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Emotional interference and attentional control in schizophrenia-spectrum disorders: The special case of neutral faces

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ABSTRACT

Background and objectives: Schizophrenia-spectrum disorders (SSD) are characterized by impaired emotion processing and attention. SSD patients are more sensitive to the presence of emotional distractors. But despite growing interest on the emotion-attention interplay, emotional interference in SSD is far from fully understood. Moreover, research to date has not established the link between emotional interference and attentional control in SSD. This study thus aimed to investigate the effects of facial expression and attentional control in SSD, by manipulating perceptual load.

Methods: Twenty-two SSD patients and 22 healthy controls performed a target-letter discrimination task with task-irrelevant angry, happy, and neutral faces. Target-letter was presented among homogenous (low load) or heterogenous (high load) distractor-letters. Accuracy and RT were analysed using (generalized) linear mixed-effect models.

Results: Accuracy was significantly lower in SSD patients than controls, regardless of perceptual load and facial expression. Concerning RT, SSD patients were significantly slower than controls in the presence of neutral faces, but only at high load. No group differences were observed for angry and happy faces.

Limitations: Heterogeneity of SSD, small sample size, lack of clinical control group, medication.

Conclusions: One possible explanation is that neutral faces captured exogenous attention to a greater extent in SSD, thus challenging attentional control in perceptually demanding conditions. This may reflect abnormal processing of neutral faces in SSD. If replicated, these findings will help to understand the interplay between exogenous attention, attentional control, and emotion processing in SSD, which may unravel the mechanism underlying socioemotional dysfunction in SSD.

Author note

This is a correction of a retracted study due to an error found by the authors (https://doi.org/10.1016/j.psychres.2021.114077); see Grave (2021, *Nature Human Behaviour*) for more information on this experience. To assure there were no more errors, we re-merged data from questionnaires (paper), clinical assessment (paper), and experimental task to create a new database. The error (stimuli coding/labelling) and minor lapses concerning reporting of results were fully corrected. Database and scripts are available (https://osf.io/z3d7w/)

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for full transparency. Besides results, introduction and discussion were significantly revised, and statistical analyses were reformulated to consider individual variation among participants and stimuli.

Since publication, we became aware of growing evidence of abnormal processing of neutral faces in schizophrenia (e.g., Derntl & Habel, 2017; Dugré, Bitar, Dumais, & Potvin, 2019; Filkowski & Haas, 2017; Potvin, Tikàsz, & Mendrek, 2016), also considered an endophenotype of schizophrenia (Yan et al., 2020). Hence, our original hypothesis that schizophrenia patients would be more prone to inference "by negative faces (anger), compared to positive (happy) and neutral ones" is no longer supported. We formulated new hypotheses based on these state-of-the-art updates, prior to data analysis. A preprint of this manuscript is posted on PsyArXiv (https://psyarxiv.com/ev7rp/).

1. Introduction

1.1. Schizophrenia-spectrum disorders and social cognition

Schizophrenia-spectrum disorders (SSD), including schizophrenia and schizoaffective disorders, are severe mental disorders characterized by a varied array of positive, negative, and disorganized symptoms (American Psychiatric Association, 2013), accompanied by social cognitive deficits (Green, Horan, & Lee, 2015). Social cognitive deficits can appear at early stages of the disorder, such as during the first psychotic episode (e.g., McCleery et al., 2020), are largely unaffected by medication (Kucharska-Pietura & Mortimer, 2013), strongly correlate to poor functioning (Halverson et al., 2019), and mediate the neurocognition-functioning relationship (Schmidt, Mueller, & Roder, 2011). Therefore, social cognition has been considered a prominent target for intervention in SSD (Horan & Green, 2019).

1.2. Emotion processing

Four social cognitive processes have been proposed: theory of mind/mentalizing, attributional style/bias, social perception, and emotion processing (Pinkham, Penn, et al., 2014). Particularly, emotion processing refers to perceiving and using emotional information, such as emotional facial expressions (Green et al., 2008). In SSD, meta-analyses demonstrate large and consistent deficits in emotional face identification and discrimination (Kohler, Walker, Martin, Healey, & Moberg, 2010; Savla, Vella, Armstrong, Penn, & Twamley, 2013). Emotional face processing is also associated with altered neurophysiological activity in SSD (Dong et al., 2018; Li, Chan, McAlonan, & Gong, 2010; Taylor et al., 2012). Of relevance, SSD patients exhibit abnormal hyperactivation of areas involved in emotion processing (e.g., amygdala) when neutral faces are displayed (Dugré et al., 2019; Potvin et al., 2016). Although neutral faces represent a "blank" emotional expression, their processing depends on contextual information and characteristics of the observer, such as personality traits, affective knowledge, and cognitive biases (e.g., Suess, Rabovsky, & Abdel Rahman, 2015; see; Wieser & Brosch, 2012). Hence, an abnormal processing of neutral faces in SSD may reflect a tendency to put emotional or threatening meaning into neutral stimuli (Kring & Elis, 2013) – especially in social settings (Green & Phillips, 2004) –, possibly linked to the predominant sense of threat in psychotic experiences (Underwood, Kumari, & Peters, 2016). This aligns with a bias in categorizing neutral faces as angry in schizophrenia patients with paranoid delusions (Pinkham, Brensinger, Kohler, Gur, & Gur, 2011).

1.3. Emotion-attention interaction

Besides emotion processing, attentional deficits have long been described in SSD (Bleuler, 1950; Kraepelin, 1919) and are hypothesized as pivotal in developing and maintaining psychotic symptoms (Tully & Niendam, 2014). For instance, delusions can be explained by an abnormal association of irrelevant or unrelated events, which in turn can result from increased attention to irrelevant stimuli (e.g., Morris, Griffiths, Le Pelley, & Weickert, 2013). Also, anomalous attention to social information in SSD can lead to emotion dysregulation and inappropriate responses to social events – often associated with maladaptive threat appraisals (Underwood et al., 2016). Emotion-attention interaction has thus emerged as an area of interest to understand socioemotional dysfunction in SSD (Duggirala, Schwartze, Pinheiro, & Kotz, 2020; Tully & Niendam, 2014).

Attention involves two partially segregated systems: an endogenous system, responsible for the voluntary selection of target stimuli; and an exogenous system, automatically activated when salient stimuli are exhibited outside attentional focus (Egeth & Yantis, 1997; Posner, 1980; Theeuwes, 1994), as can happen for emotional stimuli (Carretié, 2014). There is compelling evidence of preferential processing of emotional versus non-emotional stimuli in healthy individuals – mainly for threat-related stimuli, such as snakes (e.g., Gomes, Soares, Silva, & Silva, 2018; Langeslag & van Strien, 2018; Soares, Lindström, Esteves, & Öhman, 2014; Öhman, Soares, Juth, Lindström, & Esteves, 2012) and angry faces (e.g., Gong & Li, 2022; Pinkham, Griffin, Baron, Sasson, & Gur, 2010; Shasteen, Sasson, & Pinkham, 2014; Öhman, Lundqvist, & Esteves, 2001), but see Pool, Brosch, Delplanque, and Sander (2016). This appears to arise from a subcortical pathway to the amygdala (e.g., McFadyen, Mattingley, & Garrido, 2019; Méndez-Bértolo et al., 2016) and to enhance the detection of a potential hazard in the environment (LeDoux, 2022; Öhman, 2005). Moreover, this preferential processing occurs even when emotional stimuli are not task-relevant (e.g., Burra, Coll, Barras, & Kerzel, 2017), thus interfering with the ongoing task (e.g., Carboni, Kessel, Capilla, & Carretié, 2017; Huang, Chang, & Chen, 2011; Soares et al., 2017).

In SSD, only a few studies show an intact emotion-cognition interaction, suggesting an analogous influence of emotional stimuli on cognitive processes in patients and healthy controls (HC) (e.g., Aichert et al., 2013; Linden et al., 2010). For instance, despite schizophrenia patients demonstrating an overall higher error rate (compared to first-degree relatives and HC) during an antisaccade task with emotional faces, there was a similar effect of fearful faces across the three groups, with those stimuli leading to higher antisaccade errors than disgusted and neutral faces (Aichert et al., 2013).

Yet, most evidence suggests that SSD patients are more susceptible to distraction by emotional stimuli (e.g., Derntl & Habel, 2017; Eack et al., 2016; Guimond et al., 2018; Navalón et al., 2022; Park, Kim, Kim, Kim, & Lee, 2011; Strauss, Allen, Duke, Ross, & Schwartz, 2008, 2011). This is consistent with an atypical emotion-attention interaction in SDD, although much uncertainty still exists about which stimuli impair performance the most or whether there is a more generalized emotional interference. Guimond et al. (2018) observed lower accuracy in a working memory task when SSD patients (compared to HC) were exposed to fearful and happy face distractors, but only at high working memory load. Additionally, in SSD, decreased neural activity in the inferior frontal gyrus – linked to attentional control (Hampshire, Chamberlain, Monti, Duncan, & Owen, 2010) – was associated with decreased performance at high working memory load when fearful faces were presented, reflecting impaired attentional control mechanisms involved in fear inhibition (Guimond et al., 2018). During a continuous performance task, Park et al. (2011) found that schizophrenia patients had a steeper performance decline when target stimuli were displayed with happy versus sad distractor faces. Derntl and Habel (2017) showed lower accuracy in schizophrenia patients than HC when neutral, but not angry, faces were presented during an emotional stop-signal task, suggesting that neutral faces worsen response inhibition in schizophrenia. These mixed findings may be attributed to the heterogeneity of SSD (e.g., positive/negative symptoms, medication), individual differences, cognitive domains (e.g., response inhibition), task instructions (i.e., implicit/explicit), stimuli type (e.g., social/non-social), and facial expression (e.g., angry/fearful) (Duggirala et al., 2020). Also, research to date has not fully established if emotional interference in SSD is modulated by attentional control, one of the key components of attention in SSD (Luck & Gold, 2023).

1.4. Attentional control

Attentional control refers to the mechanisms involved in selective attention, and it is responsible for selecting the target stimulus for enhanced processing by putting together information about explicit goals, implicit memory, and salience (Luck, Leonard, Hahn, & Gold, 2019; Luck & Gold, 2008). Behavioral and neurophysiological data point to impaired attentional control in SSD, with patients being more distracted by task-irrelevant stimuli only in "demanding" tasks requiring to focus on a low-salient target in the presence of a high-salient distractor (e.g., Hahn et al., 2022; see; Luck & Gold, 2023). For instance, during a visual search task with eye tracking, SSD patients and HC were asked to find a non-salient (low-contrast) or salient (high-contrast) target-circle among non-salient and salient distractor-circles (Bansal et al., 2019). Both groups avoided directing their gaze to non-salient distractors when the target was salient, but SSD patients were more likely to focus on salient distractors when searching for non-salient targets. Luck and Gold (2023) recently proposed that this greater distractibility in SSD is not explained by a decrease in focus, but instead by an aberrant hyperfocusing on non-target stimuli. Hence, if SSD is indeed associated with a misattribution of emotional salience to neutral faces, exploring attentional control in a socioemotional context may help to understand the atypical processing of such stimuli in SSD, consequently unravelling the nature and extending the knowledge on increased emotional interference. This is particularly relevant since impairments in complex social cognitive phenomena, such as theory of mind/mentalizing and emotion regulation, can arise from deficits in fundamental aspects of emotion perception, including the ability to effectively control emotional distractors (Koch, Mars, Toni, & Roelofs, 2018).

1.5. Current study

This study sets out to investigate emotional interference by facial expressions and attentional control in SSD. SSD patients and HC performed a target-letter discrimination task, adapted from Soares, Rocha, Neiva, Rodrigues, and Silva (2015). In each trial, a target-letter was centrally presented, together with distractor-letters. To control the salience of the target- and distractor-letters (to manipulate the recruitment of attentional control mechanisms), we included two perceptual load conditions: low perceptual load (LPL), in which all distractor-letters were the same; and high perceptual load (HPL), in which the distractor-letters were different angular letters. Simultaneously, a task-irrelevant face was presented in the periphery, showing either a threatening (angry), positive (happy) or neutral expression. We used angry faces (instead of other threat-related faces, namely fearful or disgusted ones) because angry faces with direct gaze tend to communicate an intention to approach the "observer". This allowed for a more direct comparison with happy faces, as they are also approach-oriented (Adams, Ambady, Macrae, & Kleck, 2006). Participants had to discriminate the target-letter, while ignoring the task-irrelevant face.

We hypothesized that, if there is a bias to put emotional (or threatening) meaning into neutral faces in SSD – susceptible to an increased interference by neutral faces –, attentional performance would be poorer (i.e., lower accuracy and/or longer RT) in SSD patients than HC, but only in the presence of neutral faces. Although happy and angry faces could be atypically processed in SSD, they are still perceived as emotionally valenced (e.g., Lee et al., 2022) and, therefore, less likely to capture exogenous attention to a greater extent in SSD than HC. Moreover, we expected this effect of neutral faces to be more pronounced in HPL than LPL due to the impaired attentional control in SSD, shown by a significant group-load-emotion interaction. Hence, we hope this study contributes to a better understanding of the link between exogenous attention, attentional control, and emotion processing in socioemotional context in SSD, by providing preliminary data concerning the role of attentional mechanisms on aberrant neutral versus emotional face processing.

2. Material and methods

2.1. Participants

Twenty-two individuals diagnosed with SSD and 22 age- and sex-matched HC were recruited. Sample size justification is described in Supplementary Materials (SM). Inclusion criteria were 18–65 years and normal or corrected-to-normal vision. Exclusion criteria were substance dependence/abuse, head injury, and/or neurological diseases. The study was approved by the Ethics Committee (CE-010/2014) and conducted in accordance with the Declaration of Helsinki and the American Psychological Association. Participants gave written informed consent and were not rewarded for their participation.

Patients were recruited in outpatients' mental health units from the centre region of Portugal. Additional inclusion criteria were diagnosis of schizophrenia or schizoaffective disorder, based on the DSM-5 (American Psychiatric Association, 2013), being on a stable medication regimen, and having no psychiatric hospitalization within the past six months.

HC were recruited from the local community via social media advertising. Additional inclusion criteria included no psychiatric history, confirmed with the Mini International Neuropsychiatric Interview (Portuguese version: Amorim, 2000), and no psychotic disorders in first-degree biological relatives.

2.2. Neuropsychological assessment

We used the Stroop Neuropsychological Screening Test (Portuguese version: Castro, Martins, & Cunha, 2003) to evaluate cognitive flexibility, selective attention, cognitive inhibition, and information processing speed (Trenerry, Crosson, DeBoe, & Leber, 1989); the Zung Self-Rating Anxiety Scale (Portuguese version: Ponciano, Vaz Serra, & Relvas, 1982) to control anxiety effects; and the expanded Brief Psychiatric Rating Scale (Portuguese version: Caldas de Almeida, Gusmão, Talina, & Xavier, 1996) to measure the severity of psychiatric symptoms. See SM for more details.

2.3. Stimuli

An X or N target-letter was displayed together with five identical (LPL; "O") or different (HPL, randomly chosen from G, H, K, J, S, or Y) distractor-letters (Fig. 1) in an imaginary circle around a black fixation cross (centre of the screen), with a 2.52° radius (e.g., Forster & Lavie, 2008; Gupta, Young-Jin, & Lavia, 2016; Gupta & Srinivasan, 2015; Soares et al., 2015). Letters were presented in black colour, font type "Lucida Console", with 0.50° in width by 0.50° in height.

Task-irrelevant stimuli were coloured pictures of angry, happy, and neutral faces of eight Caucasian actors (four women and four men, facing forward), retrieved from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). Faces were exhibited in the parafoveal area. The distance from the fixation point to the picture center was 9.45°, and the picture size was 4.85° in width by 6.46° in height.

2.4. Procedures

Participants signed the informed consent and completed the sociodemographic questionnaire and anxiety scale. They were asked to sit comfortably at about 40 cm from a laptop with a 13.3″ monitor (1280 × 1024 pixels; 60 Hz refresh rate). The laptop was connected to the electricity through a power supply cable, and brightness was adjusted to

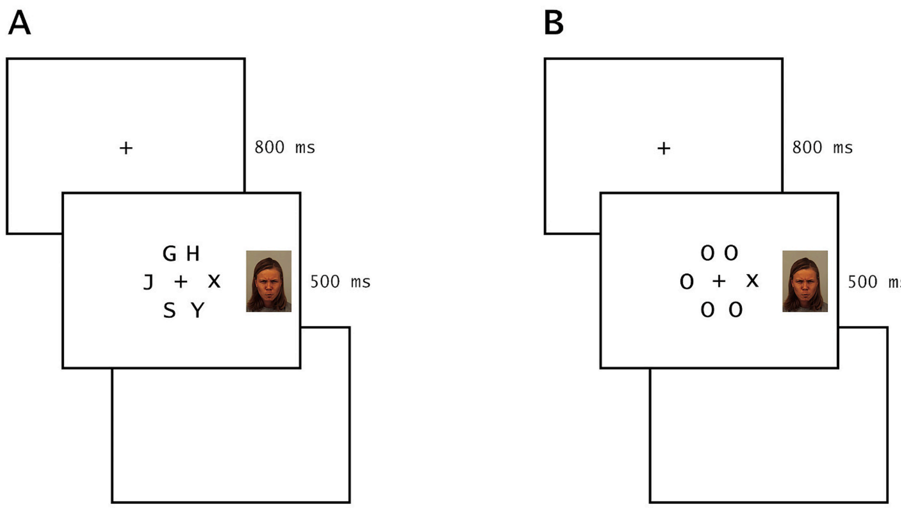

Fig. 1. An example of two trials at HPL (A) and LPL (B) with an angry face.

100%.

Each trial started with a black fixation cross, randomly presented for 800 or 1200 ms to preclude anticipation effects. The target- and distractor-letters were then shown, together with the task-irrelevant face. Letters were equally likely to appear in any of the six positions. The face was exhibited left or right from the fixation cross (in equal probability). All stimuli were presented on a white background screen for 500 ms, followed by a blank screen until response (Fig. 1). Participants were instructed to ignore the face and to discriminate, as rapidly and accurately as possible, the target-letter by pressing the designated key on the keyboard (X or N). They were also instructed to keep their gaze on the fixation cross and their index fingers near the keyboard keys to increase response speed. The intertrial interval was 500 ms. The conditions' order was fully randomized for each participant. The task was programmed in, and displayed with, E-Prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2002).

Participants completed 48 practice trials and 384 experimental trials, all equally distributed by emotion and load. Feedback on participants' accuracy was displayed in the practice, but not on the experimental traits. We used a repeated-measures factorial design by 2 (load: HPL, LPL) $\times$ 3 (emotion: angry, happy, neutral) $\times$ 2 (target-letter: X, N) $\times$ 2 (stimuli position: right, left) $\times$ 2 (actors' sex: women, men) $\times$ 4 actors, with group varying between participants. RT (in ms) and accuracy were collected. Lastly, participants completed the Stroop task and were fully debriefed.

2.5. *Statistical analysis*

Significance levels were set at $\alpha = .05$. Sociodemographic and neuropsychological data were analysed with independent samples *t*-test or Mann-Witney test (for continuous data), and Chi-Squared or Fisher's exact test (for categorical data) in Jamovi (The Jamovi Project, 2021). Effect sizes were computed and an adjustment to degrees of freedom was used in case of violation of the homogeneity assumption.

Separated analyses were performed for RT and accuracy. Data and scripts are available (https://osf.io/z3d7w/). RT was analysed with linear mixed-effect models using the *lmer* function in the *lmer4* package (Bates, Mächler, Bolker, & Walker, 2015) in R (R Core Team, 2020). Incorrect trials (5.72% of total trials in HC; 11.26% in patients) and outliers were excluded (1.36% of total trials in HC; 1.50% in patients). Outliers were identified as follows: RT leading ± 3 *SD* away from *M*, calculated for each participant, load, and emotion.

The simpler model comprised of untransformed RT as the dependent variable; group-load-emotion interaction as fixed factors; and by-subject and by-actor intercepts and slopes as random-effects. Covariates were individually added: handedness, education, participants' sex, actor, actors' sex, age, and anxiety levels. Models were contrasted for fit with the simpler model using the *anova* function in the *car* package (Fox & Weisberg, 2019), and the best-fitting model was selected. Once the best-fitting model was selected, we used the *anova* function to compute Type-III tests with Satterthwaite approximation for degrees of freedom, and the *emmeans* package (Lenth, 2022) to compute post-hoc comparisons with Tukey correction. See SM for more details.

Accuracy was analysed with generalized linear mixed-effect models using the *gmer* function in the *lmer4* package (Bates et al., 2015). We employed a binominal distribution and a logit link function. Model selection and analysis followed the same procedure, except for the use of the *Anova* function in the *car* package (Fox & Weisberg, 2019) to compute Type-III Wald Chi-squared tests.

3. Results

3.1. *Sample characterization*

We tested 44 participants (10 women, 22.73%), aged from 19 to 58 years ($M = 36.82$, $SD = 12.14$). Patients and HC were well-matched for age, $U = 240.50$, $p = .981$, $rrb = 0.01$, and sex, $p = 1.000$. Twenty-one patients were diagnosed with schizophrenia (95.45%) and one with schizoaffective disorder (4.54%). Sociodemographic and clinical data are in Table 1.

3.2. *Neuropsychological assessment*

Groups significantly differed in the Stroop task, $U = 104.50$, $p = .001$, $rrb = 0.57$, and anxiety levels, $t(42) = 3.20$, $p = .003$, $d = 0.96$. Patients showed significantly lower Stroop scores ($M = 82.32$, $SD=21.07$) and significantly higher anxiety ($M = 33.73$, $SD = 5.58$) than HC (Stroop: $M = 104.27$, $SD = 13.23$; anxiety: $M = 29.18$, $SD = 3.65$).

3.3. *Accuracy*

The best-fitting model contained by-subject intercept and slope for load (1+load|subject), and by-item intercept (1|actor) as random-effects; as well as group-load-emotion as fixed factors. Covariates failed to improve the fit (SM: Table S1). The marginal R-squared was 0.045 (SM: Table S2).

Type-III Wald Chi-squared tests revealed a main group effect, $\chi^2(1) = 6.03$, $p = .014$. Patients showed significantly lower accuracy than

Table 1
Sociodemographic and clinical data. *Notes*. AP, antipsychotic; BPRS, Brief Psychiatric Rating Scale. ***$p < .001$.

		HC (n = 22)	SSD (n = 22)	*p-value*
Sex, n(%)	Male	17 (77.27)	17 (77.27)	1.000
	Female	5 (22.73)	5 (22.73)	
Age, *M(SD)*		36.95 (13.14)	36.68 (11.37)	.981
Formal education, n(%)	5–6 years	0 (0.00)	1 (4.54)	<.001***
	7–9 years	0 (0.00)	8 (36.36)	
	10–12 years	4 (18.18)	13 (59.09)	
	Graduation	12 (54.54)	0 (0.00)	
	Master or higher	6 (27.27)	0 (0.00)	
Handedness, n(%)	Right-handed	21 (95.45)	19 (86.36)	.607
	Left-handed	1 (4.54)	3 (13.63)	
Vision, n(%)	Corrected-to-normal	10 (45.45)	6 (27.27)	.347
	Normal	12 (54.54)	16 (72.73)	
Medication, *n(%)*	Atypical AP		10 (45.45)	
	Typical AP		1 (4.54)	
	Atypical AP + typical AP		2 (9.09)	
	Atypical AP + benzodiazepine		5 (22.73)	
	Atypical AP + typical AP + benzodiazepine		2 (9.09)	
	Atypical AP + antidepressant + benzodiazepine		1 (4.54)	
	Atypical AP + mood stabilizer		1 (4.54)	
BPRS, *M(SD)*			36.36 (10.83)	
Age of diagnosis, *M(SD)*			28.04 (9.91)	
Duration of disorder, *M(SD)*			8.32 (8.28)	
Number of hospitalizations, *M(SD)*			1.68 (2.17)	

controls (Fig. 2). No load effect, $\chi^2(1) = 1.56$, $p = .212$, emotion effect, $\chi^2(2) = 0.76$, $p = .685$, and group-load, $\chi^2(1) = 1.73$, $p = .188$, group-emotion, $\chi^2(2) = 0.03$, $p = .986$, load-emotion, $\chi^2(2) = 1.28$, $p = .527$, or group-load-emotion interactions, $\chi^2(2) = 1.75$, $p = .417$, were reported.

3.4. Response time

The best-fitting model contained by-subject intercept and slope for load (1+load|subject), and by-item intercept (1|actor) as random-effects; as well as group-load-emotion as fixed factors. Covariates failed to improve the fit (SM: Table S3). The ICC was 0.31, and marginal and conditional R-squared were 0.104 and 0.384, respectively (SM: Table S4).

Type-III F-test with Satterthwaite's method revealed a main load effect, $F(1,42.9) = 94.48$, $p < .001$. RT was significantly longer at HPL ($M = 792.34$, $SE = 30.04$) than LPL ($M = 630.88$, $SE = 22.90$). There was a main group effect, $F(1,44.0) = 7.40$, $p = .010$, and a significant group-load interaction, $F(1,42.2) = 6.47$, $p = .015$. Post-hoc analysis showed patients ($M = 882.46$, $SE = 42.49$) were significantly slower than HC at HPL ($M = 702.22$, $SE = 42.46$, $ps = .014$), but not at LPL (SSD: $M = 678.76$, $SE = 32.37$; HC: $M = 583.00$, $SE = 32.36$, $ps = .155$). Both groups were significantly slower at HPL than at LPL ($ps < .001$).

There was a significant group-load-emotion interaction, $F(2,15126.1) = 3.46$, $p = .031$. Patients were significantly slower than HC at HPL for neutral faces ($ps = .040$), but not for angry ($ps = .314$) or happy faces ($ps = .098$). At LPL, no significant differences emerged between groups ($ps > .050$) (Fig. 3). Patients were significantly slower for neutral than angry faces at HPL only ($ps = .007$), with no other significant differences between emotions in both groups ($ps > .050$). Lastly, HPL led to significantly longer RT than LPL for all emotional conditions in both groups ($ps > .001$). No emotion effect, $F(2,15125.1) = 2.38$, $p = .093$, and group-emotion, $F(2,15125.0) = 2.90$, $p = .055$, or load-emotion interactions, $F(2,15125.8) = 0.59$, p=.556, were observed. See SM for secondary analyses of RT within the clinical group.

4. Discussion

This study explored emotional interference by facial expressions and attentional control in SSD. By manipulating perceptual load in a socio-emotional context in SSD, we expected to deliver preliminary data on this missing piece of the emotion-attention puzzle. Firstly, accuracy analysis revealed a main group effect, with SSD patients being

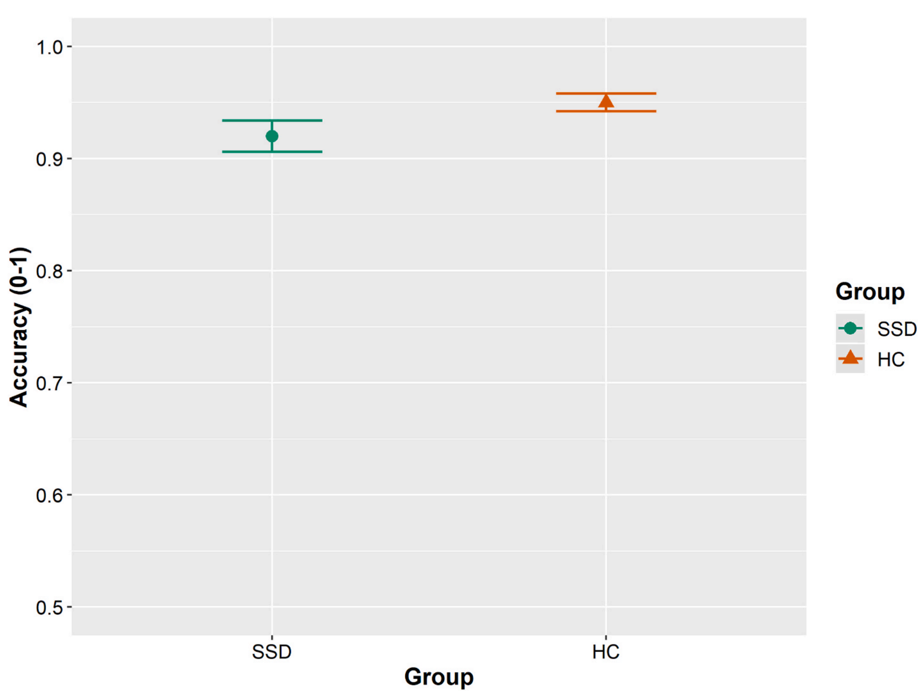

Fig. 2. Estimated marginal mean accuracy as a function of the group. In general, accuracy was significantly lower in SSD patients than HC ($p = .014$). Error bars represent standard error.

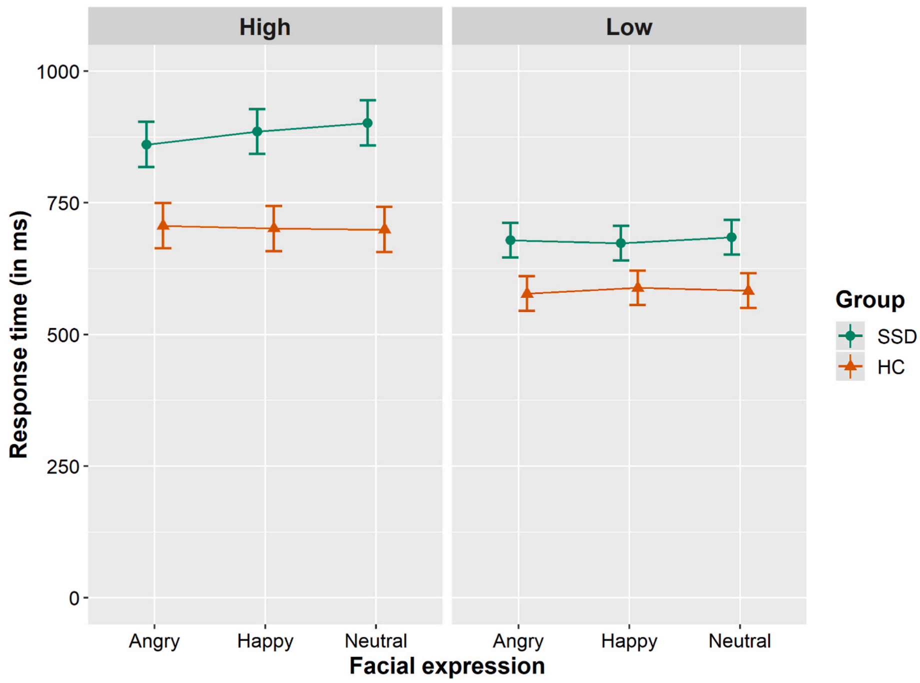

Fig. 3. Estimated marginal mean RT at HPL and LPL as a function of group and emotion. SSD patients were significantly slower than HC at HPL, but only for neutral faces (*ps* = 0.040). No other significant differences were found (*ps* > .050). Error bars represent standard error.

significantly less accurate than HC, regardless of the load and emotion. Secondly, there was a significant group-load-emotion interaction in RT: patients were significantly slower than HC at HPL (but not at LPL) when neutral faces were presented, while angry and happy faces yielded no significant differences between groups at both loads. Also, patients were significantly slower for neutral than angry faces at HPL, while no emotion effect was observed in HC. Lastly, RT was not affected by age, education, sex, handedness, anxiety, or clinical variables (see SM).

Our data supports the hypothesis that SSD patients are more distracted by neutral faces. Particularly, we found that neutral faces significantly decreased processing efficiency in SSD patients, compared to HC, as showed by the significantly longer RT in the clinical versus non-clinical group. Since faces were task-irrelevant stimuli (and displayed outside attentional focus), this effect might be caused by an enhanced attentional capture by neutral faces in SSD, increasing the effort or resources needed to perform the task. Similar findings were reported by Derntl and Habel (2017). Using an emotional stop-signal task, they found that schizophrenia patients made more errors than HC in stop trials with neutral (but not angry) faces. This suggests that neutral faces impair response inhibition in schizophrenia, possibly due to abnormal neutral face processing (Derntl & Habel, 2017).

Importantly, as expected, this detrimental effect of neutral faces in SSD was only observed at HPL. The fact that patients and HC were significantly slower at HPL than at LPL may indeed confirm the need for increased attentional control at HPL. In fact, while an angular target-letter "pops out" among homogenous distractor-letters ("O") at LPL, this is not observed at HPL (angular target-letter among heterogeneous distractor-letters). Thus, the selection of non-salient targets in detrimental of salient (yet task-irrelevant) face stimuli becomes dependent on attentional control, resulting in longer RT. This may be particularly relevant because attentional control is impaired in SSD (e.g., Bansal et al., 2019; Gold et al., 2018; Hahn et al., 2022; see; Luck & Gold, 2008), meaning that patients are worse at selecting non-salient targets for enhanced processing in the presence of competitive information. Hahn et al. (2022) performed a house/face-target discrimination task with faces and houses presented either sequentially or as face-house overlays (to increase stimuli competition and challenge attentional control). In sequential trials, the authors found abnormal fusiform face area hyperactivation in SSD for face-target, suggesting an enhanced implementation of selection – the mechanisms responsible for prioritizing the processing of selected stimuli and filtering out task-irrelevant ones (Luck & Gold, 2008) – in SSD when competition and attention requirements are minimal. In overlaid conditions, however, they reported elevated response in the parahippocampal place area in HC, but not in SSD, when it was required to attend to less salient (house) over more salient (face) stimuli, congruent with impaired attentional control in SSD. Likewise, Duggirala et al. (2020) demonstrated that abnormal pre-frontal hypo-activation in SSD during emotion-cognitive control tasks is associated with poor attentional control, which can lead to emotion dysregulation (amygdala hyperactivation). Therefore, we suggest that, when attention resources are not automatically directed toward a salient target, SSD patients are less able to filter out the processing of neutral faces than HC, thus affecting attentional control. This, together with evidence that poor (self-reported) attentional control predicts greater emotional interference (Peers & Lawrence, 2009), reinforces the assumption that neutral faces are especially relevant in SSD by capturing attention to a greater extent.

In a previous study, Tsakanikos (2006) reported that increasing the perceptual load strongly biased the perception of (neutral) words in non-word trials in healthy individuals; and that this effect was positively correlated with psychotic-like experiences, but only at medium load. According to the author, HPL (e.g., carrying out a perceptually demanding task during a hallucinatory experience) can reduce the intensity of psychotic-like experiences. Our results, however, challenge this conclusion by demonstrating that HPL impairs the processing efficiency of task-relevant stimuli in SSD, particularly in the presence of emotionally neutral (yet socially relevant) events. These conflicting findings may be explained by the use of distinct populations (clinical/non-clinical) and stimuli (faces/words), as social and non-social social processing is differently affected in SSD (e.g., Lee et al., 2019; Peterman, Bekele, Bian, Sarkar, & Park, 2015; Pinkham, Sasson, et al., 2014). For instance, using an implicit reinforcement learning task, Peterman et al. (2015) found a decreased neural sensitivity in SSD to social reward, but otherwise intact to non-social reward. Nevertheless, both studies highlight that perceptual load should be further explored and could be a hint to understanding the psychotic-spectrum.

Although its exact causal mechanism remains unclear, the increased exogenous attention to neutral faces in SSD might be due to an over-attribution of emotional or threatening relevance to neutral events (Dugré et al., 2019; Kring & Elis, 2013; Potvin et al., 2016; Underwood et al., 2016). There is evidence that putting emotional/motivational relevance into neutral faces (via associative learning with monetary reward/losses) enhances neutral face processing in healthy individuals (Saito, Sato, & Yoshikawa, 2022). In SSD, researchers reported stronger self-reported aversion and arousal in response to neutral stimuli (Cohen & Minor, 2010; Kring & Elis, 2013; Llerena, Strauss, & Cohen, 2012), and overattribution of negative emotions to neutral faces (e.g., Habel et al., 2010; Kohler et al., 2003), particularly in paranoid patients (e.g., Pinkham et al., 2011). Consistently, a meta-analysis showed abnormal hyperactivation of the amygdala – involved in threat detection (Öhman, 2005) and defensive survival circuits (LeDoux, 2022) – when SSD patients were viewing neutral faces (Dugré et al., 2019). Moreover, neuroimaging data demonstrated that abnormal hyperactivation of the right posterior superior temporal sulcus in response to neutral faces may be an endophenotype of schizophrenia (Yan et al., 2020).

Neurobiological models of psychosis have been proposing that elevated dopamine signalling – a core feature of psychosis, linked to motivational value and salience (including detection of potentially relevant events) – can cause an overattribution of (emotional) salience to non-salient stimuli, which in turn can be associated with development and maintenance of psychotic experiences (Howes & Nour, 2016; Kapur, 2003; Miyata, 2019; Winton-Brown, Fusar-Poli, Ungless, & Howes, 2014). Particularly, aberrant salience can produce a "delusional atmosphere" in which internal representations and external events are perceived as excessively meaningful and uncertain by SSD patients (Howes & Nour, 2016). Nonetheless, anomalous psychotic experiences are often associated with maladaptive appraisals and a predominant sense of threat (Underwood et al., 2016), which can be a result of aberrant salience.

Besides the hypothesis that neutral faces may be more emotionally salient or threatening for SSD patients, another explanation for our findings concerns the ambiguity of such stimuli. Neutral faces are ambiguous social stimuli whose processing depends on contextual information (Aviezer, Ensenberg, & Hassin, 2017; Wieser & Brosch, 2012) and/or characteristics of the observer (e.g., Suess et al., 2015). Therefore, SSD patients may require more cognitive resources to overcome this uncertainty and to disambiguate the "meaning" of neutral faces (Potvin et al., 2016). Consequently, the presence of a neutral face can divert patients' cognitive resources of the target stimulus, thus requiring an additional effort to perform the task. Future studies should address this using an emotion recognition task and collecting ratings of, for instance, trustworthiness, attractiveness, and dominance. Furthermore, adding neurophysiological and/or ocular measures would be key to test the extent to which attention is being captured by task-irrelevant stimuli in SSD (Carretié, 2014).

There is evidence that angry faces draw attention to the individual expressing anger, possibly due to their direct and certain communication of threat (e.g., Davis et al., 2011). Hence, and since psychotic experiences are characterized by exaggerated threat appraisals (Underwood et al., 2016), it could be the case that SSD patients perceive angry faces as more threatening, salient, or arousal, thus leading to an increased attentional capture by such stimuli. Yet, this effect was not observed, which aligns with evidence of impaired angry processing in SSD. For instance, previous studies showed a tendency to categorize angry faces as expressing disgust or fear (Lee et al., 2022) and an absent threat-superiority effect for angry faces during a visual search task in SSD (Pinkham, Sasson, et al., 2014).

Lastly, although our statistical analysis revealed significantly longer RT for SSD patients than HC at HPL solely in the presence of neutral faces, data visualization showed qualitatively longer RT for both angry and happy faces in the clinical versus non-clinical group. Considering our modest sample size, we cannot fully dismiss that the lack of statistical significance for those stimuli might be due to insufficient power, rather than a particular effect of neutral faces. If this is the case, our results could suggest a more generalized emotional interference effect in SSD when precise attentional control is required. Still, such a conclusion would only be possible if we had included trials with non-emotional stimuli or without task-irrelevant stimuli. Thus, we encourage researchers to continue this research line with a larger sample size and to adopt a more complex experimental design.

4.1. Implications

The maladaptive interplay between emotion processing and attentional control can lead to inappropriate responses to social events and has been linked to symptom severity and poor social skills in SSD (Duggirala et al., 2020). Therefore, training attentional control abilities in a socioemotional context may improve social and non-social cognitive dysfunction, consistent with growing evidence on the effectiveness of cognitive remediation techniques in SSD (Vita et al., 2021). Although this is yet to be explored in SSD, attentional bias modification training tasks seem to decrease depressive symptoms (Hsu et al., 2021) and affect brain activity associated with emotional appraisal in depression (Hilland et al., 2020). Yet, it should be noted that attentional bias modification training was not designed to improve attentional control and that a more tailored intervention towards impaired attentional control in SSD may be preferable. For instance, Luck and Gold (2023) briefly stated that the use of video games for attentional interventions could help to reduce hyperfocusing in SSD. Furthermore, if SSD patients are more distracted by neutral social stimuli (e.g., neutral face/speech) due to aberrant salience, interventions aiming to shift the meaning of those stimuli may be valuable. Lastly, given that auditory verbal hallucinations are among the most frequent and negatively appraised psychotic experiences (Larøi et al., 2019; Thomas et al., 2007), a replication of this study with auditory stimuli would be key to drawing further implications for clinical practice.

4.2. Limitations and recommendations

Several limitations need to be considered when interpreting our findings. We did not include trials without task-irrelevant stimuli because it would increase the task's duration. Hence, it is not possible to fully distinguish between the effects of overall attentional deficits and emotional interference in SSD. Despite not being our goal, this would also allow us to test, for the first time in SSD, whether emotional interference is reduced at HPL (consistent with perceptual load effect; see Brockhoff, Schindler, Bruchmann, & Straube, 2022; Murphy, Groeger, & Greene, 2016) or not (consistent with emotional stimuli being a special case of attention, even at HPL; e.g., Gupta et al., 2016; Gupta & Srinivasan, 2015; Lavie, Ro, & Russell, 2003; Müller-Bardorff et al., 2016; Thoma & Lavie, 2013; Öhman et al., 2012). Moreover, future studies should carefully control for visual conspicuity of facial stimuli to confirm if group differences were driven by facial expression or additive effects of their physical features (e.g., luminance, contrast, spatial frequency).

Another limitation concerns the sample size, as previously stated. Besides strengthening our conclusions, a larger sample size would allow subgroup analyses, such as positive versus negative symptoms. For instance, Strauss et al. (2008, 2011) showed that people with high levels of negative symptoms (i.e., deficit syndrome) have greater difficulty disengaging attention from negative words, compared to people with non-deficit syndrome and HC. A retrospective power analysis assuming an effect of interest of $d = 0.30$ suggests that the study was sufficiently powered (see SM) and, by including multiple observations per load and emotion, we hoped to increase power and decrease variance within conditions (Brysbaert, 2019). Nevertheless, results should be interpreted with caution until being replicated.

Formal education was significantly lower in patients than HC. Despite being possible that lower accuracy in SSD is (at least in part) explained by difficulties understanding and following instructions (Lui et al., 2018), education level did not significantly improve model fit. Also, schizophrenia is often associated with psychomotor slowing (Morrens, Hulstijn, & Sabbe, 2007), which can be problematic for RT data. Although it is unlikely that psychomotor slowing explains the emotional effects observed in RT, we recommend that researchers adapt their experimental tasks to decrease the effects of psychomotor slowing, and add a broader neurocognitive assessment.

We did not include a control clinical sample and, thus, cannot fully assure our outcomes are restricted to SSD. Filkowski and Haas (2017) demonstrated abnormal neural activity in response to neutral faces in major psychiatric disorders (e.g., depression, anxiety, schizophrenia, bipolar disorder), arguing against the use of neutral faces as baseline conditions. Particularly, the schizophrenia-bipolar disorder comparison is of foremost importance given their genetic, cognitive, and perceptual similarities (Addington & Addington, 1997; Tamminga et al., 2014; The International Schizophrenia Consortium, 2009). A recent study using the emotional Stroop task showed that, while SSD patients are slower than HC regardless of valence, bipolar patients are slower than HC in negative valence only (i.e., pseudowords previously associated with angry faces) (Sollier-Guillery et al., 2021). Social cognitive domains also seem to be differently affected in schizophrenia and bipolar disorder (Bora & Pantelis, 2016). Still, this research field would benefit from a direct comparison between SSD and bipolar disorder.

Lastly, medication effects were not tested. Although antipsychotics can improve cognitive functions (Clissold & Crowe, 2019; Veselinović et al., 2019), they have little (Gabay, Kempton, & Mehta, 2015) or no effect on emotion processing (Kucharska-Pietura & Mortimer, 2013). Nevertheless, it is still possible that our results are explained by medication.

5. Conclusions

Notwithstanding our limitations, we demonstrated that SSD patients are more susceptible to distraction by neutral faces at HPL than HC – an effect not observed for angry and happy faces. Our results might be explained by an overattribution of salience to non-salient (or neutral) stimuli in SSD. This would lead to an increased exogenous attention to neutral faces in SDD, thus challenging attentional control to a greater extent in perceptually demanding conditions. Nevertheless, these findings should be considered preliminary until being replicated with a larger sample size. Since attentional control has been linked to the development and maintenance of psychotic symptoms, particularly in a socioemotional context, our findings may provide critical evidence to understand socioemotional dysfunction across the psychotic-spectrum.

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CRediT authorship contribution statement

Joana Grave: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – original draft. **Nuno Madeira:** Conceptualization, Methodology, Resources, Supervision, Writing – review & editing. **Sofia Morais:** Investigation, Methodology, Resources, Writing – review & editing. **Paulo Rodrigues:** Data curation, Methodology, Resources, Software, Writing – review & editing. **Sandra C. Soares:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have shared the link to my data/code.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2023.101892.

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