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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.

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

3

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.

1   Several studies have shown that individuals with high SPTs have impaired FER

2   abilities compared with control samples (e.g., Statucka & Walder, 2017). As in schizophrenia

3   spectrum disorders, but to a lesser extent (Bortolon et al., 2016; Brown & Cohen, 2010), they

4   have been found to present a *negative bias*, with a greater tendency to label emotions as

5   negative (Statucka & Walder, 2017). However, some studies have failed to demonstrate any

6   FER deficit in schizotypy (van 't Wout et al., 2004). These mixed findings are probably due to

7   methodological variability (i.e., FER measurement and schizotypy definition). Where FER

8   deficits have been observed in individuals with SPTs, the authors have highlighted a positive

9   correlation between these deficits and disorganized traits (Statucka & Walder, 2017).

10   However, some studies have reported links between FER deficits and either interpersonal

11   symptoms (Abbott & Green, 2013) or all type of symptoms (Germine & Hooker, 2011). In

12   addition, whilst interpersonal traits were found to be negatively correlated with the

13   recognition of negative emotions, disorganized traits, in turn, showed a positive correlation

14   with the recognition of negative emotions (Dawes et al., 2021). Thus, the impact of

15   schizotypy dimensions (cognitive/perceptual, interpersonal and/or disorganized) on FER

16   abilities in individuals with high SPTs and the nature of any possible link remain unclear in

17   the literature (Abbott & Green, 2013; Dawes et al., 2021; Statucka & Walder, 2017).

18   FER is related to the integration of visuospatial processes and specific eye movement

19   patterns (Duchowski, 2002). Based on the synchronized online capture of fixations and

20   saccades (Bruneau et al., 2002), eye-tracking has become a commonplace technique,

21   providing a relatively direct and continuous measurement of overt visual attention

22   (Kolakowska et al., 2020). It is highly useful, as it captures the spatial (e.g., distance between

23   fixations), temporal (e.g., fixation duration) and spatiotemporal (e.g., fixations on relevant

24   facial features) variables of gaze with great precision (Rayner, 2009). Research has

25   highlighted eye movement abnormalities during the processing of facial emotion in several

1   pathologies, including a reduced or increased scanpath length, and active avoidance of gaze in

2   autism spectrum disorder (Black et al., 2017; de Vries et al., 2021) social phobia (Horley et

3   al., 2004), bipolar disorder (Peckham et al., 2016), and schizophrenia spectrum disorder

4   (Loughland et al., 2002).

5   Patients with schizophrenia have a more restricted visual scanpath, longer fixation

6   durations, and focus less their attention on salient facial features such as the eyes or mouth)

7   during FER processing. Loughland et al. (2002) observed avoidance of facial features for both

8   happy and sad expressions compared to neutral expressions in schizophrenia. Moreover, Jang

9   et al. (2016) highlighted preservation of initial orientation of attention (initial fixation) in

10 schizophrenia, but difficulties in late attentional processes. Studies of individuals with

11 schizophrenia have shown that social functioning difficulties are correlated with positive

12 symptoms and poorer FER abilities (Nikolaides et al., 2016), and are especially associated

13 with visual scanpath alterations during the processing of negative emotions (Jang et al., 2016).

14 Given its valuable contribution in different clinical contexts, eye-tracking seems a promising

15 technique for investigating the gaze patterns of individuals with high SPTs during FER, and

16 could help to overcome the lack of clarity about the nature of FER alterations in this

17 population (Blondon & Lovis, 2015).

18   Indeed, Eye-tracking studies have highlighted altered eye movement behaviors in

19 individuals with high SPTs (Faiola et al., 2020; Metropoulou et al., 2011). However, , only

20 one Eye-tracking study has investigated the processing of facial features during a non-

21 emotional face recognition task, pointing to negative correlations between SPTs and both, the

22 duration of fixations on the eyes and scanpath length, and facial recognition performances

23 (Hills et al., 2016). Despite these differences in oculomotor behavior during the processing of

24 non-emotional facial features, no eye-tracking study has yet investigated FER performances

25 in individuals with high SPTs, even though exploring differences in spatial and/or temporal

1   oculomotor features during emotion processing would help to better characterize typical and

2   atypical gaze behavior in individuals with high SPTs.

3   In addition, FER accuracy can be negatively impacted by anxiety and depressive

4   symptoms (Köther et al., 2018) and alexithymia (Larøi et al., 2007). Eye movement patterns

5   are also affected by these emotional disturbances. For example, a review of eye-tracking

6   studies among participants with major depression highlighted a significant decrease in

7   fixation duration for positive emotional stimuli and an increase for negative ones (Suslow et

8   al., 2020). Likewise, schizotypy is associated with increased levels of anxiety, depressive

9   symptoms, and alexithymia (Kemp et al., 2018; Larøi et al., 2008), especially when

10   individuals exhibit disorganized traits (Kemp et al., 2018; Larøi et al., 2008). However, these

11   emotional variables are rarely considered or controlled in studies exploring FER in

12   individuals with SPTs. Thus, given their impact on gaze behavior and emotion recognition,

13   the failure to take account of these variables in previous research could explain the absence of

14   consensus and mixed findings in the literature. For this reason, we decided to specifically

15   analyze the impact of these variables on FER performances in participants with SPTs, and

16   more particularly on the spatial and temporal oculomotor correlates of FER processes.

17   The aim of this study was thus to test the hypothesis of altered gaze behavior

18   associated with FER through the recording of eye movements in individuals exhibiting SPTs

19   from a dimensional perspective. For this purpose, we assessed levels of psychometric SPT in

20   a non-clinical population, and measured frequently associated emotional difficulties (anxiety,

21   depressive symptoms, alexithymia). We predicted that schizotypy, as measured by the

22   Schizotypal Personality Questionnaire (SPQ; Raine, 1991), would be correlated with FER

23   abilities on the behavioral level. Furthermore, we expected the SPQ score to correlate with

24   spatial and temporal variables of gaze behavior during FER. More precisely, we predicted that

25   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

1 in accordance with the Declaration of Helsinki. All participants gave their written informed

2 consent to participate in the study, after receiving a detailed explanation of the procedures and

3 goals.

4 **2.2. Measures**

5 *2.2.1. Questionnaires*

6 To assess SPTs, participants were asked to complete the self-report Schizotypal

7 Personality Questionnaire (SPQ) (Raine, 1991). This questionnaire consists of 74 items with

8 binary yes/no responses, and nine subscales reflecting the nine SPTs listed in the Diagnostic

9 and Statistical Manuel of Mental Disorders - IV (DMS-IV, American Psychological

10 Association, 1994). There are three main subfactors: cognitive/perceptual (ideas of reference,

11 magical thinking, unusual perceptual experiences, paranoid ideation), interpersonal (social

12 anxiety, no close friends, blunted affect), and disorganization (odd behavior, odd speech). The

13 French version of the SPQ used in this study (Dumas et al., 1999, 2000) has high internal

14 reliability (Cronbach's alpha = 0.91).

15 All participants were screened for depressive symptoms using the Beck Depression Inventory

16 (Beck et al., 1998), for anxiety with the State-Trait Anxiety Inventory (Spielberger et al.,

17 1970), and for alexithymia with the Toronto Alexithymia Scale (Bagby et al., 1994).

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

19 *2.2.2. Eye-tracking paradigm*

20 The stimuli were 42 photographs (6 of each emotion, plus 6 neutral expressions) selected

21 from the Karolinska Directed Emotional Faces set (Lundqvist et al., 1998). This electronic

22 database contains colored, equiluminant photographs of the six primary emotions (*i.e.,* anger,

23 disgust, fear, happiness, sadness, surprise) plus neutral expressions. The selected photographs

24 had the highest interrater agreement for expression categorization (Lundqvist et al., 1998).

25 Each face was presented once, for 3 s, and was followed by a screen showing seven emotion

1 labels. Participants were told to use a mouse to select the emotion that best described the

2 facial expression they had just seen on the screen. They were allowed to take as much time as

3 they needed to make their decision but were instructed to be as quick and accurate as possible.

4 They received no feedback. Response accuracy and response times were recorded for each

5 face. The testing phase was preceded by a short training phase (seven practice trials, one for

6 each label). This task was programmed in Experiment Builder v 2.1.512 (SR Research Ltd.,

7 Ontario, Canada). We used EyeLink Data Viewer 3.2. software to collect oculomotor

8 variables.

9 Stimuli were presented on a 27-inch LCD monitor. The position of the left eye was

10 recorded using an EyeLink 1000 tower-mounted eye tracker (SR Research Ltd, Canada), with

11 a monocular sampling rate of 1000 Hz and mean spatial accuracy of ~.25–.50°. A chin- and

12 forehead rest was used to stabilize the head and positioned at 95 cm from the screen. For each

13 participant, an initial tracker calibration was performed, in which participants sequentially

14 fixated nine target points on the screen. Calibrations were not accepted until the average

15 spatial error was less than 0.49°, and the maximum error was less than 0.99°. The saccade

16 velocity threshold was set to 30 ms and the acceleration threshold to 8000 ms.

17 At the beginning of each trial, participants were instructed to fixate the center of the

18 screen, and the presentation of each stimulus was only initiated when the participant

19 maintained the fixation on a central cross area ($\pm 0.75°$). During the experiment, each trial

20 was preceded by a drift correction to ensure that the accuracy of the calibration parameters

21 was maintained. When the drift error exceeded 1°, the trial was only continued after further

22 calibration (Holmqvist et al., 2011). The experimenter was present in the room and monitored

23 the stimulus presentation and eye-tracking data collection throughout the experiment.

24 **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

1   four initial fixations on relevant facial features (eyes, nose, mouth) relative to total fixation

2   durations on the face and the proportion of total dwell time on relevant facial features (eyes,

3   nose, mouth) relative to total dwell time on the face. These spatiotemporal indices give insight

4   into different stages of attentional processing. Whilst the proportion of the four initial

5   fixations is commonly considered to reflect the initial orienting of attention (e.g., Armstrong

6   et al., 2012), total dwell time reflects processes of sustained attentional engagement over the

7   whole trial-period (e.g., Peckham et al., 2017). To ascertain that potential differences for

8   spatiotemporal indices were specifically related to the processing of relevant facial features

9   for emotional processing (areas of interest) and not to differences regarding the processing

10   and the allocation of attention to the photographs in general, we also collected the mean

11   number of fixations and the mean fixation durations for the whole face for each emotion.

12   For spatiotemporal indices, normalized proportions of eye-movement measures were

13   computed to correct for the size of areas of interest which could vary across trials. A higher

14   proportion of fixations may fall on larger areas of interest due to mere chance. Computing

15   normalized proportions of fixation durations and total dwell time allows to control for this

16   confound. To this purpose, we computed the proportion of each area of interest relative to the

17   total size of each face in pixels on a trial-to-trial basis and subtracted this value from the

18   proportion of the durations of the four initial fixations and from the proportion of total dwell

19   time (see Zelinsky & Schmidt, 2009). A proportion of zero reflects a random allocation of

20   gaze to the area of interest. Positive proportions indicate that the area of interest is more often

21   and/or longer fixated than would be expected by random chance. Conversely, negative

22   proportions indicate that the area of interest is less often and/or less longer fixated than would

23   be expected by random chance.

24   All statistical analyses were performed using SPSS 24 (IBM Corp., Armonk, NY,

25   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, $t(82) = 0.643$, $p = .522$.

1 **Table 1**

2 Demographic and psychological measures ($N = 83$).

3

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. 12

13 **3.2. Correlation Analyses Between SPQ Scores and Behavioral Data (Accuracy and**

14 **Response Time)**

15   These correlation analyses are set out in Table 2. Descriptive statistics (means and

16 standard deviations) for the behavioral data are included as Supplemental Material (Table S3).

17   After applying Bonferroni corrections, the total SPQ score showed a significant

18 negative correlation with the surprise accuracy score ($r = -0.38$, $p = .035$), indicating that

19 higher SPQ scores were associated with lower recognition accuracy scores for the emotion of

20 surprise (Fig. 2A). More in-depth correlation analyses between the three SPQ subfactors and

21 surprise accuracy scores indicated that surprise recognition accuracy was significantly

22 associated with the interpersonal ($r = -0.34$, $p = .035$) and disorganized subfactors of the SPQ

23 ($r = -0.35$, $p = .029$), but was not related to the cognitive/perceptual subfactor ($r = -0.26$, $p =$

24 .382). When applying Bonferroni corrections, there were no significant associations between

14

1. the total SPQ score and recognition accuracy for the other emotions we investigated (all *p*s >

2. .142).

3.   We found no significant correlations between the total SPQ score and either overall

4. response times (*p* = .999) or response times for specific emotions (all *p*s > .722).

5. **Table 2**

6. Spearman correlation coefficients between SPQ total scores, behavioral and eye-tracking
7. 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.

8.

9. **3.3. Correlation Analyses Between the Total SPQ Score and Eye-Tracking**

10. **Variables**

11.   These correlation analyses are set out in Table 2. Descriptive statistics (means and

12. standard deviations) for the eye-tracking measures are included as Supplemental Material

13. (Table S4).

14. *3.3.1. Initial orienting of attention*

15.   No significant correlations emerged between the SPQ total score and the normalized

16. proportion of the four initial fixation durations (all *p*s > .705), whichever type of emotion was

17. investigated.

3.3.2. Attentional engagement

2   The SPQ total score was negatively correlated with the normalized proportion of total

3   dwell time for sadness after applying Bonferroni corrections ($r = -0.30$, $p = .047$), indicating

4   that a higher SPQ total score was associated with a lesser tendency to fixate on relevant facial

5   features (eyes, nose, mouth) during sadness recognition (Fig. 2B). Subsequent correlation

6   analyses between the SPQ subfactors and the normalized proportion of total dwell time for

7   sadness indicated that this link was global in nature. No single SPQ subfactor was

8   significantly associated with the normalized proportion of total dwell time for sadness even

9   though the interpersonal ($r = -0.26$, $p = .059$) and positive ($r = -0.25$, $p = .071$) SPQ

10   subfactors were close to significance. Furthermore, regarding specific areas of interest, no

11   single area of interest was significantly associated with the total SPQ score in terms of

12   normalized proportions of total dwell time during sadness recognition (all ps > .074).
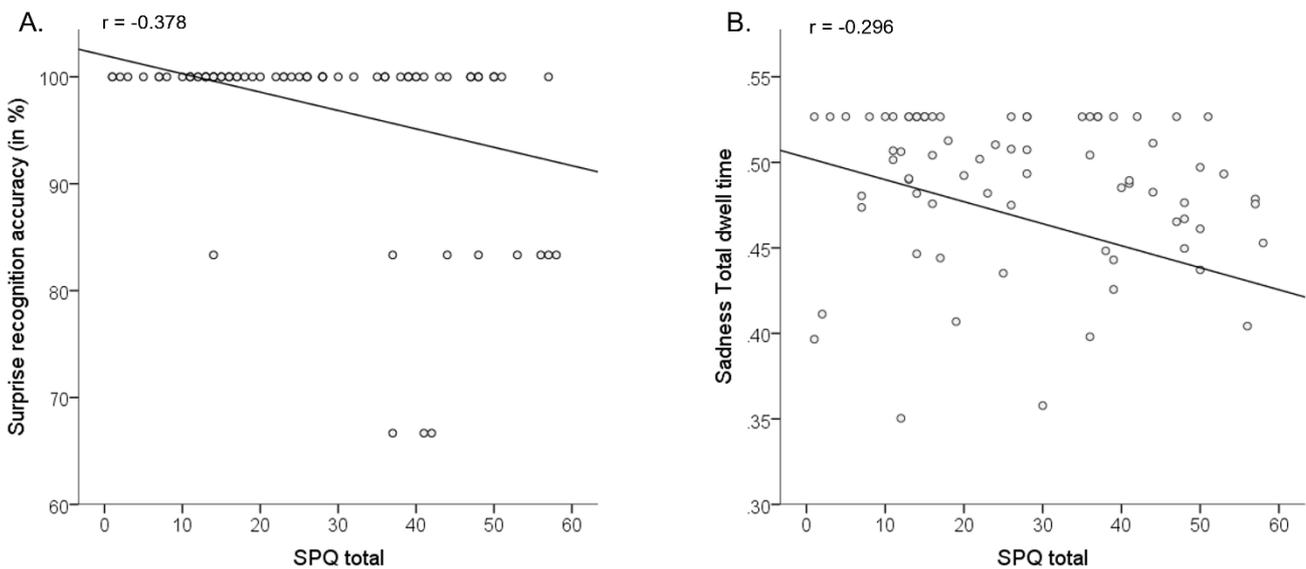
Figure 2. Scatter plots showing significant correlations between SPQ total scores and behavioral and eye-tracking measures. A. Correlations between SPQ total scores and surprise recognition accuracy. B. Correlations between SPQ total scores and total dwell time for sadness recognition (i.e., the normalized proportion of total dwell time on relevant facial features relative to total dwell time on the face).

13

1 *3.3.3. Mean number of fixations and fixation durations*

2 No significant correlations emerged between the SPQ total score and either the mean

3 number of fixations (all ps > .221) or the mean fixation duration (all ps > .875), whichever

4 type of emotion was investigated. Hence, the differences observed for the normalized

5 proportion of total dwell time during sadness recognition seem to be specifically related to the

6 processing of relevant facial features (eyes, nose, mouth) rather than to differences regarding

7 the general overall processing of emotional faces.

8 **3.4. Correlations of Significant Emotion Recognition Measures with Depressive**

9 **Symptoms, Anxiety, and Alexithymia**

10 SPQ total scores were positively correlated with depressive symptoms on the Beck

11 Depression Inventory ($r = 0.67$; $p < .001$), anxiety on the State-Trait Anxiety Inventory

12 part – B ($r = 0.60$; $p < .001$), and alexithymia as measured by the Toronto Alexithymia Scale -

13 20 ($r = 0.60$; $p < .001$).

14 Surprise recognition accuracy scores were negatively correlated with alexithymia ($r = $

15 0.29, $p = .023$), depressive symptoms ($r = -0.37$; $p = .002$) and anxiety ($r = -0.37$; $p = .002$).

16 The normalized proportion of total dwell time during sadness recognition was

17 negatively correlated with alexithymia ($r = -.034$, $p = .005$) and anxiety ($r = -0.30$, $p = .019$)

18 but unrelated to depressive symptoms ($r = -0.19$, $p = .250$).

19

20 **3.6. Regression Analyses**

21 *3.6.1 Predictive value of SPQ scores for significant behavioral and oculomotor*

22 *emotion recognition measures*

23 To investigate whether SPQ total scores were a significant predictor of behavioral

24 performances and gaze pattern, we carried out multiple regression analyses. This step also

25 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

18

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, $F(1, 81) = 7.30$, $p = 0.008$, $R^2 = 0.083$.

1 **Table 4**

2 Multiple regression analyses assessing the predictive value of significant eye-tracking measures

3 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 **4. Discussion**

5   This study was the first to explore eye movement patterns during FER in individuals

6 with SPTs, and to consider the contribution of common emotional difficulties such as anxiety,

7 depressive symptoms, and alexithymia.

8

9   4.1. FER accuracy and schizotypal traits

10   At the behavioral level, we predicted that SPTs would be associated with reduced FER

11 accuracy, especially for negative emotions. However, results only partly supported this initial

12 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.

1   Our results however showed that SPTs are associated with decreased normalized of

2   total dwell-time spent on relevant facial areas for sadness. This suggests that people with high

3   SPQ scores have more difficulty maintaining attention during the exploration of relevant key

4   areas (eyes, nose, and mouth), thus highlighting an attentional bias toward nonrelevant facial

5   features for sadness. These results may indicate a tendency to avoid facial AOIs expressing

6   feelings of sadness. In addition, independent to the dimensions (interpersonal, disorganized,

7   cognitive-perceptual), higher SPTs are the only predictor of lesser time spent on key AOI

8   (eyes, mouth, nose) for the emotion of sadness leading to collect less emotional cues. It is

9   noteworthy that this attentional bias is consistent with previous research showing similar

10   results toward irrelevant facial features during FER of sadness in patients with schizophrenia,

11   compared with controls (Jang et al., 2016). Once again, this lends support to the hypothesis

12   that SPTs lie on the same continuum as schizophrenia spectrum disorders and may share

13   common symptoms and related difficulties in daily life.

14   Moreover, while the normalized proportion of total dwell time does not predict

15   percentages of correct responses for sadness emotions, it is the only predictor of response

16   times when presenting sad faces. Moreover, the SPTs are in turn the only predictor of the lack

17   of sustained attentional engagement on the relevant areas of faces of sadness. Thus, the higher

18   the schizotypal traits would be, the less participants with high SPTs look at the sad faces and

19   the longer their response time is. While further research is required to confirm these results,

20   we could nonetheless hypothesize that this longer response time could impact daily

21   functioning. Indeed, considering the complexity of ecological social situation and the number

22   of psychological processes involved (Achim, 2020), quickness could be the key to act on

23   time. People with SPTs, even if capable to identify sadness as accurately as controls, could

24   thus be encountered difficulties in everyday life situations because of the time they needed to

25   process social cues.

1   Furthermore, these differences in the visual exploration of sadness were observed even

2   though SPTs were not linked to the accuracy of sadness recognition. Although these results

3   might appear contradictory at first sight, it is important to bear in mind that the present study

4   assessed SPTs in a nonclinical sample and that an association between SPTs and recognition

5   accuracy scores may only emerge when individuals transition to a psychopathological state

6   and meet the diagnostic criteria for schizotypal personality disorder and/or schizophrenia

7   spectrum disorder. Prior to this stage, individuals at high risk for schizophrenia spectrum

8   disorder may implement compensatory mechanisms to counteract the differential visual

9   processing of sadness and anger, thereby normalizing recognition performances. In this

10   context, it is noteworthy that no significant link with SPTs emerged for the other emotions

11   investigated, which may therefore constitute a basis for emotion-centered remediation

12   techniques in clinical schizotypy.

13   Concerning the SPTs' role, we found no dimension-specific correlation, but rather an

14   overall SPQ score's negative impact on sustained attentional engagement during sadness

15   recognition. These results contrast with those obtained in previous FER studies on SPTs,

16   suggesting a stronger and more general impact of cognitive/perceptual (hallucinations, strange

17   perceptions) and interpersonal symptoms (e.g., Abbott & Green, 2013). They are however in

18   line with Germine and Hooker's data (2011), in which the author showed a global effect of

19   SPTs on FER independently of face processing. Our study extended these results, by showing

20   that SPTs are linked not only to FER accuracy, but also to the underlying patterns of visual

21   exploration. Since our study was the first to use eye-tracking data to explore SPTs' impact on

22   FER, further research on this topic is required in order to see if domains specific interactions

23   could be found. On top of that, they should also confirm that schizotypy is characterized by

24   avoidance of emotional cues. Eventually, the alterations found for participants with SPTs,

1 regardless of their nature, is a sign for healthcare professionals to not underestimate their

2 repercussions depending on the concerned domain or main symptoms.

3

4   4.3. Impact of affective symptoms and schizotypal traits on behavioral and eye-

5 tracking measures

6   One strength of the present study assessing the link between SPTs and FER was that it

7 explored the impact of emotional difficulties that are frequently associated with SPTs

8 (anxiety, depressive symptoms, and alexithymia). Moreover, although authors have identified

9 these difficulties as potentially disturbing FER processing (Claudino et al., 2019; Demenescu

10 & Kortekaas, 2010; Starita et al., 2018; Suslow et al., 2020), few studies have explored their

11 influence on FER in schizotypy (Dawes et al., 2021). On the behavioral level, we highlighted

12 that depression and anxiety were negatively correlated with surprise recognition accuracy in

13 our sample. Furthermore, depressive symptoms, but not SPQ dimensions, were the only

14 significant predictor of surprise recognition accuracy. Prior studies did not always report on

15 the potential impact of other affective measures which might also influence behavioral FER

16 performances, as suggested by the contribution of depressive symptoms in our study. We

17 would therefore like to encourage researchers to systematically screen for affective symptoms

18 in their samples and to investigate their contribution to FER abilities. In contrast, regarding

19 eye-tracking measures, anxiety, depressive symptoms, and alexithymia did not predict eye

20 movement behavior in our study for sadness recognition (decreased normalized of total dwell-

21 time spent on relevant facial areas for sadness.). Importantly, only global schizotypal traits

22 (SPQ total score) significantly predicted these gaze patterns. In the literature, the relationship

23 between schizotypal dimensions and FER remains inconclusive (e.g., Abbott & Green, 2013;

24 Statucka & Walder, 2017; Williams et al., 2007). These could also influence gaze pattern

25 during FER. Hence, whilst depressive symptoms are likely to contribute to behavioral

1 recognition performances, SPTs seem to have the strongest impact on eye movements

2 compared to other affective variables. This differential impact of SPTs on behavioral and eye-

3 tracking measures might, however, be related to the non-clinical nature of our sample. Whilst

4 subclinical SPTs might only lead to an alteration of gaze pattern without significant alteration

5 of FER accuracy, people displaying clinical schizotypal personality disorder, may indeed

6 show more behavioral FER alterations. The predominance of subclinical rather than

7 pathological traits could also be an explanation for the current lack of consensus in the

8 literature, considering that most of the studies on FER processing and SPTs are based on non-

9 clinical cohorts (Abbott & Green, 2013; Dawes et al., 2021; Germine & Hooker, 2011,

10 Statucka & Walder, 2017).

11   In this context, eye-tracking could constitute an interesting and promising method to

12 explore the specific contribution of SPTs to FER abilities given that eye movement measures

13 were only predicted by SPTs and might be less biased by participants' affective states.

14 Measuring alterations of gaze pattern could be more informative than solely relying on

15 behavioral clues in non-clinical samples.

16

17   4.4. Limitations

18 The present study had several limitations. First, the use of static material (photos) contrasted

19 with dynamic face-to-face interactions. In dynamic real-life interactions, the facial features vary

20 in intensity and provide additional clues for the interpretation of facial affect. However, it is

21 worth noting that the use of more ecological media, such as videos, may not necessarily be more

22 efficient than that of static stimuli when studying FER alteration (Fiorentini & Viviani, 2011;

23 Kätsyri et al., 2008), especially with negative stimuli like anger (Recio et al., 2011). More

24 research is therefore needed on this issue. Second, participants could not choose any response

25 option before the end of the stimulus presentation time (3 seconds). Future studies using the

1 same design should explore response times and eye-tracking metrics with paradigms using non-

2 standardized presentation times in which participants can choose from response options during

3 stimulus presentation. Thirdly, the nonclinical character of the experimental group and the

4 dimensional approach we adopted limit the scope of the results for two reasons. Firstly,

5 correlational approach generates many statistical tests. To reduce the biases regarding this

6 approach we have determined sample size a priori using G*Power3 (Faul et al., 2007), 2), used

7 Bonferroni corrections to reduce false positive risks and 3) only included significant factors to

8 the regression models in order to reduce the number of variables. Secondly, although the sample

9 included participants with high SPTs that could be considered a risk factor for the development

10 of schizophrenia spectrum disorder, applying this protocol to a clinical sample diagnosed with

11 schizotypal personality disorder might take these initial results one step further and indicate

12 how far they can be generalized to clinical SPT conditions. Finally, the participants in our

13 sample were undergraduates, and even though their SPQ scores were comparable to those

14 reported in other studies, the present results need to be replicated with more diversified samples

15 in terms of education level.

16

17   4.5. Conclusion

18   This was the first study to explore gaze behavior during FER in schizotypy from a

19 dimensional perspective, to deepen our understanding of the impact of SPTs and at-risk states

20 for schizophrenia spectrum disorders on FER processes through the use of eye-tracking. SPTs

21 were associated with less accurate FER for surprise. In addition, SPTs seemed to impact the

22 allocation of attentional resources to key areas of interest of the face (eyes, nose, mouth)

23 during the processing of sadness, as indicated by lesser normalized proportion of total dwell

24 time spent on relevant facial features. Interestingly, our results highlighted a general influence

25 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.

1   The authors declare that they have no conflicts of interest affecting this article.

2   **Data availability statement:**

3   The data that support the findings of this study are available from the corresponding author

4   upon reasonable request.

5

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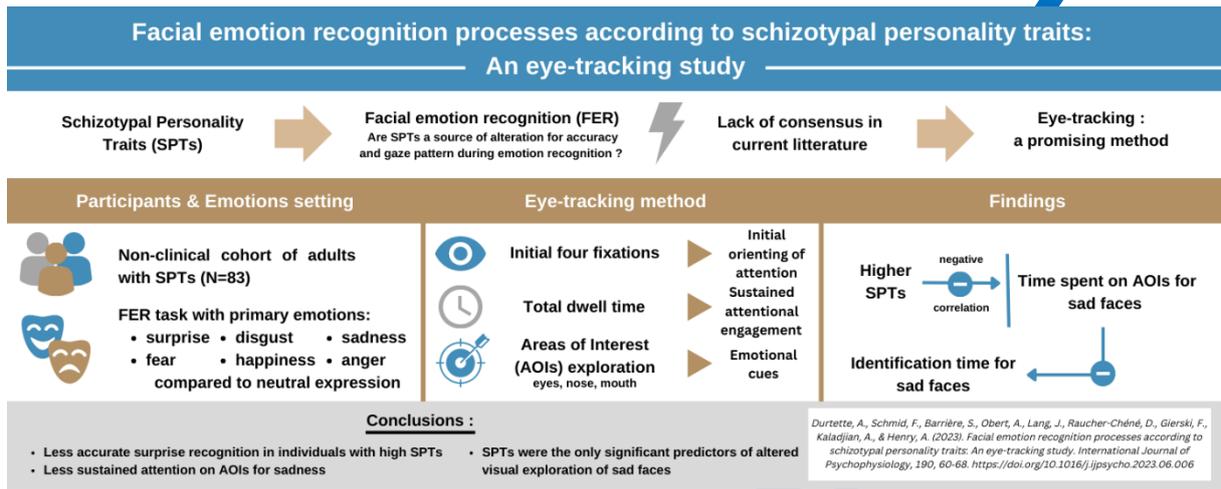23   DSM-III-R criteria. *Schizophrenia Bulletin*, *17*(4), 555-564.

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1 **Graphical abstract**

Facial emotion recognition processes according to schizotypal personality traits: An eye-tracking study

Schizotypal Personality Traits (SPTs) → Facial emotion recognition (FER) — Are SPTs a source of alteration for accuracy and gaze pattern during emotion recognition? → Lack of consensus in current litterature → Eye-tracking: a promising method

Participants & Emotions setting | **Eye-tracking method** | **Findings**

Non-clinical cohort of adults with SPTs (N=83)

FER task with primary emotions:
- surprise • disgust • sadness
- fear • happiness • anger
compared to neutral expression

Initial four fixations → Initial orienting of attention

Total dwell time → Sustained attentional engagement

Areas of Interest (AOIs) exploration eyes, nose, mouth → Emotional cues

Higher SPTs —negative correlation→ Time spent on AOIs for sad faces

Identification time for sad faces

Conclusions:
- Less accurate surprise recognition in individuals with high SPTs
- Less sustained attention on AOIs for sadness
- SPTs were the only significant predictors of altered visual exploration of sad faces

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