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Revisiting attentional processing of non-emotional cues in social anxiety: A specific impairment for the orienting network of attention

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ABSTRACT

People with social anxiety disorder (SAD) exhibit an attentional bias for threat (AB). Nevertheless, the focus on AB for emotional stimuli has led to neglect the exploration of basic attention deficits for non-emotional material among SAD patients. This study aimed to investigate the integrity of the attentional system in SAD. The Attention Network Test was used to precisely explore attentional deficits, and centrally the differential deficit across the three attentional networks, namely *alerting* (allowing to achieve and maintain a state of alertness), *orienting* (allowing to select information from sensory input by engaging or disengaging attention to one stimulus among others and/or shifting the attentional resources from one stimulation to another), and *executive control* (involving the top-down control of attention and allowing to resolve response conflicts). Twenty-five patients with SAD were compared to 25 matched controls. SAD patients exhibited a specific impairment for the orienting network ($p < 0.001$) but preserved performance for the alerting and executive networks. Complementary analyses revealed that this impairment may result from a faster attentional engagement to task-irrelevant material. The orienting impairment was highly correlated with the intensity of the social anxiety symptoms, but did not correlate either with trait-anxiety, state-anxiety, or depressive symptoms.

1. Introduction

It is now well established that individuals with social anxiety disorder (SAD), when compared to nonanxious controls, consistently demonstrate an attentional bias (AB) for threatening cues (e.g., facial expression of anger or disgust; Amir et al., 2003; Mogg et al., 2004). Cognitive theorists have argued that AB may be causally implicated in the maintenance, and perhaps in the etiology, of SAD (Clark and Wells, 1995; Rapee and Heimberg, 1997; for a review, see Morrison and Heimberg (2013)). Accordingly, it has been evidenced that reducing AB (through attention bias modification procedures) alleviates SAD symptoms (e.g., Amir et al., 2009; De Voogd et al., 2014; Heeren et al., 2012). Moreover, recent findings also suggested that experimentally inducing an AB towards threat among healthy volunteers increases SAD symptoms (Heeren et al., 2012).

These research advances to date have generated far-reaching interest in AB for SAD within the scientific and practitioners community. Nevertheless, although several cognitive theorists have suggested that AB might be the consequence of a reduced general ability to control the allocation of attention (for a review, see Heeren et al. (2013)), the focus on AB for emotional stimuli has led to neglect the empirical exploration of basic attention deficits for non-emotional material. Consequently, it has hampered the accumulation of comprehensive evidence regarding the attentional abilities among SAD patients. In particular, the hypothesis that the AB observed in SAD might not be specific to disorder-related stimuli but might rather result from more global attentional impairments has not yet been tested. Clarifying these basic mechanisms involved in AB is critical as this latter has been widely considered as a key process in the maintenance of SAD.

General attentional abilities have been little studied in SAD. First, an eye-tracking study has shown that the attentional difficulties presented by SAD individuals when processing emotional faces are independent of the threatening valence of the stimuli (Wieser et al., 2009). Second, electrophysiological studies (Peschard et al., 2013; Rossignol et al., 2012) have shown that SAD is associated with a general deficit in the ability to regulate the attentional allocation towards emotional as well as non-emotional material (i.e. neutral faces or objects). Finally, very few studies have been conducted regarding the attentional deficits in SAD by means of usual neuropsychological

Abbreviations: AB, Attentional bias; ANT, Attention Network Task; BDI, Beck Depression Inventory; CP, control participants; LSAS, Liebowitz Social Anxiety Scale; MINI, Mini Neuropsychiatric Interview; RT, reaction time; SAD, social anxiety disorder; STAI, State and Trait Anxiety Inventory

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assessment. Their outcomes led to mixed conclusions: some studies have shown preserved abilities on several common tasks assessing attentional and executive abilities (i.e., Sutterby and Bedwell, 2012) while others have described altered performance on tasks assessing selective attention (O'Toole and Pederson, 2011), and altered performance on tasks targeting the executive control of attention (i.e., Judah et al., 2013).

A possible explanation for these discrepancies is that previous studies only used isolated tasks focusing on specific sub-components. Consequently, they were unable to precisely compare the impairments across the different sub-components of the attentional system. A more systematic exploration of attentional system is thus clearly needed and should be based on a unified task offering a differential evaluation of each attentional sub-component. The Attention Network Test (ANT; Fan et al., 2002), based on a recent and validated model of attention (Petersen and Posner, 2012; Posner and Rothbart, 2007), constitutes an adapted tool for this purpose. This task, combining Posner's cueing task (Posner, 1980) and the Flanker task (Eriksen and Eriksen, 1974), efficiently evaluates the three independent attentional networks identified in the model (thus allowing a direct comparison between components in a unified task), namely (1) the *alerting network*, allowing to achieve and maintain a state of alertness, i.e. high sensitivity or readiness to react to incoming stimulation; (2) the *orienting network*, allowing to select information from sensory input by engaging or disengaging attention to one stimulus among others and/or shifting the attentional resources from one stimulation to another; (3) the *executive control network*, involving the top-down control of attention and allowing to resolve response conflicts.

Regarding the metric properties of the ANT, MacLeod et al. (2010) noted several positive features concerning its validity. First, the ANT is based on flanker and cued RT tasks which are well-established in attention research. Second, behavioral studies indicate independence of the ANT scores. Finally, neuroimaging studies reinforced the validity of this task by showing distinct cerebral activations related to each network, i.e. superior temporal and thalamic activations for alerting, superior parietal lobule and temporal fusiform gyrus activations for orienting, thalamic and superior–inferior frontal activations for executive control (Fan et al., 2005). The ANT thus constitutes a powerful and theoretically grounded task to explore attentional components.

Recently, Pacheco-Unguetti et al. (2011) provided the first experimental evidence of attentional impairments among individuals suffering from anxiety disorders using the ANT. In this study, a sample of patients suffering from either generalized anxiety disorder, panic disorder, posttraumatic stress disorder, or obsessive–compulsive disorder were compared to a matched healthy comparison group. While anxious patients exhibited preserved alerting and orienting networks, they evidenced impairments in the executive network. However, despite its potential for bringing new insights concerning attentional deficits in SAD, this task has surprisingly not yet been used among SAD individuals. Given that this study is the first in its kind, several hypotheses can be formulated. Because Moriya and Tanno (2009) reported a negative correlation between orienting network performance and the fear of negative evaluation among healthy volunteers, one possibility is that SAD patients exhibit an impaired orienting network. Alternatively, following the study of Pacheco-Unguetti et al. (2011), SAD individuals may exhibit a selective impairment for the executive network. Finally, because two recent studies reported improvement in the alerting and executive networks among SAD patients following an attention bias modification procedure (Heeren et al., 2015; McNally et al., 2013), one may wonder whether SAD individuals may show impairments for both alerting and executive networks. Hence, the main aim of our study was thus investigate this issue among a selected sample of individuals with SAD.

2. Method

2.1. Participants

The SAD participants were recruited via notices posted in public places and in the waiting room of private practitioners in the Louvain-la-Neuve area. The study was presented as an experiment on basic attention mechanisms underlying social anxiety. Volunteers who had expressed an interest in the study were administered the French version of Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987; for validation of the French version, see Heeren et al., 2012), a self-report questionnaire assessing symptoms of SAD. To confirm the presence of SAD, we administered the social anxiety section of the Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998), a structured interview assessing specific DSM-IV axis I disorders. One assessor administered the MINI to all participants. He had a postgraduate clinical training certification and over 4 y of clinical training, including 1 y of intensive training on using the MINI to make reliable diagnoses. Participants eligible for the SAD group were then selected, with the following inclusion criteria (a) being between 18 and 60 years old, (b) having a total score above 60 on the LSAS (based on the cut-off for SAD for the French version), (c) having a diagnosis of SAD at the MINI, (d) having normal or corrected-to-normal vision. Moreover, participants were not included in the study if they presented: (a) current substance abuse or dependence, (b) current/history of neurological problems, (c) current psychotropic medications.

The SAD group (SAD) consisted in 25 participants (19 women) aged between 19 to 59 years old (M=47.68, S.D.=12.93). SAD participants were matched for age (±2 y), gender, and education level with 25 paired control participants (CP) who were free of SAD symptoms (assessed using the MINI) and of any history of psychiatric and neurological disorder (verbally assessed). CP were recruited through the volunteer pool of the Université Catholique de Louvain (Belgium). Education level was assessed according to the number of years of education completed since starting primary school. Participants were paid 5 euros for their participation. Their demographic characteristics appear in Table 1.

2.2. Materials and measurements

2.2.1. Control measures

Complementarily to the screening measurements, validated self-completion questionnaires were used to assess depression (Beck Depression Inventory 2nd Edition, BDI; Beck et al., 1996) and state- and trait-anxiety (State and Trait Anxiety Inventory; STAI; Spielberger et al., 1983). In the present experiment, the validated

Table 1
Demographic and clinical measures for individuals with social anxiety disorder (SAD) and matched control participants (CP): mean (S.D.).

	SAD (N=25)	CP (N=25)	t or χ^2	p
Demographic measures				
Age	47.28 (12.93)	48.08 (12.78)	0.32[a]	0.75
Gender ratio (male/female)	6/19	6/19	0.01 [b]	0.99
Educational level (in years)	15.16 (2.30)	15.56 (2.58)	0.58[a]	0.56
Clinical measures				
Beck Depression Inventory (BDI)	14.04 (7.50)	4.40 (4.74)	5.43[a]	<0.01
State and Trait Anxiety Inventory-Trait (STAI-T)	40.52 (7.08)	32.68 (10.04)	3.19[a]	<0.01
State and Trait Anxiety Inventory-State (STAI-S)	51.72 (2.93)	50.23 (3.61)	0.77[a]	0.44
Liebowitz Social Anxiety Scale (LSAS)	77.88 (13.11)	27.04 (15.63)	12.46[a]	<0.01

[a] Value for $t(48)$.
[b] Value for $\chi^2(1, N=50)$.

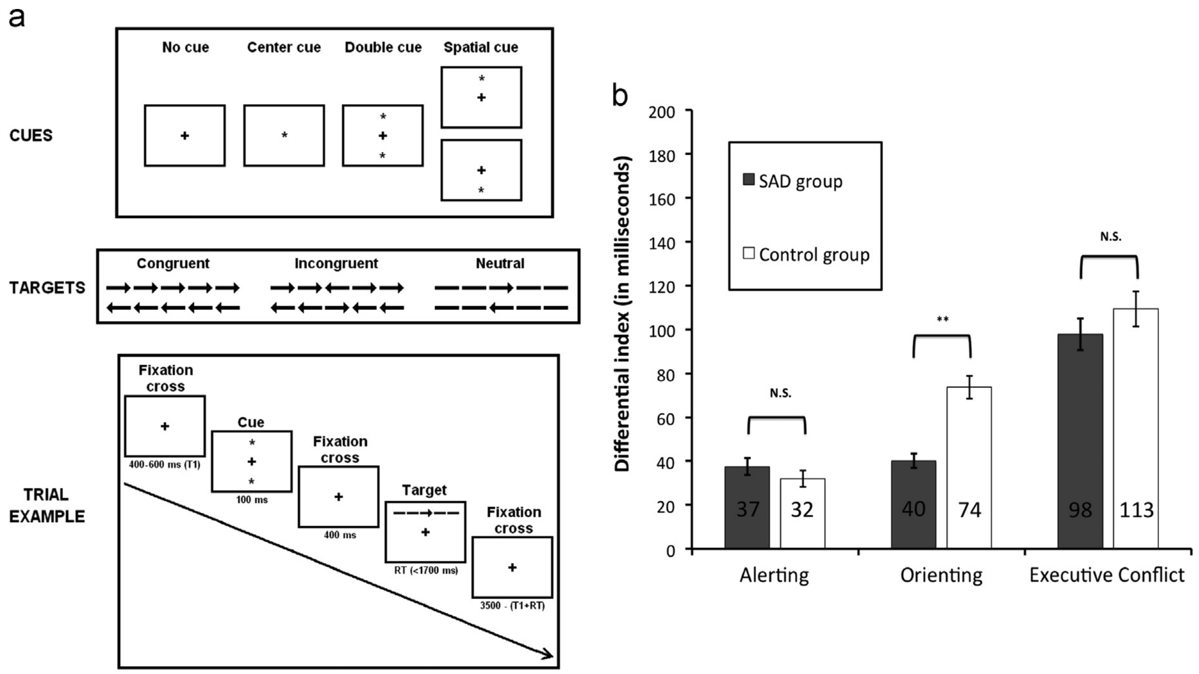

Fig. 1. Description of the Attention Network Test and Differential reaction times (RT) indexes (in milliseconds) among individuals with a social anxiety disorder and matched controls for the three attentional networks. Note. (a) Description of the Attention Network Test, illustrating the four possible cues (upper part), the six possible targets (middle part) and an example of the trials used in the task (lower part, i.e. neutral trial preceded by a double cue, the correct response being "right"). Adapted from Fan et al. (2002). (b) Differential reaction times (RT) indices (in milliseconds) for the three attentional networks, namely Alerting ($RT_{No\ Cue} - RT_{Double\ Cue}$), Orienting ($RT_{Central\ Cue} - RT_{Spatial\ Cue}$) and Executive Conflict ($RT_{Incongruent} - RT_{Congruent}$). For each attentional network, the mean value of the index (rounded to the nearest integer) is provided separately for individuals with social anxiety disorder and control participants. Social anxiety disorder is associated with a specific impairment for the orienting network (*$p < 0.001$).

French versions of these scales were used (BDI-II: Beck et al., 1998; STAI: Bruchon-Schweitzer and Paulhan, 1993).

2.2.2. Experimental measures

The Attention Network Test (ANT) was administered in order to determine the efficiency of three independent attentional networks: alerting, orienting, and executive control (Fan et al., 2002). Participants had to determine as fast and accurately as possible the direction of a central arrow (the target) located in the middle of a horizontal line projected either at the top or at the bottom of a computer screen. They provided their answer by pressing the corresponding button (left or right) on a keyboard. Each target was preceded by a cue, with four possible cue types (Fig. 1, upper part): no cue, center cue (an asterisk replacing the fixation cross), double cue (two asterisks respectively appearing above and below the fixation cross) or spatial cue (an asterisk appearing above or below the fixation cross and indicating the location of the upcoming target). Moreover, flankers were located on the horizontal line on each side of the target, with three possible flanker types (Fig. 1, middle part): either two arrows in the same direction as the target (congruent condition), two arrows in the opposite direction (incongruent condition), or two dashes (neutral condition). As shown in Fig. 1a (lower part), each trial had the following structure: (1) a central fixation cross (random duration between 400 and 1600 ms); (2) a cue (100 ms); (3) a central fixation cross (400 ms); (4) a target and its flankers, appearing above or below the fixation cross (the target remained on the screen until the participant responded or for 1700 ms if no answer was given); (5) a central fixation cross [lasting for 3500 ms minus the sum of the first fixation period's duration and the reaction time (RT)].

RT (in milliseconds) and accuracy (percentage of correct responses) were recorded for each trial. The experiment comprised 288 trials, divided in three blocks of 96 trials each (with a short break between blocks). There were 48 possible trials, based on the combination between four cues (no cue, center cue, double cue, spatial cue), three flankers (congruent, incongruent, neutral), two directions of the target arrow (left, right) and two localizations (upper or lower part of the screen). Trials were presented in a random order and each possible trial was presented twice within a block. The task was programmed and presented using E-Prime 2 Professional® (Psychology Software Tools, Pittsburgh, PA, USA). The distance between participant's eyes and the screen was around 50 cm, and the target stimuli subtended a visual angle of about 4° in the horizontal field. The task was administrated individually in a dimly lit and quiet room during a single session of 40 min.

2.3. Procedure

Each participant first filled in the questionnaires. Then, they read the instructions on the computer screen. The experimenter verbally emphasized these instructions. Prior to start the task, participants performed a training session started, consisting in 24 randomly selected trials. Finally, the experimenter recalled the instructions and answered the remaining questions before starting the experimental task. After the experimental task, each participant was debriefed individually. All participants gave their written informed consent. The study was approved by the Ethical Committee of the Psychological Science Research Institute of the Université Catholique de Louvain and conducted according to the Declaration of Helsinki.

2.4. Data analysis

2.4.1. Power analysis

An *a priori* power analysis was conducted to calculate an adequate sample size for testing our hypotheses using a 2 (groups) × 4 (cues) × 3 (flankers) repeated-measures design (which is the more powerful statistical test used in the present study). Based on previous studies (e.g., Judah et al., 2013; O'Toole and Pederson, 2011), we expected a medium effect size of Cohen's $f = 0.25$ (Cohen, 1988). Setting α at 0.05, power $(1 - \beta)$ at 0.95, and expecting a correlation of $\rho = 0.50$ between repeated measures, the power analysis (G*Power 3.1.3; Faul et al., 2007) indicated that a sample size of at least 22 participants per group would yield an adequate power to detect a medium effect size. These results thus confirmed that the present study has enough statistical power to test our hypothesis.

2.4.2. Data reduction

Data reduction was first performed following the recommendations of Ratcliff (1993): (1) trials with incorrect responses were excluded from the RT analyses (2.97% of trials); (2) RT lower than 200 ms or greater than 2000 ms were removed from analyses (0.002% of trials with correct responses); (3) RT more than two standard deviations below or above each participant's mean for each experimental condition were discarded as outliers (0.013% of the remaining trials). A preliminary analysis showed no difference in RT or accuracy according to the direction (left or right) and localization (upper or lower) of the arrow, and these trials were thus merged, leading to 24 trials for each of the 12 experimental conditions (four cues × three flankers).

A subtraction method (Fan et al., 2002) was then used to isolate the evaluation of the three attentional networks (i.e. RT or accuracy score). We computed the *alerting* effect by subtracting the mean for double cue trials from the mean for no cue trials (No cue − Double cue); the *orienting* effect by subtracting the mean for spatial cue trials from the mean result for center cue trials (Center cue − Spatial cue); and the *executive conflict* effect by subtracting the mean for congruent trials (summed across cue types) from the mean for incongruent trials (Incongruent − Congruent). For both alerting and orienting effects, greater subtraction scores for RT (and lower for accuracy) indicated greater efficiency. In contrast, greater subtraction scores for RT (and lower for accuracy) on executive conflict indicated increased difficulty with executive control of attention (Fan et al., 2005).

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2.4.3. Data analytic plan

With respect to the three indices we computed, two separate 2×3 repeated-measures ANOVAs were first performed for RT and accuracy with Group (SAD, CP) as between-subjects factor and Attention Network (Alerting, Orienting, Executive Conflict) as within-subjects factor. In a subsequent analysis, a general $2 \times 4 \times 3$ repeated-measures analysis of variance (ANOVA) was then performed separately for RT and accuracy with Group (SAD, CP) as between-subjects factor, Cue (no cue, central cue, double cue, spatial cue) and Flanker (congruent, incongruent, neutral) as within-subjects factors. For each ANOVA, significant main effects and interactions were followed by univariate post-hoc (Bonferonni corrected) independent samples *t*-tests. Finally, two-tailed Pearson correlations were used to explore the links between the experimental data and the clinical measurements (i.e., LSAS, STAI-State, STAI-Trait, BDI-II). As our main interest concerns the exploration of a potential deficit in SAD as compared to CS, the results section focuses on group comparison.

3. Results

3.1. Group description

As shown in Table 1, SAD and CP were indistinguishable in terms of age, gender, and years of education, thus confirming the correct matching between groups. Nevertheless, although the two groups did not significantly differ on STAI-State, SAD showed higher scores than CP for BDI-II, STAI-Trait, and LSAS, confirming the clinical status of our sample.

3.2. Experimental measures

3.2.1. Attention networks analysis

The 2 (groups) × 3 (attentional networks) repeated-measures ANOVAs were performed separately for RT and accuracy. The RTs for these three attentional networks are illustrated in Fig. 1.

- Accuracy: Neither main effect of group [$F(1,48)=0.03$, $p=0.87$] nor interaction between group and attentional network [$F(2,96)=1.23$, $p=0.40$] was found.
- RT: A main effect of group [$F(1,48)=10.18$, $p<0.01$] as well as an interaction between group and attentional network [$F(2,96)=6.23$, $p<0.01$] was found. As compared to CP, SAD exhibited a specific impairment for the orienting index [$t(48)=5.47$, $p<0.001$], but neither for Alerting [$t(48)=1.02$, $p=0.31$] nor for Executive conflict [$t(48)=1.46$, $p=0.15$]. Because SAD showed higher scores than CP for BDI-II and STAI-Trait, a covariance analysis (ANCOVA) was performed to examine the influence of these variables. The ANCOVA revealed that the group effect for the orienting index remains significant when entering the BDI-II and STAI-Trait scores as covariates.

3.2.2. General analysis

A 2 (groups) × 4 (cues) × 3 (flankers) repeated-measures ANOVA was performed separately for RT and accuracy. RT and accuracy data for all the possible combination of flankers and cue types are reported in Table 2.

- Accuracy: Neither main effect of group was found [$F(1,48)=0.32$, $p=0.57$] nor any interaction with cue [$F(3,144)=2.56$, $p=0.12$], flanker [$F(2,116)=0.85$, $p=0.43$], or group × cue × -flanker [$F(6,288)=1.00$, $p=0.43$].
- RT: A main group effect [$F(1,48)=5.96$, $p<0.02$] as well as an interaction between group and cues was found [$F(3,144)=10.43$, $p=0.001$]. There was neither group × flanker interaction [$F(2,96)=1.93$, $p=0.15$], nor group × Cue × flanker interaction [$F(6,288)=1.49$, $p=0.18$]. In order to follow-up the group × cue interaction, post-hoc between-group comparison *t*-tests were computed. SAD presented shorter RT than CP for Central, [$t(48)=2.87$, $p<0.01$, $M_{CP}=603$ ms, $S.D._{CP}=97$, $M_{SAD}=531$, $S.D._{SAD}=80$], Double [$t(48)=2.76$, $p<0.01$, $M_{CP}=585$ ms, $S.D._{CP}=85$, $M_{SAD}=522$, $S.D._{SAD}=76$] and No [$t(48)=2.41$, $p<0.05$, $M_{CP}=616$ ms, $S.D._{CP}=86$, $M_{SAD}=559$, $S.D._{SAD}=82$] cues, but not for spatial cues, [$t(48)=1.56$, $p=0.13$, $M_{CP}=529$ ms, $S.D._{CP}=95$, $M_{SAD}=490$, $S.D._{SAD}=80$]. Centrally, as compared to CP, SAD presented shorter RT for all type of cues with the exception of the spatial ones. Because SAD showed higher scores than CP for BDI-II and STAI-Trait, and an ANCOVA was performed to examine the influence of these variables. Results revealed that the group effect as well as the interaction between group and cues remains significant when entering the BDI-II and STAI-Trait scores as covariates.

3.3. Complementary analyses

To explore the potential relationships between each attentional network index and the clinical measurements (i.e. LSAS, STAI-State, STAI-Trait, and BDI-II), Pearson's correlations were performed separately for CP and SAD. For CP, none of these correlations were significant [all *rs* <0.23, all *ps* >0.19]. For SAD, the efficiency of the orienting network was significantly correlated with the LSAS [$r(25)=0.43$, $p=0.03$]. There were no other significant correlations for SAD [all *rs* <0.29, all *ps* >0.16].

4. Discussion

This study was the first to directly investigate the integrity of attention networks in SAD by means of the ANT. The main finding of this study is the observation that individuals with SAD do not present a general attentional deficit but rather a specific impairment for the attentional network related to the orientation of attention.

As the fear of negative evaluation constitutes a core component of SAD, the present findings are clearly in line with Moriya and Tanno (2009) who found a negative correlation between the performance on the orienting network and the fear of negative evaluation among healthy volunteers. Moreover, because earlier studies have clearly shown a reverse pattern of results (i.e. preserved orienting network with impaired alerting or executive ones) in other clinical populations (e.g., Heeren et al., 2014; Maurage et al., 2014; Urbanek et al., 2010), this impairment for the orienting network cannot be explained by a higher complexity of this network as compared to alerting and executive networks. Furthermore, our results are also consistent with earlier studies pointing out the relationship between negative affect and the ability to orient attention towards non-emotional material (e.g., Compton, 2000; Jongen et al., 2007). For instance, Compton (2000) reported that participants who revealed an increase of negative affect following a distressing film had difficulty to orient their attention in a task involving non-emotional stimuli. As the orienting network mostly relied on the parietal cortex (e.g., Raz and Buhle, 2006), particularly the superior parietal lobe and the temporal parietal junction, future neuroimaging studies should also explore the potential difference between SAD and CP on the activations of these regions during such a manipulation.

Remarkably, it should also be noted that, although it tends to prove that all the participants correctly understood the requirement of the task, no group difference was observed for the accuracy levels in any attention network. There are various potential explanations for this lack of effect. First, in line with earlier studies using the ANT among clinical populations (e.g., Fernández et al., 2011; Heeren et al., 2014; Pacheco-Unguetti et al., 2011), one cannot exclude a ceiling effect for accuracy that, in turn, hampers to identify group differences. Second, in line with the attentional control theory (Derakshan and Koster, 2010; Eysenck et al., 2007), one cannot exclude the hypothesis that SAD has greater impact on performance efficiency than performance effectiveness. Indeed, a cornerstone of this theory is the distinction between these two constructs. While the latter

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Table 2
Reaction times (in milliseconds) and accuracy (percentage of correct answers) measures for individuals with Social anxiety disorder (SAD) and matched control participants (CP) in each experimental condition of the Attention Network Test (ANT): mean (S.D.).

	Group	No cue	Center cue	Double cue	Spatial cue
Congruent					
Reaction times (ms)	SAD	532 (74)	488 (72)	484 (65)	478 (85)
	CP	579 (81)	561 (92)	548 (81)	471 (86)
Accuracy (% correct)	SAD	99.33 (1.56)	100.00 (0.00)	99.83 (0.83)	99.66 (1.15)
	CS	99.33 (1.56)	99.17 (2.08)	99.33 (1.56)	99.66 (1.15)
Incongruent					
Reaction times (ms)	SAD	621(107)	614 (116)	595 (100)	536 (84)
	CP	688 (85)	689 (116)	668 (99)	594 (120)
Accuracy (% correct)	SAD	95.83 (5.77)	95.50 (5.09)	95.83 (5.77)	98.50 (2.37)
	CP	96.33 (4.55)	96.17 (4.65)	96.33 (5.42)	97.33 (3.58)
Neutral					
Reaction times (ms)	SAD	525 (72)	493 (77)	489 (74)	462 (75)
	CP	583 (99)	562 (92)	540 (82)	496 (82)
Accuracy (% correct)	SAD	99.83 (0.83)	99.50 (1.38)	99.67 (1.15)	99.67 (1.15)
	CP	98.83 (2.50)	99.00 (2.19)	99.50 (1.38)	99.83 (0.83)

refers to an individual's competence in doing a task (i.e. response accuracy), the former refers to the amount and the manner in which processing resources are invested in doing the task (i.e. reaction times). Accordingly, Derakshan and Koster (2010) reported that anxiety was associated with reduced performance efficiency. Yet this cannot explain why no group difference was observed at the accuracy level in the previous studies that administrated the ANT to patients suffering from disorders that are not directly related to anxiety, such as tinnitus (Heeren et al., 2014) or Wilson's disease (Han et al., 2014).

Interestingly, even if SAD presented globally shorter RT than CP, which is in line with earlier results (e.g., Peschard et al., 2013), a further exploration of the specific trials involved in the computation of the orienting index, that are both the center and the spatial cues (as shown in the general analysis including all the possible combination of flankers and cue types) revealed that the impairment for the orienting network may derive from a reduction in RT provoked by center cues, as the spatial cues were not significantly different than CP. As a consequence, the present findings suggest that the orienting impairment in SAD reflects more a faster attentional engagement on cues that do not provide relevant information about the upcoming target (as evidenced trough significant reduced RT among SAD for center, double, and no cues trials) than on cues that do (i.e. spatial cues trials). One explanation may be that SAD has difficulty filtering out task-irrelevant distractors. This proposal is consistent with recent studies showing that anxious individuals could not inhibit the processing of task-irrelevant information (e.g., Moriya and Sugiura, 2013, Vogt et al., 2013). Accordingly, the present results revealed that SAD correctly process task-relevant material (even if they globally exhibited shorter RTs for all the trials). However, they processed the task-irrelevant material significantly more quickly, while CP did not. Nevertheless, because this proposal relies on *post-hoc* interpretation, it should be interpreted with caution until future experiments directly address this issue with appropriated experimental design. At this end, studies may benefit from directly manipulating the number of spatial task-irrelevant material (e.g., adding uninformative spatial cues that do not predict the target's location).

At a theoretical level, however, the present findings are not at odds with the previous observation that individuals with SAD, when compared to nonanxious controls, often demonstrate an attentional bias (AB) for threatening cues (e.g., Amir et al., 2003; Mogg et al., 2004). Conversely, it does not preclude that a specific impairment for the orienting network may act as a putative mechanism underlying AB. This hypothesis makes sense in the context of previous works suggesting that AB for threat may result from an impairment in the ability to regulate the allocation of attention to task-irrelevant distractors due to that anxious people could not inhibit and resist the interference from those stimuli (Heeren et al., 2013; Moriya and Tanno, 2009; Moriya and Sugiura, 2013). However, as we did not assess AB, uncertainty still abounds regarding the hypothesis of a link between the impaired orienting network and the presence of AB for threat. Future research should thus further investigate this issue.

At a therapeutic level, although replications are clearly needed to first confirm the presence of this specific impairment for the orienting network of attention, the current findings already raised important issue for future translational therapeutic studies that would promote its restoration. Moreover, by directly manipulating the orienting network, such a translational therapeutic approach would allow to directly examine whether the orienting network is causally involved in the maintenance of SAD. Indeed, if this specific impairment for the orienting network is causally involved in the maintenance of SAD, then improving this attentional network should alleviate SAD symptoms. Influential programs have already been developed (e.g. Wells, White, and Carter, 1997) to rehabilitate attention for non-emotional material in SAD and some preliminary proofs of efficiency have been found. Nevertheless, these programs only proposed a global rehabilitation of attention using multi-determined tasks. In view of the present findings, program should more directly promote the orienting network of attention in the context of non-emotional material. Interestingly, several proposals have already been specifically developed at this end in other disorders (e.g., Cerasa et al., 2013; Pisella et al., 2006). Stimulating parietal and temporal areas in SAD by means of neuromodulation may also constitute a promising therapeutic candidate to rehabilitate the orienting network. Indeed, it has been recently reported that these techniques significantly modulate parietal and temporal activity (e.g., Jacobson et al., 2012).

The present study has several limitations. First, although we did administer the SAD section of the MINI, we did not evaluate the other diagnoses. As such, one cannot determine whether the present findings were specific to SAD. However, given the previous observation that patients suffering from other types of psychiatric disorders, including generalized anxiety disorder and panic disorder, exhibit a specific impairment for the executive network (e.g., Gooding et al., 2006; Lyche et al., 2011; Maurage et al., 2014; Pacheco-Unguetti et al., 2011), it is unlikely that the present findings are the mirror of a broader psychopathological construct, such as trait-anxiety. Moreover, the absence of significant correlations between the efficiency of the orienting network and the other clinical measurements renders this possibility unlikely. Nevertheless, follow-up studies may benefit from the inclusion of additional clinical comparison groups (e.g., Lyche et al., 2011). Second, we did not evaluate the participants' potential sleep disturbance. Accordingly, because it has been reported that SAD related to insomnia (Raffray et al., 2011) and that insomnia hampered the efficiency of the attentional networks (Jugovac and Cavallero, 2012), we cannot determine whether the present findings might have been influenced by potential sleep disturbance. However, the previous observation that sleep deprivation exclusively affected the executive network (e.g., Jugovac and Cavallero, 2012) tends to rule out this hypothesis. Nevertheless, future studies should control for this potential influence. Third, as we did not assess performance anxiety and that individuals with SAD were faster than CP for all type of cues with the exception of the spatial ones, certain may wonder whether this global reduction in RT may merely result from an increased situational anxiety during the testing instead of SAD per se. However, the absence of significant correlations between the task performance and situational anxiety (STAI-State) runs counter to this interpretation. Nevertheless, future studies may benefit from the assessment of performance anxiety. Fourth, although the present sample size yields an adequate power to detect medium-sized effects, one cannot exclude that some analyses would require a larger sample size. However, neither the *p*-Values nor the effects sizes that were not significant even approached a statistical tendency. Moreover, it should be noted that a complementary power analysis indicated that a total sample size of at least 260 participants would be required to yield enough power to detect a small effect size in the present study. Consequently, these points tend to indicate that a replication in a larger sample (unless we would be interested to detect small effect sizes) is likely to generate the same pattern of results. Finally, in a study investigating the psychometric properties of the ANT, MacLeod et al. (2010) have shown that orienting and alerting efficiency indices are less reliable than the executive one. However, they also pointed out that the orienting index has the greatest power when used in between-subjects designs. Nevertheless, future studies may directly profit from warranting that the present findings are not circumscribed to RT indices by including additional measurement tools, such as eye-tracking devices or event-related brain potentials recordings during the ANT.

Despite its limitations, we believe that the present study, by offering the first exploration of the integrity of the attentional networks in SAD by means of the ANT and by showing a specific impairment for the orienting network but preserved alerting and executive networks, is a valuable first step towards a better understanding of the neuropsychological processes involved in SAD.

Author contributions

Conceived and designed the experiment: AH, PM, PP. Performed the experiments: AH, PM. Analyzed the data: AH, PM. Wrote the paper: AH, PM. Revised the paper: AH, PM.

Conflicts of interest

All authors declare that no competing interests exist.

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