Biological Psychology 160 (2021) 108045

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Attentional biases to emotional scenes in schizophrenia: An eye-tracking study

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ARTICLE INFO

Keywords:
Eye movements
Psychosis
Emotion
Psychopathology

ABSTRACT

Attentional biases to emotional information may play a key role in the onset and course of schizophrenia. The aim of this experiment was to examine the attentional processing of four emotional scenes in competition (happy, neutral, sad, threatening) in 53 patients with schizophrenia and 51 controls. The eye movements were recorded in a 20-seconds free-viewing task. The results were: (i) patients showed increased attention on threatening scenes, compared to controls, in terms of attentional engagement and maintenance; (ii) patients payed less attention to happy scenes than controls, in terms of attentional maintenance; (iii) whereas positive symptoms were associated with a late avoidance of sad scenes, negative symptoms were associated with heightened attention to threat. The findings suggest that a threat-related bias and a lack of sensitivity to positive information may represent an underlying psychological mechanism of schizophrenia. Importantly, schizophrenia symptoms modulated the attentional biases, which has aetiological and therapeutic implications.

1. Introduction

Schizophrenia (SZ) is a heterogeneous disorder characterized by positive symptoms (e.g. hallucinations or delusions) and negative symptoms (e.g. social withdrawal or flat affect) (American Psychiatric Association, 2013; Andreasen & Olsen, 1982). The underlying mechanisms of SZ symptoms are not well documented, highlighting the importance of investigating basic cognitive processes involved in understanding information processing (Blackwood, Howard, Bentall, & Murray, 2001). Notably, cognitive biases that occur during information processing play a central role in the development and maintenance of psychosis (Underwood, Kumari, & Emmanuelle, 2016). Unlike the ample evidence on reasoning biases (i.e., “jumping to conclusions” bias) or interpretation biases (see Savulich, Shergill, & Yiend, 2017), research on attentional biases in SZ is relatively scarce. This is somewhat surprising because attention is the basis of information processing (Schneider, Einhäuser, & Horstmann, 2013). Although prior research has revealed atypical attentional patterns to emotional information in individuals with SZ (see Savulich, Shergill, & Yiend, 2012; Underwood, Peters, & Kumari, 2015, for reviews), it is still unknown what emotional content is attended to or ignored depending on the presence and severity of positive or negative symptoms. The present eye movement experiment was designed to examine the impact of emotional information upon the capture of attention in SZ and its association with positive and negative symptoms.

At a theoretical level, affective information-processing theories posit the selective and priority processing of emotional pathology-relevant information (Beck, 1976; Niedenthal & Kitayama, 1994). Due to their maladaptive appraisal of reality characterized by threat, patients with SZ may show heightened attention to threatening stimuli (Ullmann & Krasner, 1975). However, attention to threat may also be modulated by specific psychopathological symptoms (Savulich et al., 2012). As for positive symptoms, scanning the environment for threats may have an aetiological role in the formation of auditory hallucinations (Garety, Kuipers, Fowler, Freeman, & Bebbington, 2001). This could readily explain why their content is often intimidating (Dodgson & Gordon,

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https://doi.org/10.1016/j.biopsycho.2021.108045
Received 26 October 2020; Received in revised form 6 February 2021; Accepted 7 February 2021
Available online 10 February 2021
0301-0511/

2009). Likewise, attentional biases toward threatening stimuli are supposed to be associated with the onset and maintenance of persecutory delusions. In this regard, Bentall, Howard, and Kinderman (2001) put forward that threats to the self-esteem may give rise to external attributions that, together with attentional biases toward threatening information, may result in persecutory delusions to defence paranoid individuals from depression. Freeman, Garety, Kuipers, Fowler, and Bebbington (2002) also suggested that attentional biases toward threatening information contribute to maintain delusional beliefs in paranoid individuals searching for a meaning of their negative internal emotional experiences. However, Green and Phillips (2004) indicated that assuming a necessary relationship between heightened attention to threat and persecutory delusions could be an oversimplification. They suggested a pattern of "vigilance–avoidance", where threat-related stimuli would preconsciously capture attention, followed by a strategic avoidance to reduce anxiety associated because of an affective vulnerability and hypersensitivity to negative emotions. Conversely, regarding negative symptoms, attentional biases may be conditioned by a markedly overall neurocognitive dysfunction (Cohen et al., 2007) and desensitization to threat (Carpenter, Heinrichs, & Wagman, 1988; Kirkpatrick & Buchanan, 1990). This may lead SZ patients with negative symptoms to a maladaptive behaviour perpetuating their focus on negative information and result in a chronic negative mood (Strauss, Allen, Duke, Ross, & Schwartz, 2008). However, the theoretical models on attentional biases for negative symptoms have been less developed than for the positive ones (Millan, Fone, Steckler, & Horan, 2014).

At an empirical level, the findings from reaction time-based experiments on attentional bias to emotional information in SZ have been heterogeneous, with some studies reporting an attentional bias toward threatening information (Bentall & Kaney, 1989; Besnier et al., 2009; Hu, He, Fan, & Lupianez, 2014) and others failing to find any attentional bias (Demily et al., 2010; Muroi, Kasai, Uetsuki, & Suga, 2007; Taylor & John, 2004). These discrepant results may be related to a wide array of methodological and psychopathological factors. As for methodological factors, different paradigms measuring attentional allocation have been used. However, caution is necessary here, as these techniques may tap into different attentional processes (Petersen & Posner, 2012). For example, the emotional Stroop task evaluates emotional interference, whereas the dot-probe task or spatial cueing measures spatial-visual attention (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Regarding psychopathological variables, when SZ patients have been grouped according to the intensity of negative symptoms, those patients with higher negative symptoms showed difficulties in disengaging attention from unpleasant stimuli in the emotional Stroop task, while no bias was found in SZ patients without negative symptoms (Strauss, Llerena, & Gold, 2011; Strauss et al., 2008; Taylor & John, 2004). Conversely, when patients were classified according to positive symptoms (paranoid and non-paranoid participants) in a cueing task (Moritz & Steffen, 2007), threatening stimuli captured the patient's attention regardless of their paranoid status, suggesting that persecutory delusions are not specifically associated with an attentional bias toward threat. Taking together, these reaction-time based experiments may point to an attentional bias toward threatening information in SZ that may be related to the presence of negative symptoms.

Reaction time-based tasks offer important information about the underlying interaction between attention and emotional processes. However, these tasks only offer data at the end of the attentional processing. To determine the spatio-temporal location of attention, recording eye movements provides an excellent marker of the way visual stimuli are processed, generating a map in real-time that traces the direction and extent of gaze when participants watch a stimulus (Noton & Stark, 1971). Registering eye movements allows to obtain a detailed measurement of attentional processing to stimulus presented simultaneously, which competes for the observer's attention (Hermans, Vansteenwegen, & Eelen, 1999). Of note, eye movements capture cognitive processes during visual tasks, as shifts in gaze position are guided by shifts in attentional focus (Rayner, 2009). Moreover, recording eye movements in experimental psychopathology avoids the problems derived from slow responses and motor retardation commonly observed in psychiatric patients (Mathews, Ridgeway, & Williamson, 1996). Therefore, eye-tracking methodology is a strong test for assessing information processing bias.

Although eye-tracking paradigms have been widely used to examine attentional biases in psychiatric disorders such as major depression (Armstrong & Olatunji, 2012) or bipolar disorder (García-Blanco, Perea, & Salmerón, 2013; García-Blanco, Salmerón, & Perea, 2015), research in SZ is scarce and inconclusive. Previous eye-tracking experiments in SZ have assessed attention to emotional faces individually displayed (Green, Williams, & Davidson, 2003; Loughland & Gordon, 2002; Loughland, Williams, & Anthony, 2004; Zhu et al., 2013). These eye-tracking studies have reported an attentional bias toward negative emotional content of faces in stable SZ patients (Loughland & Gordon, 2002; Loughland et al., 2004; Zhu et al., 2013). However, when SZ patients with active persecutory delusions were examined, they showed the opposite pattern, that is, an attentional bias away (i.e. avoidance) from negative information (Green et al., 2003). Jang, Kim, Kim, Lee, and Choi (2016); Jang, Park, Lee, Cho, and Choi (2016) reached similar conclusions using a dot-probe task with eye-tracker technology, displaying a happy, a sad, or an angry face together with a neutral one during 1500 ms in patients with SZ and schizoaffective disorder. They found that patients showed lower attentional maintenance on threatening and sad faces than the control group. Interestingly, whereas positive symptoms were associated with an attentional avoidance of threatening faces during initial orientation, negative symptoms were associated with an attentional avoidance of happy faces during attentional maintenance.

Among the eye-tracking studies using complex scenes, Strauss et al. (2015) administered a 3 s directed attention task, which requires to focus attention voluntarily on a target. They demonstrated that unpleasant stimuli capture attention in SZ. However, similar to recognition tasks with eye-tracker technology (Green et al., 2003), when SZ patients with active persecutory delusion were examined, the opposite pattern was observed. For instance, Phillips, Senior, and David (2000), in a 10 s free-viewing task, found that SZ patients with persecutory delusions directed gaze to less threatening areas of an emotionally ambiguous scene, in comparison to SZ patients suffering non-persecutory delusions and healthy individuals. A bias away from threatening information associated with persecutory delusions was suggested again.

Apparently, the above-mentioned eye-tracker studies showed some discrepant results. Whereas some studies have found that negative emotions captured attention in SZ (Loughland & Gordon, 2002; Loughland et al., 2004; Strauss et al., 2015; Zhu et al., 2013), others have reported an attentional bias away from threatening information associated with positive symptoms (Green et al., 2003; Jang, Kim et al., 2016; Phillips et al., 2000). Therefore, it is essential to examine the moderators of attentional biases in SZ, including psychopathology, the time-course of the attentional processing, and the content specificity of the stimuli. That is, it is still unclear to what extent emotionally positive or negative information are abnormally attended depending on the severity of positive and negative symptoms in SZ. And more specifically, it would be of interest to compare biases toward materials that have a stronger and weaker association with psychopathology (Savulich et al., 2012). To our knowledge, no eye-tracking studies have been conducted displaying several emotional stimuli in competition in a free-viewing task, which is a highly ecological scenario (see Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009, for discussion). In the current experiment, neutral, happy, sad, and threatening scenes were presented in each trial for 20 s, and several measures were computed for each type of emotional scene: (i) initial orienting (i.e. location of first fixation); (ii) attentional engagement (i.e. first-pass fixations and gaze duration); and (iii) attentional maintenance (i.e. the total number of fixations and the total fixation duration, dividing into 5 s segments the exposure time for each trial).

To summarize, the present experiment is the first eye-tracking study that examines the time-course of attentional biases to four types of emotional stimuli in competition during a relatively long period (20 s). Additionally, the design will also allow us to discern the role of psychopathology in the obtained effects in terms of positive and negative symptoms severity. Following affective information-processing theories in SZ (Ullmann & Krasner, 1975; Underwood et al., 2016), we expected that threatening stimuli would capture the attention of SZ patients to a greater extent than healthy individuals' in terms of initial orienting, attentional engagement, and attentional maintenance—note that the attentional biases to threatening scenes could be modulated by the severity of positive and negative SZ symptoms. Following the affective vulnerability approaches related to hypersensitivity and strategic avoidance of negative emotions (Green & Phillips, 2004), we hypothesized that the intensity of positive symptoms would be associated with an avoidance of negative emotions during the attentional maintenance (later stages of the attentional time-course). Conversely, according to the emotional desensitization (Carpenter et al., 1988; Kirkpatrick & Buchanan, 1990) and/or by the overall neurocognitive dysfunction that hinders attentional control strategies in patients with negative symptomatology (Cohen et al., 2007), we hypothesized that higher negative symptoms would be associated with a greater attention on negative information in both attentional engagement and attentional maintenance measurements (see Strauss et al., 2008, 2011).

2. Methods

2.1. Participants

Eligible participants were 53 patients referred by their psychiatrists from the Department of Psychiatry at a tertiary hospital, and 51 healthy individuals recruited through advertising in the community.

Inclusion criteria were age 18–65 years for all participants and SZ diagnoses for the clinical group. Clinical diagnoses were carried out according to the DSM-5 (American Psychiatric Association, 2013) diagnostic criteria. A postgraduate psychiatrist corroborated diagnoses by the case note review and a semi-structured clinical interview based on the *Structured Clinical Interview for the DSM-5* (SCID; First, 2015). The *Positive and Negative Syndrome Scale* (PANSS, Kay, Fiszbein, & Opler, 1987) was administered to assess the positive and negative symptoms in the SZ group. The SZ sample was highly representative: 10 patients (18.9 %) were categorized as "positive syndrome", 14 (26.4 %) as "negative syndrome", 16 (30.2 %) as "mixed syndrome", and 13 (24.5 %) as "undifferentiated syndrome" following the restricted criteria of the PANSSS.[1] All patients were receiving psychopharmacological treatment, support psychotherapy, psychoeducation, and/or social support. Additionally, every participant filled out the *Beck Depression Inventory II* (BDI-II; Beck, Steer, & Brown, 1996) and the *State-Trait Anxiety Inventory* (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). Exclusion criteria for all participants were: (1) neurological disorders (e.g. epilepsy) or intellectual disability diagnosis; (2) visual impairments or calibration problems; (3) major medical disorders; (4) non-psychotropic medication that could influence cognition (e.g. corticosteroids); (5) electroconvulsive therapy within the previous 3 months; and (6) primary affective disorders for the SZ group (diagnosis of bipolar disorder, schizoaffective disorder, or major depression) or history of any mental disorder in the control group.

The ethics committee at La Fe Health Research Institute authorized this study (approval number 2017/0478), and all participants provided written informed consent before their inclusion in the study. See Fig. 1 for the recruitment process. See Table 1 for demographic and clinical details.

2.2. Stimuli

The stimuli included 80 images selected from the *International Affective Picture System* (Lang, Bradley, & Cuthbert, 2005). The stimuli were categorized as sad, happy, threatening, or neutral. Importantly, IAPS stimuli are rated in emotional parameters on a 9-point scale for valence (unpleasant-pleasant) and arousal (calm-excited), but not for specific emotional valence. Therefore, the stimuli were categorized following a pilot study (see Kellough, Beevers, Ellis, & Wells, 2008, for pilot study details). Valence ratings for the threatening and sad images ranged from 2 to 4. Happy images were rated from 6 to 8. Neutral images had valence ratings of approximately 5. The valence ratings for happy and neutral scenes were significantly different from the other categories, whereas the valence ratings for sad and threatening scenes did not differ from each other. Threatening scenes did have a significantly greater arousal rating than sad, positive, or neutral scenes. Neutral images had a significantly lower arousal rating than sad, happy, or threatening scenes, whereas the sad and happy images did not differ from each other in arousal. The images did not differ in visual complexity, which was assessed in terms of the number of bytes of the compressed image file size in JPEG format, with the assumption that the more complex the image is, the larger the file (see Nummenmaa, Hyönä, & Calvo, 2006).

2.3. Task

Twenty trials (12 study trials – 8 filler trials) containing four images simultaneously presented were displayed. Before each trial, a central fixation cross was presented for 1000 ms. Then, trials were presented for 20 s. The study trials contained four images, each image with one of the following emotional content: sad, happy, threatening, or neutral. The position of the images was randomly selected, with the constrain that each valence must occur in each of the four positions three times across the 12 trials. The presentation order of the trials was also randomized across the participants. Eight not-analysed trials with four neutral images were presented to obscure the nature of the task. See Fig. 2.

2.4. Apparatus

A remote eye-tracking binocular system (SMI RED250) was used to measure the participants' eye movements. The sampling rate of the eye positions was 250 Hz. The system allows a free range of head movement. Participants were seated 60 cm away from the screen in a height-adjustable chair, so that participants' eyes were level with the middle of the 17-inch monitor on which the stimuli were presented. This ensured that all participants' eyes were in the same location relative to the camera and the monitor. Camera adjustments were made to best capture the participant's eyes.

2.5. Procedure

Firstly, participants signed an informed consent form. After that, all participants responded to demographic and clinical interview and the BDI-II and STAI rating scales. Separately, a postgraduate psychiatrist had completed the semi-structured clinical interview and the PANSS before the task. Secondly, participants carried out the task individually in a quiet room. The experimental session began once the eye-tracker was calibrated (average error was less than 1.5° of the visual angle for

[1] Patients are rated from 1 to 7 on 7 positive symptoms and 7 negative symptoms items. Patients are classified as "positive subtype" when punctuated 4 or more in 3 or more positive items, and less than 3 negative items with 4 or more. They are classified as "negative subtype" when punctuated 4 or more in 3 or more negative items and less than 3 positive items with 4 or more. They are classified as "mixed subtype" when punctuated 4 or more in 3 items of both scales. They are classified as "undifferentiated" when no one of these criteria are met.

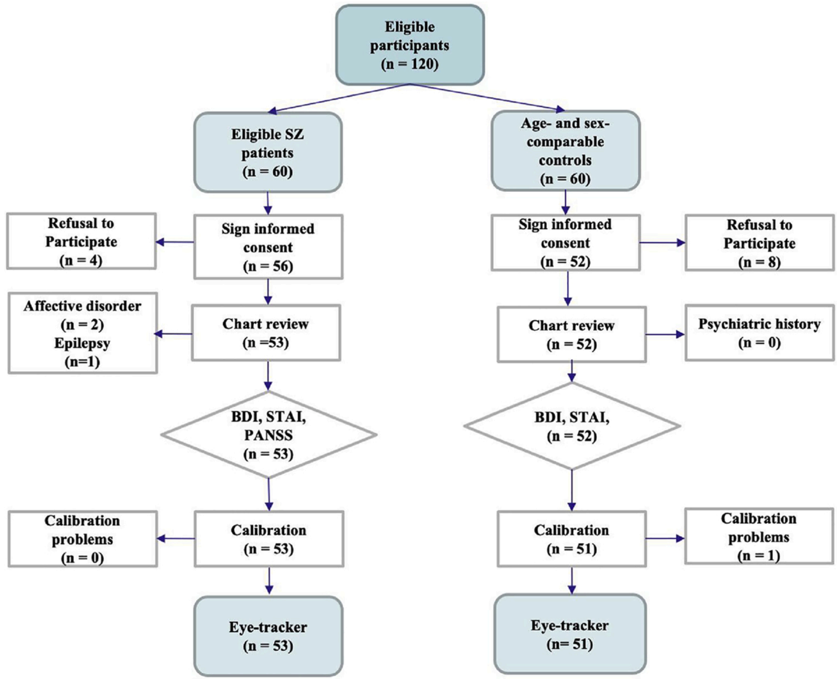

Fig. 1. Flow diagram describing the recruitment process.

Table 1
Sociodemographic and clinical data.

	Control (N=51)	SZ (N=53)	*p*	*d*
% Female (n)	57 (29)	43 (23)	.173	
Age	35.3 (10.3)	39.55 (11.2)	.08	
STAI-T	14.5 (8.8)	25.5 (8.7)	<.001	.49
STAI-S	11.53 (6.5)	24.88 (10)	<.001	.62
BDI-II	4.2 (4.5)	9.4 (7.9)	<0.01	.38
PANSSG		45.5 (10)		
PANSSP		21.7 (5.5)		
PANSSN		24.3 (7.5)		
Illness duration		15.02 (10.46)		
Range		1–44		
Age of Onset		26 (9.8)		
Education (n)				
Primary studies	18	22	.03	
Secondary studies	14	23		
University studies	19	8		
Treatment				
% Antipsychotic (n)		100 (53)		
%FGA (n)		18.9 (10)		
%SGA (n)		73.6 (39)		
%Both (n)		7.5 (4)		
% Antidepressant (n)		22.6 (12)		
%SRI (n)		11.3 (6)		
%SNRI (n)		7.5 (4)		
%Tricyclic (n)		3.8 (2)		
%Benzodiazepine (n)		62.3 (33)		
%Antiepileptic (n)		7.5 (4)		

Note. BDI-II: Beck Depression Inventory-II; FGA: First Generation Antipsychotic; PANSSG: Positive and Negative Syndrome Scale: General Psychopathology Scale; PANSSP: Positive and Negative Syndrome Scale: Positive Psychopathology Scale; PANSSN: Positive and Negative Syndrome Scale: Negative Psychopathology Scale; SGA: Second Generation Antipsychotic; SNRI: Serotonine and Norepinephrine Reuptake Inhibitor; SRI: Serotonine Reuptake Inhibitor; STAI-T/S: State-Trait Anxiety Inventory-Trait/State; SZ: Schizophrenia Group; The *p* values correspond to the omnibus test/chi square for both groups.

9 calibration points). After that, instructions appeared on the screen, displaying "look at the images as if you were watching television or looking at a photo album". The experimenter was placed in the same room during the procedure, monitoring the task (see García-Blanco, Salmerón, Perea, & Livianos, 2014, for a similar procedure in a bipolar disorder study).

2.6. Data analysis

Data were computed using a velocity-based algorithm with a minimum fixation duration threshold of 100 ms and a peak velocity threshold of 40°/s. The areas of interest were also identified for each trial, and corresponded to the total area for each of the four images. The measurements computed to evaluate the attention across different emotional valences were as follows: (i) percentage of first fixation (i.e. percentage of times that the first fixation lands on images of a particular valence); (ii) first-pass fixations (i.e. the number of fixations on the image when looking at it for the first time, before fixating away from it); (iii) mean gaze duration (i.e. the average time that each participant's gaze stayed within the boundaries of a particular valence, that is, a period beginning when the gaze entered the image, and ending when the gaze left the image); (iv) the percentage of total fixations (i.e. percentage of times that each participant fixated, and re-fixated, on a particular valence); and (v) the percentage of total duration (i.e. fixation time attending to each valence).

An omnibus analysis of variance (ANOVA) for each dependent measure was conducted. Specifically, the percentage of first fixation, first-pass fixation, gaze duration, percentage of total duration, and percentage of total fixations were examined in separate ANOVAs with Group (SZ, control) as a between-subject factor and Valence (neutral, happy, sad, threatening) as a within-subject factor. The analyses of the percentage of total duration and percentage of total fixations also included time segments (0–5 s, 5–10 s, 10–15 s, 15–20 s) as a within-subject factor.

To characterize the relation between attentional biases to negative information and SZ symptoms, we performed correlational analyses. The PANSS positive and negative subscales scores were correlated with the outcomes for sad and threatening scenes (i.e., percentage of first fixation, first-pass fixations, gaze duration, and the percentage of total fixation and total duration for each time-segment). To that end, we employed the Spearman correlation coefficient with adjusted alpha level (.01) (two-tailed *p*) to control for type-I errors due to multiple testing.

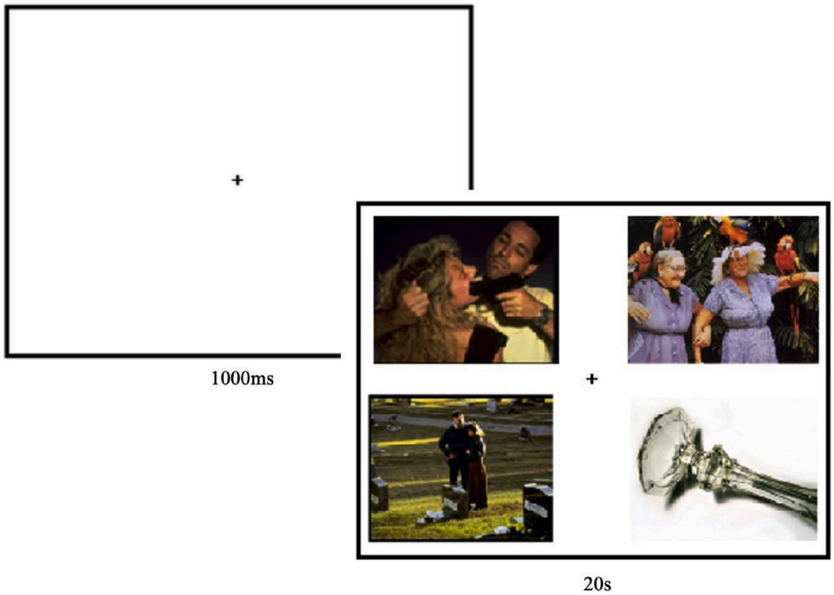

Fig. 2. Free-viewing task.

3. Results

The descriptive data for each condition is presented in Table 2. All main effects and interactions of ANOVAs are displayed in Table 3.

3.1. Percentage of first fixation

As revealed by Bonferroni comparisons, the Valence effect showed that the participants' first fixations were more directed toward emotional stimuli (happy, sad, and threatening) than toward neutral stimuli (all *ps* < 0.001).

3.2. First-pass fixations

The Valence × Group interaction, examined by a one-way ANOVA, showed that the SZ group exhibited more first-pass fixations on threatening stimuli than the control group, $F(1,102) = 4.020$, $p = .048$, $f = .19$. There were, however, no across-groups differences for the rest of valences (all *ps* $> .27$) (see Fig. 3a).

3.3. Gaze duration

The Valence × Group interaction, analyzed by a one-way ANOVA, revealed that gaze duration for threatening stimuli was higher for the SZ group than for controls, $F(1,102) = 5.646$, $p = .019$, $f = .23$. There were no differences across groups for the other types of stimuli (all *ps* $> .19$) (see Fig. 3b).

3.4. Percentage of total fixations

The Valence × Group interaction, examined by a one-way ANOVA, showed that the percentage of total fixations on threatening stimuli were higher for the SZ group than the control group, $F(1,102) = 10.965$, $p = .001$, $f = .22$, Conversely, the percentage of total fixations on happy stimuli was higher for the control group than the SZ group, $F(1,102) = 9.571$, $p = .003$, $f = .23$. No across-groups differences for neutral or sad ones were found (all *ps* > 0.16) (see Fig. 3c).

The Time x Valence interaction, assessed by an ANOVA for each Valence with Time as within-subject factor, revealed a Time effect for neutral, $F(3,309) = 5.626$, $p = .001$, $\eta^2 = .052$; happy, $F(3,309) = 6.761$, $p < .001$, $\eta^2 = .062$; and threatening images, $F(3,309) = 11.697$, $p < .001$, $\eta^2 = .102$, but nor for sad stimuli ($F < 1$). Bonferroni comparisons revealed that the percentage of time duration attending to neutral stimuli significantly increased from the first segment to the second segment ($p = .005$). This difference was also found between the first and fourth-time segment ($p = .006$). For happy stimuli, the percentage of time duration increased in later stages, that is, between the first segment and the third and fourth segments, ($p = .001$ and $p = .004$, respectively). For threatening stimuli, there was a quick decline of the percentage of total fixations, revealed by significant differences in the first segment compared with the second ($p = .005$), the third ($p < .001$), and the fourth segment ($p < .001$). No other differences were found for any Time segment (all *ps* $> .151$) (see Fig. 4a).

3.5. Percentage of total duration

Similar to the percentage of total fixations, the Time x Valence interaction, analyzed by an ANOVA for each Valence with Time as within-subject factor, exhibited a Time effect for neutral, $F(3,309) = 3.132$, $p = 0.026$, $\eta^2 = .030$; happy, $F(3,309) = 3.556$, $p = .015$, $\eta^2 = .033$; and threatening stimuli, $F(3,309) = 6.678$, $p < .001$, $\eta^2 = .061$; but nor for sad ones, $F(3,309) = 1.240$, $p = .295$. Bonferroni comparisons revealed that the percentage of time duration attending to neutral stimuli significantly increased in the second segment relative to the first segment ($p = .037$). Regarding happy stimuli, the percentage of time duration increased in the third time segment relative to the first one ($p = .019$). For threatening stimuli, there was a quick decline of percentage of time duration from the first segment, revealed by significant differences in comparison with the second ($p = .034$), the third ($p = .029$), and the fourth time segment ($p < .001$). No other differences were found for any Time segment (all *ps* $> .076$) (see Fig. 4b).

3.6. Correlational analyses

We found that the PANSS positive subscale score was significantly associated (alpha was set to .01) with the late measures of processing of sad stimuli: percentage of total duration ($r_s = -.383$, $p = .006$) and total fixations ($r_s = -.388$, $p = .005$) in the last time segment (15–20s). The other correlation coefficients were not significant (all *ps* $> .077$). In addition, the PANSS negative subscale score was significantly associated with the gaze duration ($r_s = .352$, $p = .009$) and the percentage of total duration 15–20s ($r_s = .355$, $p = .009$) to threatening stimuli.

Table 2
Mean (standard deviation) for the percentage of first fixation, first-pass fixation, gaze duration, percentage of total duration, and percentage of total fixations for each stimulus category for the control (C) and schizophrenia (SZ) groups.

	Percentage of first fixation (% of total)		First-pass fixations (n)		Gaze duration (ms)		Percentage of total duration (% of total)							
							0–5 s		*5–10 s*		*10–15 s*		*15–20 s*	
	C	SZ	C	SZ	C	SZ	C	SZ	C	SZ	C	SZ	C	SZ
Neutral	18.61	18.19	2.68	2.87	748	864	22	18	23	22	23	20	23	23
	(11.27)	(10.98)	(1.24)	(1.28)	(409)	(585)	(7)	(9)	(6)	(11)	(7)	(11)	(8)	(12)
Happy	31.70	29.64	3.92	3.49	1117	1078	28	27	30	28	31	33	31	31
	(9.67)	(12.53)	(2.10)	(1.90)	(619)	(721)	(9)	(10)	(13)	(12)	(13)	(16)	(13)	(15)
Sad	25.30	25.22	3.19	3.53	904	1068	24	23	24	24	22	22	24	24
	(11.48)	(10.22)	(1.68)	(1.91)	(525)	(740)	(7)	(8)	(9)	(19)	(9)	(12)	(10)	(11)
Threat	24.40	26.94	3.09	3.76	863	1188	26	32	23	26	24	26	22	23
	(10.49)	(12.54)	(1.58)	(1.84)	(533)	(826)	(6)	(16)	(9)	(14)	(10)	(17)	(9)	(12)

	Percentage of total fixations (% of total)							
	0–5 s		*5–10 s*		*10–15 s*		*15–20 s*	
	C	SZ	C	SZ	C	SZ	C	SZ
Neutral	18	17	20	23	20	20	20	23
	(6)	(7)	(7)	(11)	(9)	(10)	(9)	(13)
Happy	30	27	37	27	38	31	39	30
	(9)	(10)	(17)	(12)	(18)	(14)	(20)	(15)
Sad	27	24	22	26	23	24	23	23
	(8)	(7)	(11)	(10)	(12)	(12)	(12)	(10)
Threat	25	32	21	24	19	25	18	23
	(7)	(14)	(12)	(12)	(12)	(15)	(11)	(12)

Table 3
Analysis of variance for eye-tracker parameters according to the Group, Valence, and Time Segment.

Eye-tracker parameter Effect	*df*	*F*	*p*	η2
Percentage of first fixation				
Group	1, 102	.205	.652	.002
Valence	**3, 306**	**15.781**	**.000**	**.134**
Group x Valence	3, 306	.564	.639	.005
Time x Valence	–	–	–	–
Time x Valence x Group	–	–	–	–
Gaze duration				
Group	1, 102	1.709	.194	.016
Valence	**3, 306**	**12.208**	**.000**	**.107**
Group x Valence	**3, 306**	**4.464**	**.004**	**.042**
Time x Valence	–	–	–	–
Time x Valence x Group	–	–	–	–
First-pass fixations				
Group	1, 102	.435	.511	.004
Valence	**3, 306**	**14.990**	**.000**	**.128**
Group x Valence	**3, 306**	**5.245**	**.002**	**.049**
Time x Valence	–	–	–	–
Time x Valence x Group	–	–	–	–
Percentage of total fixations				
Group	–	–	–	–
Valence	**3, 306**	**31.678**	**.000**	**.237**
Group x Valence	**3, 306**	**7.595**	**.000**	**.069**
Time x Valence	**9, 918**	**6.597**	**.000**	**.061**
Time x Valence x Group	9, 918	1.432	.170	.014
Percentage of total duration				
Group	–	–	–	–
Valence	**3, 306**	**17.215**	**.000**	**.144**
Group x Valence	3, 306	1.768	.153	.017
Time x Valence	**9, 918**	**3.876**	**.000**	**.037**
Time x Valence x Group	9, 918	.891	.532	.009

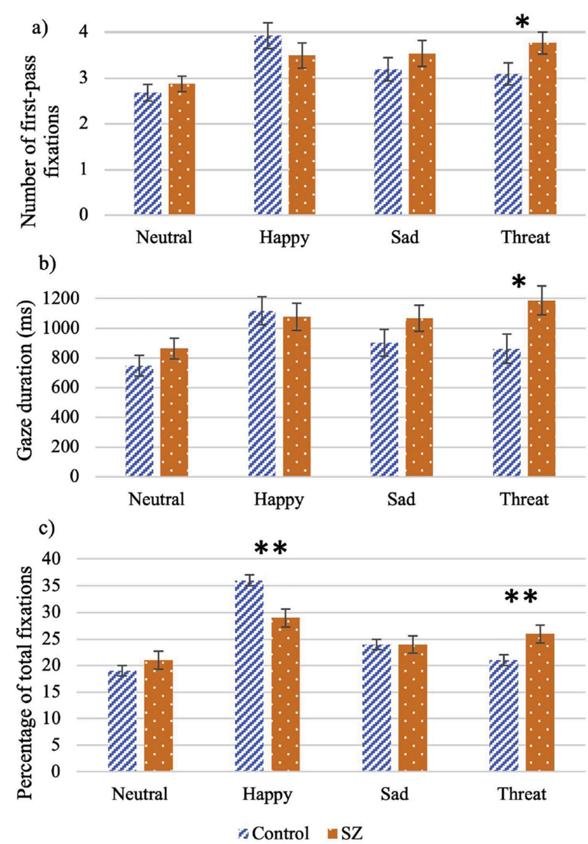

Fig. 3. Number of first-pass fixations (a), mean gaze duration (b), and percentage of total fixations (c) on each category for the SZ and control groups. * p < .05, ** p < .01.

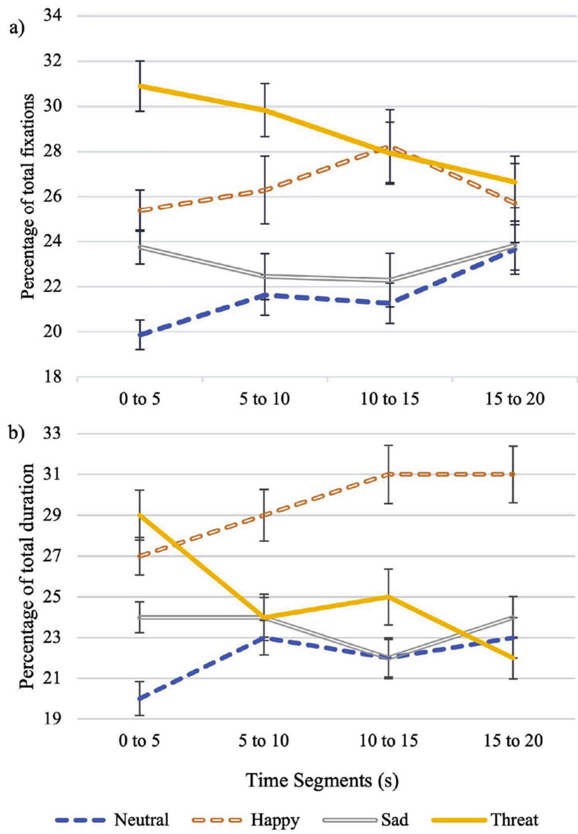

Fig. 4. Percentage of total fixations (a), and percentage of total duration (b) on each category across 5 s time segments for all the participants.

Finally, to further examine the role of psychological outcomes (i.e., STAI-T/S and BDI-II scores) in the experiment, we conducted exploratory analyses for the SZ group between eye-movement measures for sad and threatening stimuli and the BDI-II and STAI-T/S scores. None of the Spearman correlation coefficients were significant at a pre-established restricted alpha (0.01, two-tailed) level (all $ps > .01$).

4. Discussion

To the best of our knowledge, this is the first eye-tracking experiment that examines attentional biases during the free-viewing of multiple emotional stimuli simultaneously displayed, including threatening stimuli, in a heterogeneous group of individuals with SZ. The main finding of this experiment was that individuals with SZ showed higher attentional engagement (i.e. first-pass fixations and gaze duration) and higher attentional maintenance (in terms of percentage of total duration) on threatening scenes than the control group. Additionally, the correlational analyses suggested that positive symptoms intensity is associated with an attentional maintenance bias away from sad stimuli in terms of the percentage of total fixations and total duration in the last time segment (15–20 s); and negative symptoms intensity is associated with attentional biases toward threatening scenes in terms of attentional engagement (i.e. gaze duration) and attentional maintenance (i.e. the percentage of total duration in the last time-segment). Moreover, the control group showed a higher percentage of total fixations on happy scenes than the SZ group, suggesting an attentional maintenance bias away from positive information in the clinical group. As secondary finding, when all the participants were assessed, the percentage of total fixation and the percentage of total duration on happy and neutral scenes increased along the time-course of attentional processing. Conversely, this attentional maintenance parameters decreased over time for threatening stimuli.

Therefore, a bias toward threatening scenes in SZ has been demonstrated. In addition, psychopathology may modulate the attentional processing of emotional information. As we discussed above, this may have a key role in the etiology and course of SZ symptoms.

The main finding was that SZ patients demonstrated heightened attention to threatening information in two key attentional processes: attentional engagement and attentional maintenance. Similar to previous studies (Jang, Kim et al., 2016), we did not find an attentional bias in the initial orienting of attention by measuring the percentage of first fixation. The results are consistent with previous response-time experiments that demonstrated an attentional bias toward threatening information in patients with SZ (Besnier et al., 2011; Hu et al., 2014; Strauss et al., 2015). The findings are also in line with affective information-processing models in SZ, suggesting a maladaptive appraisal of the world characterized by perceptions of externalized threat, which could be associated with the transition to psychosis (Underwood et al., 2015). Indeed, it has been suggested that paranoia-related material is relevant to all patients with psychosis when assessing other information-processing biases (see Savulich et al., 2017, for evidence in interpretation biases). Other possible explanation is that the arousal-level of threatening stimuli accounts for the attentional effects (sad and threatening stimuli only differed in the arousal level), since arousal may independently influence attention (Nummenmaa et al., 2006). Previous theories have pointed out an etiological role for attention to threat in the formation of positive symptoms such as persecutory delusions (Bentall et al., 2001; Garety et al., 2001). However, we found a robust bias toward threatening information in a representative sample of SZ patients composed of participants with different psychopathological manifestations. In this regard, some neurofunctional studies have found abnormalities of regulatory structures such as the prefrontal cortex and hippocampus in heterogeneous SZ samples when attending to threatening stimuli (Dichter, Bellion, Casp, & Belger, 2010; Fakra, Salgado-Pineda, Delaveau, Hariri, & Blin, 2008; Hempel, Hempel, Schönknecht, Stippich, & Schröder, 2003; Holt et al., 2005). Importantly, these brain regions are responsible for the identification and regulation of the emotional significance of stimuli. Therefore, the current results endorse affective information-processing models and neurofunctional findings suggesting that attentional biases toward threatening information are not specific to any sub-type of psychosis, which may indicate that heightened attention to threat is a trait marker of SZ and may confer psychological vulnerability in the disorder.

The correlation analyses revealed an association between positive symptoms severity an attentional avoidance of sad stimuli in later stages (15–20 s) of the attentional processing. Previous eye-movement experiments reported an attentional bias away from sad emotional information (i.e. sad faces) related to persecutory delusions (Green et al., 2003). Therefore, these findings can be consistent with the hypothesis proposed by Green and Phillips (2004), in which persecutory delusions would give rise to effortful avoidance strategies to counteract hypersensitivity to negative emotions, thus leading to an apparent bias away from negative stimuli. Interestingly, we found that this effect did not occur for threatening stimuli. Similar to our findings, Phillips et al. (2000) did not find differences between SZ patients with persecutory delusions and controls when overtly threatening scenes were displayed, but they found a reduced appraisal of threatening areas in ambiguous scenes. They suggested that the threat avoidance effect could be evident only in low-arousal unpleasant emotional stimuli associated with the perception of threat in inappropriate places within ambiguous scenes. Likewise, the sad stimuli used in this experiment are low-arousal unpleasant images that may be interpreted as threatening by SZ patients. In fact, paranoid patients have demonstrated content-specific interpretation biases, showing a stronger paranoid interpretation of material permitting paranoid interpretations (Savulich et al., 2017). Another possible explanation is that depression-related information is more significant for patients with persecutory delusions that threatening information and, consequently, paranoid patients specifically avoid this information. This could endorse the defensive cognitive model of persecutory delusions proposed by Bentall et al. (2001) suggesting that externalizing negative beliefs about the self would give rise to persecutory delusions, preventing depressive symptoms (see Murphy, Bentall, Freeman, O'Rourke, & Hutton, 2018, for meta-analytic evidence). Neither did we find any effect of negative emotions on initial orienting of attention, as the "vigilance-avoidance" hypothesis could have predicted (Green & Phillips, 2004). This may have been due to the difficulty of processing four complex emotional scenes simultaneously presented. Moreover, no eye-movement studies have found an initial orienting bias toward negative emotions related to positive symptoms (Jang, Kim et al., 2016) or paranoid ideation (Provencio, Vázquez, Valiente, & Hervas, 2012). The vigilance effect associated to persecutory delusions only have been observed in very early and pre-conscious stages of attentional processing evaluated with previous response-time based tasks with less complex stimuli such as emotional words or faces (Blackwood et al., 2001). In this regard, Moritz and Steffen (2007) found that negative stimuli can alert SZ patients in very early and automatic stages of attention (<400 ms). With all of this in mind, the results of the present experiment can be congruent with the threat-avoidance hypothesis related to persecutory delusions (Green & Phillips, 2004).

Another interesting finding was that negative symptoms intensity was associated with heightened attention engagement and attentional maintenance to threat. Our findings are consistent with previous eye-tracking and response-time based studies that showed an attentional bias toward negative stimuli in patients with higher negative symptoms (Strauss et al., 2008, 2011). Several factors associated with negative symptoms, like social cognition impairments, affective deficits, or neurocognitive impairments, could explain these results. These factors may result in: i) less sensitivity to threat; ii) more time to recognize threatening emotions, and iii) impaired cognitive capacity to avoid threatening cues once they have detected them. Regarding social cognition (i.e., mental operations used to monitor social signals from others, and to decipher their emotional status and intentions), its impairment shows a significant overlap with negative symptoms while at the same time it may contribute to such negative symptoms as well (Millan et al., 2014). In other words, negative symptoms, because of their interrelation with social cognition, may lead to desensitization to threatening stimuli and could partially explain the reduced requirement to avoid negative emotional experiences related to threatening information processing. As for affective deficits, negative symptoms have been associated with reduced capacity for rating threatening emotions, such as hostility, suspicion, and stress, which could result in more time evaluating threatening information (Carpenter et al., 1988; Kirkpatrick & Buchanan, 1990; Strauss et al., 2008). Finally, concerning neurocognitive impairments, SZ patients with higher negative symptoms display marked neurocognitive deficits, mainly in terms of executive function and top-down cognitive control (Cohen et al., 2007; Kring & Barch, 2014). It may give rise to a difficulty to disengage attentional focus once it has been captured by salient negative stimulus, and have a greater propensity to persevere in negative information due to limited cognitive resources (Strauss et al., 2008; Strauss, Catalano, Llerena, & Gold, 2013). Indeed, this interpretation is supported by neurofunctional findings. Negative symptoms of SZ are associated with abnormalities in the activation of regulatory structures (i.e. anterior cingulate gyrus) when aversive stimuli were processed (Dichter et al., 2010). Moreover, SZ patients showing social dysfunction demonstrated pronounced loss of activation in the neural systems for processing threat-related signals (Williams et al., 2007).

Finally, the control group demonstrated higher percentage of total fixations on happy scenes that the SZ group, suggesting an attentional maintenance bias away from positive stimuli in individuals with SZ. Other studies have demonstrated a lack of attentional capture (Jang, Park et al., 2016; Strauss et al., 2008) or reduced sustained attention (Jang, Kim et al., 2016) to happy stimuli in SZ. In this regard, impairments in the allocation of attentional resources to rewarding stimuli as happy scenes may be associated with dysfunction in the neural processing of positive emotions (Walsh-Messinger et al., 2014), which may be related to inherent SZ symptoms as anhedonia, amotivation, and low interpersonal functioning (Frewen, Dozois, Joanisse, & Neufeld, 2008).

The present experiment has some strengths that must be highlighted. Registering eye movements of the participants during a free-viewing task of four stimuli in competition allowed us to measure different attentional processes during a relatively long period of time. As Fletcher-Watson et al. (2009) suggested, the setting used is a more ecological scenario than other response-time based tasks, where simpler stimuli (i.e., faces, words) are usually presented isolated. Moreover, the stimuli are complex emotional scenes reflecting social and non-social situations extracted from a validated and well-established database (Lang et al., 2005). Of note, socio-emotional information needs to be gathered not only by processing other people's faces, but also their body posture, gestures, and contextual elements (Nikolaides et al., 2016). The characteristics of the sample, showing high psychopathological heterogeneity and with a high age range and different illness courses, confer external validity to the study. Therefore, the results reflect the attentional capture of emotional information in a close to real world scenario and present high representativeness.

Nevertheless, the present experiment comes with certain limitations. First, we did not examine the specific effect of antipsychotic dosage. In this sense, although medication may partly explain some between-group differences in terms of duration and number of fixations, our interest was to study the within-subject differences on emotional processing, so the potential effect of the medication is less relevant. Second, one might consider that anxiety and depression could modulate some of the effects. Although we found no reliable correlations between these traits and attentional outcomes, these null results must be interpreted with caution due to the moderate sample size—keep in mind that anxiety and depression have been systematically associated with attentional biases (Armstrong & Olatunji, 2012). Future research should include a patient group with affective disorders to help delineate this issue. Third, although the use of complex scenes may increase the generalization of findings, it may also decrease experimental control. Fourth, although we excluded subjects with intellectual disability, we did not measure IQ, neither other neuropsychological outcomes. Moreover, we found significant differences regarding years in education. However, attentional processing biases are basic cognitive mechanisms that are scarcely susceptible to these variables (Sadek, Daniel, & Langdon, 2021). In addition, this experiment is cross-sectional, and further research is needed to assess temporal stability and predictive utility of attentional parameters on the course of symptoms of SZ.

To sum up, the present eye-movement experiment revealed abnormal features in the emotional processing of SZ patients, compared to healthy controls. In the framework of affective information-processing models on SZ (Ullmann & Krasner, 1975; Underwood et al., 2016), this pattern endorses that heightened attention to threat is associated with the transition to psychosis. Additionally, a lack of sensitivity to positive information may represent a trait marker in the disorder. Importantly, the attentional bias appears to be modulated by positive and negative symptoms severity in SZ. These results contribute to the progressive paradigm shift related to the association of negative SZ symptoms and attentional bias toward negative information (Strauss et al., 2008, 2011), revealing the clear oversimplification of equating persecutory delusions to heightened attention to threat in SZ (Green et al., 2003; Jang, Park et al., 2016; Phillips et al., 2000). In addition to the theoretical implications, these findings may impact upon specific treatments. In this regard, cognitive biases modification paradigms, in particular attentional bias modification, are promising tools to treat emotional regulation in SZ together with psychotherapy and pharmacological treatments (Hoppitt, Mathews, Yiend, & Mackintosh, 2010; Van Bockstaele et al., 2019; Yiend et al., 2017). Particularly, clinicians should design interventions managing threatening information in SZ, especially when negative symptoms are prominent. Moreover, interventions focusing on sensitization to depression-related information can be considered when positive symptoms are severe.

Funding

PN (CM19/00078), BA (FPU18/01997), and AGB (JR17/00003, PI18/01352) are supported by Instituto Carlos III grants (Spanish Ministry of Economy and Innovation). The financial support had no involvement in study design; in the collection, analysis or interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

Declaration of Competing Interest

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

Acknowledgments

We would like to express our gratitude to the Department of Psychiatry of La Fe Hospital (Valencia, Spain), for allowing us to use the infrastructures, specially to Dr. Livianos. We borrowed the Eye-tracking hardware (SMI RED250) from the Department of Psychology of the University of Valencia. Special thanks to Arash Javadinejad for professional language and writing editing support.

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