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Abstract:

Facial emotion recognition has been shown to be impaired among patients with schizophrenia and, to a lesser extent, among individuals with high levels of schizotypal personality traits. However, aspects of gaze behavior during facial emotion recognition among the latter are still unclear. This study therefore investigated the relations between eye movements and facial emotion recognition among nonclinical individuals with schizotypal personality traits.

A total of 83 nonclinical participants completed the Schizotypal Personality Questionnaire (SPQ) and performed a facial emotion recognition task. Their gaze behavior was recorded by an eye-tracker. Self-report questionnaires measuring anxiety, depressive symptoms, and alexithymia were also administered.

At the behavioral level, participants with higher SPQ scores exhibited less accurate recognition of surprise than participants with lower SPQ scores. Analysis of eye-tracking data revealed that higher SPQ scores were significantly associated with fewer fixations on relevant facial areas for sadness. Regression analyses revealed that the total SPQ score was the only significant predictor of eye movements for sadness, and depressive symptoms were the only significant predictor of surprise recognition accuracy.

This study highlighted that schizotypal traits predict a decrease in attentional engagement to sadness emotions and this attentional engagement decrease predicts response times when presenting sad faces. This slowing processing speed linked to an altered gaze pattern could leading to difficulties in everyday life social situations where the information processing must be rapid to enable successful processing of higher level processes such as the interpretation of the intentions of others.

Keywords:

Schizotypy, Facial emotion recognition, Eye movements, Personality disorders, Schizotypal Personality Questionnaire

Highlights:

- Schizotypal traits were associated with less accurate surprise recognition.
- Altered visual exploration of sad faces was related to schizotypal traits.
- Schizotypal traits impact attentional engagement in facial features.
- Schizotypal traits were the only significant predictor of gaze patterns.
- Depressive symptoms predicted surprise recognition accuracy but not gaze patterns.

1. Introduction

Over the past two decades, social cognition has become a central topic of research, mainly owing to its impact on daily functioning and quality of life, thus leading to an increase in social cognition-based remediation techniques (Fernández-Sotos et al., 2018). *Social cognition* refers to mental processes involved in social interaction, namely perceiving, integrating and responding to one's own and others' representations in a specific context or environment (Beer & Ochsner, 2006). Facial emotion recognition (FER) is a core component of social cognition (Green et al., 2015). The ability to accurately perceive facial emotions in others is critical for effective social interaction, and disturbances can lead to misinterpretations and inappropriate social interactions (Lee, 2022).

A large number of studies have shown that FER impairment is a robust feature of schizophrenia in all phases of the illness, and contributes to poor interpersonal communication and social functioning (Doop & Park, 2009; Fett et al., 2011; Tan et al., 2018). People with schizophrenia exhibit impaired recognition of negative emotions such as sadness and anger and, less consistently, of positive emotions (e.g., Martin et al., 2020). These impairments are negatively correlated with their negative and positive symptoms (Fett & Maat, 2013; Martin et al., 2020). FER deficits are also observed in the first episode of schizophrenia (e.g., Green et al., 2012), first-degree relatives of patients with schizophrenia (Kohler et al., 2014), and individuals at high clinical and psychometric risk of psychosis (Addington et al., 2012; Statucka & Walder, 2017), suggesting that FER impairment is a trait marker of this disorder, if not a vulnerability factor for schizophrenia spectrum disorders (Brown & Cohen, 2010). It would therefore be advantageous to pinpoint social cognition impairments in individuals with high susceptibility for the development of schizophrenia spectrum disorders. In this regard, FER is a key dimension to explore and could help to promote the early detection of schizophrenia spectrum disorder and implementation of more effective prevention strategies.

Schizotypy refers to a set of personality traits characterized by three dimensions of symptoms englobing cognitive/perceptual or positive behaviors (unusual perceptions, kinesthetic hallucinations), interpersonal or negative behaviors (apathy, social isolation), and disorganization behaviors (eccentric behaviors, thought distortion). This dimensional approach considers that these traits lie on a continuum, where the extreme form is schizophrenia. Schizotypy is conceptualized as the nonclinical manifestation of the same underlying genetic, neurological, and environmental risk factors observed in schizophrenia and other schizophrenia spectrum disorders (Hazlett et al., 2015; Morton et al., 2017). Longitudinal studies indicate that high schizotypal personality traits (SPTs) at baseline are significant predictors of the development of schizophrenia spectrum disorders at follow-up (Chapman et al., 1994; Tandon et al., 2012). Since FER impairments are potential vulnerability markers for schizophrenia, it is particularly important to explore FER abilities in nonclinical individuals with SPTs, especially since this has the advantage of avoiding the confounding effects of medication and illness duration in schizophrenia.

Several studies have shown that individuals with high SPTs have impaired FER abilities compared with control samples (e.g., Statucka & Walder, 2017). As in schizophrenia spectrum disorders, but to a lesser extent (Bortolon et al., 2016; Brown & Cohen, 2010), they have been found to present a *negative bias*, with a greater tendency to label emotions as negative (Statucka & Walder, 2017). However, some studies have failed to demonstrate any FER deficit in schizotypy (van 't Wout et al., 2004). These mixed findings are probably due to methodological variability (i.e., FER measurement and schizotypy definition). Where FER deficits have been observed in individuals with SPTs, the authors have highlighted a positive correlation between these deficits and disorganized traits (Statucka & Walder, 2017). However, some studies have reported links between FER deficits and either interpersonal symptoms (Abbott & Green, 2013) or all type of symptoms (Germine & Hooker, 2011). In addition, whilst interpersonal traits were found to be negatively correlated with the recognition of negative emotions, disorganized traits, in turn, showed a positive correlation with the recognition of negative emotions (Dawes et al., 2021). Thus, the impact of schizotypy dimensions (cognitive/perceptual, interpersonal and/or disorganized) on FER abilities in individuals with high SPTs and the nature of any possible link remain unclear in the literature (Abbott & Green, 2013; Dawes et al., 2021; Statucka & Walder, 2017).

FER is related to the integration of visuospatial processes and specific eye movement patterns (Duchowski, 2002). Based on the synchronized online capture of fixations and saccades (Bruneau et al., 2002), eye-tracking has become a commonplace technique, providing a relatively direct and continuous measurement of overt visual attention (Kołakowska et al., 2020). It is highly useful, as it captures the spatial (e.g., distance between fixations), temporal (e.g., fixation duration) and spatiotemporal (e.g., fixations on relevant facial features) variables of gaze with great precision (Rayner, 2009). Research has highlighted eye movement abnormalities during the processing of facial emotion in several pathologies, including a reduced or increased scanpath length, and active avoidance of gaze in autism spectrum disorder (Black et al., 2017; de Vries et al., 2021) social phobia (Horley et al., 2004), bipolar disorder (Peckham et al., 2016), and schizophrenia spectrum disorder (Loughland et al., 2002).

Patients with schizophrenia have a more restricted visual scanpath, longer fixation durations, and focus less their attention on salient facial features such as the eyes or mouth) during FER processing. Loughland et al. (2002) observed avoidance of facial features for both happy and sad expressions compared to neutral expressions in schizophrenia. Moreover, Jang et al. (2016) highlighted preservation of initial orientation of attention (initial fixation) in schizophrenia, but difficulties in late attentional processes. Studies of individuals with schizophrenia have shown that social functioning difficulties are correlated with positive symptoms and poorer FER abilities (Nikolaides et al., 2016), and are especially associated with visual scanpath alterations during the processing of negative emotions (Jang et al., 2016). Given its valuable contribution in different clinical contexts, eye-tracking seems a promising technique for investigating the gaze patterns of individuals with high SPTs during FER, and could help to overcome the lack of clarity about the nature of FER alterations in this population (Blondon & Lovis, 2015).

Indeed, Eye-tracking studies have highlighted altered eye movement behaviors in individuals with high SPTs (Faiola et al., 2020; Metropoulou et al., 2011). However, , only one Eye-tracking study has investigated the processing of facial features during a non-emotional face recognition task, pointing to negative correlations between SPTs and both, the duration of fixations on the eyes and scanpath length, and facial recognition performances (Hills et al., 2016). Despite these differences in oculomotor behavior during the processing of non-emotional facial features, no eye-tracking study has yet investigated FER performances in individuals with high SPTs, even though exploring differences in spatial and/or temporal oculomotor features during emotion processing would help to better characterize typical and atypical gaze behavior in individuals with high SPTs.

In addition, FER accuracy can be negatively impacted by anxiety and depressive symptoms (Köther et al., 2018) and alexithymia (Larøi et al., 2007). Eye movement patterns are also affected by these emotional disturbances. For example, a review of eye-tracking studies among participants with major depression highlighted a significant decrease in fixation duration for positive emotional stimuli and an increase for negative ones (Suslow et al., 2020). Likewise, schizotypy is associated with increased levels of anxiety, depressive symptoms, and alexithymia (Kemp et al., 2018; Larøi et al., 2008), especially when individuals exhibit disorganized traits (Kemp et al., 2018; Larøi et al., 2008). However, these emotional variables are rarely considered or controlled in studies exploring FER in individuals with SPTs. Thus, given their impact on gaze behavior and emotion recognition, the failure to take account of these variables in previous research could explain the absence of consensus and mixed findings in the literature. For this reason, we decided to specifically analyze the impact of these variables on FER performances in participants with SPTs, and more particularly on the spatial and temporal oculomotor correlates of FER processes.

The aim of this study was thus to test the hypothesis of altered gaze behavior associated with FER through the recording of eye movements in individuals exhibiting SPTs from a dimensional perspective. For this purpose, we assessed levels of psychometric SPT in a non-clinical population, and measured frequently associated emotional difficulties (anxiety, depressive symptoms, alexithymia). We predicted that schizotypy, as measured by the Schizotypal Personality Questionnaire (SPQ; Raine, 1991), would be correlated with FER abilities on the behavioral level. Furthermore, we expected the SPQ score to correlate with spatial and temporal variables of gaze behavior during FER. More precisely, we predicted that the higher the SPQ score, the longer the fixation duration, and the lower the interest in key areas of interest, specifically the eyes. We also explored initial orienting of attention (four initial fixations on areas of interest) and subsequent attentional engagement (overall number and durations of fixations on areas of interest during each trial), given previous observations in schizophrenia (Jang et al., 2016). Regarding the dimensions of the SPQ, the strongest correlations should be observed for the interpersonal and disorganized dimensions (Abbott & Green, 2013; Dawes et al., 2021; Germine & Hooker, 2011, Statucka & Walder, 2017), however, no consensus has yet been reached in the literature. Therefore, the associations between SPQ dimensions and FER for behavioral and eye-tracking data will be studied for exploratory purposes.

Finally, we expected the behavioral and oculomotor alterations during FER in individuals with SPTs to persist, even after controlling for emotional confounds (i.e., anxiety, depressive symptoms, and alexithymia).

2. Method

2.1. Participants and Procedure

A total of 83 nonclinical participants took part in the experiment, all undergraduates from the University of Reims Champagne-Ardenne. All of them reported that they had normal or corrected-to-normal vision. Exclusion criteria were any recent history of substance abuse, history of neurological disorders, diagnosis of psychiatric illness (personal or first-degree relatives), and current psychotropic medication. No participants had been diagnosed with schizophrenia or schizotypal personality disorder. The study used a correlation design. Sample size was determined through the 3.1 version of G*Power3 (Faul et al., 2007). With an expected medium to large effect size and the significance level fixed at .05, at least 67 participants had to be recruited to reach the sufficient statistical power of .80. The study protocol was approved by the local ethics committee of the Cognition, Health and Society laboratory, University of Reims Champagne-Ardenne (no.: CERi-2018-4) and was conducted in accordance with the Declaration of Helsinki. All participants gave their written informed consent to participate in the study, after receiving a detailed explanation of the procedures and goals.

2.2. Measures

2.2.1. Questionnaires

To assess SPTs, participants were asked to complete the self-report Schizotypal Personality Questionnaire (SPQ) (Raine, 1991). This questionnaire consists of 74 items with binary yes/no responses, and nine subscales reflecting the nine SPTs listed in the Diagnostic and Statistical Manuel of Mental Disorders - IV (DMS-IV, American Psychological Association, 1994). There are three main subfactors: cognitive/perceptual (ideas of reference, magical thinking, unusual perceptual experiences, paranoid ideation), interpersonal (social anxiety, no close friends, blunted affect), and disorganization (odd behavior, odd speech). The French version of the SPQ used in this study (Dumas et al., 1999, 2000) has high internal reliability (Cronbach’s alpha = 0.91).

All participants were screened for depressive symptoms using the Beck Depression Inventory (Beck et al., 1998), for anxiety with the State-Trait Anxiety Inventory (Spielberger et al., 1970), and for alexithymia with the Toronto Alexithymia Scale (Bagby et al., 1994).

All participants completed the questionnaires after the eye-tracking paradigm.

2.2.2. Eye-tracking paradigm

The stimuli were 42 photographs (6 of each emotion, plus 6 neutral expressions) selected from the Karolinska Directed Emotional Faces set (Lundqvist et al., 1998). This electronic database contains colored, equiluminant photographs of the six primary emotions (*i.e.,* anger, disgust, fear, happiness, sadness, surprise) plus neutral expressions. The selected photographs had the highest interrater agreement for expression categorization (Lundqvist et al., 1998). Each face was presented once, for 3 s, and was followed by a screen showing seven emotion labels. Participants were told to use a mouse to select the emotion that best described the facial expression they had just seen on the screen. They were allowed to take as much time as they needed to make their decision but were instructed to be as quick and accurate as possible. They received no feedback. Response accuracy and response times were recorded for each face. The testing phase was preceded by a short training phase (seven practice trials, one for each label). This task was programmed in Experiment Builder v 2.1.512 (SR Research Ltd., Ontario, Canada). We used EyeLink Data Viewer 3.2. software to collect oculomotor variables.

Stimuli were presented on a 27-inch LCD monitor. The position of the left eye was recorded using an EyeLink 1000 tower-mounted eye tracker (SR Research Ltd, Canada), with a monocular sampling rate of 1000 Hz and mean spatial accuracy of ~.25–.50°. A chin- and forehead rest was used to stabilize the head and positioned at 95 cm from the screen. For each participant, an initial tracker calibration was performed, in which participants sequentially fixated nine target points on the screen. Calibrations were not accepted until the average spatial error was less than 0.49°, and the maximum error was less than 0.99°. The saccade velocity threshold was set to 30 ms and the acceleration threshold to 8000 ms.

At the beginning of each trial, participants were instructed to fixate the center of the screen, and the presentation of each stimulus was only initiated when the participant maintained the fixation on a central cross area (± 0.75°). During the experiment, each trial was preceded by a drift correction to ensure that the accuracy of the calibration parameters was maintained. When the drift error exceeded 1°, the trial was only continued after further calibration (Holmqvist et al., 2011). The experimenter was present in the room and monitored the stimulus presentation and eye-tracking data collection throughout the experiment.

2.3. Data analysis

As behavioral data, we collected the recognition accuracy and response time for each emotion.

Regarding eye-tracking, eye movement data in which there was a loss of tracking integrity, *off screen* gazes, or fixation outliers with durations greater than 2000 ms were automatically excluded (see supplementary data S1 and S2 for number and percentage of cleaned data).

Areas of interest were mapped onto the face images individually, using DataViewer 3.2 software®, as shown in Figure 1. The areas of interest chosen were based on facial features that are typically used in the literature (e.g., Hills et al., 2016): eyes, nose, and mouth.

Figure 1. A face image used in this experiment with five areas of interest mapped onto it: (a) forehead; (b) eyes; (c) nose; (d) mouth; (e) chin and cheeks. The relevant facial features (eyes, nose, mouth) are framed in yellow, and the nonrelevant feature areas (forehead, chin and cheeks) are framed in white. Color should be used online only.

Regarding eye-movement measures, we decided to compute two spatiotemporal indices as the variables of primary interest in this study: the proportion of the durations of the four initial fixations on relevant facial features (eyes, nose, mouth) relative to total fixation durations on the face and the proportion of total dwell time on relevant facial features (eyes, nose, mouth) relative to total dwell time on the face. These spatiotemporal indices give insight into different stages of attentional processing. Whilst the proportion of the four initial fixations is commonly considered to reflect the initial orienting of attention (e.g., Armstrong et al., 2012), total dwell time reflects processes of sustained attentional engagement over the whole trial-period (e.g., Peckham et al., 2017). To ascertain that potential differences for spatiotemporal indices were specifically related to the processing of relevant facial features for emotional processing (areas of interest) and not to differences regarding the processing and the allocation of attention to the photographs in general, we also collected the mean number of fixations and the mean fixation durations for the whole face for each emotion.

For spatiotemporal indices, normalized proportions of eye-movement measures were computed to correct for the size of areas of interest which could vary across trials. A higher proportion of fixations may fall on larger areas of interest due to mere chance. Computing normalized proportions of fixation durations and total dwell time allows to control for this confound. To this purpose, we computed the proportion of each area of interest relative to the total size of each face in pixels on a trial-to-trial basis and subtracted this value from the proportion of the durations of the four initial fixations and from the proportion of total dwell time (see Zelinsky & Schmidt, 2009). A proportion of zero reflects a random allocation of gaze to the area of interest. Positive proportions indicate that the area of interest is more often and/or longer fixated than would be expected by random chance. Conversely, negative proportions indicate that the area of interest is less often and/or less longer fixated than would be expected by random chance.

All statistical analyses were performed using SPSS 24 (IBM Corp., Armonk, NY, USA). We used descriptive statistics to summarize the data and Spearman correlations coefficients to explore the relationships between the variables of interest. To avoid multiplying the number of correlations, we proceeded as follows: first, correlations between the SPQ total score and behavioral and eye-tracking measures were computed, then correlations with the SPQ subfactors were investigated, but only for significant correlations. Furthermore, Spearman correlations assessed the potential links of significant behavioral and oculomotor emotion recognition measures with anxiety, depressive symptoms and alexithymia. Finally, multiple regression analyses were used to test for the predictive value of SPQ scores for significant behavioral and oculomotor emotion recognition measures compared to age, education level, depressive symptoms, anxiety and alexithymia. Multiple regression analyses also tested for the predictive value of significant eye-tracking variables for behavioral emotion recognition measures (accuracy and response time).

Bonferroni corrections for multiple comparisons were applied to all correlational analyses. The results and discussion sections present the results which remained significant after applying corrections. A *p* value of .05 was considered statistically significant.

3. Results

3.1. Sample Characteristics

The sample comprised 30 men and 53 women, aged 18-25 years (M_{age}: 19.83 ± 1.85), with a mean education level of 12.82 ± 1.08 years (range: 12-17). The participants' characteristics are set out in Table 1.

One-sample *t* tests indicated that participants' mean SPQ scores did not differ significantly from the mean scores reported in the validation study (Raine, 1991), indicating that our sample was representative of psychometric schizotypal traits in the general population, $t(82) = 0.643$, $p = .522$.

Table 1

Demographic and psychological measures (*N* = 83).

Variable	Mean (*SD*)	Range
Age	19.82 (1.86)	[18–25]
Sex (M/F)	30/53	
Education level (in years)	12.81 (1.08)	[12–17]
SPQ		
Total	28.02 (15.93)	[1–58]
Interpersonal	10.28 (6.72)	[0–24]
Cognitive-perceptual	8.13 (5.44)	[0–20]
Disorganized	6.40 (4.59)	[0–15]
Beck Depression Inventory	5.49 (4.57)	[0–20]
State-Trait Anxiety Inventory		
Part A	29.82 (7.70)	[20–48]
Part B	41.30 (11.03)	[21–66]
Toronto Alexithymia Scale -20	47.31 (11.95)	[21–74]

Note: SPQ = Schizotypal Personality Questionnaire.

3.2. Correlation Analyses Between SPQ Scores and Behavioral Data (Accuracy and Response Time)

These correlation analyses are set out in Table 2. Descriptive statistics (means and standard deviations) for the behavioral data are included as Supplemental Material (Table S3).

After applying Bonferroni corrections, the total SPQ score showed a significant negative correlation with the surprise accuracy score (r = -0.38, p = .035), indicating that higher SPQ scores were associated with lower recognition accuracy scores for the emotion of surprise (Fig. 2A). More in-depth correlation analyses between the three SPQ subfactors and surprise accuracy scores indicated that surprise recognition accuracy was significantly associated with the interpersonal (r = -0.34, p = .035) and disorganized subfactors of the SPQ (r = -0.35, p = .029), but was not related to the cognitive/perceptual subfactor (r = -0.26, p = .382). When applying Bonferroni corrections, there were no significant associations between the total SPQ score and recognition accuracy for the other emotions we investigated (all *ps* > .142).

We found no significant correlations between the total SPQ score and either overall response times (p = .999) or response times for specific emotions (all *ps* > .722).

Table 2

Spearman correlation coefficients between SPQ total scores, behavioral and eye-tracking measures during the emotion recognition task (N = 83).

	Anger	Disgust	Happiness	Surprise	Fear	Sadness	Neutral
Behavioral variables							
Accuracy score (in %)	-.022	-.260 *	-.013	**-.378** ***	-.102	.044	-.193
Response time (in ms)	.031	.080	.187	.144	.036	.070	.086
Eye-tracking variables							
Initial fixation durations [a]	-.015	.181	.177	-.075	.175	-.017	.058
Total dwell time [b]	-.152	-.272*	-.228	-.118	-.189	**-.296***	-.158

Note: * p < .05; ** p < .01; *** p < .001
P values were adjusted for multiple comparisons with Bonferroni corrections. Significant correlations after correction are shown in bold (p < .05).

[a] Normalized proportions of initial fixation durations on relevant facial features (eyes, mouth, nose) relative to total fixation durations on the face.
[b] Normalized proportions of total dwell time on relevant facial features (eyes, mouth, nose) relative to total dwell time on the face.

3.3. Correlation Analyses Between the Total SPQ Score and Eye-Tracking Variables

These correlation analyses are set out in Table 2. Descriptive statistics (means and standard deviations) for the eye-tracking measures are included as Supplemental Material (Table S4).

3.3.1. Initial orienting of attention

No significant correlations emerged between the SPQ total score and the normalized proportion of the four initial fixation durations (all *ps* > .705), whichever type of emotion was investigated.

3.3.2. *Attentional engagement*

The SPQ total score was negatively correlated with the normalized proportion of total dwell time for sadness after applying Bonferroni corrections (*r* = -0.30, *p* = .047), indicating that a higher SPQ total score was associated with a lesser tendency to fixate on relevant facial features (eyes, nose, mouth) during sadness recognition (Fig. 2B). Subsequent correlation analyses between the SPQ subfactors and the normalized proportion of total dwell time for sadness indicated that this link was global in nature. No single SPQ subfactor was significantly associated with the normalized proportion of total dwell time for sadness even though the interpersonal (*r* = -0.26, *p* = .059) and positive (*r* = -0.25, *p* = .071) SPQ subfactors were close to significance. Furthermore, regarding specific areas of interest, no single area of interest was significantly associated with the total SPQ score in terms of normalized proportions of total dwell time during sadness recognition (all *p*s > .074).

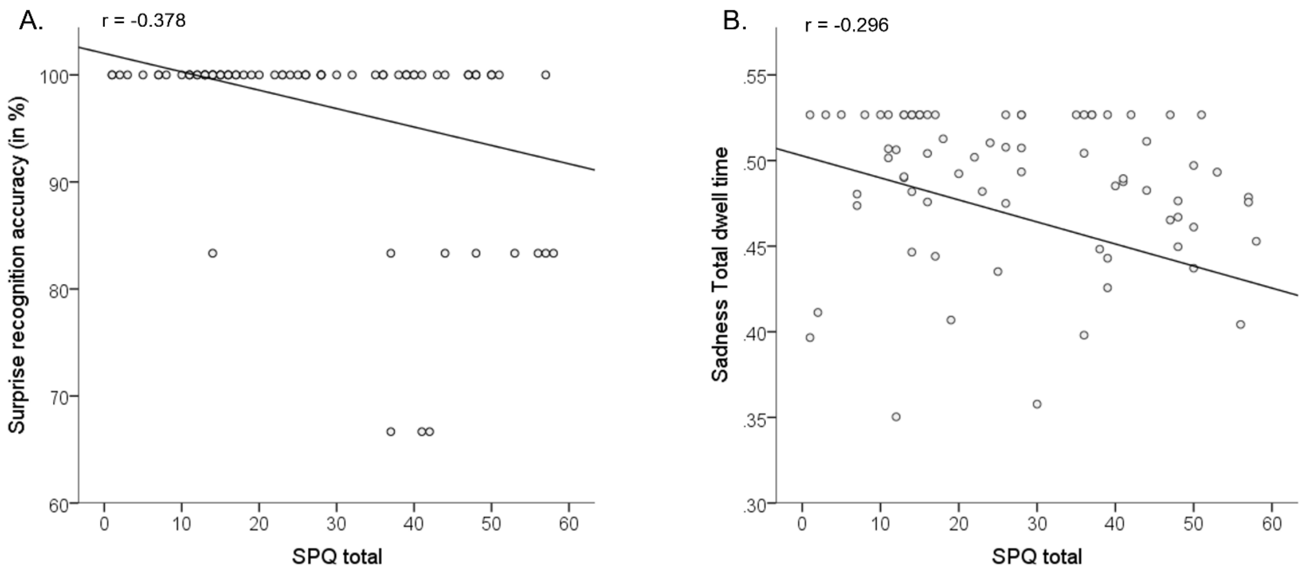

Figure 2. Scatter plots showing significant correlations between SPQ total scores and behavioral and eye-tracking measures. A. Correlations between SPQ total scores and surprise recognition accuracy. B. Correlations between SPQ total scores and total dwell time for sadness recognition (i.e., the normalized proportion of total dwell time on relevant facial features relative to total dwell time on the face).

3.3.3. Mean number of fixations and fixation durations

No significant correlations emerged between the SPQ total score and either the mean number of fixations (all *p*s > .221) or the mean fixation duration (all *p*s > .875), whichever type of emotion was investigated. Hence, the differences observed for the normalized proportion of total dwell time during sadness recognition seem to be specifically related to the processing of relevant facial features (eyes, nose, mouth) rather than to differences regarding the general overall processing of emotional faces.

3.4. Correlations of Significant Emotion Recognition Measures with Depressive Symptoms, Anxiety, and Alexithymia

SPQ total scores were positively correlated with depressive symptoms on the Beck Depression Inventory ($r = 0.67$; $p < .001$), anxiety on the State-Trait Anxiety Inventory part – B ($r = 0.60$; $p < .001$), and alexithymia as measured by the Toronto Alexithymia Scale - 20 ($r = 0.60$; $p < .001$).

Surprise recognition accuracy scores were negatively correlated with alexithymia ($r = 0.29$, $p = .023$), depressive symptoms ($r = -0.37$; $p = .002$) and anxiety ($r = -0.37$; $p = .002$).

The normalized proportion of total dwell time during sadness recognition was negatively correlated with alexithymia ($r = -.034$, $p = .005$) and anxiety ($r = -0.30$, $p = .019$) but unrelated to depressive symptoms ($r = -0.19$, $p = .250$).

3.6. Regression Analyses

3.6.1 Predictive value of SPQ scores for significant behavioral and oculomotor emotion recognition measures

To investigate whether SPQ total scores were a significant predictor of behavioral performances and gaze pattern, we carried out multiple regression analyses. This step also allowed us to assess whether SPQ scores significantly contributed to the regression models compared to other affective variables (*i.e.*, depressive symptoms, trait anxiety, alexithymia) that were shown to be positively correlated with total SPQ scores and negatively correlated with emotion recognition measures in our sample.

Two multiple stepwise linear regression models were computed, one for each significant behavioral or oculomotor emotion recognition measure that was shown to be correlated with SPQ total scores: surprise recognition accuracy scores and the normalized proportion of total dwell time during sadness recognition (Table 3). Each model included age, education level (in years) and the total scores on the Beck Depression Inventory, the State-Trait Anxiety Inventory part - B, the Toronto Alexithymia Scale - 20 and the SPQ total score as predictors, and one of the previously significant emotion recognition measures as the dependent variable. At each step, variables were included in the model based on *p* values ($\alpha_E = 0.05$, $\alpha_R = 0.10$).

The regression analysis on behavioral results indicated that depressive symptoms, but not the SPQ total score, were the only significant predictor of surprise recognition accuracy, $F(1, 81) = 11.86$, $p = .001$, $R^2 = 0.128$.

Conversely, for eye-tracking measures, the results revealed that the SPQ total score was the only significant predictor of the normalized proportion of total dwell time during sadness recognition, $F(1, 81) = 5.14$, $p = 0.026$, $R^2 = 0.060$.

Table 3
Multiple regression analyses assessing the predictors of significant behavioral and eye-tracking measures (*N* = 83).

Variables	β	*t*	*p*
Model 1: Surprise recognition accuracy score (in %) [a]			
Age	0.076	0.72	.473
Education level (in years)	-0.063	-0.60	.552
Beck Depression Inventory	**-0.357**	**-3.44**	**.001****
State-Trait Anxiety Inventory - Part B	-0.136	-0.88	.382

Toronto Alexithymia Scale - 20	-0.110	-0.93	.356
SPQ total	-0.209	-1.51	.136
Model 2: Sadness Total dwell time on areas of interest (Normalized proportion) [b]			
Age	0.072	0.65	.515
Education level (in years)	0.074	0.66	.513
Beck Depression Inventory	0.120	0.83	.411
State-Trait Anxiety Inventory - Part B	-0.031	-0.22	.824
Toronto Alexithymia Scale - 20	-0.099	-0.74	.464
SPQ total	**-0.244**	**-2.27**	**.026***

Note: SPQ = Schizotypal Personality Questionnaire. Significant predictors of behavioral and eye-tracking variables are highlighted in bold.

* $p < .05$; ** $p < .01$

[a] $F(1, 81) = 11.86$, $p = .001$, $R^2 = 0.128$, adjusted $R^2 = 0.117$
[b] $F(1, 81) = 5.14$, $p = 0.026$, $R^2 = 0.060$, adjusted $R^2 = 0.048$

3.6.2 Predictive value of significant oculomotor measures for behavioral outcomes

If oculomotor measures reflect attentional processing, they most likely contribute to behavioral outcomes (König et al., 2016). We therefore conducted two multiple regression analyses to assess if the eye-tracking measure which showed a significant link with SPQ total scores in this study (normalized proportion of total dwell time during sadness recognition) was a significant predictor of behavioral outcomes (sadness recognition response accuracy, response time for sadness recognition), compared with age, education level, depressive symptoms, anxiety, alexithymia, and SPQ total scores.

As can be seen in Table 4, only age significantly predicted sadness recognition accuracy, indicating higher response accuracy in older participants in our sample, $F(1, 81) = 4.74$, $p = .032$, $R^2 = 0.055$. Conversely, normalized proportion of total dwell time significantly predicted the response time for sadness recognition, indicating that shorter dwell times on relevant facial features were associated with longer response times during sadness recognition, $F(1, 81) = 7.30$, $p = 0.008$, $R^2 = 0.083$.

Table 4

Multiple regression analyses assessing the predictive value of significant eye-tracking measures for behavioral outcomes (*N* = 83).

Variables	β	*t*	*p*
Model 1: Sadness recognition accuracy score (in %) [a]			
Age	**0.235**	**2.18**	**.032***
Education level (in years)	0.023	0.16	.870
Beck Depression Inventory	-0.002	-0.02	.987
State-Trait Anxiety Inventory - Part B	0.040	0.37	.714
Toronto Alexithymia Scale - 20	-0.016	-0.15	.883
SPQ total	0.114	1.03	.306
Sadness Total dwell time	0.052	0.47	.637
Model 2: Sadness Response time (in ms) [b]			
Age	0.022	0.21	.837
Education level (in years)	0.060	0.56	.578
Beck Depression Inventory	0.077	0.72	.473
State-Trait Anxiety Inventory - Part B	0.003	0.30	.976
Toronto Alexithymia Scale - 20	-0.019	-0.18	.861
SPQ total	-0.003	-0.03	.977
Sadness Total dwell time	**-0.288**	**-2.70**	**.008****

Note: SPQ = Schizotypal Personality Questionnaire. Significant predictors of behavioral variables are highlighted in bold.

* $p < .05$; ** $p < .01$

[a] $F(1, 81) = 4.74$, $p = .032$, $R^2 = 0.055$, adjusted $R^2 = 0.044$
[b] $F(1, 81) = 7.30$, $p = 0.008$, $R^2 = 0.083$, adjusted $R^2 = 0.071$

4. Discussion

This study was the first to explore eye movement patterns during FER in individuals with SPTs, and to consider the contribution of common emotional difficulties such as anxiety, depressive symptoms, and alexithymia.

4.1. FER accuracy and schizotypal traits

At the behavioral level, we predicted that SPTs would be associated with reduced FER accuracy, especially for negative emotions. However, results only partly supported this initial hypothesis, as the behavioral data only highlighted one significant correlation between SPTs and FER accuracy, for surprise recognition. Higher SPQ scores were significantly associated with poorer performances on surprise recognition. Given that surprise can be interpreted as either a positive or a negative stimulus, it may constitute an ambiguous target for people with SPTs (Fontaine et al., 2007). These findings are in line with Brown & Cohen (2010), who found that implicit and ambiguous emotional stimuli, such as surprise, elicited less accurate responses from participants with schizotypal personality disorder. However, we did not observe any association between schizotypy and the recognition of other emotions, in contrast to other studies (e.g., Dawes et al., 2021). Inconsistent findings probably stem from methodological variability. Some previous studies did not distinguish between results for each primary emotion, and often adopted a categorical approach, comparing individuals according to their SPQ score, such that they roughly represented the top and bottom 10% of the sample (e.g., Brown & Cohen, 2010; Williams et al., 2007).

In addition, in our study, surprise accuracy was associated with disorganized and interpersonal symptoms. These results are in line with previous research on FER and SPTs (Statucka & Walder, 2017), and support the idea that disorganized (eccentric behaviors, thought distortion) and interpersonal (apathy, social isolation) SPTs have a substantial impact on FER abilities, here for surprise (Abbott & Green, 2013).

4.2. Gaze patterns during facial emotional processing and schizotypal traits

Regarding patterns of visual exploration during FER, we also hypothesized that SPTs would be associated with longer fixation durations and less interest in key areas of interest.

To that regard, we did not find any correlation between SPTs and the four initial fixations, thus underlining that SPTs does not appear to be associated with changes in the initial orientation of attention when exploring FERs.

Our results however showed that SPTs are associated with decreased normalized of total dwell-time spent on relevant facial areas for sadness. This suggests that people with high SPQ scores have more difficulty maintaining attention during the exploration of relevant key areas (eyes, nose, and mouth), thus highlighting an attentional bias toward nonrelevant facial features for sadness. These results may indicate a tendency to avoid facial AOIs expressing feelings of sadness. In addition, independent to the dimensions (interpersonal, disorganized, cognitive-perceptual), higher SPTs are the only predictor of lesser time spent on key AOI (eyes, mouth, nose) for the emotion of sadness leading to collect less emotional cues. It is noteworthy that this attentional bias is consistent with previous research showing similar results toward irrelevant facial features during FER of sadness in patients with schizophrenia, compared with controls (Jang et al., 2016). Once again, this lends support to the hypothesis that SPTs lie on the same continuum as schizophrenia spectrum disorders and may share common symptoms and related difficulties in daily life.

Moreover, while the normalized proportion of total dwell time does not predict percentages of correct responses for sadness emotions, it is the only predictor of response times when presenting sad faces. Moreover, the SPTs are in turn the only predictor of the lack of sustained attentional engagement on the relevant areas of faces of sadness. Thus, the higher the schizotypal traits would be, the less participants with high SPTs look at the sad faces and the longer their response time is. While further research is required to confirm these results, we could nonetheless hypothesize that this longer response time could impact daily functioning. Indeed, considering the complexity of ecological social situation and the number of psychological processes involved (Achim, 2020), quickness could be the key to act on time. People with SPTs, even if capable to identify sadness as accurately as controls, could thus be encountered difficulties in everyday life situations because of the time they needed to process social cues.

Furthermore, these differences in the visual exploration of sadness were observed even though SPTs were not linked to the accuracy of sadness recognition. Although these results might appear contradictory at first sight, it is important to bear in mind that the present study assessed SPTs in a nonclinical sample and that an association between SPTs and recognition accuracy scores may only emerge when individuals transition to a psychopathological state and meet the diagnostic criteria for schizotypal personality disorder and/or schizophrenia spectrum disorder. Prior to this stage, individuals at high risk for schizophrenia spectrum disorder may implement compensatory mechanisms to counteract the differential visual processing of sadness and anger, thereby normalizing recognition performances. In this context, it is noteworthy that no significant link with SPTs emerged for the other emotions investigated, which may therefore constitute a basis for emotion-centered remediation techniques in clinical schizotypy.

Concerning the SPTs' role, we found no dimension-specific correlation, but rather an overall SPQ score's negative impact on sustained attentional engagement during sadness recognition. These results contrast with those obtained in previous FER studies on SPTs, suggesting a stronger and more general impact of cognitive/perceptual (hallucinations, strange perceptions) and interpersonal symptoms (e.g., Abbott & Green, 2013). They are however in line with Germine and Hooker's data (2011), in which the author showed a global effect of SPTs on FER independently of face processing. Our study extended these results, by showing that SPTs are linked not only to FER accuracy, but also to the underlying patterns of visual exploration. Since our study was the first to use eye-tracking data to explore SPTs' impact on FER, further research on this topic is required in order to see if domains specific interactions could be found. On top of that, they should also confirm that schizotypy is characterized by avoidance of emotional cues. Eventually, the alterations found for participants with SPTs, regardless of their nature, is a sign for healthcare professionals to not underestimate their repercussions depending on the concerned domain or main symptoms.

4.3. Impact of affective symptoms and schizotypal traits on behavioral and eye-tracking measures

One strength of the present study assessing the link between SPTs and FER was that it explored the impact of emotional difficulties that are frequently associated with SPTs (anxiety, depressive symptoms, and alexithymia). Moreover, although authors have identified these difficulties as potentially disturbing FER processing (Claudino et al., 2019; Demenescu & Kortekaas, 2010; Starita et al., 2018; Suslow et al., 2020), few studies have explored their influence on FER in schizotypy (Dawes et al., 2021). On the behavioral level, we highlighted that depression and anxiety were negatively correlated with surprise recognition accuracy in our sample. Furthermore, depressive symptoms, but not SPQ dimensions, were the only significant predictor of surprise recognition accuracy. Prior studies did not always report on the potential impact of other affective measures which might also influence behavioral FER performances, as suggested by the contribution of depressive symptoms in our study. We would therefore like to encourage researchers to systematically screen for affective symptoms in their samples and to investigate their contribution to FER abilities. In contrast, regarding eye-tracking measures, anxiety, depressive symptoms, and alexithymia did not predict eye movement behavior in our study for sadness recognition (decreased normalized of total dwell-time spent on relevant facial areas for sadness.). Importantly, only global schizotypal traits (SPQ total score) significantly predicted these gaze patterns. In the literature, the relationship between schizotypal dimensions and FER remains inconclusive (e.g., Abbott & Green, 2013; Statucka & Walder, 2017; Williams et al., 2007). These could also influence gaze pattern during FER. Hence, whilst depressive symptoms are likely to contribute to behavioral recognition performances, SPTs seem to have the strongest impact on eye movements compared to other affective variables. This differential impact of SPTs on behavioral and eye-tracking measures might, however, be related to the non-clinical nature of our sample. Whilst subclinical SPTs might only lead to an alteration of gaze pattern without significant alteration of FER accuracy, people displaying clinical schizotypal personality disorder, may indeed show more behavioral FER alterations. The predominance of subclinical rather than pathological traits could also be an explanation for the current lack of consensus in the literature, considering that most of the studies on FER processing and SPTs are based on non-clinical cohorts (Abbott & Green, 2013; Dawes et al., 2021; Germine & Hooker, 2011, Statucka & Walder, 2017).

In this context, eye-tracking could constitute an interesting and promising method to explore the specific contribution of SPTs to FER abilities given that eye movement measures were only predicted by SPTs and might be less biased by participants' affective states. Measuring alterations of gaze pattern could be more informative than solely relying on behavioral clues in non-clinical samples.

4.4. Limitations

The present study had several limitations. First, the use of static material (photos) contrasted with dynamic face-to-face interactions. In dynamic real-life interactions, the facial features vary in intensity and provide additional clues for the interpretation of facial affect. However, it is worth noting that the use of more ecological media, such as videos, may not necessarily be more efficient than that of static stimuli when studying FER alteration (Fiorentini & Viviani, 2011; Kätsyri et al., 2008), especially with negative stimuli like anger (Recio et al., 2011). More research is therefore needed on this issue. Second, participants could not choose any response option before the end of the stimulus presentation time (3 seconds). Future studies using the same design should explore response times and eye-tracking metrics with paradigms using non-standardized presentation times in which participants can choose from response options during stimulus presentation. Thirdly, the nonclinical character of the experimental group and the dimensional approach we adopted limit the scope of the results for two reasons. Firstly, correlational approach generates many statistical tests. To reduce the biases regarding this approach we have determined sample size a priori using G*Power3 (Faul et al., 2007), 2), used Bonferroni corrections to reduce false positive risks and 3) only included significant factors to the regression models in order to reduce the number of variables. Secondly, although the sample included participants with high SPTs that could be considered a risk factor for the development of schizophrenia spectrum disorder, applying this protocol to a clinical sample diagnosed with schizotypal personality disorder might take these initial results one step further and indicate how far they can be generalized to clinical SPT conditions. Finally, the participants in our sample were undergraduates, and even though their SPQ scores were comparable to those reported in other studies, the present results need to be replicated with more diversified samples in terms of education level.

4.5. Conclusion

This was the first study to explore gaze behavior during FER in schizotypy from a dimensional perspective, to deepen our understanding of the impact of SPTs and at-risk states for schizophrenia spectrum disorders on FER processes through the use of eye-tracking. SPTs were associated with less accurate FER for surprise. In addition, SPTs seemed to impact the allocation of attentional resources to key areas of interest of the face (eyes, nose, mouth) during the processing of sadness, as indicated by lesser normalized proportion of total dwell time spent on relevant facial features. Interestingly, our results highlighted a general influence of SPTs on FER and eye movements. Furthermore, the emotional difficulties that are frequently associated with SPTs (anxiety, depressive symptoms, and alexithymia) were not associated with the alterations of gaze patterns in the present sample, leading us to suggest that SPTs are the main predictors of oculomotor FER alterations.

Although further research based on eye-tracking is needed among this population, the present study has already yielded valuable insights into the link between FER and SPTs. When it comes to social cognition alterations, and more precisely FER difficulties, it might be useful to consider these results when designing prevention techniques for individuals at high risk of developing schizophrenia spectrum disorder and improving intervention strategies for those with an established schizophrenia spectrum disorder diagnosis. In this vein, previous work has already underlined the efficiency of emotional remediation techniques (Tan et al., 2018; Yamada et al., 2019), which can help to reduce attentional bias and improve quality of life (Brosey & Woodward, 2015). However, these interventions targeted individuals who had been diagnosed with schizophrenia spectrum disorder and who displayed particularly high proportions of negative traits (Kalin et al., 2015). Future studies will have to be conducted among individuals with clinical schizotypal personality disorder, to test whether these interventions are just as efficient among individuals with more subtle forms of the schizophrenic spectrum.

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Data availability statement:

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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