Cognition and Emotion

ISSN: 0269-9931 (Print) 1464-0600 (Online) Journal homepage: http://www.tandfonline.com/loi/pcem20

Attentional networks and visuospatial working memory capacity in social anxiety

Jun Moriya

COGNITION AND EMOTION, 2016
http://dx.doi.org/10.1080/02699931.2016.1263601

Routledge
Taylor & Francis Group

BRIEF ARTICLE

Attentional networks and visuospatial working memory capacity in social anxiety

Jun Moriya

Faculty of Sociology, Kansai University, Osaka, Japan

ABSTRACT
Social anxiety is associated with attentional bias and working memory for emotional stimuli; however, the ways in which social anxiety affects cognitive functions involving non-emotional stimuli remains unclear. The present study focused on the role of attentional networks (i.e. alerting, orienting, and executive control networks) and visuospatial working memory capacity (WMC) for non-emotional stimuli in the context of social anxiety. One hundred and seventeen undergraduates completed questionnaires on social anxiety. They then performed an attentional network test and a change detection task to measure visuospatial WMC. Orienting network and visuospatial WMC were positively correlated with social anxiety. A multiple regression analysis showed significant positive associations of alerting, orienting, and visuospatial WMC with social anxiety. Alerting, orienting networks, and high visuospatial WMC for non-emotional stimuli may predict degree of social anxiety.

ARTICLE HISTORY
Received 28 August 2016
Revised 21 October 2016
Accepted 17 November 2016

KEYWORDS
Social anxiety; attentional network; working memory capacity; orienting; alerting

Research has shown a clear relationship between cognitive impairment and social anxiety, with attentional and working memory systems being especially important (Amir & Bomyea, 2011; Van Bockstaele et al., 2014). Previous studies have shown impaired attentional control, enhanced attentional sensitivity, and limited working memory capacity for emotional or threatening stimuli, such as angry faces, in social anxiety (Amir & Bomyea, 2011; Moriya & Tanno, 2011). Recent studies, however, have shown that attentional systems and working memory capacity for *non-emotional* stimuli are also related to anxiety and social anxiety (Caparos & Linnell, 2012; Moriya & Sugiura, 2012; Moriya & Tanno, 2009a; Moser, Becker, & Moran, 2012; Stout & Rokke, 2010). These results suggest that attention and working memory for not only emotional stimuli but also non-emotional stimuli may predict degree of social anxiety. Clarifying the general attentional and working memory mechanisms in social anxiety is necessary to move to the next step in understanding this relationship.

To investigate general attentional systems for non-emotional stimuli, the attention network test (ANT) works efficiently (Fan, McCandliss, Sommer, Raz, & Posner, 2002). According to Posner and Petersen (1990), the attentional system is based on three specialised networks: alerting, orienting, and executive control. The alerting network is involved in maintaining a sensitivity level for incoming stimulation. The orienting network involves selecting information from sensory input by engaging with or disengaging from one stimulus. The executive control network involves resolving response conflict and providing top-down control of attention. In the sequence of the ANT, first, an alerting cue, such as an abrupt flash, enhances the sensitivity for incoming stimulation. An orienting cue then indicates the location in which a target will appear. Attention to the orienting cue enhances the efficient detection of the target, although the cue sometimes indicates the opposite location to the target. Finally, a target, which is a horizontal arrow, appears with other arrows (i.e. flankers), and participants determine the direction of the target. When the target and the flankers point in different directions from each other, conflict occurs, and participants resolve the conflict with the executive control

CONTACT Jun Moriya jmoriya@kansai-u.ac.jp

network. The ANT can measure the functioning of these three attentional networks briefly, easily, and simultaneously.

The ANT is widely used to investigate attention in social anxiety and anxiety, because it is useful to examine several theories about attentional mechanisms in anxiety at once. Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, and van IJzendoorn (2007) proposed cognitive mechanisms in anxiety, in which a state of physiological alertness is evoked under threatening conditions. High alerting conditions, then, enhance the orienting network to allocate attentional resources to threat-related stimuli. Based on this model, social anxiety might be associated with enhanced alerting and the orienting network. In Eysenck, Derakshan, Santos, and Calvo (2007), and Bishop (2008), it was proposed that enhanced stimulus-driven, bottom-up attentional systems and impaired goal-directed, top-down attentional systems play a role in anxiety. Enhanced bottom-up attention responds to salient stimuli, such as threatening stimuli, and attention is engaged toward the stimuli whereas impaired top-down attention could explain why anxious individuals cannot inhibit threat-related distractors; because of low-functioning executive control networks. Because threat-related distractors interrupt goals and reduced top-down control is observed in anxiety, anxious individuals cannot resolve conflict between goals and distractors, as they are disrupted by the distractors. Although these mechanisms are based on the premise that anxious individuals encounter threatening situations, socially anxious individuals who are regularly afraid of social situations might show high alerting and orienting and low executive control, based on the mechanisms.

Previous studies using the ANT in social anxiety and anxiety, have shown several valuable results. The results regarding the alerting and executive control networks are consistent in finding that anxiety is related to activated alerting and impaired executive control (Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010; Pacheco-Unguetti, Acosta, Marqués, & Lupiáñez, 2011). A decline of anxiety via attention bias modification improves alerting and executive control (Heeren, Mogoase, Mcnally, Schmitz, & Philippot, 2015). Although orienting is also associated with anxiety (Heeren, Maurage, & Philippot, 2015; Moriya & Tanno, 2009b; Pacheco-Unguetti et al., 2010, 2011), interestingly, the effects of orienting are inconsistent among previous studies.

In Heeren, Maurage, et al. (2015) and Moriya and Tanno (2009b), orienting effect was negatively correlated with social anxiety, whereas Pacheco-Unguetti et al. (2010, 2011) showed that orienting effect was positively correlated with anxiety. These differences might not be due to different participants (i.e. social anxiety vs. anxiety), but variations in voluntary and involuntary attention. In Heeren, Maurage, et al. (2015), and Moriya and Tanno (2009b), when the target was presented, more than 300 ms had passed after the orienting cue appeared. Moreover, in what the authors termed valid conditions, the orienting cue was presented before the target, and always predicted the location of the target. In such situations, attention is operated voluntarily by participants. Because voluntary attention is impaired in anxious people (Bishop, 2009), the individuals with social anxiety showed delayed responses to the target, which may explain why orienting effect decreased in Heeren, Maurage, et al. (2015) and Moriya and Tanno (2009b). In Pacheco-Unguetti et al. (2010, 2011), on the other hand, the target appeared 50 ms after the orienting cue was presented. Under such conditions, attention operates involuntarily, and attention is automatically attracted to the cue. Because involuntary attention is enhanced with anxiety (Moriya & Tanno, 2009a; Moser et al., 2012), the anxious individuals directed attention to the target more rapidly compared to controls. Moreover, in Pacheco-Unguetti et al. (2010, 2011), the orienting cue did not necessarily predict the target location, and sometimes the target appeared opposite to the location of the orienting cue, in what was called an invalid condition. In such a condition, participants needed to disengage their attention from the location of the orienting cue and shift it to the target. Because individuals with social anxiety have difficulty in disengaging attention (Moriya & Tanno, 2011), they delayed their responses in the invalid condition. The combination of rapid attention to the target in the valid condition and delayed responses in the invalid condition may have resulted in the increased orienting effect. However, the role of the orienting network in social anxiety is still unclear, because it is possible that other differences between these studies (e.g. visual vs. auditory alerting cues and anxiety vs. social anxiety) affected the results.

Studies of working memory (WM) for non-emotional stimuli in social anxiety are still scant. Although some previous studies have shown a deficit in WM for non-emotional stimuli in anxiety

(Amir & Bomyea, 2011), the research on visuospatial WM is still in its infancy, especially in the context of social anxiety. While working memory capacity (WMC) is defined as a capacity-limited cognitive resource, in which stimuli remain active for a short duration, visuospatial WMC is defined as a cognitive resource for visual features, such as oriented bars, colour patches, symbols, or objects (Luck & Vogel, 1997). Visuospatial WMC is measurable using a change detection task in which participants are required to retain the features of the items (e.g. colour and orientation) and their location for a short duration (e.g. 1000 ms), while retaining as many features as possible (Luck & Vogel, 1997). The research on visuospatial WM is promising in social anxiety because it is strongly related to attentional networks. Machizawa and Driver (2011) showed coloured squares on either the left or right side in a change detection task, and participants remembered the stimuli displayed on one hemifield. They showed that visuospatial WMC in the change detection task was related to the alerting network in the ANT, and suggested that individuals with high visuospatial WMC might activate an alert state and be ready for encoding multiple stimuli in WM. The visuospatial WMC is also related to the orienting network. Fukuda and Vogel (2011) measured visuospatial WMC using a change detection task and also investigated the orienting effect in a visual search task, in which participants disengaged from a task-irrelevant distractor (e.g. coloured squares) and engaged attention toward a target (e.g. Landolt C). Individuals with low visuospatial WMC had difficulty voluntarily disengaging their attention from stimuli whereas engagement toward a target was not influenced by visuospatial WMC. They suggested that individuals with low visuospatial WMC had difficulty disengaging from distractors and could not exclude the distractors from WM. According to these results, visuospatial WMC might be associated with alerting and orienting networks. Moreover, because impaired attentional disengagement is observed in social anxiety (Moriya & Tanno, 2011), it is possible that social anxiety is related to low visuospatial WMC.

However, the research on social anxiety and visuospatial WMC is still controversial (Moriya & Sugiura, 2012; Qi et al., 2014; Stout & Rokke, 2010). In some studies, reduced visuospatial WMC is observed in anxiety (Qi et al., 2014). Low WMC in anxiety is certainly observed when task-irrelevant distractors are presented. That is, colour-square targets were presented on one side (e.g. left side) and task-irrelevant colour-square distractors were presented on the other side (e.g. right side). However, other research has shown that visuospatial WMC increases in social anxiety when no distractors are presented (Moriya & Sugiura, 2012). When task-irrelevant distractors are presented, participants have to inhibit their processing of them. Individuals with social anxiety, however, have impaired filtering efficiency (Moriya & Sugiura, 2012; Stout & Rokke, 2010). Therefore, when distractors are presented, anxious individuals are not able to efficiently filter the distractors from memory resources, so that low visuospatial WMC is observed in anxiety. Without distractors, participants need not inhibit stimuli. Because anxious individuals may have high attentional resources (Moriya & Tanno, 2010), high visuospatial WMC has been observed in previous research.

Although previous studies have shown the important roles of attention and WM systems in social anxiety, few studies have investigated the roles of both simultaneously. Considering the strong relationships between attentional networks and visuospatial WM (Fukuda & Vogel, 2011; Machizawa & Driver, 2011), it is possible that the impaired attentional networks observed in social anxiety could be explained by visuospatial WMC. It is important to be clear whether social anxiety is influenced by attentional networks, visuospatial WMC, or both.

In the present study, I investigated the relationships of attentional networks and visuospatial WMC for non-emotional stimuli to social anxiety in healthy individuals. Multiple regression analysis was used to explain which cognitive functions could predict the degree of social anxiety. I modified the ANT used in Heeren, Maurage, et al. (2015), in which a visual orienting cue was used and the target was presented 500 ms after the orienting cue, which necessarily predicted the target location. To address the problems mentioned above regarding the orienting network, the inter-stimulus intervals between orienting cue and target were shortened to 100 ms to enhance the effects of involuntary attention to the cue. Moreover, the orienting cue did not necessarily predict the target location in the present experiment. In these invalid conditions, participants must disengage their attention from the cue voluntarily. Considering the enhanced involuntary attention (Moriya & Tanno, 2009a; Moser et al., 2012) and impaired voluntary attention in anxiety (Bishop, 2009), I predicted that orienting effect would be positively associated with social anxiety in the present study, as in Pacheco-Unguetti et al. (2010, 2011). With respect to other attentional networks, previous studies have suggested that social anxiety may be positively correlated with alerting network and negatively correlated with executive control (Pacheco-Unguetti et al., 2010, 2011). In the WM task, I used the change detection task without distractors. Although few studies have investigated the relationship between visuospatial WMC and anxiety, I hypothesised that high visuospatial WMC would predict trait anxiety and social anxiety according to Moriya and Sugiura (2012), in which the authors used the same task without distractors.

Methods

Participants

Participants were 117 undergraduates (96 women, age range 18–25 years, mean age = 19.6, $SD = 1.0$). An a priori power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). For a multiple regression analysis with four predictors (alerting, orienting, executive control, and visuospatial WMC) with a medium effect size ($f = .15$), $\alpha = .05$, and $1 - \beta = .90$, the analysis suggested that a total sample size of 108 would be sufficient. All participants had normal or corrected-to-normal vision. Informed consent was obtained from all participants before inclusion in the study. The study was approved by the institutional review board of Rikkyo University.

Questionnaires

Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983) assesses the common cognitive symptoms of social anxiety, that is, apprehension related to others' negative evaluations. The scale comprises 12 items and uses a 5-point Likert scale. The scale has high internal consistency and test–retest reliability.

Experimental tasks

Attention network test (ANT)

In this task, participants were shown five horizontal black arrows (one central target and four flankers, two on each side), with leftward- or rightward-pointing arrowheads, and they were required to identify the direction of the centre arrow by pressing the designated buttons (Fan et al., 2002). The four flankers always pointed in the same direction. The target-and-flanker array, which was subtended to 5.2°, was presented 2.5° above or below the centre of a box.

First, two boxes were presented above and below the centre. Before the appearance of the target and flankers, a fixation cross appeared at the centre of the screen for a random amount of time between 300 and 1500 ms. Then, there were four conditions: no-cue, double-cue, spatial-cue valid, and spatial-cue invalid. In the no-cue condition, boxes did not flash before the target appeared (24 trials). In the double-cue condition, both cue boxes flashed for 50 ms before the target appeared (24 trials). In the spatial-cue valid and invalid conditions, one cue box flashed for 50 ms before the target appeared (96 trials). The validity of the cue was manipulated such that in 75% of the trials (72 trials), the spatial cues were valid, that is, the target appeared in the flashed box, and in 25% of the trials (24 trials), the cues were invalid, that is, the target appeared in the box opposite to the flashed box. Followed by a 100-ms interval, the target and flankers were presented above or below the fixation cross. Participants were required to respond to the target as quickly and accurately as possible. The target and flankers remained on the screen until the participants responded or until 5000 ms had elapsed.

The direction of the target arrow and flankers were also manipulated to induce conflict effects. In the congruent condition, the target and flanker stimuli pointed in the same direction, while in the incongruent condition, they pointed in different directions. Half of the stimuli in each cue condition were in the congruent condition, and the other half were in the incongruent condition. There were eight trial types (four cue conditions and two target conditions), which were presented at random.

Change detection task

In this task, participants were briefly shown an array of visual stimuli to encode (Luck & Vogel, 1997). Visuospatial WMC was estimated based on the number of visual stimuli presented and the accuracy rates of encoding. All stimulus arrays were presented within a 9.8° × 7.3° region on a monitor with a grey background. Stimuli were placed at least 2.0° (centre to centre) apart. Within the memory array, participants were presented with brief arrays of seven coloured squares (0.65° × 0.65°) for 100 ms and asked to remember the items. Each square was selected at random from a set of eight colours (red, blue, violet, green, yellow, cyan, black, and white), and no two squares had the same colour within a single array. Followed by a 900-ms blank interval, a test array was presented, which was either identical to the memory array or different by one colour, for 1000 ms. Participants were required to press one of two buttons to indicate whether the two arrays were identical or different. The colour of one item in the test array differed from the corresponding item in the memory array in 50% of the trials. In the other half of the trials, the memory and test arrays were identical. Stimulus positions were randomised in each trial. There were 80 trials.

Procedure

After informed consent was obtained from the participants, they first completed the questionnaires. Then, they were required to perform the two experimental tasks. The order of the experimental tasks was counterbalanced.

Data analysis

In the ANT, the index for each attentional network was operationally defined as a comparison of RTs between one condition and the appropriate reference condition: alerting network = (no cue) − (double-cue); orienting network = (invalid) − (valid); executive control network = (incongruent) − (congruent). In the change detection task, each individual's WMC was defined by Pashler's K (Pashler, 1988) due to the use of the whole-display recognition paradigm, $K = S\ (H - F)/(1 - F)$, where K is the memory capacity, S is the size of the array, H is the observed hit rate, and F is the false alarm rate.

Results

First, RTs in the ANT data were analysed to verify that the functioning of each attentional network was measurable. Incorrect responses were excluded. Based on visual inspection, RTs shorter than 200 ms or longer than 1000 ms were removed from the data (0.9%). Thereafter, I also excluded trials where RTs deviated by more than three standard deviations from the individual mean for each participant (1.4%). Mean RTs and error rates are shown in Table 1. A four (cue condition: no-cue, double-cue, spatial-cue valid, and spatial-cue invalid) × 2 (congruency: congruent and incongruent) ANOVA for RTs showed the main effects of cue condition, $F\ (3, 348) = 610.88$, $p < .001$, $\eta_p^2 = .84$, and congruency, $F\ (1, 116) = 1137.25$, $p < .001$, $\eta_p^2 = .91$. RTs between all cue conditions differed significantly. Shorter RTs in the double-cue condition than those in the no-cue condition reflected the alerting effects. Shorter RTs in the spatial-cue valid condition than those in the invalid condition reflected the orienting effects. RTs in the congruent condition were significantly shorter than those in the incongruent condition, which reflected executive control network effects. The two-way interaction was also significant, $F\ (3, 348) = 4.70$, $p = .003$, $\eta_p^2 = .04$. Simple main effects on congruent and incongruent conditions were significant, $F\ (3, 696) = 378.40$, $p < .001$, $\eta_p^2 = .77$, $F\ (3, 696) = 399.32$, $p < .001$, $\eta_p^2 = .78$. RTs between all conditions differed significantly, and these results confirmed that the ANT can measure the three attentional networks. Then, I analysed the correlations between social anxiety and RTs for each condition (Table 1). Social anxiety was positively correlated with RTs in the congruent and invalid-cue condition.

Descriptive statistics and correlations are presented in Table 2. Correlations between the attentional networks were not significant except for a negative correlation between orienting and executive control. Visuospatial WMC was not significantly correlated

Table 1. Mean RTs (ms) and error rates (*SD* in parenthesis) and correlations between social anxiety and RTs for each condition in ANT.

	No-cue	Double-cue	Valid-cue	Invalid-cue
RTs (ms)				
Congruent	528 (52)	505 (52)	449 (49)	569 (63)
Incongruent	596 (59)	588 (55)	519 (55)	644 (59)
Correlations with RTs				
Congruent	.17	.15	.04	.20*
Incongruent	.16	.05	.03	.12
Error rates (%)				
Congruent	0.6 (2.7)	0.6 (2.1)	0.4 (1.2)	1.0 (2.9)
Incongruent	4.8 (8.8)	8.1 (9.4)	4.8 (5.0)	6.6 (9.7)

*$p < .05$

Table 2. Summary of means, standard deviations, and correlations for questionnaires and experimental tasks.

	1	2	3	4	5	Mean	*SD*
1. Social anxiety	—	.16	.20*	−.07	.19*	41.9	10.7
2. Alerting		—	−.09	.08	−.03	17.1	27.2
3. Orienting			—	−.18*	.01	121.0	39.7
4. Executive control				—	−.01	71.7	22.1
5. Working memory					—	5.5	1.2

*$p < .05$.

with attentional networks, either. Social anxiety was positively correlated with the orienting network and visuospatial WMC. Then, a regression analysis was conducted using data on social anxiety, the three attentional networks, and visuospatial WMC. The model significantly predicted social anxiety, $R^2 = .11$, F (4, 112) = 3.53, $p = .009$. Higher alerting efficiency, orienting efficiency, and visuospatial WMC were significantly associated with higher social anxiety (alerting: $\beta = .19$, $p = .037$; orienting: $\beta = .21$, $p = .025$; WMC: $\beta = .20$, $p = .030$), while regression coefficients for executive control efficiency were not significant ($\beta = -.05$, $p = .59$).

Discussion

In the present study, I investigated the relationship of general attentional functioning and visuospatial WMC for non-emotional stimuli to social anxiety. The correlation analysis showed that the orienting network and visuospatial WMC were positively associated with social anxiety. Moreover, the alerting effect, orienting effect, and visuospatial WMC positively predicted the degree of social anxiety when controlling for the interrelations among cognitive functions.

The positive association between orienting and social anxiety was consistent with the hypothesis. In previous studies, negative correlations between orienting effect and social anxiety were found (Heeren, Maurage, et al., 2015; Moriya & Tanno, 2009b), possibly due to impaired voluntary attention toward a target in social anxiety. In the present study, I shortened the inter-stimulus intervals and included the invalid conditions of the ANT to increase the effects of enhanced involuntary attention to orienting cues and difficulty in disengaging attention. This manipulation may emphasise the rapid detection of a target in the valid condition and delayed detection of a target in the invalid condition in the context of social anxiety. Therefore, orienting efficiency increased with the degree of social anxiety, which is consistent with Pacheco-Unguetti et al. (2010, 2011). The present results suggest that enhanced engagement with, and impaired disengagement from, non-emotional stimuli are predictable variables in social anxiety. Pacheco-Unguetti et al. (2011) have shown that engagement cannot, but impaired disengagement can, be observed in anxiety disorder patients. Although the present results could not clarify these differences, the results of correlations between social anxiety and RTs for each condition suggest not engagement but impaired disengagement in social anxiety. Social anxiety was positively correlated with RTs in congruent and invalid-cue conditions. In the invalid-cue condition, participants needed to disengage their attention from a spatial-cue to a target. Increased RTs in this condition suggest that participants had difficulty disengaging from a cue. In the valid-cue condition, rapid engagement of a spatial-cue decrease RTs. However, social anxiety was not correlated with RTs in the valid-cue conditions. Therefore, impaired disengagement, rather than engagement, might be associated with social anxiety.

High visuospatial WMC was also positively associated with social anxiety, which was consistent with previous research (Moriya & Sugiura, 2012). It is possible that high attentional resources, which could help participants retain information, are a feature of social anxiety. Although some previous studies have shown low visuospatial WMC in anxiety (Qi et al., 2014), these studies presented task-irrelevant distractors, which had the same visual features as targets but appeared in different space, differing from the current study. When distractors were presented, socially anxious individuals had difficulty in filtering out the distractors because of impaired attentional control (Bishop, 2009); socially anxious individuals also showed decreased visuospatial WMC compared to controls (Moriya & Sugiura, 2012; Stout & Rokke, 2010). This decreased visuospatial WMC under distractor conditions could explain the findings in the context of social anxiety. Further research should control for the effects of low filtering efficiency on visuospatial WMC in social anxiety, by using tasks with and without distractors. The present results have shown the importance of high visuospatial WMC for predicting degree of social anxiety.

Although the alerting network positively predicted degree of social anxiety, which was consistent with previous studies in anxiety (Pacheco-Unguetti et al., 2010), the executive control network data could not predict it. It is possible that the role of attentional networks in social anxiety and general anxiety differs, although I assume that the problems are not so simple because the decline of anxiety in social anxiety disorders also improves executive control network functioning (Heeren, Mogoase, et al., 2015). The lack of significant correlations between executive control and social anxiety in the present study was not predictable according to previous studies (Pacheco-Unguetti et al., 2010, 2011). It is possible that more focused attention in social anxiety affects the result. In the present study, as well as in Heeren, Maurage, et al. (2015), the target and flankers in the ANT were very close, with about 1° between them. Caparos and Linnell (2012) showed that highly anxious individuals focused more attention on the target compared to low-anxiety individuals, and processing of very close distractor letters was diminished. Increased response conflict in the presence of anxiety was observed for more distant peripheral and salient distractor letters (Bishop, 2009; Moriya & Tanno, 2010). It is also possible that shifting or updating rather than inhibition is more associated with social anxiety. Executive control networks consist of three functions: inhibition, shifting, and updating. Recent studies have investigated the relationships between these functions and anxiety (Berggren & Derakshan, 2013). Although in the flanker task in the ANT, participants are required to inhibit the processing of task-irrelevant distractors, further studies are required to investigate the different aspects of the executive control network and their associations with social anxiety.

No significant correlations were observed between attentional networks and visuospatial WMC, although previous studies found correlations between visuospatial WMC and alerting or orienting (Fukuda & Vogel, 2011; Machizawa & Driver, 2011). Machizawa and Driver (2011) proposed that WM capacity was related to readiness for rapid encoding, which could facilitate the entry of multiple items into WM. Fukuda and Vogel (2011) proposed that individuals with low visuospatial WMC had difficulty in disengaging from distractor stimuli, and could not exclude the distractors from their WM. There is one point of difference between the present study and previous studies in how visuospatial WMC was measured in a change detection task; in the present study, seven coloured targets were abruptly presented whereas in the previous studies, an arrow cue was presented to make participants attend to one hemifield before targets were presented. The arrow might increase readiness for upcoming targets, and a state of enhanced alerting might help to encode more targets. Therefore, high visuospatial WMC was associated with the alerting network in the previous studies, whereas the association was not observed in the present study. Surprisingly, the visuospatial WMC was not correlated with executive control in the present task. However, this result might also be explained by the differences between the previous and present studies. Machizawa and Driver (2011), in other experiment, showed task-irrelevant distractors (i.e. non-target coloured stimuli) close to the targets on the same hemifield. The distractors were so close that participants needed to inhibit the distractors. Individuals with high executive control could efficiently inhibit the distractors and showed high visuospatial WMC in this condition. In the present study, on the other hand, there were no visual distractors and visuospatial WMC might not be associated with executive control.

There are some limitations to the present study. First, it is unclear whether the enhanced alerting efficiency, orienting efficiency, and high visuospatial WMC could predict the occurrence or maintenance of social anxiety disorder. Because the present study was a cross-sectional study and participants were all healthy undergraduates, the present results may not apply to the prediction of disorders. This limitation is important because, in the Research Domain Criteria (RDoC) project, researchers try to classify mental disorders by behavioural and neurobiological measures of cognitive systems, such as attention and working memory. It is important to reveal whether the behavioural performances in the ANT and change detection task could help the classification of social anxiety disorder. Further research should address this issue using longitudinal methods.

Secondly, in the present study, I only measured social anxiety symptoms about fear of negative evaluation, whereas I could not measure any other symptoms (e.g. avoidance of social situations). Interestingly, depending on anxiety symptoms, each attentional network works in social anxiety. Heeren and McNally (2016) showed that the orienting network was associated with fear of social situations in the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987), whereas the alerting network was associated with avoidance symptoms in LSAS. Considering that the BFNE scale in the present research includes items about anxiety in social situations (e.g. When I am talking to someone, I worry about what they may be thinking about me), the positive association between BFNE and orienting network was consistent with Heeren and McNally (2016), whereas the positive association between BFNE and alerting was not consistent. Collins, Westra, Dozois, and Stewart (2005) showed that the BFNE was also positively correlated with social avoidance. Therefore, in the present study, alerting also predicted the degree of social anxiety. It is important to measure several symptom scales and investigate association between the scales, attentional networks, and visuospatial WMC by controlling for each symptom scale.

Thirdly, I could not measure other psychopathological states (e.g. state-anxiety and depression), either. Although previous research showed that social anxiety was more strongly related to impaired attentional control than other types of anxiety or depression (Moriya & Tanno, 2008), it is possible that attentional networks and visuospatial WMC also predict degree of other types of anxiety or depression. Moreover, it is still unclear whether visuospatial WMC is strongly related to social anxiety. Using several scales about social anxiety symptoms and other forms of psychological distress could address these problems.

In conclusion, I was able to clarify the association of orienting with social anxiety, which was inconsistent among previous studies. Increased visuospatial WMC was observed with higher social anxiety in a sufficiently powered sample. Alerting, orienting, and visuospatial WMC predicted the degree of social anxiety. The present study could be helpful in understanding the cognitive systems used to process non-emotional stimuli in the context of social anxiety. Further investigation of these systems in detail (e.g. inhibition, updating, and switching for executive control) might elucidate a link between social anxiety and cognitive functions.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was supported by the Japan Society for the Promotion of Science (JSPS) under Grant-in-Aid for Research Activity Start-up (25885079).

References

Amir, N., & Bomyea, J. (2011). Working memory capacity in generalized social phobia. *Journal of Abnormal Psychology*, *120*(2), 504–509. http://doi.org/10.1037/a0022849

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. http://doi.org/10.1037/0033-2909.133.1.1

Berggren, N., & Derakshan, N. (2013). Attentional control deficits in trait anxiety: Why you see them and why you Don't. *Biological Psychology*, *92*(3), 440–446. http://doi.org/10.1016/j.biopsycho.2012.03.007

Bishop, S. J. (2008). Neural mechanisms underlying selective attention to threat. *Annals of the New York Academy of Sciences*, *1129*, 141–152. http://doi.org/10.1196/annals.1417.016

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience*, *12*(1), 92–98. http://doi.org/10.1038/nn.2242

Caparos, S., & Linnell, K. J. (2012). Trait anxiety focuses spatial attention. *Emotion*, *12*(1), 8–12. http://doi.org/10.1037/a0026310

Collins, K. A., Westra, H. A., Dozois, D. J. A., & Stewart, S. H. (2005). The validity of the brief version of the fear of negative evaluation scale. *Journal of Anxiety Disorders*, *19*(3), 345–359. http://doi.org/10.1016/j.janxdis.2004.02.003

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*(2), 336–353. http://doi.org/10.1037/1528-3542.7.2.336

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, *14*(3), 340–347. http://doi.org/10.1162/089892902317361886

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. http://doi.org/10.3758/BF03193146

Fukuda, K., & Vogel, E. K. (2011). Individual differences in recovery time from attentional capture. *Psychological Science*, *22*(3), 361–368. http://doi.org/10.1177/0956797611398493

Heeren, A., Maurage, P., & Philippot, P. (2015). Revisiting attentional processing of non-emotional cues in social anxiety: A specific impairment for the orienting network of attention. *Psychiatry Research*, *228*(1), 136–142. http://doi.org/10.1016/j.psychres.2015.04.030

Heeren, A., & McNally, R. J. (2016). An integrative network approach to social anxiety disorder: The complex dynamic interplay among attentional bias for threat, attentional control, and symptoms. *Journal of Anxiety Disorders*, *42*, 95–104. http://doi.org/10.1016/j.janxdis.2016.06.009

Heeren, A., Mogoase, C., Mcnally, R. J., Schmitz, A., & Philippot, P. (2015). Does attention bias modification improve attentional control? A double-blind randomized experiment with individuals with social anxiety disorder. *Journal of Anxiety Disorders*, *29*, 35–42. http://doi.org/10.1016/j.janxdis.2014.10.007

Leary, M. R. (1983). A brief version of the fear of negative evaluation scale. *Personality and Social Psychology Bulletin*, *9*(3), 371–375. http://doi.org/10.1177/0146167283093007

Liebowitz, M. R. (1987). Social phobia. *Modern Problems of Pharmacopsychiatry*, *22*, 141–173. http://doi.org/10.1159/000414022

Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, *390*(6657), 279–281. http://doi.org/10.1038/36846

Machizawa, M. G., & Driver, J. (2011). Principal component analysis of behavioural individual differences suggests that particular aspects of visual working memory may relate to specific aspects of attention. *Neuropsychologia*, *49*(6), 1518–1526. http://doi.org/10.1016/j.neuropsychologia.2010.11.032

Moriya, J., & Sugiura, Y. (2012). High visual working memory capacity in trait social anxiety. *PloS One*, *7*(4), e34244. http://doi.org/10.1371/journal.pone.0034244

Moriya, J., & Tanno, Y. (2008). Relationships between negative emotionality and attentional control in effortful control. *Personality and Individual Differences*, *44*(6), 1348–1355. http://doi.org/10.1016/j.paid.2007.12.003

Moriya, J., & Tanno, Y. (2009a). Competition between endogenous and exogenous attention to nonemotional stimuli in social anxiety. *Emotion*, *9*(5), 739–743. http://doi.org/10.1037/a0016817

Moriya, J., & Tanno, Y. (2009b). Dysfunction of attentional networks for non-emotional processing in negative affect. *Cognition & Emotion*, *23*(6), 1090–1105. http://doi.org/10.1080/02699930802335018

Moriya, J., & Tanno, Y. (2010). Attentional resources in social anxiety and the effects of perceptual load. *Cognition & Emotion*, *24*(8), 1329–1348. http://doi.org/10.1080/02699930903378503

Moriya, J., & Tanno, Y. (2011). The time course of attentional disengagement from angry faces in social anxiety. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(1), 122–128. http://doi.org/10.1016/j.jbtep.2010.08.001

Moser, J. S., Becker, M. W., & Moran, T. P. (2012). Enhanced attentional capture in trait anxiety. *Emotion*, *12*(2), 213–216. http://doi.org/10.1037/a0026156

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. *Psychological Science*, *21*(2), 298–304. http://doi.org/10.1177/0956797609359624

Pacheco-Unguetti, A. P., Acosta, A., Marqués, E., & Lupiáñez, J. (2011). Alterations of the attentional networks in patients with anxiety disorders. *Journal of Anxiety Disorders*, *25*(7), 888–895. http://doi.org/10.1016/j.janxdis.2011.04.010

Pashler, H. (1988). Familiarity and visual change detection. *Perception & Psychophysics*, *44*(4), 369–378. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3226885

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25–42. http://doi.org/10.1146/annurev.ne.13.030190.000325

Qi, S., Chen, J., Hitchman, G., Zeng, Q., Ding, C., Li, H., & Hu, W. (2014). Reduced representations capacity in visual working memory in trait anxiety. *Biological Psychology*, *103*, 92–99. http://doi.org/10.1016/j.biopsycho.2014.08.010

Stout, D. M., & Rokke, P. D. (2010). Components of working memory predict symptoms of distress. *Cognition & Emotion*, *24*(8), 1293–1303. http://doi.org/10.1080/02699930903309334

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. W. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin*, *140*(3), 682–721. http://doi.org/10.1037/a0034834