williams, Lenze & Waring, 2020).

For instance, Pessoa, Padmala, Kenzer and Bauer (2012) studied the effects of participants' levels of anxiety – assessed using the State and Trait Anxiety Inventory (STAI; Spielberger, Gorsuch & Lushene, 1970) –, on response inhibition to emotional faces using a Stop-Signal Task. In experiment Experiment 1, took part 32 college students. Go trials started with the presentation of a shape (1000ms) followed by a blank screen (1000ms) and participants were instructed to respond to the shape (i.e., circle or square). Stop trials were structured exactly as the go trials, but a face was presented inside of the shape during 500ms, after a variable stop-signal which informed participants that they had to withhold their response. The task consisted of 6 blocks of 150 trials (120 go and 30 stop trials for each block). There were 180 faces [60 identities -half male and half female with 3 different emotions (happy, fearful, and neutral)]. Results showed that emotion had a significant effect on the response inhibition as stop-signal reaction time was lower for both fearful and happy faces compared to neutral ones. This finding suggests that facial emotion did not interfere with inhibitory processes. Importantly, there was a strong relationship between higher anxiety levels and increased inhibitory performance during the fearful condition compared to the neutral and happy ones.

Furthermore, Waters and Valvoi (2009) investigated the effects of paediatric anxiety to emotional stimuli. Thirty-one children with anxiety along with 30 healthy controls performed an emotional Go/NoGo task. Participants were instructed to press a button as quickly as they saw the target and to withhold response when the non-target appeared onscreen. Face stimuli consisted of coloured pictures of angry, happy, and neutral faces –12 identities, half male and half female–. Pictures were not cropped and included a mix of open and closed mouth expressions for each emotional category. Task was divided into 4 blocks of 60 trials each (70% Go and 30% NoGo trials). In each block, angry or happy emotional expressions were presented alone with the neutral expression. In 2 blocks the emotional faces served as target (Go condition) while for the other 2 blocks it was used as non-target (NoGo condition). Order of blocks and trial orders was random between participants. Separate analyses were conducted for Go-neutral (with NoGo emotional) trials and for Go-emotional trials (with NoGo neutral). Results for the Go-neutral/NoGo-emotional phase showed more commissions for happy faces compared to when angry faces were used as a NoGo signal. No effect was found for neutral faces when used as NoGo signal compared to angry or happy faces. Results suggest that emotional context interferes with response inhibition, but that emotional information does not affect such process.

More recently, Yu and colleagues (2017) in an EEG study explored response inhibition in a sample of females with depression. Twenty females with unipolar depression (assessed by the DSM-IV, American Psychiatric Association, 1994) and 21 matched controls performed an emotional Go/NoGo task divided into an implicit and an explicit part (order counterbalanced). During the implicit version, participants were asked to respond or to withhold responses based on gender judgments (male-Go/female-NoGo and female-Go/male-NoGo) while for the explicit version they were asked to respond or to suppress responses based on facial expressions (neutral-Go/sad-NoGo, sad-Go/neutral-NoGo). Stimuli were 40 faces (20 females and 20 males) each with a neutral and sad expression. Task comprised 4 blocks, 2 for the explicit version and 2 for implicit one (120 trials of which 84 Go and 36

NoGo, following a 70:30 proportion). Each trial started with a fixation cross (200-400ms), followed by the face (1000ms). Findings showed that females with depression had overall lower sensitivity compared to healthy participants. Moreover, depressed participants had smaller d’ when sad faces were used as NoGo signals. Response times were shorter for the depression group compared to the control group. For the ERP components, there was a smaller amplitude of N1 and P3 components for females with depression. These findings suggest that emotional context interferes with response inhibition and that individual characteristics such depression are related with increased difficulties to process emotional context and emotional information as reflected by the behavioural and brain activity analysis.

Similarly, Liang and collaborators (2021) explored response inhibition to emotional face stimuli among individuals with subclinical depression. Thirty-nine healthy university students along with 36 college students with depression performed three versions of the Stop-Signal Task. All three versions comprised 240 trials. For the non-emotional stop-signal task participants were asked to press the button as quickly and accurately as possible to judge the presented shape (“G” for square and “H” for circle), during the Go phase, and not to press any button during the Stop condition. In the emotional versions, 40 neutral and 40 sad face images were used. In the implicit version of the emotional stop-signal task, participants responded to gender, while for the explicit version of the emotional stop-signal task, participants were instructed to respond to expressions (“G” for neutral and “H” for sad). For the non-emotional version, the result did not reach statistical significance. Interestingly, when tasks demanded deeper processing, emotional stimuli engendered longer response times and greater stop-signal delays compared to neutral expression. Additionally, results also showed that college students with depression had increased inhibitory difficulties (longer reaction times and greater stop-signal delays) compared to healthy students, independently of the valence of the facial expression.

Williams, Lenze and Waring (2020) across 3 studies explored the influence of emotional expressions on response inhibition processes among young and older adults. Study 1 included 39 young adults and 38 older adults performed an emotional Stop-Signal Task. The task consisted of 6 blocks of 150 trials each (900 trials in total) of which 120 Go and 30 Stop trials, ensuring that responding was an over-learned response. There were 180 faces [60 identities –half male and half female– portraying three different emotions (happy, fearful, and neutral)]. Go trials started with the presentation of a shape (1000ms) followed by a blank screen (1000ms) and they were instructed to respond to the shape (i.e., circle or square), stop trials were structured exactly as the go trials, but a face was presented inside of the shape during 500ms, after a variable stop-signal which informed participants that they had to withhold their response. Results indicated that compared to younger adults, elderly participants had increased reaction times, however there was no effect of emotional expression. Study 2, which included 37 young adults and 36 older adults, required deeper indirect processing of faces as they were instructed to respond or not based on faces gender (i.e., some blocks required to respond to male faces and withhold responses for female faces, while others required the opposite). During go-face trials participants were instructed to respond to selected faces that appeared inside the go stimulus (which remained onscreen for1200ms) after a variable delay. Stimuli comprised 360 face images of which 120 neutral, 120 angry, and 120 happy faces. There were 6 blocks of 90 go trials, 30 go-face trials and 30 stop trials, both go and stop trials were equally divided per condition –10 fearful, 10 happy and 10 neutral faces–. Results did not reveal any effects of age or condition on the stop-signal response times and accuracy. For such, Study 3 participants (N=29 young adults and N=38 older adults) were asked to respond or to withhold responses based on the facial expression of the faces. Stimuli and procedure were similar to Study 2, with the difference that go-face trials in a given block were divided equally in 2 conditions –e.g., 15 happy and 15 neutral–

whereas the stop-trials corresponded all to one emotion –e.g., fearful–. Results revealed a main effect of expression for which fearful faces engender greater response times compared to neutral and happy faces for both young and older participants. Contrarily, for both groups happy faces facilitated response inhibition. Overall findings suggest that task-relevant emotional information impacts inhibition response.

In summary, typical findings obtained with the emotional Go/NoGo task in which the proportion of Go and NoGo has been manipulated to be 70/30 to increase task difficulty and engage cognitive control show that it is difficult to inhibit responding to emotional stimuli when emotion is task-relevant. In general, it has been pointed out that happy faces increase commission errors. This effect has also been noted when comparing effects separately for Go and for NoGo conditions, in which happy faces engender greater attentional distractions which results in greater inhibition difficulties (i.e., higher commission errors, e.g., Shultz et al., 2007; Valvoi & Waters, 2009; Saylik et al., 2021). Additionally, there is also evidence that other emotions may impair response inhibition as it has been found that sad faces are related to decreased accuracy (i.e., decreased sensitivity).

The effect of social exclusion on response inhibition to emotional faces

Indeed, Otten and Jonas (2013) in an EEG study explored the effects of social exclusion manipulated by the Cyberball game on response inhibition. Thirty-four university students performed a Go/NoGo task after playing a virtual ball-tossing game (i.e., Cyberball; Williams & Jarvis, 2006). For the Go/NoGo task participants were instructed to react to a central letter sided by other three flankers on each side. If the central letter was a “T” participants had to press the spacebar (Go condition) whereas if the central letter was “H” participants had to withhold their response (NoGo condition). Trials started with a fixation cross (time randomly varied between 400 and 600ms) after which the Go or NoGo stimulus was presented for

200ms, followed by a 50ms mask. Participants completed 500 trials of which 350 Go and 150 NoGo (randomly intermixed). For the ERPs data, the N2 and P3 components related to cognitive control (conflict monitoring and conflict resolution, respectively) were analysed. Behavioural findings did not show any difference between socially included and socially excluded participants on response times and on false alarms. Importantly, excluded participants showed larger N2 and a smaller P3 effect during NoGo trials, indicative that social exclusion makes people deploy more attention to the response conflict induced by NoGo trial and that they exert less inhibitory control than included participants.

In another study, Ernst, Mohr, Schött, Rickmeyer, Fischmann, Leuzinger-Bohleber, Weib and Grabhorn (2018) investigated the effects of social exclusion –induced by the means of the Cyberball game– on response inhibition. After playing the virtual ball-tossing game, 66 female participants (22 healthy controls, 20 with mayor depressive disorder and 22 with major depression and comorbid borderline personality disorder), performed a Go/NoGo task. Stimuli involved “X” for the NoGo condition and all of the other letters of the alphabet for the Go condition. Duration of the stimuli presentation randomly varied between 1100 and 1300ms, after which a fixation cross was presented centrally in the screen (200-400ms). Each block of the Go/NoGo task had 16 trials (presented in a pseudorandomised order) of which 10 Go and 6 NoGo. Lastly, participants completed the Self-Assessment Manikin (SAM; Bradley and Lang, 1994). Results showed that excluded healthy controls as well as participants with mayor depressive disorder had fewer false alarms compared to included participants. Whereas, socially excluded participants –independently of group– reacted more slowly, participants with comorbid depression and borderline disorder reacted faster and had higher false alarms rates than the participants with mayor depressive disorder and healthy controls. In conclusion, these findings emphasize the complex relationship between social situations and mental health, for which more research is needed to understand the underlying mechanisms behind this patterns.

Similarly, Chester, Lynman, Milich and DeWall (2017) randomly assigned 363 university students to either an inclusion or exclusion condition of the Cyberball task, after which they completed a cognitive battery test and performed an emotional Go/NoGo task. During the task, participants were instructed to press a button whenever they viewed the “M” letter and to withhold response if the letter “W” was presented. Letter were overlaid on negative, positive, and neutral images of the International Affective Picture System. Each trial begun with the presentation of a fixation cross that randomly lasted 1250, 1500 or 1750ms –in order to prevent anticipation– followed by the pair of image-letter which lasted 500ms. Participants completed 3 blocks of 60 trials, for a total of 180 trials (135 Go and 45 NoGo). Findings showed that accuracy was higher for negative trials compared to both positive and neutral trials in NoGo condition, in line with negative affect being linked to an inhibitory state. However, regarding the effect of social rejection no further conclusion can be drawn as analysis did not include participants’ social condition (i.e., they did not report group analysis based on included and excluded conditions).

As perceived social isolation has been associated with inhibitory control processes (Cacioppo et al., 2000; Cacioppo & Hawkley, 2009), other studies have assessed the effects of perceived loneliness on response inhibition. In these studies, evidence has shown that when individuals report increased feelings of loneliness, inhibitory control is impaired (Cacioppo & Patrick, 2008) and there is less efficient prefrontal cortex activation during a self-control task (Campbell et al., 2006).

To our knowledge, few studies have explored the role of perceived loneliness on response inhibition. First, Fujisawa, Nishitani, Ishii and Shinihara (2011) investigated the effects of loneliness on impulsivity among adolescents. Thirty-six female adolescents completed the revised UCLA Loneliness Scale (Russell, 1996) and performed a traditional Go/NoGo task, in which they were instructed to press a key button whenever they a sample of two-digit numbers and to withhold responses when the other sample of two-digit numbers appeared onscreen for 100 trials (30 practice and 70 test). Results showed that loneliness scores were correlated to the commission error index, such that higher loneliness is associated to a greater number of commissions made, and therefore to decrease response inhibition. Recently, the study of Kyaw and Levine (2023) has shown that higher loneliness levels are negatively correlated to performance in the Go/NoGo task. In their cross-sectional study, 541 middle aged adults with a history of depressions (assessed by the Center for Epidemiologic Studies-Depression, CES-D) performed a traditional Go/NoGo task. Findings showed interrelation between loneliness and performance, unfortunately without specifying which measures were considered (e.g., commission, omission, sensitivity, or response times) for the analysis.

Moreover, the study of Daly and colleagues (2020), investigated the effect of loneliness on response inhibition during lockdown in the United Kingdom. Participants (789 participants aged between 18 and 59 years) completed a modified social distancing questionnaire, to assess the extent to which they were following social distancing recommendations, the UCLA Loneliness Scale (Russell, Peplau & Ferguson, 1978), the Coping Using Sex Inventory (CUSI; Cortoni & Marshall, 1994), the Difficulties in Emotion Regulation Scale (DERS-16; Bjureberg, Ljótsson, Tull et al., 2016), and the Worries About COVID19 Questionnaire (Gillespie et al., 2020), after which they performed a two stimulus (square and circle) Go/NoGo task. Participants completed 5 blocks of 50 trials each, in which the first 3 blocks participants had to press a button whenever they saw a circle and withhold response when a square was presented, while during the last 2 blocks rules inverted (square = GO, circle =

NoGo). Each trial begun with a fixation cross presented in the centre of the screen for 50ms, followed by a blank screen (150ms), and then the shape (for 1000s or until the response was made), then feedback was displayed. Correlation analysis showed that higher loneliness is related to increased overall Go/NoGo errors. Interestingly, increased difficulties for emotional regulation were also related to increased errors on the Go/NoGo. Even if findings are in line with research characterising loneliness to diminished ability to inhibit prepotent responses, caution has to be taken as results do not clarify which performance measure was taken into consideration (i.e., commissions or omissions).

In an EEG study, Brush, Kallen, Meynadasy, King, Hajcak & Sheffler (2022) assessed the role of loneliness in conflict resolution abilities. Seventy-one older adults aged between 61 and 75 after completing two questionnaires assessing cognitive abilities and personality, participants performed a Go/NoGo task. The task was a three-stimulus (aliens, asteroids, or astronauts) Go/NoGo task where one of three stimuli could be displayed on the screen at once. Trials started with a fixation cross (duration randomly varied between 300 and 700ms), followed by the stimulus presentation (200ms) and a blank screen (1000ms). Participants completed 10 blocks of 40 trials, in which they were instructed to execute a motor response as quickly as possible as an alien or an asteroid appeared onscreen [Go condition; 85% of the total number of trials of which trials with aliens were frequent Go (280 trials;70% of total trials) and asteroids infrequent Go (60 trials, 15% of total trials)] and to withhold the response if the astronaut was displayed (NoGo condition; 15% of the total number of trials). Behavioural results are indicative of lower inhibition rates for infrequent condition (for both go and no-go trials), and of lower response times on go trials compared to no-go trials. For the ERPs data, the P3 component related to conflict resolution was analysed. Simple correlation analysis showed a negative relation, in which higher loneliness is related to reduced P3 amplitude on infrequent Go trials. Multiple linear regressions analysis showed that loneliness moderates the relationship between infrequent no-go P3 and depression. Results suggest that deficits in inhibitory control processes are particularly pronounced among older adults with increased depression and loneliness. These findings have been interpreted as showing that difficulties in inhibiting the most likely response may rely on a general difficult in inhibiting a prepotent habit.

In conclusion, idiosyncrasies in psychological distresses such as anxiety (Waters & Valvoi 2009) or depression (Yu et al., 2017) may be characterised by decreased successful inhibition response in emotional contexts. Importantly, social exclusion and loneliness can significantly impact cognitive processes, particularly response inhibition. Individuals who experience social exclusion or loneliness may struggle more with inhibiting impulsive responses (Otten & Jonas; 2013, Ernst et al., 2018; Brush et al., 2022; Fujisawa et al., 2011 Daly et al., 2020; Brush et al., 2022). However, interpretation of the conclusions of these studies has to be made with caution due to the lack of specificity regarding the analytical methods employed, while associations between variables were identified their causality remains uncertain.

The present study: the effect of loneliness in response inhibition to emotional faces

The reviewed studies described so far show that emotional expression in the Go/NoGo task are related to increased impairments in inhibiting dominant responses (i.e., increased error rates). However, it is not clear which stimulus valence engenders greater impairment. For instance, it has been found that happy faces sometimes increase commission errors, this his heightened attention towards happy faces may result in increased distraction and difficulty in inhibiting prepotent responses, leading to greater impairment in inhibition tasks (Unkelbach, Alves & Koch, 2020). There is also evidence that other emotions, such as sad faces, may impair response inhibition as it has been found that they are related to decreased accuracy (i.e., decreased sensitivity). This has been attributed to threat-related distractors being processed faster and therefore increase difficulties inhibiting automatic responses (e.g., Unkelbach, Alves & Koch, 2020).

The aim of the study is to examine whether individuals who report high loneliness show impaired response inhibition to emotional stimuli. To achieve this, we used a Go/NoGo task, in which participants were instructed to attend to stimuli that varied in emotional valence (i.e., angry, happy, and neutral faces) and response demands (i.e.,Go and NoGo). Based on previous literature we hypothesised that increased perceived social isolation would be associated with slower responses on the emotional Go condition compared to the neutral Go condition, and higher false alarms and omission errors rates on the emotional NoGo condition, indicative of more pronounced deficits in response inhibition to emotional stimuli for both angry and happy faces. These predictions are based on theories on loneliness predicting that loneliness motivates people toward affiliative signals (e.g., Eslinger et al., 2021) to re-establish social connections (e.g., Tomova et al., 2022). In contrast, there is evidence that lonely individuals are sensitive to signals of social rejection and to protect themselves from further rejections, they prioritise social threats (e.g., Cacioppo & Hawkley, 2009). Consequently, as both emotions –angry and happy– signal possible social threats and possible social affiliations respectively, they should be salient stimuli for lonely individuals. Thus, if loneliness motivates toward affiliative signals (i.e., happy faces), lonely participants should display an increased commission errors during the NoGo condition with happy faces compared to angry and neutral ones, whereas, if loneliness motivates to avoid social threats, high loneliness participants should display increase commission errors during the NoGo condition towards angry faces compared to happy and neutral faces.

Method

All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Psychology Department Ethic Committee, Sapienza University of Rome: Institutional Review Board Approval Prot. n. 0000867. Informed consent was obtained from the study participants.

Participants

Eighty-three university students took part in the experiment, however, due to technical issues the data of one participant was discarded because incomplete [females= 59; males= 23; age range= 18-33 years (M=24.04, sd=2.58)]. Sensitivity analysis conducted using G*Power software (Faul et al., 2007) showed that with the current sample size we would have 80% power to detect effect sizes of n^2_p=.02, or a small-medium effect size.

As in previous studies (Chapter 3 and Chapter 4), pre-screening of participants based on scores at the UCLA Loneliness Scale (Boffo et al., 2012) proved to be difficult as high in-loneliness individuals were hesitant to come to the laboratory following the completion of the online questionnaire, we decided to recruit independently from the UCLA scores. Therefore, participants were *a posteriori* divided into two groups based on the loneliness scores.

Go/NoGo Task

Twelve identities (6 males and 6 females) were selected from the Radboud Face Database (Langner et al., 2010, see Table 12). For each identity, neutral, angry, and happy expressions were selected. Images were in colour and 335 by 418 pixels in size.

Female		Male	
RAFD01	RAFD27	RAFD09	RAFD30
RAFD14	RAFD32	RAFD15	RAFD33
RAFD 26	RAFD 61	RAFD24	RAFD36

Table 12. Stimuli IDs of the selected Faces from the Radboud Face Database.

Based on available validation data (Langner et al., 2010), the selected stimuli were balanced for agreement ($t_{(10)}$=0.62 p=.955), intensity ($t_{(10)}$=1.16 p=.284), clarity ($t_{(10)}$=0.44 p=.702), genuineness ($t_{(10)}$=0.17 p=.886), valence ($t_{(10)}$=1.10 p=.299), and attractiveness ($t_{(10)}$= -0.59 p=680, see Table 13).

	Male	Female	*p*
Agreement on emotional categorization	95.83 *(5.38)*	94.00 *(4.76)*	*.955*
Intensity of facial expression	3.69 *(.25)*	3.57 *(.08)*	*.284*
Clarity of facial expression	3.90 *(.22)*	3.85 *(.16)*	*.702*
Genuineness of facial expression	4.04 *(.22)*	4.02 (*.23)*	*.886*
Valence of facial expression	3.20 *(.17)*	3.10 *(0.15)*	*.299*
Attractiveness of facial expression	2.45 *(.38)*	2.60 (*.49)*	*.680*

Table 13. Ratings of male and female faces [mean (sd)].

Questionnaires

The Italian version of the UCLA Loneliness Scale (Boffo, Mannarini & Munari, 2012) consisting of a 10 items scale was used to assess perceived loneliness. The Italian version of the Interpersonal Acceptance–Rejection Loneliness Scale (IPARLS; Senese, Nasti, Mottola, Sergi, Massaro & Gnisci, 2021) consisting of 15 items was used to assess perceived loneliness. We decided to use both questionnaires as they measure slightly different constructs. The UCLA questionnaire measures general loneliness whereas the IPARLS measures subjective feelings of distress by loneliness (i.e., emotional component).

Apparatus

The Go/NoGo task was presented using E-Prime Version 2.0 Professional software for Windows 7, which also recorded participants' responses. Stimuli were presented on a Pentium IV computer via a 17" CRT monitor (1024 x 768 pixels, 60 Hz). Participants seated comfortably in front of a computer screen at a viewing distance of approximately 60cm.

Procedure

After participants provided their informed consent, they were presented with the 10 items of the Italian version of the UCLA loneliness scale (Boffo & Municcio, 2012) with the 15 items of the Italian version of the Interpersonal Acceptance–Rejection Loneliness Scale (Senese et al., 2021). We opted for asking participants to complete these items before the Go/NoGo Task to allow participants to think about their social interactions. Upon completion of the questionnaires, the task instructions were presented on the computer screen. Participants were asked to press the "B" key whenever an emotional face appeared onscreen and to withhold response when the face had a neutral expression. After the second block, instructions were reversed, and participants were asked to respond (pressing the "B" key) when a neutral face was presented and to withhold response when an emotional face appeared.

Participants completed 240 trials (4 blocks of 60 trials) resulting from the repetition of the 12 faces (6 male faces portraying either happy, angry, or neutral facial expressions as well as 6 female faces portraying either happy, angry, or neutral facial expressions), and instruction given (“Go”, “NoGo”). Within each block each identity could appear up to 6 times, (2 times with angry and 2 times with happy). Task was programmed with E-prime to randomly select which identities were presented and the proportion of Go/NoGo trials being 70:30. In the first 2 blocks participants pressed, the key “B” as fast and accurately as possible when an emotional face appeared (angry expression in block 1, happy expression in block 2), and were instructed to withhold response when neutral faces appeared. During the last 2 blocks, instructions changed, and participants pressed the key “B” as fast and as accurately as possible whenever a neutral face appeared, but they had to withhold response when an emotional face was presented (angry expression in block 3, happy expression in block 4).

Four versions of the task were used in order to counterbalance for the Go/NoGo condition, so for half the participants the NoGo blocks corresponded to blocks 1 and 2, and the Go blocks were blocks 3 and 4. As in Williams et al., (2020) consecutive presentations of blocks for each instruction were presented to reduce errors due to task switch.

Trials started with a centrally presented fixation cross for 500ms, then a face appeared, until a response was made or 1000ms elapsed. In order to make the task less predictable the inter-trial interval, ITI, randomly varied between 500ms and 1250ms. Upon completion, participants were debriefed, thanked for their participation, and dismissed.

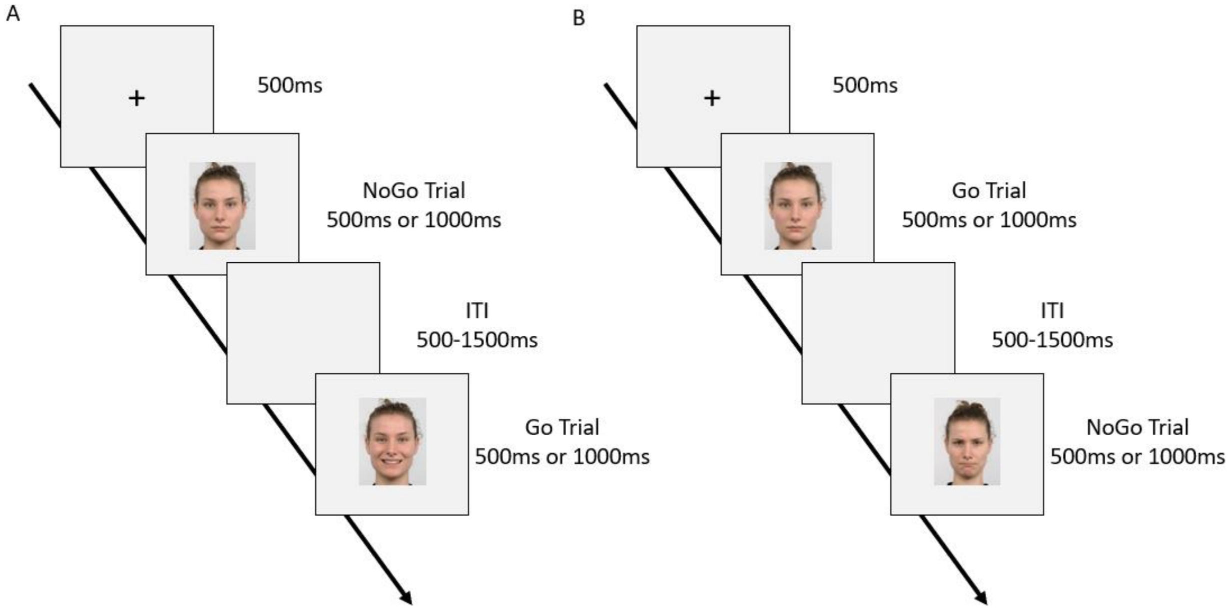

Figure 13. Schematic representation of events in a typical trial of the emotional Go/NoGo task. The example shows emotional (happy) Go and neutral NoGo condition (**A**) and neutral Go and emotional NoGo condition (**B**). The ITI randomly varied between 500ms and 1500ms.

Experimental Design

The experimental design is a 2 (Group: high loneliness, low loneliness) by 2 (Signal: Go, NoGo) by 3 (Face: angry, happy, neutral) mixed-factorial ANOVA with the first factor between-subjects.

Data analysis

Loneliness. For the Italian adaptation of the UCLA a total score was computed after reverse scoring five items: scores typically range from a minimum of 10 to a maximum of 50 and higher scores indicate more loneliness. In the present sample, the UCLA lower score was 12 and the higher score was 47. For the Italian adaptation of the IPARLS a total score was computed: scores typically range from a minimum of 15 to a maximum of 75 with higher scores indicating higher levels of loneliness. In the present sample, the IPARLS lower score was 15 and the higher score was 65.

As the UCLA and IPARLS assess different aspects of loneliness, data were analysed with group based on the general measure of loneliness (UCLA) as well as with group based on the social isolation and rejection measure of loneliness (IPARLS).

For the UCLA scores, participants who scored below the median (<25.0) were considered as low in loneliness (N=39; females=31; males=8), whereas participants who scored above (>25.0) were considered as high in loneliness (N=43; females=28; males=15). The same procedure was conducted also for the IPARLS scores: participants who scored below the median (<29.0) were considered as low loneliness (N=39; females=27; males=12), while participants who scored above the median (>29.0) were considered as high loneliness (N=43; females=32; males=11).

Behavioural data. All data processing and analysis were conducted in SPSS v.27. Trials in which an error was made (3.89%) and trials with RTs not within 120ms and 2.5 SD from the mean (2.08% of the remaining trials) were excluded from analyses. Mean RTs for correct responses were computed for each condition. Mean RTs and correct responses (i.e., accuracy) were computed for each condition.

Go-NoGo Task. For Go trials, if the participants did not press any button or pressed the button too late an omission error was coded (OE). For NoGo trials, participants were required not to press, yet if they still pressed the button, a commission error (CE) was coded. Omission and Commission errors were analysed with two individual ANOVAs with Group (2: high vs low loneliness) by Face (3: Happy, Angry, Neutral).

Results

Reaction Times (RTs) for Go Condition

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,80}$=.90, *p*=.35). The main effect of Face ($F_{2,79}$=81.31, *p*<.001, n^2_p=.673) was significant, with slower reaction times for angry faces (M=575 SE=8.4) compared to happy faces (M=502 SE=7.9) *p*<.001. The 2-way interaction Group × Face ($F_{2,79}$=.88, *p*=.89) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,80}$=.15, *p*=.70). The main effect of Face ($F_{2,79}$=84.16, *p*<.001, n^2_p=.681) was significant, with slower reaction times for angry faces (M=575 SE=8.4) compared to happy faces (M=502 SE=7.9) *p*<.001. The 2-way interaction Group × Face ($F_{2,79}$=1.66, *p*=.19) failed to reach statistical significance.

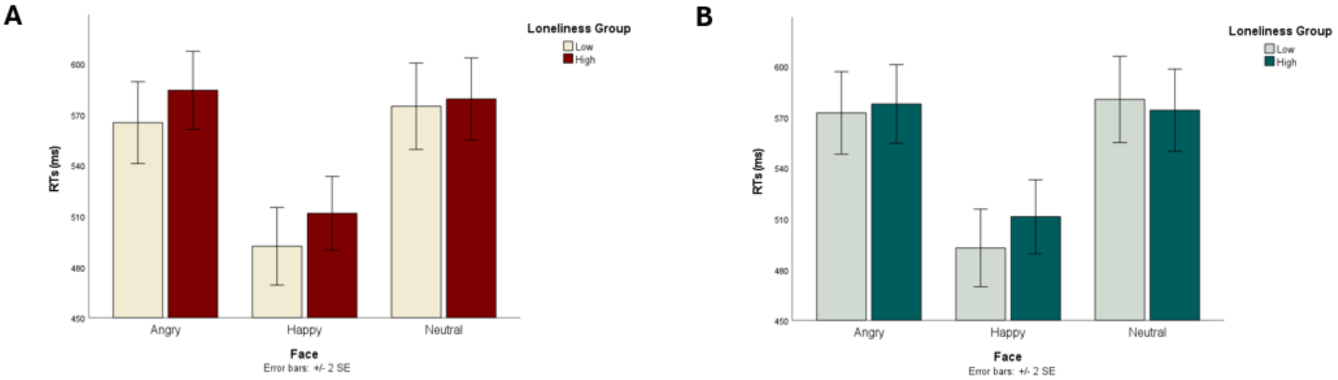

Figure 14. Reaction Times (RTs) on trials with angry, happy, and neutral go faces for the UCLA questionnaire (**A**) and for the IPARLS questionnaire (**B**) groups. Error bars represent SE of the means.

	General Loneliness		Social Isolation	
	Low	High	Low	High
Angry	565 *(12.1)*	584 *(11.51)*	572 *(12.2)*	578 *(11.6)*
Happy	492 *(11.4)*	512 *(10.9)*	493 *(11.4)*	511 *(10.9)*
Neutral	575 *(12.7)*	579 *(12.1)*	580 *(12.3)*	574 *(12.1)*

Table 14. Mean (and SE) Reaction Times for the Go condition on the Go/NoGo task.

Omission Errors

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,80}$=.82, p=.37). The main effect of Face ($F_{2,79}$=8.58, p<.001, n^2_p=.178) was significant, with greater omission errors for neutral faces (M=1.5 SE=.4) compared to happy faces (M=.23 SE=.13) p<.001. The 2-way interaction Group × Face ($F_{2,79}$=.120, p=.89) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,80}$=.26, p=.61). The main effect of Face ($F_{2,79}$=8.47, p<.001, n^2_p=.176) was significant, with greater omission errors for neutral faces (M=1.5 SE=.4) compared to happy faces (M=.23 SE=.13) p<.001. The 2-way interaction Group × Face ($F_{2,79}$=.07, p=.94) failed to reach statistical significance.

Commission Errors

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,80}$=.17, p=.68). The main effect of Face ($F_{2,79}$=13.32, p<.001, n^2_p=.252) was significant, with greater commission errors for angry faces (M=1.6 SE=.19) compared to happy faces (M=.7 SE=.11), *p*<.001, and compared to neutral faces (M=.8 SE=.13), *p*<.001. The 2-way interaction Group × Face ($F_{2,79}$=.02, *p*=.98) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,80}$=.14, *p*=728). The main effect of Face ($F_{2,79}$=13.44, *p*<.001, n^2_p=.254) was significant, with greater commission errors for angry faces (M=1.6 SE=.19) compared to happy faces (M=.7 SE=.11), *p*<.001, and compared to neutral faces (M=.8 SE=.13), *p*<.001. The 2-way interaction Group × Face ($F_{2,79}$=.256, *p*=.78) failed to reach statistical significance.

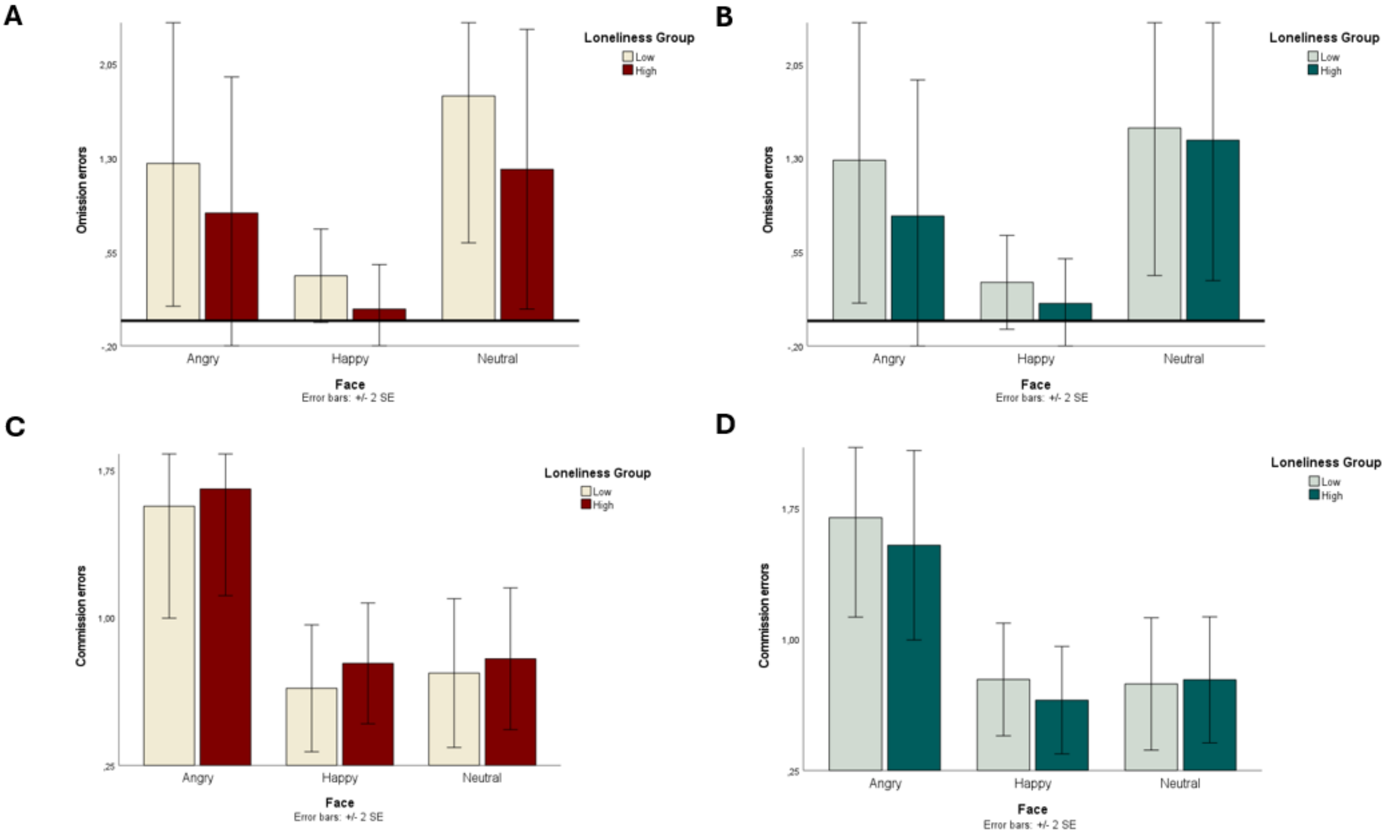

Figure 15. Group effect for Omission Errors [UCLA questionnaire (**A**) and IPARLS questionnaire (**B**)] and Group effect for Commission Errors [UCLA questionnaire (**C**) and IPARLS questionnaire (**D**)]. Error bars represent SE of the means.

Response Accuracy for Go Condition

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,80}$=.795, *p*=.38). The main effect of Face ($F_{2,79}$=6.96, *p*=.002, n^2_p=.150) was significant, with greater accuracy for happy faces (M=.99 SE=.003) compared to angry faces (M=.97 SE=.009), *p*>.05. The 2-way interaction Group × Face ($F_{2,79}$=.02, *p*=.98) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,80}$=.331, *p*=.33). The main effect of Face ($F_{2,79}$=6.88, *p*=.002, n^2_p=.1480) was significant, with greater accuracy for happy faces (M=.99 SE=.003) compared to angry faces (M=.97 SE=.009), *p*>.05. The 2-way interaction Group × Face ($F_{2,79}$=.22, *p*=.80) failed to reach statistical significance.

Response Accuracy for NoGo Condition

ANOVA results conducted with Group based on the UCLA showed that the Group main effect was not statistically significant ($F_{1,80}$=.17, *p*=.68). The main effect of Face ($F_{2,79}$=29.11, *p*<.001, n^2_p=.424) was significant, with lower accuracy for angry faces (M=.91 SE=.011) compared to happy faces (M=.96 SE=.006), *p*<.001, and compared to neutral faces (M=.98 SE=.004), *p*<.001, and with lower accuracy for happy faces (M=.96 SE=.004) compared to neutral faces (M=.98 SE=.004), *p*<.001. The 2-way interaction Group × Face ($F_{2,79}$=.11, *p*=.89) failed to reach statistical significance.

ANOVA results conducted with Group based on the IPARLS showed that the Group main effect was not statistically significant ($F_{1,80}$=.19, *p*=.66). The main effect of Face ($F_{2,79}$=29.61, *p*<.001, n^2_p=.428) was significant, with lower accuracy for angry faces (M=.91 SE=.011) compared to happy faces (M=.96 SE=.006), *p*<.001, and compared to neutral faces (M=.98 SE=.004), *p*<.001, and with lower accuracy for happy faces (M=.96 SE=.004) compared to neutral faces (M=.98 SE=.004), *p*=.003. The 2-way interaction Group × Face ($F_{2,79}$=.32, *p*=.73) failed to reach statistical significance.

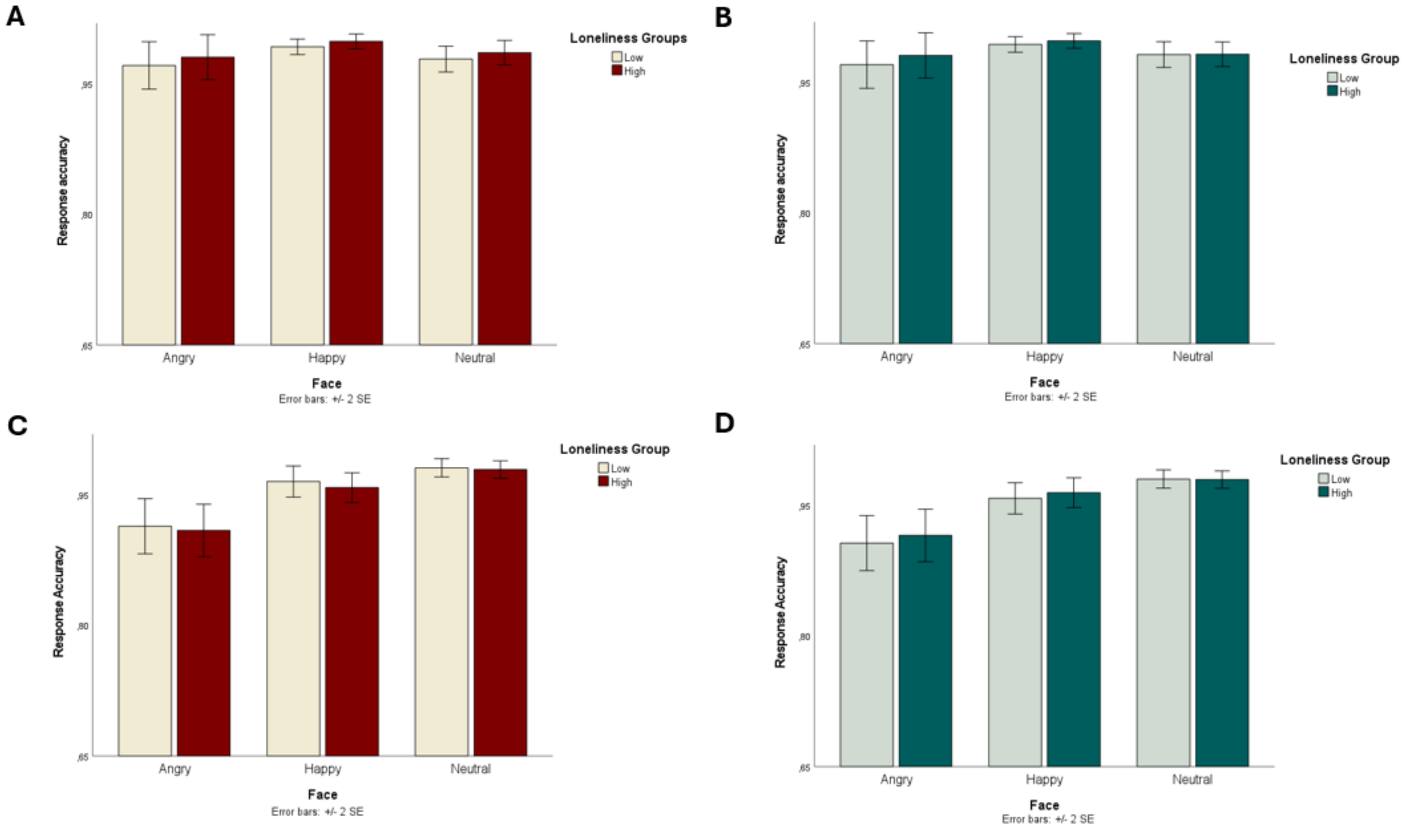

Figure 16. Group effect for Response Accuracy on Go Condition [UCLA questionnaire (**A**) and IPARLS questionnaire (**B**)] and Group effect for Response Accuracy on NoGo Condition [UCLA questionnaire (**C**) and IPARLS questionnaire (**D**)]. Error bars represent SE of the means.

	Go condition				NoGo condition			
	Geneal Loneliness		Social Isolation		General Loneliness		Social Isolation	
	Low	High	Low	High	Low	High	Low	High
Angry	.97	.98	.97	.98	.91	.91	.91	.92
	(.01)	*(.01)*	*(.01)*	*(.01)*	*(.016)*	(.015)	*(.016)*	(.008)
Happy	.99	.99	.99	.99	.96	.96	.96	.96
	(.004)	*(.004)*	*(.004)*	*(.004)*	*(.009)*	*(.009)*	*(.009)*	*(.009)*
Neutral	.98	.98	.98	.98	.98	.98	.98	.98
	(.007)	*(.007)*	*(.007)*	*(.007)*	*(.005)*	*(.005)*	*(.005)*	*(.005)*

Table 15. Mean (and SE) Response Accuracy for the Go condition on the Go/NoGo task

Discussion

Research investigating the effects of social exclusion and loneliness on response inhibition consistently indicates that individuals facing social exclusion or loneliness encounter challenges in suppressing impulsive responses (e.g., Otten & Jonas, 2013; Daly et al., 2020). Here, we investigated the emotional modulation of response inhibition, that is the ability to suppress or control an impulsive or prepotent response (Botvinick, Nystrom, Fissell, Carter & Cohen, 1999). To this aim, participants completed a Go/NoGo task in which participants were instructed to respond to a Go stimulus and to withhold response whenever a NoGo stimulus was presented.

In line with past studies assessing the emotional modulation on response initiation (Go condition) our study evidence that the response times were higher for angry faces compared to both happy and neutral faces (e.g., Schulz, Fan, Magidina, Marks, Hahn & Halpering, 2007). The results suggest that higher attentional resources were displayed in presence of angry face and in consequence they increase difficulty to initiate an action (i.e., respond to a given emotional face; Pandey, & Gupta, 2022b). This effect is interpreted as angry faces capturing attention more strongly than happy and neutral faces which results in a delay of attention disengagement (e.g., Pandey & Gupta, 2022b). Findings are also consistent with previous studies demonstrating that emotional stimuli elicited slower response times, indicative of an attentional bias to negative stimuli (e.g., Cooper & Langton, 2006). However, self-reported loneliness – regardless of whether it is a general measure or a social isolation measurement– did not affect this bias to threat-distractors.

Assessing accuracy performance, we found that overall, participants performed better on trials with happy faces both on the Go (i.e., pressing when required), and on the NoGo conditions (i.e., supressing a response) compared to angry faces. As evidenced by the study carried by Saylik, Castiello & Murphy (2021), this effect seems to be driven by a facilitation effect of happy faces, which is indicative that happy faces may help in the process of inhibiting inappropriate responses (i.e., supressing prepotent responses), thereby enhancing cognitive control efficiency. Interestingly for the NoGo condition, results were indicative that participants performed better for neutral faces compared to both angry and happy faces. This implies that participants had greater interference from emotional stimuli compared to neutral and consequently were less accurate to correctly respond (e.g., Saylik et al., 2021). Overall, the results suggest that emotion and condition have significant effects on accuracy scores in both the Go and NoGo conditions. Angry faces consistently generated lower accuracy scores compared to happy faces. To sum up, there is strong evidence that emotional stimuli interfere greatly in response inhibition, especially when negative valence stimuli appear (i.e., angry faces), as they consume a great amount of attentional resources. However, there is no strong evidence on the direction of such effect for positive valenced stimuli (i.e., happy faces). Lastly, and contrarily to our hypothesis, we failed to identify whether loneliness, independently of how loneliness was measured, did not influenced response inhibition.

In terms of omission errors, that is to not respond when a response is required, and commission errors, which refers to responding when no response was required, results indicate that the type of emotion displayed had a significant impact. We found that higher omissions were made for neutral faces compared to happy faces, suggesting that neutral faces may not capture attention as effectively as emotionally expressive faces (e.g., Schultz et al., 2007). Consequently, it is possible that happy or angry faces may elicit faster automatic responses, leading to fewer omissions compared to neutral faces (Öhman, 2002). We found that commission errors were more likely to be made for angry faces compared to happy faces. To sum up, we have provided evidence suggesting that emotional context interferes with response inhibition (e.g., Waters & Valvoi, 2006; Yu et al., 2017) and that this effect is enhanced when individuals have to process negative or threatening stimuli (e.g., Pandey & Gupta 2022ab; Saylik et al., 2021). This may be due to heightened salience and threat perception associated with angry facial expressions (Öhman & Mineka, 2001, Öhman, Lundqvist & Esteves, 2001), which may lead individuals to respond impulsively, whereas, happy and/or neutral faces may not evoke the same level of urgency, leading to fewer commission errors as individuals may be less inclined to make premature responses in their presence.

Contrarily to our hypothesis, loneliness did not appear to have an impact on response inhibition. Similar to past studies, it is possible that traditional behavioural measures do not reflect subtle impairments, as some studies have found altered brain activity patterns (e.g., Otten & Jonas, 2013; Brush et al., 2022) even when behavioural performance was not dissimilar between lonely and non-lonely individuals (e.g., Otten & Jonas, 2013; Brush et al., 2022). Overall, our study provided insights into the emotional modulation of response inhibition, highlighting the influence of emotional stimuli on attentional processes, response initiation, accuracy, and error rates. These findings contribute to our understanding of how emotions can impact cognitive control and provide valuable information for future research in this area.

Lastly, some limitations have to be acknowledged. Firstly, our study sample predominantly represents individuals with moderate levels of loneliness rather than those with high levels, similar to previous studies we made efforts to include very-high lonely individuals however, while non-lonely participants readily volunteered, individuals experiencing severe loneliness were hesitant to participate. Secondly, it is worth noting that although the psychometric properties of self-reported questionnaires such as the UCLA and IPARLS have been evaluated, these questionnaires may elicit responses influenced by social desirability (e.g., Richman et al., 1999). This influence can potentially lead participants to underestimate their feelings of loneliness. Lastly, considering that loneliness has been associated with heightened levels of anxiety and depression, it is plausible that the absence of response inhibition impairments is more related to the relevance of the stimuli used. In previous studies on the attentional effects of emotional faces on anxious participants, impairments are evidence when fearful faces are included in contrast to when angry or happy faces are used (MacLeod, Mathews & Tata, 1986; Price et al., 2013). Therefore, future studies should consider incorporating a fearful condition to delve deeper into this phenomenon and shed light on the underlying mechanisms of response inhibition processing among lonely individuals.

CHAPTER 6

DETECTION OF THE EARLIEST NEURAL INDICES OF EMOTIONAL PROCESSING

Research period abroad at the Affective Neuroscience Laboratory directed by PhD Luis Carretié at the Universidad Autónoma de Madrid, Spain

Introduction

Much research has focused on how the brain is able to correctly detect and evaluate incoming sensory input and marks it as dangerous, appetitive, or, in general affectively loaded, and which brain structures are accountable for such processing. There are several proposals on which these initial evaluation structures are and on to which latencies are related to being the most noteworthy the amygdala (e.g., Öhman, 2002), around 74ms in response to emotional faces and over 150ms in response to non-facial emotional scenery (Vuilleumier, 2005; Méndez-Bértolo et al., 2016). In primates, other structures like the ventral prefrontal cortex (vPFC) and the insula have been suggested as initial evaluation structures, although latencies are longer in their different response to emotional stimuli (Carretié, Yadav & Méndez-Bértolo, 2021). Other evidence suggests that initial evaluation may lie in first–order structures (i.e., lateral geniculate nucleus and thalamic reticular nucleus), as they are able to modulate visual inputs and they have short latencies (30-40ms).

Such processes are mainly studied with electroencephalography which has great temporal resolution compared to other methodologies (e.g., fMRI) even if it can only provide limited spatial resolution on the source generator (e.g., Vitacco, Brandeis, Pascual-Marqui & Martin, 2002). Even though processing in the visual domain occurs in early stages –the earliest event–related potential (ERP) the C1, develops at around 60ms and peaks around

80ms–, other non-visual inputs such as somatosensorial or auditorial stimulus are processes much faster: the first somatosensory ERP (i.e., P20) originates around 20ms from stimulus onset, while the first auditive ERP (i.e., Pa) originates around 25-30ms.

In this context, the present project which is divided into 4 distinct phases –increasing complexity and with separate goals– has been planned to be carried out at the laboratory of PhD Luis Carretié during a 4-years period. The experiments were aimed at detecting the first neural traces of emotional processing. Based on prior evidence, neural traces of emotional detection before 50-60ms would point to thalamic sensory nuclei over those proposing the amygdala to be responsible of initial emotional detection, as the amygdala or other higher-order structures would intervene in later phases. Importantly, stimuli evaluation is not a single, static process, but it involves several stages of increasing complexity (Dixon, Thiruchselvam, Todd & Christoff, 2017).

There are some gaps regarding the meaning of the C1 ERP component. Firstly, it has mainly been reported for emotional modulation on facial expressions, secondly, while pre-C1 components are sensitive to stimulus relevance it is still unclear whether they also reflect specific emotional content. Given that generally, these components have relatively low amplitudes, increasing signal to noise ratio, is the main goal of the methodology applied in the four studies by including a larger number of trials and variating stimuli proprieties such shape or location as evidence suggests that they increase neuron response, such that closed contours or compact shapes are more likely to boost response of contour–sensitive neurons in V1 and V2 (e.g., Ko & von der Heyd, 2018), and using different locations may modulate early visual components (e.g., Mohr & Kelly, 2018).

The present study: aims of the research practicum

The project intends to introduce several novel strategies to explore these earliest traces of emotional processing. First, in order to increase the signal-to-noise ratio several methodological elements will be implemented. This is pertained crucial due to the low relative amplitude of early ERP components. Secondly, the project aims to develop a sensory multimodal approach to extend the focus beyond the visual modality. This is considered of special relevance to our scopes as early emotional detection processes probably occur faster in non-visual modalities than visual. Lastly, and non-facial emotional stimuli will be employed given that no information is available up to the present on their capability to modulate the earliest ERP components. This is thought to occur because these components were not the scope in previous studies and, consequently, operations to increase their S/R were not implemented.

During the research training at the laboratory, I was involved in the phase 2 of the overall project. As mentioned early, the project is separate among different phases, each phase contains one empirical study that covers a specific goal and hypothesis. Study 1 and Study 2 are aimed to investigate the first ERP components of emotional detection in the visual domain, Study 3 for the somatosensory domain, and lastly, Study 4 for the auditory modality. In particular I was involved in the data collection process.

Method

Participants

Sample size was a priori calculated for each of the studies using MorePower© engine (Campbell & Thomson, 2012). In order to detect a moderate-large effect –at least 0.8– for both main and interaction effects usual in early ERPs, Study 1 needed to include 36 participants, Study 2 96 and 94 participants for both Study 3 and Study 4. Participants recruitment is done through PsInvestiga, an indirect recruitment system approved by Universidad Autónoma de Madrid Ethics Committee.

Stimuli

Experiment 1 images were 20 spiders and 20 wheels silhouettes presented in various locations (i.e., fixation, upper-left, upper-right, lower-left, or lower-right). Images were converted to greyscale to avoid colour intereference, size of stimuli was 15º * 15º and both spiders and wheels pictures were design so that spatial frequencies and figure/ground surface differences were not significant (i.e., differences between brightness and contrast did not reach statistical differences between stimuli). Each image was presented 10 times, twice per location, this resulted in 2000 total trials (200 * 2 * 5) divided into 8 blocks of 250 trials each. In order to engage attention, fixation cross colour changed randomly (from red to blue), and participants at the end of each block were asked to report how many times the fixation cross changed its colour. Each trial started with a fixation cross (1000ms) followed by the image (150ms).

Experiment 2 included 4 types of images: 20 spider pictures, 20-wheel pictures (realistic spiders and wheels respectively), 20 spider silhouettes along with 20-wheel silhouettes (non-realistic spiders and wheels respectively). All images were presented in greyscale in order to avoid colour interference. Images were presented at the fixation point, as it was the related with maximum emotional vs neutral effects. Each image was randomly presented 25 times, the total number of trials was 2000 (20 images x 25 presentations x 4 categories), divided into 4 blocks of 500 trials each. In order to engage attention, fixation cross colour changed randomly (from red to blue), and participants at the end of each block were asked to report how many times the fixation cross changed its colour. As for Experiment 1, each trial started with a fixation cross (1000ms) followed by the image (150ms).

In Experiment 3 stimuli included are 80 3D short videos (8 seconds each): 40 looming negative animals –spider and snake– and 40 looming neutral animals –bird and butterfly– presented in random order. 3D videos are adapted from those employed by Fernández–Folgueiras, Méndez-Bértolo, Hernández-Lorea, Bódalo, Giménez-Fernández & Carretié (2021) and they would have been previously assessed regarding their emotional content by an independent sample of participants. In order to engage attention towards 3D contexts, participants would be asked to categorize looming animals as vertebrate or invertebrate. 64 somatosensorial stimuli would be administered during each video, resulting in 5120 trials –divided into 3 blocks–.

Stimuli used in Experiment 4 included 80 short 3D videos (same videos used for experiment 3) along with the presentation of short auditory clips (1ms) through a HI–FI speaker placed out of view. Clips had a frequency of 8Hz. In total, 64 auditory stimuli will be administered during each video, resulting in 5120 trials –divided into 3 blocks–. Auditory threshold would be defined as the lowest intensity audible by each individual.

Procedure, recording and pre–Processing

Throughout each experiment, participants would be placed in an electrically shielded sound-attenuated room, and they would be asked to rest their chin on a chinrest placed at 40 cm from the screen (VIEWpixx®, 120 Hz). Experiment 1 assessed the modulation of pre-C1 components latencies and responses for neutral and emotional stimuli. Experiment 2 investigates whether the pre-C1 ERP components are detectable when more realistic stimuli are presented. Experiment 3 explores early emotional detection in the somatosensory domain using a stimulation protocol to preserve the characteristic train of component appearing within the 50ms from stimulus onset. The ERP components of interest are the N20 due to its origin in the somatosensory cortices, and the N18 component originated –at least partially– in the somatosensory thalamus, although other components within the 16-20ms interval would be also analysed. Lastly, Experiment 4 examines the indices of emotional detection for the auditory modality following a standardise stimulation protocol to preserve the elicited train of components that develop within 50ms from stimulus onset. The main components of interest are the Pa component which peaks around 20-30ms and its originated in the auditory cortex, along with the Na (15-20ms) originated in the auditory thalamus, as for Study 3, other components in the 15-40ms range would also be considered for analysis.

Additionally, for Studies 1 and 2, following the completion of the main task and after a mandatory yet brief beak –in which participants were released from the recording EEG cap– participants were asked to complete an evaluation task for which they were asked to report the valence and arousal for each presented image. Scales were 5-point Likert-like scales, in which 1 was very negative (valence) and very relaxing (arousal) whereas 5 was very positive (valence) and very activating (arousal), in both scales 3 represented a neutral point. In order to submit their response participants used a button-pad.

EEG activity was recorded using an electrode active cap (Biosemi®) with Ag–AgCI electrodes. Sixty–four electrodes were place at the scalp following the international 10-20 system, and other 5 electrodes were placed super– and infraorbital, along with left and right orbital, to record electrooculographic (EOG) data. Voltage of each active electrode was recorded compared to a common mode sense (CMS) and a passive electrode (DRL) and referenced offline to the nose tip. An online analog low–pass filter was set to 104Hz (5th order, CIC filter) and recordings were continuously digitized at a sampling rate of 512 Hz. An offline digital Butterworth bandpass filter of 0.3 to 30 Hz (4th order, zero phase forward and reverse –twopass– filter) was applied to continuous pre–epoched data using the Fieldtrip software (http://fieldtrip.fcdonders.nl; Oostenveld et al., 2011).

Recording was then divided into 300ms epochs for each trial –beginning at 100ms before stimulus onset–, EEG epochs for both trials in which the fixation dot changed its colour, and the subsequent trial were discarded. Lastly, EOG recording would be used to delete blinking–derived artifacts through an independent component analysis (ICA) based strategy (Jung, Makeig, Westerfield, Towsend, Courchesne &Sejnowski, 2000), as provided in Fieldtrip along with a manually visual inspection in which any further artifact or of another type would be excluded.

Data analysis

For each study, baseline corrections would be applied prior to deeper analysis. The first analytic step corresponds to identifying and quantifying the first visual component of ERPs: being it C1 or pre–C1, would be quantified as the mean amplitude within the corresponding window of interest (WOI). For Experiment 1, a 2-way repeated–measures ANOVAs would be performed on average amplitudes within each WOI introducing Emotion (spiders, wheels) and Spatial Location (the five locations) as factors. Electrode variability will be reduced to one single measure (i.e., a single factor score) per relevant scalp region (different for each spatial location in which stimuli will appear) via a spatial principal component analysis (sPCA) using a Promax rotation as described in previous studies (e.g., Carretié, Ménderz-Bértolo, Bódalo, Herández-Lorca, Fernández-Folgueiras, Fondevila, Giménez-Fernández, 2020; Fernández-Folgueiras et al., 2021). Effect sizes in these ANOVAs will be computed using the partial eta-square (η2p) method.

Similarly, in Experiment 2, a 2-way repeated-measures ANOVAs would be applied on Emotion (spiders and wheels) and Realism (silhouettes or pictures) as factors. For Studies 3 and 4, 1-way repeated-measures ANOVAs would be performed having Contextual Emotion (negative and neutral) as factor. Additionally, to better characterize the activity underlying the observed effects their sources would be estimated via the dynamic statistical parametric mapping (dSPM; Dale, Lui, Fischl, Buckner, Belliveau, Lewine, 2000) algorithm as implemented in Brainstorm (Tadel, Baillet, Moscher, Pantazis & Leahy, 2011). The dSPM computations will be applied on a realistic head model defined through the openMEEG package (Gramfort, Papadopoulo, Olivi & Clerc, 2010), that includes the whole unconstrained brain volume except cerebellum and brainstem.

CHAPTER 7

GENERAL DISCUSSION AND CONLUCISION

Loneliness, an aversive state, often associated with depression or anxiety, is different from being physically alone and is characterized by the perception of being socially isolated and dissatisfied with current social relationships (Cacioppo & Cacioppo, 2014, 2018ab). While objective social isolation refers to having few contacts with others, perceived social isolation is conceptualized as a discrepancy between one's expectations about social relationships and the actual relationships (Cacioppo, Hawkley, Norman & Berntson, 2012), and it has been associated with both momentary feelings of loneliness (short-term; Qualter et al., 2015) as well as with chronic loneliness (long-term; Shiovitz-Ezra & Ayalon, 2009). Chronic loneliness has been linked to mental health issues (e.g., anxiety, depression, hopelessness (for a review see Dahlberg, McKee, Frank & Naserr, 2022), and to physical health problems, including cardiometabolic disease, poorer sleep quality, and higher mortality rates (see Holt-Lunstad, Baker, Harris & Stephenson, 2015 for a metanalysis).

As described in Chapter 1, there are several theoretical models that attempt to explain the effects of loneliness. The majority points to effects on social and psychological functioning, suggesting that loneliness triggers a cascade of responses aimed at resolving the negative feeling and establishing rewarding social connections (Eisenberg & Liberman, 2004; Tchalova & Eisenberg, 2015). Whereas others emphasize the effects of loneliness on cognitive and emotional processes (Williams, 2007; David & Szentagotai, 2006; Dodge & Crick, 1990). Although all share the assumption that loneliness results from the perception of unsatisfactory social relations, what accounts for this assessment to become chronic may tap on personality characteristics (Richman & Leary, 2009; Spithoven, Bijttebier & Goossens, 2017).

Importantly they have two common features, first, they suggest that lonely individuals are more prone to have negative thoughts, expect rejection, and evaluate themselves and others negatively (e.g., Spithoven et al., 2017). Second, they propose that feeling lonely affects attention, interpretation, and memory for negative social cues, leading to a heightened sensitivity to social threats and a bias towards negative information processing (e.g., Cacioppo & Hawkley, 2009). As a result, lonely individuals perceive their social world as threatening, have negative social expectations, and remember negative social events more vividly.

Neuroimaging studies provide evidence for the neural correlates of loneliness, including changes in brain structure, activation patterns, and functional connectivity. These findings shed light on the impact of loneliness on social perception, emotion regulation, attention, and cognitive control processes. Studies have found that perceived social isolation is associated with changes in grey matter volume in various brain regions, including the posterior Superior Temporal Sulcus, left dorsolateral Prefrontal Cortex, and areas of the ventral attention network (see Zovettu et al., 2021 for a review). Loneliness is also linked to smaller volumes of the left anterior amygdala, hippocampus, and cerebellum, as well as increased activation in the inferior temporal gyrus (e.g., Düzel et al., 2019; Yi et al., 2018). Lonely individuals show altered activation patterns in the temporoparietal junction and decreased activation in the ventral striatum in response to social stimuli (Cacioppo et al., 2009, 2015). Loneliness and social exclusion are associated with increased activation in the ventromedial prefrontal cortex and medial orbitofrontal cortex, as well as increased activation in the left lateral prefrontal cortex (see Vijayakumar et al., 2017 for a metanalysis). These findings suggest that loneliness has significant effects on brain activity and function and that altered activity and connectivity of brain areas impairs cognitive control and self-regulation, and attentional bias towards social cues (Cacioppo et al., 2018). Loneliness affects the brain areas involved in processing social stimuli. Given that these cues offer opportunities for social connection, the modified activation patterns and connectivity seen in lonely individuals might hinder their capacity to engage with such cues effectively and establishing meaningful connections. This could be the mechanism responsible for chronic loneliness, perpetuating a cycle where difficulties in social perception and regulation contribute to persistent feelings of isolation and disconnection.

Overall, evidence from studies using faces showed that momentarilly socially excluded participants are more prone to give priority to social relevant positive stimuli: they detect faster and spend more time fixating smiling faces and they interpret a wider range of face-stimuli as directed to them (e.g., Lyrra, Wirth & Hietanen, 2017). In fact, results from cone-of-gaze judgments show that social excluded individuals have wider range amplitude of direct-gaze (e.g., Syrjämaky, Lyrra, Wirth & Hietanen, 2020a). Importantly, studies have also evidenced that socially excluded individuals tend to avoid negative relevant social stimuli, in line with the hypothesis that social exclusion motivates toward affiliative related cues and away from negative social stimuli (e.g., Xu et al., 2015; DeWall, Maner & Rouby, 2009). Altogether, these findings provide support for short-lived loneliness motivating an initial approach to positive social cues, which can help ostracized individuals restore and resolve their experience of exclusion. Interestingly, findings on research assessing the effects of social exclusion have shown that even if it is momentary social exclusion has detrimental consequences on cognition, as it is related to diminished performance in decision-making and working-memory (Buelow et al., 2015; Fuhrmann et al., 2019; Xu et al., 2017; Paolini, 2019), as well as poorer cognitive control (Cacioppo et al., 2015; Gardner et al., 2005 Exp. 2; Xu et al., 2020).

If the mechanisms underlying momentary social exclusion and chronic loneliness are similar, then being exposed to prolonged periods of loneliness may have similar consequences. However, the extent to which chronic loneliness impairs attention is not clear, neither the implications of long-term feelings of loneliness on later stages of cognition such as memory, executive function, or emotional regulation. Particularly, research on chronic feelings of loneliness on decision making shows that lonely individuals are more conservative in their choices (i.e., they make less risky choices under loss expectations), and that lonely individuals show altered patterns of emotional recognition for which they easily recognise angry or painful faces but have troubles recognising happy faces (Smith et al., 2020). Other studies have also found that long-term loneliness is related to memory bias to negative emotions, that is, lonely individuals are more prone to remember negative past events (Pearce et al., 2020). Studies assessing social cognition suggests that lonely individuals are characterised by altered social evaluations of others (compared to non-lonely individuals, when lonely participants experience negative social interactions they judge others as not-trust worthies; Lieberz et al., 2021; Cacioppo et al., 2016). However, caution has to be made when drawing conclusions due to the limited availability of research.

Given the growing concern regarding the effects of loneliness observed during the COVID-19 pandemic, the present research focused on the impact of loneliness on social attention, incidental memory, and inhibition by conducting 4 studies with a total of 551 participants.

The first study aimed to investigate whether loneliness and social contacts modulated the Own Age Memory Bias, i.e., the enhanced recognition for faces pertaining to the individuals own age group. To this end, participants performed a two-phase experiment. In the first part they were presented a set of emotional faces (angry, happy, and neutral) of young (i.e., in-group) and old adults (i.e., out-group) and they were asked to categorise them based on age. In the second part they were presented a set of previously presented and novel faces, participants were asked to respond for each face if they had already seen or not. Our results indicate that the Own Age Memory Bias occurs for both seen faces (i.e., enhanced accuracy for young faces) and for novel faces (i.e., enhanced accuracy and faster responses for young faces), and that this effect is enhanced for emotional faces compared to neutral faces (i.e., greater accuracy to angry and happy young faces). Importantly, only individuals who reported less loneliness were more likely to show an Own Age Bias for novel signs of affiliation (i.e., novel happy faces), whereas this bias was not found for higher loneliness,), whereas this bias was not found for higher loneliness, suggesting that loneliness may reduce approaching new signals of social connection and possibly contributing to maintaining the causes of loneliness. This is important considering that evidence indicates a bias toward signals of social connection in response to momentary social exclusion (e.g., Xu et al., 2015; Syrjämäki & Hietanen, 2018) whereas it links loneliness to a bias toward social threat signals (e.g., Cacioppo et al., 2009, Cacioppo et al., 2015, Cacioppo et al., 2016).

Following this finding, two studies explored whether loneliness was indeed characterised by attentional biases to threat signals. The first study assessed whether loneliness modulates the attentional shift to emotional faces. Young individuals completed a two-phase experiment. First, they completed a gaze-cueing task, in which participants were presented a series of angry, happy, and neutral cue faces with adverted gaze followed by a target, participants had to categorise the target based on identity (i.e., identify whether stimuli were a “L” or a “T”). In a later phase, they were presented a set of already seen and novel faces, and their task was to respond for each face if they had already seen or not. In line with the studies of Yu and collaborators (2021) and Bayliss and colleagues (2010) on gaze-cueing we found cue validity effects –faster and more accurate responses to targes presented at the cued location–, suggesting that individuals orient their attention based on social gaze cues (Frischen et al., 2007). Importantly, cue validity was consistent across all emotional expressions. Similar to past studies (see McKay et al., 2021 for a review), we believe that this effect can be due to the fact that cueing is an automatic and strong response, and emotional modulation of this effect is found when task demands increase or when contextual features are at play. This suggests the possibility that more naturalistic environments maybe required to observe this emotional modulation of gaze cueing that has been deemed of importance as it enhances survival opportunities (Öhman & Mineka, 2001). To our knowledge only the study of Capellini and colleagues (2019) explored the effects of social exclusion on gaze-cueing. For the first study they used a dynamic gaze-cueing task whereas for the second study they used schematic figures (ovals), in both cases there were gaze-cueing effects, but no group differences between included and excluded.

For emotional recognition, different to the study described in Chapter 2 (González et al., 2022), in which participants were explicitly instructed to remember the faces as they would be tested after, participants, in this study findings showed that for faces already seen before, angry faces were better recognized, whereas for novel faces, happy faces were better recognized, and this effect was independent of loneliness. These findings suggest that both avoidance of social threat and approach of social affiliation are at play when individuals encode social stimuli (Elliot, Gable & Mapes, 2006). When individuals are faced with angry faces, it triggers an innate response to avoid potential threats or negative situations (e.g., Becker & Detweiller-Bedell, 2008), and as they tend to pay more attention to threatening stimulation it leads to enhanced recognition (e.g., Ohman, Lundqvist & Esteves, 2001). This heightened recognition serves as a defence mechanism, allowing individuals to quickly identify potential threats and take appropriate action to avoid harm. On the other hand, when individuals encounter novel faces heightens approach motivation, as a results it facilitates better recognition and memory, as individuals are motivated to explore and engage with new social stimuli (González et al., 2022). However, in contrast to the findings of experiment 1 described in Chapter 2, the present study shows that loneliness did not have any impact on incidental face recognition.

The third study was aimed to assess the modulation effect of loneliness on selective attention to emotional faces. Young adults completed a face-word interference task, in which they were presented a series of angry, happy, and neutral-scrambled distractor-faces and positive or negative target-words. Like in Beall & Herbert (2008), the findings suggest a general modulation of selective attention by emotional content due to interference from emotional distractors, resulting in slower and less accurate responses when the valence of target words did not align with the valence of distractor facial expressions (e.g., Beall & Herbert, 2008), and facilitation from emotional distractors, leading to faster and more accurate responses when the valence of target words matched the valence of distractor facial expressions (Song et al., 2017). Findings regarding interference and facilitation scores revealed a consistently higher interference from angry distractor faces (e.g., Öhman & Mineka, 2021) emphasizing the prioritization of threatening stimuli such as angry faces due to their evolutionary advantage in faster detection. However, regardless of the method used to assess loneliness, self-reported loneliness did not influence this bias toward threat distractors. Conversely, facilitation scores indicated no differences suggesting that in tasks interference effects are more prominent than facilitation effects (e.g., Beall & Herbert, 2008).

In addition, findings are consistent with past evidence on accuracy performance interference effects of incongruent stimuli on accuracy scores, as increased errors were committed when target's word valence did not match the facial expression portrayed (e.g., Beall & Herbert, 2008). Interestingly, when analysing social rejection –as assess by the

IPARLS scale– results evidence that non-lonely participants were more accurate for positive-target than for negative-target words, whereas no difference between target's valence was to be found for the high loneliness group. These findings suggest that the influence of loneliness on selective attention may be context-dependent, that is, that the emotional distress associated with social isolation (IPARLS) may influence attention in emotional contexts. Altogether, the present study examined the potential influence of loneliness on selective attention to emotional distractor-faces and in contrast to our hypotheses, there were no effects of loneliness.

Lastly, the forth study was aimed to explore loneliness effects on later processes of cognition, in particular whether loneliness influenced response inhibition to emotional stimuli. Young individuals performed an emotional Go/NoGo task in which they were asked to respond to Go stimuli and to withhold response when the NoGo stimuli were presented. In line with past studies assessing the emotional modulation on response initiation (Go condition) our study shows that slower responses for angry faces compared to both happy and neutral faces (e.g., Schulz, Fan, Magidina, Marks, Hahn & Halpering, 2007). The results suggest that higher attentional resources were deployed to angry face and in consequence they increase difficulty to initiate an action (i.e., respond to a given emotional face; Pandey, & Gupta, 2022b). This effect is interpreted as angry faces prioritizing attention more than happy and neutral faces which results in a delay of attention disengagement (e.g., Pandey & Gupta, 2022b). However, in this case too self-reported loneliness –regardless of whether it is a general measure or a social isolation measurement– did not affect this bias to threat-distractors. Additionally, we found that overall participants were more accurate on trials with happy faces both on the Go (i.e., pressing when required), and on the NoGo conditions (i.e., supressing a response) compared to angry faces. In line with the study carried by Saylik, Castiello & Murphy (2021), this effect seems to be driven by a facilitation effect of happy faces, which is indicative that happy faces may help in the process of inhibiting inappropriate responses (i.e., supressing prepotent responses), thereby enhancing response inhibition.

In terms of omission errors, that is to not respond when required, and commission errors, which refers to responding when no response was required, results indicate that the type of emotion displayed had a significant impact. We found that higher omissions were made for neutral faces compared to happy faces, suggesting that neutral faces may not capture attention as effectively as emotionally expressive faces (e.g., Schultz et al., 2007). We found that commission errors were more likely to be made for angry faces compared to happy faces. In contrast to our hypothesis, loneliness did not have an impact on response inhibition. It is possible that traditional behavioural measures cannot detect subtle impairments, as some studies have found altered brain activity patterns (e.g., Otten & Jonas, 2013; Brush et al., 2022) even when behavioural performance was not dissimilar between lonely and non-lonely individuals (e.g., Otten & Jonas, 2013; Brush et al., 2022).

It is important to acknowledge certain limitations in our study that can be addressed in future research. Firstly, in the first study, young adults reported moderate levels of loneliness and it is crucial for future research to investigate whether our findings on the Own Age Bias can be generalized to individuals experiencing high levels of loneliness. Secondly, we need to address how loneliness is assessed. When trying to include both non-lonely individuals and those experiencing very high levels of loneliness by pre-screening participants, we encountered problems. In fact, only non-lonely individuals and young adults reporting moderate to low levels of loneliness actively participated in data collection, whereas the response rate for very high individuals was very low. This suggests that individuals with very high levels of loneliness may be more hesitant to take part, not only in controlled experimental settings but also in real-life setups. In addition, loneliness was assessed with the

UCLA and IPARLS questionnaires due to their validity and reliability. We decided to use both questionnaires as they measure slightly different constructs. The UCLA questionnaire measures general loneliness whereas the IPARLS measures subjective feelings of distress by loneliness (i.e., emotional component). However, results failed to provide insights on whether performance impairments in attentional processes, memory recognition and response inhibition were related to a general feeling of loneliness or was more connected to the emotional component of social isolation. Additionally, it is important to note that self-report measures may be prone to social desirability bias (Richman, Kiesler, Weisband, & Drasgow, 1999). Although the use of standardized questionnaires allows to counteract these problems, it is still possible that participants still underestimate their levels of social isolation. Secondly, it has been shown that loneliness is related to other psychological disorders such anxiety and depression. Both of these conditions are related to increased attentional biases to social threats, but in particular to fearful and sad faces. In this light, future research should explore whether attentional biases on lonely individuals are more pronounced for fearful or sad stimuli, rather than angry faces.

Regardless of these limitations, the novel finding that loneliness affects the Own Age Memory Bias, with individuals reporting less loneliness showing a bias towards novel signs of affiliation is promising and provides opportunities for future research. For instance, future research could explore manipulating stimulus encoding to understand how loneliness influences the recognition of specific characteristics of social stimuli. Importantly, future research could include other methodologies, such as eye-tracking technology to explore the temporal dynamics of attention allocation patterns in response to different social stimuli, or neuroimaging techniques to assess neural circuits involved in processing socials cues in lonely individuals.

Understanding how loneliness affects different aspects of social cognition is important, but it has become more urgent in recent years, especially for young individuals, who have suffered from the lack of social contacts with their peers during the lockdown for the Covid-19 pandemic. Future research on the effects of loneliness on social cognition could help understanding whether the mechanisms that contribute to maintaining loneliness are characterized first by reduced recognition memory for novel social affiliation signals, followed by hypervigilance for novel social threat signals.

REFERENCES

(2023, January). *Loneliness*. APA Dictionary of Psychology. Retrieved January 31, 2023, from https://dictionary.apa.org/loneliness

Aartsen, M., & Jylhä, M. (2011). Onset of loneliness in older adults: results of a 28-year prospective study. *European Journal of Ageing, 8*(1), 31–38. https://doi.org/10.1007/s10433-011-0175-7

Adams Jr, R. B., & Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion, 5*(1), 3. doi:10.1037/1528-3542.5.3.311

Altabácker, A., Plózer, E., Darnai, G., Perlaki, G., Horváth, R., Orsi, G., … & Janszky, J. (2016). Problematic Internet use is associated with structural alterations in the reward system in females. *Brain imaging and behavior, 10*(4), 953-959. doi:10.1007/s11682-015-9454-9

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390–412. https://doi.org/10.1016/j.jml.2007.12.005

Baggott, S., Palermo, R., & Fox, A. M. (2011). Processing emotional category congruency between emotional facial expressions and emotional words. *Cognition & Emotion, 25*(2), 369–379. https://doi.org/10.1080/02699931.2010.488945

Barch, D. M., Braver, T. S., Sabb, F. W., & Noll, D. C. (2000). Anterior cingulate and the monitoring of response conflict: Evidence from an fMRI study of overt verb generation. *Journal of Cognitive Neuroscience, 12*(2), 298-309. https://doi.org/10.1162/08989290056211

Baron-Cohen, S. & Cross, P. (1992). Reading the eyes: evidence for the role of perception in the development of a theory of mind. *Mind & Language*, *7*(1-2), 172-186. https://doi.org/10.1111/j.1468-0017.1992.tb00203.x

Baron-Cohen, S. (1995). Mindblindness: an essay on autism and theory of mind. The MIT Press. https://doi.org/10.7551/mitpress/4635.001.0001

Baron-Cohen, S. (1999). *The evolution of a theory of mind.* In M. C. Corballis & S. E. G. Lea (Eds.), The descent of mind: Psychological perspectives on hominid evolution (pp. 261-277). Oxford University Press.

Baron-Cohen, S. (2001). Theory of mind in normal development and autism. *Prisme, 34*(1), 74-183.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind" ? *Cognition, 21*(1), 37–46. https://doi.org/10.1016/0010-0277(85)90022-8

Barreto, M., Victor, C., Hammond, C., Eccles, A., Richins, M. T., & Qualter, P. (2021). Loneliness around the world: Age, gender, and cultural differences in loneliness. *Personality and Individual Differences, 169,* 110066. https://doi.org/10.1016/j.paid.2020.110066

Bater, D., Kliegl, R., Vasishth, S. & Baayen, H. (2015). Parsimonious Mixed Models. ArXiv:1506.04967 [Stat]. Retrieved from arxiv: 1506.04967.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Usinglme4. *Journal of Statistical Software, 67*(1). https://doi.org/10.18637/jss.v067.i01

Baumeister, R. F. & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Interpersonal Development,* 57–89. https://doi.org/10.4324/9781351153683-3

Baumeister, R. F., & Tice, D. M. (1990). Point-Counterpoints: Anxiety and Social Exclusion. *Journal of Social and Clinical Psychology, 9*(2), 165–195. https://doi.org/10.1521/jscp.1990.9.2.165

Baumeister, R. F., Twenge, J. M., & Nuss, C. K. (2002). Effects of social exclusion on cognitive processes: Anticipated aloneness reduces intelligent thought. *Journal of Personality and Social Psychology, 83*(4), 817–827. https://doi.org/10.1037/0022-3514.83.4.817

Bayliss, A. P., Schuch, S., & Tipper, S. P. (2010). Gaze cueing elicited by emotional faces is influenced by affective context. *Visual Cognition, 18*(8), 1214–1232. https://doi.org/10.1080/13506285.2010.484657

Beadleston, L. N., O'Donnell, A. T., McMahon, J., McMahon, G., Kinsella, E. L., Kearns, M., Jay, S., & Muldoon, O. T. (2019). Working hard and playing hard: multiple group membership, exercise and cognitive performance in boys and girls. *Social Psychology of Education, 22*(2), 501–515. https://doi.org/10.1007/s11218-019-09483-9

Beall, P. M., & Herbert, A. M. (2008). The face wins: Stronger automatic processing of affect in facial expressions than words in a modified Stroop task. *Cognition & Emotion, 22*(8), 1613–1642. doi:10.1080/02699930801940370

Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General, 140*(4), 637-659. doi: 10.1037/a0024060

Becker, M. W., & Detweiler-Bedell, B. (2008). Short article: Early detection and avoidance of threatening faces during passive viewing. *Quarterly Journal of Experimental Psychology, 62*(7), 1257–1264. https://doi.org/10.1080/17470210902725753

Beuriedl-Schmidt, C., Jobst, A., Gander, M., Seidl, E., Sabaß, L., Sarubin, N., Mauer, C., Padberg, F., & Buchheim, A. (2017). Attachment representations, patterns of emotion regulation, and social exclusion in patients with chronic and episodic depression and healthy controls. *Journal of Affective Disorders, 210*, 130–138. https://doi.org/10.1016/j.jad.2016.12.030

Blakemore, S.-J. (2010). The Developing Social Brain: Implications for Education. *Neuron, 65*(6), 744–747. https://doi.org/10.1016/j.neuron.2010.03.004

Boffo, M., Mannarini, S. & Munari, C. (2012). Exploratory structure equation modeling of the UCLA loneliness scale: A contribution to the Italian adaptation. *TPM Testing, Psychometrics, Methodology in Applied Psychology*. https:// doi. org/ 10. 4473/ TPM19.4.7 (2012).

Böger, A., & Huxhold, O. (2018). Do the antecedents and consequences of loneliness change from middle adulthood into old age? *Developmental Psychology, 54*(1), 181–197. https://doi.org/10.1037/dev0000453

Bolling, D. Z., Pitskel, N. B., Deen, B., Crowley, M. J., McPartland, J. C., Mayes, L. C., & Pelphrey, K. A. (2011). Dissociable brain mechanisms for processing social exclusion and rule violation. *Neuroimage*, 54, 2462–2471.

Borai, A., Aly, H. Y., & Ibrahim, H. K. (2020). Executive Functions Assessment in Adult Patients with Idiopathic Epilepsy. *Journal of Behavioral and Brain Science*, *10*(01), 1.

Boss, L., Kang, D.-H., & Branson, S. (2015). Loneliness and cognitive function in the older adult: a systematic review. *International Psychogeriatrics, 27*(4), 541–553. https://doi.org/10.1017/s1041610214002749

Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999). Conflict monitoring versus selection-for-action in anterior cingulate cortex. *Nature, 402*(6758), 179-181. https://doi.org/10.1038/46035.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Brennan, G. M., Crowley, M. J., Wu, J., Mayes, L. C., & Baskin-Sommers, A. R. (2018). Neural processing of social exclusion in individuals with psychopathic traits: Links to anger and aggression. *Psychiatry Research, 268,* 263–271. https://doi.org/10.1016/j.psychres.2018.07.024

Brilliant T., D., Takeuchi, H., Nouchi, R., Yokoyama, R., Kotozaki, Y., Nakagawa, S., Hanawa, S., Sekiguchi, A., Ikeda, S., Sakaki, K., Kawata, K. H. dos S., Nozawa, T., Yokota, S., Magistro, D., & Kawashima, R. (2022). Loneliness inside of the brain: evidence from a large dataset of resting-state fMRI in young adult. *Scientific Reports, 12*(1). https://doi.org/10.1038/s41598-022-11724-5

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*(3), 305–327. https://doi.org/10.1111/j.2044-8295.1986.tb02199.x

Brush, C. J., Kallen, A. M., Meynadasy, M. A., King, T., Hajcak, G., & Sheffler, J. L. (2022). The P300, loneliness, and depression in older adults. *Biological Psychology, 171,* 108339. https://doi.org/10.1016/j.biopsycho.2022.108339

Buckley, K. E., Winkel, R. E., & Leary, M. R. (2004). Reactions to acceptance and rejection: Effects of level and sequence of relational evaluation. *Journal of Experimental Social Psychology*, *40*(1), 14-28. https://doi.org/10.1016/S0022-1031(03)00064-7

Buelow, M. T., Okdie, B. M., Brunell, A. B., & Trost, Z. (2015). Stuck in a moment and you cannot get out of it: The lingering effects of ostracism on cognition and satisfaction of basic needs. *Personality and Individual Differences*, *76*, 39-43. https://doi.org/10.1016/j.paid.2014.11.051

Burgess, M. C. R., & Weaver, G. E. (2003). Interest and Attention in Facial Recognition. *Perceptual and Motor Skills,* *96*(2), 467–480. https://doi.org/10.2466/pms.2003.96.2.467

Cacioppo, J. T., & Berntson, G. G. (1994). Relationship between attitudes and evaluative space: A critical review, with emphasis on the separability of positive and negative substrates. Psychological Bulletin, 115(3), 401–423. https://doi.org/10.1037/0033-2909.115.3.401

Cacioppo, J. T., & Cacioppo, S. (2014). Social Relationships and Health: The Toxic Effects of Perceived Social Isolation. Social and Personality Psychology Compass, 8(2), 58–72. https://doi.org/10.1111/spc3.12087

Cacioppo, J. T., & Cacioppo, S. (2018a). The growing problem of loneliness. *The Lancet, 391(10119)*, 426. https://doi.org/10.1016/s0140-6736(18)30142-9

Cacioppo, J. T., & Cacioppo, S. (2018b). Loneliness in the Modern Age: An Evolutionary Theory of Loneliness (ETL). *Advances in Experimental Social Psychology,* 127–197. https://doi.org/10.1016/bs.aesp.2018.03.003

Cacioppo, J. T., & Hawkley, L. C. (2009). Perceived social isolation and cognition. *Trends in cognitive sciences*, *13*(10), 447-454. https://doi.org/10.1016/j.tics.2009.06.005

Cacioppo, J. T., Cacioppo, S., Cole, S. W., Capitanio, J. P., Goossens, L., & Boomsma, D. I. (2015). Loneliness across phylogeny and a call for comparative studies and animal models. *Perspectives on Psychological Science*, *10*(2), 202-212. https://doi.org/10.1177/1745691614564876

Cacioppo, J. T., Ernst, J. M., Burleson, M. H., McClintock, M. K., Malarkey, W. B., Hawkley, L. C., ... & Berntson, G. G. (2000). *Lonely Traits and Concomitant Physiological Processes: The MacArthur Social Neuroscience Studies.* (2002). Foundations in Social Neuroscience. https://doi.org/10.7551/mitpress/3077.003.0060

Cacioppo, J. T., Hawkley, L. C., Norman, G. J. & Berntson, G. G. (2012). Social isolation. *Annals of the New York Academy of Sciences, 1231(1)*, 17-22. https://doi.org/10.1111/j.1749-6632.2011.06028.x

Cacioppo, J. T., Norris, C. J., Decety, J., Monteleone, G., & Nusbaum, H. (2009). In the Eye of the Beholder: Individual Differences in Perceived Social Isolation Predict Regional Brain Activation to Social Stimuli. *Journal of Cognitive Neuroscience, 21*(1), 83–92. https://doi.org/10.1162/jocn.2009.21007

Cacioppo, S., & Cacioppo, J. T. (2016). Research in Social Neuroscience: How Perceived Social Isolation, Ostracism, and Romantic Rejection Affect Our Brain. *Social Exclusion*, 73–88. doi:10.1007/978-3-319-33033-4_4

Cacioppo, S., Balogh, S., & Cacioppo, J. T. (2015). Implicit attention to negative social, in contrast to nonsocial, words in the Stroop task differs between individuals high and low in loneliness: Evidence from event-related brain microstates. *Cortex*, 70, 213–233. https://doi.org/10.1016/j.cortex.2015.05.032

Cacioppo, S., Bangee, M., Balogh, S., Cardenas-Iniguez, C., Qualter, P., & Cacioppo, J. T. (2015). Loneliness and implicit attention to social threat: A high-performance electrical neuroimaging study. *Cognitive Neuroscience*, *7*(1–4), 138–159. https://doi.org/10.1080/ 17588928. 2015.1070136

Cacioppo, S., Grippo, A. J., London, S., Goossens, L. & Cacioppo, J. T. (2015). Loneliness: clinical import and interventions. *Perspectives on Psychological Science*, *10*(2), 238-249. https://doi.org/10.1177/1745691615570616

Cacioppo, S., Weiss, R. M., Runesha, H. B., & Cacioppo, J. T. (2014). Dynamic spatiotemporal brain analyses using high performance electrical neuroimaging: theoretical framework and validation. *Journal of Neuroscience Methods*, *238*, 11-34. https://doi.org/10.1016/j.jneumeth.2014.09.009

Cameron, C. D., Hutcherson, C. A., Ferguson, A. M., Scheffer, J. A., Hadjiandreou, E., & Inzlicht, M. (2019). Empathy is hard work: People choose to avoid empathy because of its cognitive costs. *Journal of Experimental Psychology: General*, *148*(6), 962-976. https://doi.org/10.1037/xge0000595

Campagne, D. M. (2019). Stress and perceived social isolation (loneliness). *Archives of Gerontology and Geriatrics*, *82*, 192–199. https://doi.org/10.1016/j.archger.2019.02.007

Campbell, J. I. D., & Thompson, V. A. (2012). MorePower 6.0 for ANOVA with relational confidence intervals and Bayesian analysis. *Behavior Research Methods, 44*(4), 1255–1265. https://doi.org/10.3758/s13428-012-0186-0

Campbell, W. K., Krusemark, E. A., Dyckman, K. A., Brunell, A. B., McDowell, J. E., Twenge, J. M., & Clementz, B. A. (2006). A magnetoencephalography investigation of neural correlates for social exclusion and self-control. *Social Neuroscience, 1*(2), 124–134. https://doi.org/10.1080/17470910601035160

Capellini, R., Riva, P., Ricciardelli, P., & Sacchi, S. (2019). Turning Away From Averted Gazes: The Effect of Social Exclusion on Gaze Cueing. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.01000

Carretié, L., Méndez-Bértolo, C., Bódalo, C., Hernández-Lorca, M., Fernández-Folgueiras, U., Fondevila, S., & Giménez-Fernández, T. (2019). Retinotopy of emotion: Perception of negatively valenced stimuli presented at different spatial locations as revealed by event-related potentials. *Human Brain Mapping, 41*(7), 1711–1724. Portico. https://doi.org/10.1002/hbm.24904

Carretié, L., Mercado, F., Tapia, M., & Hinojosa, J. A. (2001). Emotion, attention, and the 'negativity bias', studied through event-related potentials. *International Journal of Psychophysiology, 41*(1), 75–85. https://doi.org/10.1016/s0167-8760(00)00195-1

Carretié, L., Yadav, R. K. & Méndez-Bértolo, C. (2021). The missing link in early emotional processing. *Emotion Review, 13*, 225-244. https://doi.org/10.20944/preprints202005.0348.v1

Chen, T., Nummenmaa, L., & Hietanen, J. K. (2017). Eye Contact Judgment Is Influenced by Perceivers' Social Anxiety But Not by Their Affective State. *Frontiers in Psychology, 8.* https://doi.org/10.3389/fpsyg.2017.00373

Chester, D. S., Lynam, D. R., Milich, R., & DeWall, C. N. (2017). Social rejection magnifies impulsive behavior among individuals with greater negative urgency: An experimental test of urgency theory. *Journal of Experimental Psychology: General, 146*(7), 962–967. https://doi.org/10.1037/xge0000308

Chou, K.-L. (2000). Assessing Chinese adolescents' social support: the multidimensional scale of perceived social support. *Personality and Individual Differences, 28*(2), 299–307. https://doi.org/10.1016/s0191-8869(99)00098-7

Cooper, R. M., & Langton, S. R. H. (2006). Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour Research and Therapy, 44*(9), 1321–1329. https://doi.org/10.1016/j.brat.2005.10.004

Cooper, S. R., Gonthier, C., Barch, D. M., & Braver, T. S. (2017). The Role of Psychometrics in Individual Differences Research in Cognition: A Case Study of the AX-CPT. *Frontiers in Psychology, 8.* https://doi.org/10.3389/fpsyg.2017.01482

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*(3), 201–215. https://doi.org/10.1038/nrn755

Corbetta, M., Patel, G., & Shulman, G. L. (2008). The Reorienting System of the Human Brain: From Environment to Theory of Mind. *Neuron, 58*(3), 306–324. https://doi.org/10.1016/j.neuron.2008.04.017

Cornwell, E. Y., & Waite, L. J. (2009). Social Disconnectedness, Perceived Isolation, and Health among Older Adults. *Journal of Health and Social Behavior, 50(1),* 31–48. https://doi.org/10.1177/002214650905000103

Courtin, E., & Knapp, M. (2017). Social isolation, loneliness, and health in old age: a scoping review. *Health & Social Care in the Community*, *25*(3), 799-812. https://doi.org/10.1111/hsc.12311 (2017).

Crick, N. R., & Dodge, K. A. (1994). A review and reformulation of social information-processing mechanisms in children's social adjustment. *Psychological Bulletin*, *115*(1), 74. https://doi.org/10.1037/0033-2909.115.1.74

Cronin, S. L., Craig, B. M., & Lipp, O. V. (2019). Emotional expressions reduce the own-age bias. *Emotion*, *19*(7), 1206–1213. https://doi.org/10.1037/emo0000517

Cronin, S. L., Craig, B. M., & Lipp, O. V. (2020a). An own-age bias in mixed-and pure-list presentations: No evidence for the social-cognitive account. *British Journal of Psychology*, *111*(4), 702-722. https://doi.org/10.1111/bjop.12435

Cronin, S. L., Craig, B. M., & Lipp, O. V. (2020b). Stable middle-aged face recognition: No moderation of the own-age bias across contexts. *British Journal of Psychology*, *112*(3), 645-661. https://doi.org/10.1111/bjop.12481

Cudo, A., & Zabielska-Mendyk, E. (2019). Cognitive functions in Internet addiction–a review. *Psychiatria Polska*, *53*(1), 61-79. https://doi.org/10.12740/PP/82194

D'Agostino, A. E., Kattan, D., & Canli, T. (2019). An fMRI study of loneliness in younger and older adults. *Social Neuroscience*, *14*(2), 136-148. https://doi.org/10.1080/17470919.2018.1445027

Dahlberg, L., McKee, K. J., Frank, A., & Naseer, M. (2022). A systematic review of longitudinal risk factors for loneliness in older adults. *Aging & Mental Health, 26*(2), 225-249. https://doi.org/10.1080/13607863.2021.1876638

Dale, A. M., Liu, A. K., Fischl, B. R., Buckner, R. L., Belliveau, J. W., Lewine, J. D., & Halgren, E. (2000). Dynamic Statistical Parametric Mapping. *Neuron, 26*(1), 55–67. https://doi.org/10.1016/s0896-6273(00)81138-1

Dalmaso, M., Castelli, L., & Galfano, G. (2020). Social modulators of gaze-mediated orienting of attention: A review. *Psychonomic Bulletin & Review, 27*(5), 833–855. https://doi.org/10.3758/s13423-020-01730-x

Daly, N., Jones, A., Garofalo, C., Uzieblo, K., Robinson, E., & Gillespie, S. M. (2022). Coping Using Sex, Health-Related Behaviors, and Mental Health During COVID-19 Lockdown in the UK. *Frontiers in Psychiatry, 13*. https://doi.org/10.3389/fpsyt.2022.880454

David, D., & Szentagotai, A. (2006). Cognitions in cognitive-behavioral psychotherapies; toward an integrative model. *Clinical Psychology Review*, *26*(3), 284-298. https://doi.org/10.1016/j. cpr.2005.09.003

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113-126. https://doi.org/10.1037/0022-3514.44.1.113

De Luca, F. D., Petrucci, M., Monachesi, B., Lavidor, M., & Pecchinenda, A. (2020). Asymmetric Contributions of the Fronto-Parietal Network to Emotional Conflict in the Word–Face Interference Task. *Symmetry*, *12*(10), 1701. https://doi.org/10.3390/sym12101701

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews*, *3*(2), 71-100. https://doi.org/10.1177/1534582304267187

Denkinger, B., & Kinn, M. (2018). Own-Age Bias and Positivity Effects in Facial Recognition. *Experimental Aging Research, 44*(5), 411–426. https://doi.org/10.1080/0361073x.2018 .1521493

Desimone, R. & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 68,* 193–222. https://doi.org/10.1146/annurev-psych-122414-033400

DeWall, C. N., Maner, J. K., & Rouby, D. A. (2009). Social exclusion and early-stage interpersonal perception: Selective attention to signs of acceptance. *Journal of Personality and Social Psychology, 96*(4), 729–741. https://doi.org/10.1037/a0014634

Dixon, M. L., Thiruchselvam, R., Todd, R., & Christoff, K. (2017). Emotion and the prefrontal cortex: An integrative review. *Psychological Bulletin*, *143*(10), 1033–1081. https://doi.org/10.1037/bul0000096

Dodge, K. A., & Crick, N. R. (1990). Social information-processing bases of aggressive behavior in children. *Personality and Social Psychology Bulletin*, *16*(1), 8-22. https://doi.org/10.1177/0146167290161002

Dresler, T., Mériau, K., Heekeren, H. R., & Meer, E. (2008). Emotional Stroop task: effect of word arousal and subject anxiety on emotional interference. *Psychological Research Psychologische Forschung, 73*(3), 364–371. https://doi.org/10.1007/s00426-008-0154-6

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze Perception Triggers Reflexive Visuospatial Orienting. *Visual Cognition, 6*(5), 509–540. https://doi.org/10.1080/135062899394920

Du, X., Tang, Y., Jiang, Y., & Tian, Y. (2022). Individuals attention bias in perceived loneliness: an ERP study. *Brain-Apparatus Communication: A Journal of Bacomics, 1*(1), 50–65. https://doi.org/10.1080/27706710.2022.2077639

Duckworth, K. L., Bargh, J. A., Garcia, M., & Chaiken, S. (2002). The Automatic Evaluation of Novel Stimuli. *Psychological Science, 13*(6), 513–519. https://doi.org/10.1111/1467-9280.00490

Düzel, S., Drewelies, J., Gerstorf, D., Demuth, I., Steinhagen-Thiessen, E., Lindenberger, U., & Kühn, S. (2019). Structural brain correlates of loneliness among older adults. *Scientific reports, 9*(1), 1-11. https://doi.org/10.1038/s41598-019-49888-2

Eagle, D. M., Bari, A., & Robbins, T. W. (2008). The neuropsychopharmacology of action inhibition: cross-species translation of the stop-signal and go/no-go tasks. *Psychopharmacology, 199*(3), 439–456. https://doi.org/10.1007/s00213-008-1127-6

Ebner, N. C., & Johnson, M. K. (2009). Young and older emotional faces: Are there age group differences in expression identification and memory? *Emotion, 9*(3), 329–339. https://doi.org/10.1037/a0015179

Ebner, N. C., Johnson, M. R., Rieckmann, A., Durbin, K. A., Johnson, M. K., & Fischer, H. (2013). Processing own-age vs. other-age faces: Neuro-behavioral correlates and effects of emotion. *NeuroImage, 78*, 363–371. https://doi.org/10.1016/j.neuroimage.2013.04.029

Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES—A database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods, 42*(1), 351–362. https://doi.org/10.3758/brm.42.1.351

Egeth, H. E., & Yantis, S. (1997). VISUAL ATTENTION: Control, Representation, and Time Course. *Annual Review of Psychology, 48*(1), 269–297. https://doi.org/10.1146/annurev.psych.48.1.269

Egloff, B., & Hock, M. (2003). Assessing attention allocation toward threat-related stimuli: a comparison of the emotional Stroop task and the attentional probe task. *Personality and Individual Differences, 3*5(2), 475–483. https://doi.org/10.1016/s0191-8869(02)00265-9

Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2007). Dissociable Neural Systems Resolve Conflict from Emotional versus Nonemotional Distracters. *Cerebral Cortex, 18*(6), 1475–1484. https://doi.org/10.1093/cercor/bhm179

Eisenberger, N. I., & Lieberman, M. D. (2004). Why rejection hurts: A common neural alarm system for physical and social pain. *Trends in Cognitive Sciences, 8,* 294–300. https://doi.org/10.1016/j.tics.2004.05.010

Eisenberger, N. I., Lieberman, M. D., & Williams, K. D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science, 302*(5643), 290-292. https://doi.org/10.1126/science.1089134

Elliot, A. J., Gable, S. L. & Mapes, R. R. (2006). Approach and Avoidance Motivation in the Social Domain. *Personality and Social Psychology Bulletin, 32*(3), 378-391. https://doi.10.1177/0146167205282153

Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception & Psychophysics, 25*(4), 249–263. https://doi.org/10.3758/bf03198804

Ernst, M., Mohr, H. M., Schött, M., Rickmeyer, C., Fischmann, T., Leuzinger-Bohleber, M., Weiß, H., & Grabhorn, R. (2018). The effects of social exclusion on response inhibition in borderline personality disorder and major depression. *Psychiatry Research, 262,* 333–339. https://doi.org/10.1016/j.psychres.2017.03.034

Erzen, E., & Çikrikci, Ö. (2018). The effect of loneliness on depression: A meta-analysis. International *Journal of Social Psychiatry, 64*(5), 427–435. https://doi.org/10.1177/0020764018776349

Eslinger, P. J., Anders, S., Ballarini, T., Boutros, S., Krach, S., Mayer, A. V., Moll, J., Newton, T. L., Schroeter, M. L., de Oliveira-Souza, R., Raber, J., Sullivan, G. B., Swain, J. E., Lowe, L., & Zahn, R. (2021). The neuroscience of social feelings: mechanisms of adaptive social functioning. *Neuroscience & Biobehavioral Reviews, 128*, 592–620. https://doi.org/10.1016/j.neubiorev.2021.05.028

Etkin, A., Egner, T., Peraza, D. M., Kandel, E. R., & Hirsch, J. (2006). Resolving Emotional Conflict: A Role for the Rostral Anterior Cingulate Cortex in Modulating Activity in the Amygdala. *Neuron, 52*(6), 1121. https://doi.org/10.1016/j.neuron.2006.12.003

Eysenck, H. J., & Eysenck, S. (1975). *Manual of the Eysenck Personality Questionnaire.* San Diego, CA: EDITS.

Fan, M., Jie, J., Luo, P., Pang, Y., Xu, D., Yu, G., ... & Zheng, X. (2021). Social exclusion down-regulates pain empathy at the late stage of empathic responses:

electrophysiological evidence. *Frontiers in Human Neuroscience, 15,* 634714. https://doi.org/10.3389/fnhum.2021.634714

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160. https://doi.org/10.3758/brm.41.4.1149

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39,* 175–191. https://doi.org/10.3758/ BF03193146

Feldman, S., & Downey, G. (1994). Rejection sensitivity as a mediator of the impact of childhood exposure to family violence on adult attachment behavior. *Development and Psychopathology, 6*(1), 231–247. https://doi.org/10.1017/s0954579400005976

Feldmann-Wüstefeld, T., Schmidt-Daffy, M., & Schubö, A. (2010). Neural evidence for the threat detection advantage: Differential attention allocation to angry and happy faces. *Psychophysiology, 48*(5), 697–707. https://doi.org/10.1111/j.1469-8986.2010.01130.x

Fernandes, A., Garcia-Marques, T., Prada, M., & Martins, J. (2019). Emotional interference in isolation and in others' presence. *Current Psychology, 40*(12), 5783–5792. https://doi.org/10.1007/s12144-019-00534-0

Fernández-Folgueiras, U., Méndez-Bértolo, C., Hernández-Lorca, M., Bódalo, C., Giménez-Fernández, T., & Carretié, L. (2021). Realistic (3D) looming of emotional visual stimuli: Attentional effects at neural and behavioral levels. *Psychophysiology, 58*(5). Portico. https://doi.org/10.1111/psyp.13785

Floyd, K., & Woo, N. T. (2020). Loneliness and social monitoring: A conceptual replication of Knowles et al. *Personal Relationsh*ips, 27(1), 209-223. https://doi.org/10.1111/pere.12304

Fox, E., Mathews, A., Calder, A. J., & Yiend, J. (2007). Anxiety and sensitivity to gaze direction in emotionally expressive faces. *Emotion*, *7*(3), 478. https://doi.org/10.1037/1528-3542.7.3.478

Friesen C. K., Halvorson, K. M., & Graham, R. (2011) Emotionally meaningful targets enhance orienting triggered by a fearful gazing face. *Cognition and Emotion,* 25(1), 73-88. https://doi.org/10.1080/02699931003672381

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review, 5*(3), 490–495. https://doi.org/10.3758/bf03208827

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*(4), 694–724. https://doi.org/10.1037/0033-2909.133.4.694

Frith, C. D., & Frith, U. (2006a). How we predict what other people are going to do. *Brain research*, *1079*(1), 36-46. https://doi.org/10.1016/j.brainres.2005.12.126

Frith, C. D., & Frith, U. (2006b). The neural basis of mentalizing. *Neuron*, *50*(4), 531-534. https://doi.org/10.1016/j.neuron.2006.05.001

Fuhrmann, D., Casey, C. S., Speekenbrink, M., & Blakemore, S.-J. (2019). Social exclusion affects working memory performance in young adolescent girls. *Developmental Cognitive Neuroscience, 40,* 100718. https://doi.org/10.1016/j.dcn.2019.100718

Fujisawa, T., Nishitani, S., Ishii, S. & Shinihara, K. (2011). Differential modulation of impulsive behavior by loneliness and testosterone in adolescent females. *Neuroendocrinology Letters, 32*(6), 836-840.

Fuller, E. A., Majolo, B., Flack, T. R., & Ritchie, K. L. (2021). The importance of out-group characteristics for the own-group face memory bias. *Visual Cognition*, *29*(4), 263–276. https://doi.org/10.1080/13506285.2021.1905125

Gallagher, H. L., & Frith, C. D. (2003). Functional imaging of “theory of mind.” *Trends in Cognitive Sciences, 7*(2), 77–83. https://doi.org/10.1016/s1364-6613(02)00025-6

Gardner, W. L., Pickett, C. L., Jefferis, V., & Knowles, M. (2005). On the Outside Looking In: Loneliness and Social Monitoring. *Personality and Social Psychology Bulletin, 31*(11), 1549–1560. https://doi.org/10.1177/0146167205277208

Garner, M., Mogg, K., & Bradley, B. P. (2006). Orienting and maintenance of gaze to facial expressions in social anxiety. *Journal of Abnormal Psychology, 115*(4), 760–770. https://doi.org/10.1037/0021-843x.115.4.760

Gong, M., & Li, X. (2022). Attentional demand induced by visual crowding modulates the anger superiority effect. *Attention, Perception, & Psychophysics, 84*(2), 442-449. https://doi.org/10.3758/s13414-021-02408-9

Gong, M., & Smart, L. J. (2021). The anger superiority effect revisited: a visual crowding task. *Cognition and Emotion, 35*(2), 214-224. https://doi.org/10.1080/02699931.2020.1818552

González, A. P., Yankouskaya, A., Alessandri, G., Loreto, S., & Pecchinenda, A. (2022). Social contacts and loneliness affect the own age bias for emotional faces. *Scientific Reports, 12*(1). https://doi.org/10.1038/s41598-022-20220-9

Gramfort, A., Papadopoulo, T., Olivi, E., & Clerc, M. (2010). OpenMEEG: opensource software for quasistatic bioelectromagnetics. *BioMedical Engineering OnLine, 9*(1), 45. https://doi.org/10.1186/1475-925x-9-45

Grennan, G., Balasubramani, P. P., Alim, F., Zafar-Khan, M., Lee, E. E., Jeste, D. V., & Mishra, J. (2021). Cognitive and Neural Correlates of Loneliness and Wisdom during Emotional Bias. *Cerebral Cortex, 31*(7), 3311–3322. https://doi.org/10.1093/cercor/bhab012

Gum, A. M., Shiovitz-Ezra, S., & Ayalon, L. (2017). Longitudinal associations of hopelessness and loneliness in older adults: Results from the US health and retirement study. *International Psychogeriatrics, 29*(9), 1451–1459. doi:10.1017/S1041610217000904

Gwinn, J. D., Barden, J., & Judd, C. M. (2015). Face recognition in the presence of angry expressions: A target-race effect rather than a cross-race effect. *Journal of Experimental Social Psychology, 58*, 1–10. https://doi.org/10.1016/j.jesp.2014.12.001

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: an anger superiority effect. *Journal of Personality and Social Psychology, 54*(6), 917 – 924. https://doi.org/10.1037/0022-3514.54.6.917

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Advances in Psychology*, 52, 139-183. North-Holland. https://doi.org/10.1016/s0166-4115(08)62386-9

Hawkley, L. C., & Capitanio, J. P. (2015). Perceived social isolation, evolutionary fitness and health outcomes: a lifespan approach. *Philosophical Transactions of the Royal Society B: Biological Sciences, 370*(1669), 20140114. https://doi.org/10.1098/rstb.2014.0114

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4*(6), 223–233. https://doi.org/10.1016/s1364-6613(00)01482-0

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry, 51*(1), 59-67. https://doi.org/10.1016/s0006-3223(01)01330-0

Hietanen, J. K. (1999). Does your gaze direction and head orientation shift my visual attention? *NeuroReport, 10*(16), 3443–3447. https://doi.org/10.1097/00001756-199911080-00033

Hietanen, J. K., & Leppänen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues?. *Journal of Experimental Psychology: Human Perception and Performance, 29*(6), 1228. https://doi.org/10.1037/0096-1523.29.6.1228

Holmes, A., Richards, A., & Green, S. (2006). Anxiety and sensitivity to eye gaze in emotional faces. *Brain and Cognition, 60*(3), 282–294. https://doi.org/10.1016/j.bandc.2005.05.002

Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., & Stephenson, D. (2015). Loneliness and Social Isolation as Risk Factors for Mortality. *Perspectives on Psychological Science, 10*(2), 227–237. https://doi.org/10.1177/1745691614568352

Horn, N. R., Dolan, M., Elliott, R., Deakin, J. F. W., & Woodruff, P. W. R. (2003). Response inhibition and impulsivity: an fMRI study. *Neuropsychologia, 41*(14), 1959–1966. https://doi.org/10.1016/s0028-3932(03)00077-0

Howard, J. W., & Rothbart, M. (1980). Social categorization and memory for in-group and out-group behavior. *Journal of Personality and Social Psychology, 38*(2), 301–310. https://doi.org/10.1037/0022-3514.38.2.301

Hu, T., Zheng, X., & Huang, M. (2020). Absence and presence of human interaction: The relationship between loneliness and empathy. *Frontiers in Psychology*, *11*, 768. https://doi.org/10.3389/fpsyg.2020.00768

Hudac, C. M. (2018). Social priming modulates the neural response to ostracism: a new exploratory approach. *Social Neuroscience, 14*(3), 313–327. https://doi.org/10.1080/17470919. 2018.1463926

Hugenberg, K., Wilson, J. P., See, P. E., & Young, S. G. (2013). Towards a synthetic model of own group biases in face memory. *Visual Cognition*, *21*(9–10), 1392–1417. https://doi.org/10.1080/13506285.2013.821429

Hugenberg, K., Young, S. G., Bernstein, M. J., & Sacco, D. F. (2010). The categorization-individuation model: an integrative account of the other-race recognition deficit. *Psychological review*, *117*(4), 1168–1187. https://doi.org/10.1037/a0020463

Hughes, M., Lyons, A., Alba, B., Waling, A., Minichiello, V., Fredriksen-Goldsen, K., Barrett, C., Savage, T., Blanchard, M., & Edmonds, S. (2021). Predictors of Loneliness among Older Lesbian and Gay People. *Journal of Homosexuality,* 1–21. https://doi.org/10.1080/00918369.2021.2005999

Hyland, P., McGinty, G., Karatzias, T., Murphy, J., Vallières, F., & McHugh Power, J. (2019). Can the REBT theory explain loneliness? Theoretical and clinical applications. *Cognitive Behaviour Therapy*, *48*(1), 39-51. https://doi.org/10.1080/16506073.2018.1475505

Inagaki, T. K., Muscatell, K. A., Moieni, M., Dutcher, J. M., Jevtic, I., Irwin, M. R., & Eisenberger, N. I. (2015). Yearning for connection? Loneliness is associated with increased ventral striatum activity to close others. *Social Cognitive and Affective Neuroscience, 11*(7), 1096–1101. https://doi.org/10.1093/scan/nsv076

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and Aging, 21*(1), 40–48. https://doi.org/10.1037/0882-7974.21.1.40

Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology, 103*(1), 54–69. https://doi.org/10.1037/a0028347

Jung, T.-P., Makeig, S., Westerfield, M., Townsend, J., Courchesne, E., & Sejnowski, T. J. (2000). Removal of eye activity artifacts from visual event-related potentials in normal and clinical subjects. *Clinical Neurophysiology, 111*(10), 1745–1758. https://doi.org/10.1016/s1388-2457(00)00386-2

Kanai, R., Bahrami, B., Duchaine, B., Janik, A., Banissy, M. J., & Rees, G. (2012). Brain Structure Links Loneliness to Social Perception. *Current Biology, 22*(20), 1975–1979. https://doi.org/10.1016/j.cub.2012.08.045

Kaufmann, J. M., & Schweinberger, S. R. (2004). Expression Influences the Recognition of Familiar Faces. *Perception, 33*(4), 399–408. https://doi.org/10.1068/p5083

Kennedy, Q., Mather, M., & Carstensen, L. L. (2004). The Role of Motivation in the Age-Related Positivity Effect in Autobiographical Memory. *Psychological Science, 15*(3), 208–214. https://doi.org/10.1111/j.0956-7976.2004.01503011.x

Klein, J. T., Shepherd, S. V., & Platt, M. L. (2009). Social Attention and the Brain. *Current Biology, 19*(20), R958–R962. https://doi.org/10.1016/j.cub.2009.08.010

Knowles, M. L., Lucas, G. M., Baumeister, R. F., & Gardner, W. L. (2015). Choking under social pressure: Social monitoring among the lonely. *Personality and Social Psychology Bulletin, 41*(6), 805-821. https://doi.org/10.1177/0146167215580775

Kong, X., Wei, D., Li, W., Cun, L., Xue, S., Zhang, Q., & Qiu, J. (2014). Neuroticism and extraversion mediate the association between loneliness and the dorsolateral prefrontal cortex. *Experimental Brain Research, 233*(1), 157–164. https://doi.org/10.1007/s00221-014-4097-

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine, 15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Krug, M. K., & Carter, C. S. (2012). Proactive and reactive control during emotional interference and its relationship to trait anxiety. *Brain Research, 1481*, 13–36. https://doi.org/10.1016/j.brainres.2012.08.045

Kuhn, G., & Tipples, J. (2010). Increased gaze following for fearful faces. It depends on what you’re looking for! *Psychonomic Bulletin & Review, 18*(1), 89–95. https://doi.org/10.3758/s13423-010-0033-1

Kyaw, K. T., & Levine, A. (2023). Association of Loneliness with Cognitive Functions. The Journal Of Prevention of Alzheimer’s Disease. https://doi.org/10.14283/jpad.2023.60

Lam, J. A., Murray, E. R., Yu, K. E., Ramsey, M., Nguyen, T. T., Mishra, J., Martis, B., Thomas, M. L., & Lee, E. E. (2021). Neurobiology of loneliness: a systematic review. *Neuropsychopharmacology, 46*(11), 1873–1887. https://doi.org/10.1038/s41386-021-01058-7

Lamblin, M., Murawski, C., Whittle, S., & Fornito, A. (2017). Social connectedness, mental health and the adolescent brain. *Neuroscience & Biobehavioral Reviews, 80*, 57–68. https://doi.org/10.1016/j.neubiorev.2017.05.010

Lang, P. J., & Bradley, M. M. (2010). Emotion and the motivational brain. *Biological Psychology, 84*(3), 437–450. https://doi.org/10.1016/j.biopsycho.2009.10.007

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition & Emotion, 24*(8), 1377–1388. doi:10.1080/02699930903485076

Lassalle, A., & Itier, R. J. (2015). Emotional modulation of attention orienting by gaze varies with dynamic cue sequence. *Visual Cognition, 23*(6), 720–735. https://doi.org/10.1080/13506285.2015.1083067

Layden, E. A., Cacioppo, J. T., Cacioppo, S., Cappa, S. F., Dodich, A., Falini, A., & Canessa, N. (2017). Perceived social isolation is associated with altered functional connectivity in neural networks associated with tonic alertness and executive control. *Neuroimage, 145*, 58-73. https://doi.org/10.1016/j.neuroimage.2016.09.050

Le, T. M., Zhornitsky, S., Wang, W., & Li, C.-S. R. (2020). Perceived burdensomeness and neural responses to ostracism in the Cyberball task. *Journal of Psychiatric Research, 130*, 1–8. https://doi.org/10.1016/j.jpsychires.2020.06.015

Lee, H., & Kim, J. (2016). Facilitating Effects of Emotion on the Perception of Biological Motion: Evidence for a Happiness Superiority Effect. *Perception, 46*(6), 679–697. https://doi.org/10.1177/0301006616681809

Leigh-Hunt, N., Bagguley, D., Bash, K., Turner, V., Turnbull, S., Valtorta, N., & Caan, W. (2017). An overview of systematic reviews on the public health consequences of social isolation and loneliness. *Public Health, 152*, 157–171. https://doi.org/10.1016/j.puhe.2017.07.035

Liang, J., Hu, W., Gu, Y., Cheng, T., Geng, J., Wang, K., Wang, L., Yao, X., Shen, J., & Wang, Y. (2022). Impairment of response inhibition to emotional face stimuli in individuals with subclinical depression. *PsyCh Journal, 11*(3), 327–334. Portico. https://doi.org/10.1002/pchj.548

Lieberz, J., Shamay-Tsoory, S. G., Saporta, N., Esser, T., Kuskova, E., Stoffel-Wagner, B., ... & Scheele, D. (2021). Loneliness and the social brain: how perceived social isolation impairs human interactions. *Advanced Science, 8*(21), 2102076. https://doi.org/10.1002/advs.202102076

Lim, M. H., & Gleeson, J. F. (2014). Social Connectedness Across the Psychosis Spectrum: Current Issues and Future Directions for Interventions in Loneliness. *Frontiers in Psychiatry,* 5. https://doi.org/10.3389/fpsyt.2014.00154

Liu, B., Xin, S., Jin, Z., Hu, Y., & Li, Y. (2010). Emotional facilitation effect in the picture–word interference task: An ERP study. *Brain and Cognition, 72*(2), 289–299. https://doi.org/10.1016/j.bandc.2009.09.013

Lodder, G. M. A., Scholte, R. H. J., Clemens, I. A. H., Engels, R. C. M. E., Goossens, L., & Verhagen, M. (2015). Loneliness and Hypervigilance to Social Cues in Females: An Eye-Tracking Study. *PLOS ONE, 10*(4), e0125141. https://doi.org/10.1371/journal.pone.0125141

Lodder, G. M. A., Scholte, R. H. J., Goossens, L., Engels, R. C. M. E., & Verhagen, M. (2015). Loneliness and the social monitoring system: Emotion recognition and eye gaze in a real-life conversation. *British Journal of Psychology, 107*(1), 135–153. Portico. https://doi.org/10.1111/bjop.12131

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review, 91*(3), 295–327. https://doi.org/10.1037/0033-295X.91.3.295

Lu, Y., Jaquess, K. J., Hatfield, B. D., Zhou, C., & Li, H. (2017). Valence and arousal of emotional stimuli impact cognitive-motor performance in an oddball task. *Biological Psychology, 125,* 105-114. https://doi.org/10.1016/j.biopsycho.2017.02.010

Lu, Y., Wang, T., Long, Q., & Cheng, Z. (2021). Impact of Distracting Emotional Stimuli on the Characteristics of Movement Performance: A Kinematic Study. *Frontiers in Psychology, 12,* 642643. https://doi.org/10.3389/fpsyg.2021.642643

Lyyra, P., Wirth, J. H., & Hietanen, J. K. (2017). Are you looking my way? Ostracism widens the cone of gaze. *Quarterly Journal of Experimental Psychology, 70*(8), 1713-1721. https://doi.org/10.1080/17470218.2016.1204327

Ma, X., & Zhang, E. (2021). The influence of social power on neural responses to emotional conflict. *PeerJ, 9,* e11267. Portico. https://doi.org/10.7717/peerj.11267

MacDonald, G., & Leary, M. R. (2005). Why does social exclusion hurt? The relationship between social and physical pain. *Psychological Bulletin, 131*(2), 202–223. http://doi.org/10.1037/0033-2909.131.2.202

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*(1), 15–20. https://doi.org/10.1037/0021-843X.95.1.15

Maes, M., Qualter, P., Vanhalst, J., Van den Noortgate, W., & Goossens, L. (2019). Gender Differences in Loneliness across the Lifespan: A Meta–Analysis. *European Journal of Personality, 33*(6), 642-654. https://doi.org/10.1002/per.2220

Maes, M., Vanhalst, J., Van den Noortgate, W., & Goossens, L. (2017). Intimate and Relational Loneliness in Adolescence. *Journal of Child and Family Studies, 26*(8), 2059–2069. https://doi.org/10.1007/s10826-017-0722-8

Maratos, F. A., Mogg, K., & Bradley, B. P. (2008). Identification of angry faces in the attentional blink. *Cognition & Emotion, 22*(7), 1340–1352. https://doi.org/10.1080/02699930701774218

Margrett, J. A., Daugherty, K., Martin, P., MacDonald, M., Davey, A., Woodard, J. L., ... & Poon, L. W. (2011). Affect and loneliness among centenarians and the oldest old: The role of individual and social resources. *Aging & mental health, 15*(3), 385-396. https://doi.org/10.1080/13607863.2010.519327

Marini, F., Marzi, T., & Viggiano, M. P. (2011). “Wanted!” The effects of reward on face recognition: electrophysiological correlates. *Cognitive, Affective, & Behavioral Neuroscience, 11*(4), 627–643. https://doi.org/10.3758/s13415-011-0057-7

Martín-María, N., Caballero, F. F., Miret, M., Tyrovolas, S., Haro, J. M., Ayuso-Mateos, J. L., & Chatterji, S. (2019). Differential impact of transient and chronic loneliness on health status. A longitudinal study. *Psychology & Health, 35*(2), 177–195. https://doi.org/10.1080/08870446. 2019.1632312

Mather, M., & Carstensen, L. L. (2003). Aging and Attentional Biases for Emotional Faces. *Psychological Science, 14*(5), 409–415. https://doi.org/10.1111/1467-9280.01455

Mayer, J. D., & Gaschke, Y. N. (1988). The Brief Mood Introspection Scale (BMIS). *PsycTESTS Dataset*. https://doi.org/10.1037/t06259-000

McKay, K. T., Grainger, S., Coundouris, S., Skorich, D., Phillips, L. H., & Henry, J. (2022). Visual Attentional Orienting by Eye Gaze: A Meta-Analytic Review of the Gaze-Cueing Effect. *Psychological Bulletin, 147*(12), 1269–1289. https://doi.org/10.1037/bul0000353

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law, 7*(1), 3–35. https://doi.org/10.1037/1076-8971.7.1.3

Méndez-Bértolo, C., Moratti, S., Toledano, R., Lopez-Sosa, F., Martínez-Alvarez, R., Mah, Y. H., Vuilleumier, P., Gil-Nagel, A., & Strange, B. A. (2016). A fast pathway for fear in human amygdala. *Nature Neuroscience, 19*(8), 1041–1049. https://doi.org/10.1038/nn.4324

Mogg, K., Holmes, A., Garner, M., & Bradley, B. P. (2008). Effects of threat cues on attentional shifting, disengagement and response slowing in anxious individuals. *Behaviour Research and Therapy, 46*(5), 656–667. https://doi.org/10.1016/j.brat.2008.02.011

Mohr, K. S., & Kelly, S. P. (2017). The spatiotemporal characteristics of the C1 component and its modulation by attention. *Cognitive Neuroscience, 9*(1–2), 71–74. https://doi.org/10.1080/17588928.2017.1386642

Müller, H. J., & Krummenacher, J. (2006). Visual search and selective attention. *Visual Cognition, 14*(4–8), 389–410. https://doi.org/10.1080/13506280500527676

Münch, R. (1972). Mentales System und Verhalten: Grundlagen einer Allgemeinen Verhaltenstheorie [Mental System and Behaviour: Foundations for a General Behavioural Theory]. *Tübingen, West Germany, Mohr*.

Mund, M., Freuding, M. M., Möbius, K., Horn, N., & Neyer, F. J. (2019). The Stability and Change of Loneliness Across the Life Span: A Meta-Analysis of Longitudinal Studies. *Personality and Social Psychology Review, 24*(1), 24–52. https://doi.org/10.1177/1088868319850738

Newcomb, M., & Harlow, L. (1986). Life Events and Substance Use among Adolescents: Mediating Effects of Perceived Loss of Control and Meaninglessness in Life. *Journal of Personality and Social Psychology, 51*, 564-577. https://doi.org/10.1037/0022-3514.51.3.564

Nezlek, J. B., Wesselmann, E. D., Wheeler, L., & Williams, K. D. (2015). Ostracism in Everyday Life: The Effects of Ostracism on Those Who Ostracize. *The Journal of Social Psychology, 155*(5), 432–451. https://doi.org/10.1080/00224545.2015.1062351

Nikitin, J., & Schoch, S. (2013). Social Approach and Avoidance Motivations. *The Handbook of Solitude,* 202–223. Portico. https://doi.org/10.1002/9781118427378.ch12

Nyqvist, F., Nygård, M., & Scharf, T. (2019). Loneliness amongst older people in Europe: a comparative study of welfare regimes. *European Journal of Ageing*, *16*(2), 133-143. https://doi.org/10.1007/s10433-018-0487-y

Öhman, A. (2002). Automaticity and the Amygdala: Nonconscious Responses to Emotional Faces. *Current Directions in Psychological Science, 11*(2), 62–66. https://doi.org/10.1111/1467-8721.00169

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*(3), 483–522. https://doi.org/10.1037/0033-295x.108.3.483

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*(3), 466. https://doi.org/10.1037/0096-3445.130.3.466

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*(3), 381–396. https://doi.org/10.1037/0022-3514.80.3.381

Otten, M., & Jonas, K. J. (2012). Out of the group, out of control? The brain responds to social exclusion with changes in cognitive control. *Social Cognitive and Affective Neuroscience, 8*(7), 789–794. https://doi.org/10.1093/scan/nss071

Pandey, S., & Gupta, R. (2022a). Irrelevant angry faces impair response inhibition, and the go and stop processes share attentional resources. *Scientific Reports, 12*(1). https://doi.org/10.1038/s41598-022-19116-5

Pandey, S., & Gupta, R. (2022b). Implicit angry faces interfere with response inhibition and response adjustment. *Cognition and Emotion, 37*(2), 303–319. https://doi.org/10.1080/02699931.2022.2162004

Paolini, D., Giacomantonio, M., van Beest, I., Baiocco, R., & Salvati, M. (2020). Social exclusion lowers working memory capacity in gay-men but not in heterosexual-men. *Applied Cognitive Psychology*, *34*(3), 761-767.

Park, C., Majeed, A., Gill, H., Tamura, J., Ho, R. C., Mansur, R. B., Nasri, F., Lee, Y., Rosenblat, J. D., Wong, E., & McIntyre, R. S. (2020). The Effect of Loneliness on Distinct Health Outcomes: A Comprehensive Review and Meta-Analysis. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3463317

Parkhurst, J.T., & Hopmeyer, A. (1999). Developmental change in the source of loneliness in childhood and adolescence: Constructing a theoretical model. In K.J. Rotenberg & S. Hymel (Eds.), Loneliness in childhood and adolescence (pp. 56–79). New York: Cambridge University Press.

Parsons, S. (2020). Splithalf: Robust estimates of split half reliability. *figshare Software*. https://doi.org/10.6084/m9.figshare.11956746.v4

Parsons, S., Kruijt, A.-W., & Fox, E. (2018). Psychological Science needs a standard practice of reporting the reliability of cognitive behavioural measurements. https://doi.org/10.31234/osf.io/6ka9z

Pearce, E., Barreto, M., Victor, C., Hammond, C., Eccles, A. M., Richins, M. T., ... & Qualter, P. (2022). Choking under pressure: Does it get easier with age? How loneliness affects social monitoring across the life span. *International Journal of Behavioral Development*, *46*(1), 50-62. https://doi.org/10.1177/0165025420979369

Pecchinenda, A., & Heil, M. (2007). Role of working memory load on selective attention to affectively valent information. *European Journal of Cognitive Psychology, 19*(6), 898–909. https://doi.org/10.1080/09541440601095388

Pecchinenda, A., Ferlazzo, F., & Lavidor, M. (2015). Modulation of selective attention by polarity-specific tDCS effects. *Neuropsychologia, 68,* 1–7. https://doi.org/10.1016/j.neuropsychologia.2014.12.023

Pecchinenda, A., Pes, M., Ferlazzo, F., & Zoccolotti, P. (2008). The combined effect of gaze direction and facial expression on cueing spatial attention. *Emotion, 8*(5), 628–634. https://doi.org/10.1037/a0013437

Peplau, L. A., & Perlman, D. (1982). Loneliness: A sourcebook of current theory, research, and therapy. New York: John Wiley & Sons

Perlman, D., & Peplau, L. A. (1981). Toward a social psychology of loneliness. *Personal relationships, 3*, 31-56.

Pessoa, L. (2009). Cognition and emotion. *Scholarpedia, 4*(1), 4567. https://doi.org/10.4249/scholarpedia.4567

Pessoa, L., Padmala, S., Kenzer, A., & Bauer, A. (2012). Interactions between cognition and emotion during response inhibition. *Emotion, 12*(1), 192–197. https://doi.org/10.1037/a0024109

Petrucci, M., & Pecchinenda, A. (2016). The role of cognitive control mechanisms in selective attention towards emotional stimuli. *Cognition and Emotion, 31*(7), 1480–1492. https://doi.org/10.1080/02699931.2016.1233861

Pezdek, K., Abed, E., & Cormia, A. (2021). Elevated stress impairs the accuracy of eyewitness memory but not the confidence–accuracy relationship. *Journal of Experimental Psychology: Applied, 27*(1), 158–169. https://doi.org/10.1037/xap0000316

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: What is magic and what is not. *Biological Psychology, 92*(3), 492–512. https://doi.org/10.1016/j.biopsycho.2012.02.007

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: What is magic and what is not. *Biological Psychology, 92*(3), 492–512. https://doi.org/10.1016/j.biopsycho.2012.02.007

Preckel, K., Kanske, P., & Singer, T. (2018). On the interaction of social affect and cognition: empathy, compassion and theory of mind. *Current Opinion in Behavioral Sciences*, *19,* 1-6. https://doi.org/10.1016/j.cobeha.2017.07.010

Price, R. B., Siegle, G. J., Silk, J. S., Ladouceur, C., McFarland, A., Dahl, R. E., & Ryan, N. D. (2013). Sustained neural alterations in anxious youth performing an attentional bias task: A pupilometry study. *Depression and anxiety, 30*(1), 22-30. https://doi.org/10.1002/da.21966

Putman, P., Hermans, E., & van Honk, J. (2006). Anxiety meets fear in perception of dynamic expressive gaze. *Emotion, 6*(1), 94–102. ttps://doi.org/10.1037/1528-3542.6.1.94

Qualter, P., Rotenberg, K., Barrett, L., Henzi, P., Barlow, A., Stylianou, M., & Harris, R. A. (2013). Investigating hypervigilance for social threat of lonely children. *Journal of abnormal child psychology*, *41*, 325-338. https://doi.org/10.1007/s10802-012-9676-x

Qualter, P., Vanhalst, J., Harris, R., Van Roekel, E., Lodder, G., Bangee, M., Maes, M., & Verhagen, M. (2015). Loneliness Across the Life Span. *Perspectives on Psychological Science, 10*(2), 250–264. https://doi.org/10.1177/1745691615568999

Quené, H., & van den Bergh, H. (2008). Examples of mixed-effects modeling with crossed random effects and with binomial data. *Journal of Memory and Language*, *59*(4), 413–425. https://doi.org/10.1016/j.jml.2008.02.002

Rebetez, M. M. L., Rochat, L., Billieux, J., Gay, P., & Van der Linden, M. (2014). Do emotional stimuli interfere with two distinct components of inhibition? *Cognition and Emotion, 29*(3), 559–567. https://doi.org/10.1080/02699931.2014.922054

Rhodes, M. G., & Anastasi, J. S. (2012). The own-age bias in face recognition: A meta-analytic and theoretical review. *Psychological Bulletin, 138*(1), 146–174. https://doi.org/10.1037/a0025750

Richman, L., & Leary, M. R. (2009). Reactions to discrimination, stigmatization, ostracism, and other forms of interpersonal rejection: A multimotive model. *Psychological Review, 116(2)*, 365–383. https://doi.org/10.1037/a0015250

Richman, W. L., Kiesler, S., Weisband, S., & Drasgow, F. (1999). A meta-analytic study of social desirability distortion in computer-administered questionnaires, traditional questionnaires, and interviews. *Journal of Applied Psychology, 84*(5), 754–775. https://doi.org/10.1037/0021-9010.84.5.754

Riediger, M., Voelkle, M. C., Ebner, N. C., & Lindenberger, U. (2011). Beyond “happy, angry, or sad?”: Age-of-poser and age-of-rater effects on multi-dimensional emotion perception. *Cognition & Emotion, 25*(6), 968–982. https://doi.org/10.1080/02699931.2010.540812

Ros, E. Satorres, L. Fernández-Aguilar, I. Delhom, J. López-Torres, J. M. Latorre & J. C. Melendez (2021): Differential effects of faces and words in cognitive control in older adults with and without major depressive disorder: An emotional Stroop task study. *Applied Neuropsychology: Adult*. https://doi.org/10.1080/23279095.2021.1927037

Rouder, J., Kumar, A., & Haaf, J. M. (2019). Why Most Studies of Individual Differences With Inhibition Tasks Are Bound To Fail. https://doi.org/10.31234/osf.io/3cjr5

Russell, D. W. (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of personality assessment*, *66*(1), 20-40. https://doi.org/10.1207/s15327752jpa6601_2

Russell, D., Peplau, L. A., & Cutrona, C. E. (1980). The revised UCLA loneliness scale: concurrent and discriminant validity evidence. *Journal of Personality and Social Psychology, 39*(3), 472–480. https://doi.org/10.1037/0022-3514.39.3.472

Saito, T., Motoki, K., Nouchi, R., Kawashima, R., & Sugiura, M. (2020). Loneliness modulates automatic attention to warm and competent faces: Preliminary evidence from an eye-tracking study. *Frontiers in Psychology, 10,* 2967. https://doi.org/10.3389/fpsyg.2019.02967

Salinas, E., & Stanford, T. R. (2013). The countermanding task revisited: fast stimulus detection is a key determinant of psychophysical performance. *Journal of Neuroscience, 33*(13), 5668-5685. https://doi.org/10.1523/jneurosci.3977-12.2013

Saylik, R. (2021). The role of emotional interference on learning in an emotional probabilistic Go/No-Go task. *Dusunen Adam: The Journal of Psychiatry and Neurological Sciences.* https://doi.org/10.14744/dajpns.2021.00117

Schachar, R., Logan, G. D., Robaey, P., Chen, S., Ickowicz, A., & Barr, C. (2007). Restraint and Cancellation: Multiple Inhibition Deficits in Attention Deficit Hyperactivity Disorder. *Journal of Abnormal Child Psychology, 35*(2), 229–238. https://doi.org/10.1007/s10802-006-9075-2

Schmitz, W., Mauritz, S., & Wagner, M. (2021). Social relationships, living arrangements and loneliness. *Zeitschrift Für Gerontologie Und Geriatrie, 54*(S2), 120–125. https://doi.org/10.1007/s00391-021-01960-1

Schulz, K., Fan, J., Magidina, O., Marks, D., Hahn, B., & Halperin, J. (2007). Does the emotional go/no-go task really measure behavioral inhibition?Convergence with measures on a non-emotional analog. *Archives of Clinical Neuropsychology, 22*(2), 151–160. https://doi.org/10.1016/j.acn.2006.12.001

Senese, V.P., Nasti, C., Mottola, F., Sergi, I., Massaro, R. & Gnisci, A. (2021) The Relationship Between Loneliness and Psychological Adjustment: Validation of the Italian Version of the Interpersonal Acceptance–Rejection Loneliness Scale. *Frontiers in Psychology, 12*:655410. doi: 10.3389/fpsyg.2021.655410

Shiovitz-Ezra, S., & Ayalon, L. (2009). Situational versus chronic loneliness as risk factors for all-cause mortality. *International Psychogeriatrics, 22*(3), 455–462. https://doi.org/10.1017/s1041610209991426

Sleegers, W. W., Proulx, T., & van Beest, I. (2017). The social pain of Cyberball: Decreased pupillary reactivity to exclusion cues. *Journal of Experimental Social Psychology, 69,* 187-200. https://doi.org/10.1016/j.jesp.2016.08.004

Smith, K. E., Norman, G. J., & Decety, J. (2019). Medical students' empathy positively predicts charitable donation behavior. *The Journal of Positive Psychology, 15*(6), 734–742. https://doi.org/10.1080/17439760.2019.1651889

Smith, K. E., Norman, G. J., & Decety, J. (2020). Increases in loneliness during medical school are associated with increases in individuals' likelihood of mislabeling emotions as negative. *Emotion, 22*(4), 740–750. https://doi.org/10.1037/emo0000773

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*(1), 34–50. https://doi.org/10.1037/0096-3445.117.1.34

Song, S., Zilverstand, A., Song, H., d'Oleire Uquillas, F., Wang, Y., Xie, C., Cheng, L., & Zou, Z. (2017). The influence of emotional interference on cognitive control: A meta-analysis of neuroimaging studies using the emotional Stroop task. *Scientific Reports, 7*(1). https://doi.org/10.1038/s41598-017-02266-2

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). Stai. Manual for the State-Trait Anxiety Inventory (Self Evaluation Questionnaire). *Palo Alto California: Consulting Psychologist, 22*, 1-24. https://doi.org/10.53841/bpstest.2003.stai

Spithoven, A. W. M., Bijttebier, P. & Goossens, L. (2017). It is all in their mind: A review on information processing bias in lonely individuals. *Clinal Psychological Review, 58,* 97-114. https://doi.org/10.1016/j.cpr.2017.10.003.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology: General, 121*(1), 15–23. https://doi.org/10.1037/0096-3445.121.1.15

Sui, J., He, X., & Humphreys, G. W. (2012). Perceptual effects of social salience: Evidence from self-prioritization effects on perceptual matching. *Journal of Experimental Psychology: Human Perception and Performance, 38*(5), 1105–1117. https://doi.org/10.1037/a0029792

Surkalim, D. L., Luo, M., Eres, R., Gebel, K., van Buskirk, J., Bauman, A., & Ding, D. (2022). The prevalence of loneliness across 113 countries: systematic review and meta-analysis. *BMJ,* e067068. https://doi.org/10.1136/bmj-2021-067068

Syrjämäki, A. H., & Hietanen, J. K. (2018). Social inclusion, but not exclusion, delays attentional disengagement from direct gaze. *Psychological Research, 84*(4), 1126–1138. https://doi.org/10.1007/s00426-018-1108-2

Syrjämäki, A. H., Lyyra, P., & Hietanen, J. K. (2020a). I don't need your attention: Ostracism can narrow the cone of gaze. *Psychological research, 84*(1), 99-110. https://doi.org/10.1007/s00426-018-0993-8

Tadel, F., Baillet, S., Mosher, J. C., Pantazis, D., & Leahy, R. M. (2011). Brainstorm: A User-Friendly Application for MEG/EEG Analysis. *Computational Intelligence and Neuroscience, 2011*, 1–13. https://doi.org/10.1155/2011/879716

Tchalova, K. & Eisenberg, N.I. (2015). How the Brain Feels the Hurt of Heartbreak. Examining the Neurobiological Overlap Between Social and Pshycal Pain. *Brain Mapping: An Encyclopedic Reference, 3,* 15-20. https://doi.org/10.1016/b978-0-12-397025-1.00144-5

Tian, Y., Liang, S., Yuan, Z., Chen, S., Xu, P., & Yao, D. (2014). White matter structure in loneliness: preliminary findings from diffusion tensor imaging. *NeuroReport, 25(*11), 843–847. https://doi.org/10.1097/wnr.0000000000000197

Tian, Y., Yang, L., Chen, S., Guo, D., Ding, Z., Tam, K. Y., & Yao, D. (2017). Causal interactions in resting-state networks predict perceived loneliness. *PLOS ONE, 12*(5), e0177443. https://doi.org/10.1371/journal.pone.0177443

Tipples, J. (2006). Fear and fearfulness potentiate automatic orienting to eye gaze. *Cognition & Emotion, 20*(2), 309–320. https://doi.org/10.1080/02699930500405550

Tomova, L., Wang, K. L., Thompson, T., Matthews, G. A., Takahashi, A., Tye, K. M., & Saxe, R. (2022). Author Correction: Acute social isolation evokes midbrain craving responses similar to hunger. *Nature Neuroscience, 25*(3), 399–399. https://doi.org/10.1038/s41593-021-01004-2

Tottenham, N., Phuong, J., Flannery, J., Gabard-Durnam, L., & Goff, B. (2013). A negativity bias for ambiguous facial-expression valence during childhood: Converging evidence from behavior and facial corrugator muscle responses. *Emotion, 13*(1), 92–103. https://doi.org/10.1037/a0029431

Unkelbach, C., Alves, H., & Koch, A. (2020). Negativity bias, positivity bias, and valence asymmetries: Explaining the differential processing of positive and negative information. *Advances in Experimental Social Psychology,* 115–187. https://doi.org/10.1016/bs.aesp.2020.04.005

Valentine, T., & Endo, M. (1992). Towards an Exemplar Model of Face Processing: The Effects of Race and Distinctiveness. *The Quarterly Journal of Experimental Psychology Section A, 44*(4), 671–703. https://doi.org/10.1080/14640749208401305

Van Baarsen, B. (2002). Theories on coping with loss: The impact of social support and self-esteem on adjustment to emotional and social loneliness following a partner's death in later life. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *57*(1), S33-S42. https://doi.org/10.1093/geronb/57.1.s33

Van Beest, I., & Williams, K. D. (2006). When inclusion costs and ostracism pays, ostracism still hurts. *Journal of personality and social psychology*, *91*(5), 918. https://doi.org/10.1037/0022-3514.91.5.918

van Roekel, E., Scholte, R. H., Engels, R. C., Goossens, L., & Verhagen, M. (2015). Loneliness in the daily lives of adolescents: An experience sampling study examining the effects of social contexts. *The Journal of Early Adolescence*, *35*(7), 905-930. https://doi.org/10.1177/0272431614547049

van Roekel, E., Verhagen, M., Engels, R. C., Scholte, R. H., Cacioppo, S., & Cacioppo, J. T. (2018). Trait and state levels of loneliness in early and late adolescents: Examining the differential reactivity hypothesis. *Journal of Clinical Child & Adolescent Psychology*, *47*(6), 888-899. https://doi.org/10.1080/15374416.2016.1146993

Vanhalst, J., Gibb, B. E., & Prinstein, M. J. (2015). Lonely adolescents exhibit heightened sensitivity for facial cues of emotion. *Cognition and Emotion, 31*(2), 377–383. https://doi.org/10.1080/02699931.2015.1092420

Verbruggen, F., & De Houwer, J. (2007). Do emotional stimuli interfere with response inhibition? Evidence from the stop signal paradigm. *Cognition & Emotion*, *21*(2), 391–403. https://doi.org/10.1080/02699930600625081

Verhagen, M., Derks, M., Roelofs, K., & Maciejewski, D. (2022). Behavioral inhibition, negative parenting, and social withdrawal: Longitudinal associations with loneliness during early, middle, and late adolescence. *Child Development, 94*(2), 512–528. Portico. https://doi.org/10.1111/cdev.13874

Vijayakumar, N., Cheng, T. W., & Pfeifer, J. H. (2017). Neural correlates of social exclusion across ages: A coordinate-based meta-analysis of functional MRI studies. *NeuroImage, 153*, 359-368. https://doi.org/10.1016/j.neuroimage.2017.02.050

Vitacco, D., Brandeis, D., Pascual-Marqui, R., & Martin, E. (2002). Correspondence of event-related potential tomography and functional magnetic resonance imaging during language processing. *Human Brain Mapping, 17*(1), 4–12. https://doi.org/10.1002/hbm.10038

Viviani, G., De Luca, F., Antonucci, G., Yankouskaya, A., & Pecchinenda, A. (2021). It is not always positive: emotional bias in young and older adults. *Psychological Research, 86*(6), 2045–2057. https://doi.org/10.1007/s00426-021-01614-2

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585–594. https://doi.org/10.1016/j.tics.2005.10.011

Waters, A. M., & Valvoi, J. S. (2009). Attentional bias for emotional faces in paediatric anxiety disorders: An investigation using the emotional go/no go task. *Journal of Behavior Therapy and Experimental Psychiatry, 40*(2), 306–316. https://doi.org/10.1016/j.jbtep.2008.12.008

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology, 54*(6), 1063. https://doi.org/10.1037//0022-3514.54.6.1063

Wei, M., Roodenrys, S., & Miller, L. (2020). Attentional Bias for Threat and Anxiety: The Role of Loneliness. *Psychiatry*, *83*(3), 278–291. https://doi.org/10.1080/00332747.2020.1762400

Weinstein, A. M. (2023). Reward, motivation and brain imaging in human healthy participants – A narrative review. *Frontiers in Behavioral Neuroscience, 17*. https://doi.org/10.3389/fnbeh.2023.1123733

Weschke, S., & Niedeggen, M. (2015). ERP effects and perceived exclusion in the Cyberball paradigm: Correlates of expectancy violation?. *Brain research, 1624,* 265-274. https://doi.org/10.1016/j.brainres.2015.07.038

Wiese, H. (2012). The role of age and ethnic group in face recognition memory: ERP evidence from a combined own-age and own-race bias study. *Biological Psychology, 89*(1), 137–147. https://doi.org/10.1016/j.biopsycho.2011.10.002

Wiese, H., Schweinberger, S. R., & Hansen, K. (2008). The age of the beholder: ERP evidence of an own-age bias in face memory. *Neuropsychologia*, *46*(12), 2973–2985. https://doi.org/10.1016/j.neuropsychologia.2008.06.007

Wiese, H., Wolff, N., Steffens, M. C., & Schweinberger, S. R. (2013). How experience shapes memory for faces: An event-related potential study on the own-age bias. *Biological Psychology, 94*(2), 369–379. https://doi.org/10.1016/j.biopsycho.2013.07.001

Williams, J.M.G., Mathews, A., & MacLeod, C. (1996). The Emotional Stroop Task and psychopathology. *Psychological Bulletin, 120,* 3-24. https://doi.org/10.1037/0033-2909.120.1.3

Williams, K. D. (2007). Ostracism. *Annual Review of Psychology, 58*(1), 425–452. https://doi.org/10.1146/annurev.psych.58.110405.085641

Williams, K. D. (2009). Ostracism: A temporal need-threat model. *Advances in experimental social psychology*, *41*, 275-314. https://doi.org/10.1016/S0065-2601(08)00406-1

Williams, K. D., Cheung, C. K., & Choi, W. (2000). Cyberostracism: effects of being ignored over the Internet. *Journal of personality and social psychology*, *79*(5), 748. https://doi.org/10.1037//0022-3514.79.5.748

Williams, S. E., Lenze, E. J., & Waring, J. D. (2020). Positive information facilitates response inhibition in older adults only when emotion is task-relevant. *Cognition and Emotion, 34*(8), 1632–1645. https://doi.org/10.1080/02699931.2020.1793303

Wirth, B. E., & Wentura, D. (2020). It occurs after all: Attentional bias towards happy faces in the dot-probe task. *Attention, Perception, & Psychophysics, 82*(5), 2463–2481. https://doi.org/10.3758/s13414-020-02017-y

Wu ZQ, Sun L, Sun YH, Zhang XJ, Tao FB & Cui GH (2010). Correlation between loneliness and social relationship among empty nest elderly in Anhui rural area, China. *Aging and Mental Health 14,* 108–112. https://doi.org/10.1080/13607860903228796

Xu, M., Li, Z., Qi, S., Fan, L., Zhou, X., & Yang, D. (2020). Social exclusion modulates dual mechanisms of cognitive control: Evidence from ERPs. *Human Brain Mapping, 41*(10), 2669-2685. Portico. https://doi.org/10.1002/hbm.24970

Xu, M., Li, Z., Zhang, J., Sun, L., Fan, L., Zeng, Q., & Yang, D. (2015). Social exclusion influences attentional bias to social information. *Asian Journal of Social Psychology*, *18*(3), 199-208. https://doi.org/10.1111/ajsp.12101

Xu, M., Qiao, L., Qi, S., Li, Z., Diao, L., Fan, L., Zhang, L., & Yang, D. (2017). Social exclusion weakens storage capacity and attentional filtering ability in visual working memory. *Social Cognitive and Affective Neuroscience, 13*(1), 92–101. https://doi.org/10.1093/scan/nsx139

Yang, K., & Victor, C. (2011). Age and loneliness in 25 European nations. *Ageing & Society, 31*(8), 1368-1388. https://doi.org/10.1017/s0144686x1000139x

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance, 10*(5), 601–621. https://doi.org/10.1037/0096-1523.10.5.601

Yi, Y., Li, L. M. W., Xiao, Y., Ma, J., Fan, L., & Dai, Z. (2018). Brain activity mediates the relation between emotional but not instrumental support and trait loneliness. *Social Cognitive and Affective Neuroscience, 13*(9), 995-1002. https://doi.org/10.1093/scan/nsy067

Ypsilanti, A., Robson, A., Lazuras, L., Powell, P. A., & Overton, P. G. (2020). Self-disgust, loneliness and mental health outcomes in older adults: an eye-tracking study. *Journal of affective disorders, 266*, 646-654. https://doi.org/10.1016/j.jad.2020.01.166

Yu, C., Ishibashi, K., & Iwanaga, K. (2023). Effects of fearful face presentation time and observer’s eye movement on the gaze cue effect. *Journal of Physiological Anthropology, 42*(1). https://doi.org/10.1186/s40101-023-00325-4

Yu, F., Zhou, X., Qing, W., Li, D., Li, J., Chen, X., Ji, G., Dong, Y., Luo, Y., Zhu, C., & Wang, K. (2017). Decreased response inhibition to sad faces during explicit and implicit tasks in females with depression: Evidence from an event-related potential study. *Psychiatry*

Research: Neuroimaging, 259, 42–53. https://doi.org/10.1016/j.pscychresns.2016.10.013

Zadro, L., Williams, K. D., & Richardson, R. (2004). How low can you go? Ostracism by a computer is sufficient to lower self-reported levels of belonging, control, self-esteem, and meaningful existence. *Journal of Experimental Social Psychology*, *40*(4), 560-567. https://doi.org/10.1016/j.jesp.2003.11.006

Zhu, Y., & Wang, C. (2017). The lonelier, the more conservative? A research about loneliness and risky decision-making. *Psychology*, *8*(10), 1570-1585. https://doi.org/10.4236/psych.2017.810104

Ziaei, M., Persson, J., Bonyadi, M. R., Reutens, D. C., & Ebner, N. C. (2019). Amygdala functional network during recognition of own-age vs. other-age faces in younger and older adults. *Neuropsychologia, 129,* 10–20. https://doi.org/10.1016/j.neuropsychologia.2019.03.003

Zimmerman, M.E. (2011). Speed–Accuracy Tradeoff. In: Kreutzer, J.S., DeLuca, J., Caplan, B. (eds) *Encyclopedia of Clinical Neuropsychology*. Springer, New York, NY. https://doi.org/10.1007/978-0-387-79948-3_1247

Zovetti, N., Rossetti, M. G., Perlini, C., Brambilla, P., & Bellani, M. (2021). Neuroimaging studies exploring the neural basis of social isolation. *Epidemiology and Psychiatric Sciences, 30*. https://doi.org/10.1017/S2045796021000135