Introduction

Generalized anxiety disorder (GAD) is an anxiety disorder that is characterized by excessive, uncontrollable and often irrational worry about everyday things, which is disproportionate to the actual source of worry [1]. To study its psychopathology, researchers usually adopted patients with generalized anxiety disorder as clinical sample and individuals with high trait anxiety as subclinical sample [2]. Recently, studying subclinical or non clinical population was recommended for the convenient participant recruitment and the exclusion of factors of medicine and therapy.

Cognitive theories about generalized anxiety disorders propose that patients or HTA individuals have cognitive vulnerabilities at the level of attentive processing of threat that may maintain anxiety, and may even lead to the development of clinical anxiety disorders [3,4]. Several studies [5,6] have suggested that the attentional system of anxious individuals may be abnormally sensitive to threat-related stimuli in the environment, leading to an even more pronounced processing bias in favor of threat-related stimulation than is observed in non-anxious individuals. The role of the attentional bias played in the development and maintenance of anxious disorders has been studied for about two decades [7]. Mogg and Bradley [8] proposed the ''vigilance-avoidance'' pattern to interpret the cognitive processing in anxious populations. HTA individuals initially attend to threat, but this is often followed by attentional avoidance of threat. This pattern of vigilance and avoidance is hypothesized to maintain anxiety [9].

Researchers usually used a dot-probe detection paradigm [10] to investigate the attentional bias in high trait anxiety population. In this paradigm, participants were exposed to a word pair or a picture pair on a computer screen, which included one threatening and one neutral word/picture. After the exposure, a dot (the probe) appeared in the location of one of the words/pictures. Participants were instructed to press a button as fast as possible to indicate the detection of the probe. For a short presentation of the stimulus pair (i.e. 500 ms), anxious participants were faster or more accurate to detect the probe when it was in the location of the threatening stimulus [5,11,12]. They exhibited attentional vigilance towards threatening stimuli. However, for a long presentation of the stimulus pair (i.e. 1250 ms or 1500 ms), no attentional effect was found in both HTA and LTA groups [5,12]. This is not consistent with the ''vigilance-avoidance'' pattern proposed by Mogg and Bradley [8] because they predicted attentional avoidance of threatening stimuli with a long presentation. There are two potential reasons to explain the absence of attentional avoidance in previous studies: consciousness manipulation and gender difference in anxiety disorders. Our study aimed to address these two issues.

Many studies have demonstrated that attentional bias could be induced by an unconsciously presented cue [13]. For example, emotional Stroop task with backward masking was widely used in this field and researchers consistently found that HTAs exhibit attentional bias to threatening materials at subconscious level [14–16]. However, one drawback of backward masking is that this technique cannot render a stimulus invisible for a long presentation, thus is not suitable for test the ''vigilance-avoidance'' proposal.

This drawback can be overcome by another psychophysical method – binocular rivalry. When two incompatible pictures are presented to the two eyes that cannot be merged to a single visual percept, binocular rivalry occurs. Observer's perception switches back and forth between the two incompatible pictures, that is, they compete for perceptual dominance [17]. Some factors could boost the strength of one rival picture over another, such as high-contrast, brighter stimulus, moving contours, densely contoured, and stimuli presented in dominant eye [18]. Accordingly, the 'stronger' competitor enjoys an advantage in overall perceptual dominance. Jiang et al. [19] took advantage of binocular rivalry to participants were required to press one of two buttons to indicate their perceived orientation of the gabor patch regardless of the side of presentation (see Figure 2).

Total 256 trials were randomized across experimental conditions, including position of face image (left or right to the fixation point), position of the gabor probe (left or right to the fixation point), face emotion (fearful or happy), face gender (male or female) and visibility (visible or invisible). These trials were divided into four blocks, 64 trials for each block.

Before the experiment, participants practiced 50 trials for the invisible condition to get familiar with the experimental procedure. Those who reported seeing face images in the invisible condition were excluded from the experiment.

Design. For the independent variables, the between-subject variables were group (high trait anxiety vs. low trait anxiety) and gender (female vs. male). The within-subject variables were emotion (fearful vs. happy) and visibility (visible vs. invisible). The dependent variable was the orientation discrimination accuracy of the gabor patch. The working hypothesis was that if there were attentional effects (either bias or avoidance) induced by the emotional pictures as a cue, the discrimination accuracy would be increased or decreased. We quantified attentional effect as the discrimination accuracy of the gabor probe presented at the position of the intact image minus the discrimination accuracy of the gabor probe presented at the position of the scrambled image, following the method in Jiang et al. (2006) [19].

A positive value of attentional effect indicated attentional bias, which meant that attention was oriented toward emotional images, and a negative value indicated attentional avoidance, which meant that attention was oriented away from emotional images. Attentional effects were analyzed separately for the visible condition and the invisible condition, and the later one was one of the focuses of this study.

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Visible condition. Attentional effects by happy and fearful faces in HTA and LTA groups are presented in Figure 3. A $2\times2\times2$ mixed-design ANOVA, with face emotion (happy/fearful) as within-subject variable, and anxiety state (HTA/LTA) and attentional effect was dependent on anxiety state. Thus, we performed 2 (face emotion)×2 (gender) ANOVA s for the HTA and LTA groups separately. The interaction between face emotion and gender reached a significant level in the HTA group (F (1, 22) = 5.35, $p = 0.031$), but not in the LTA group (F (1, 22) = 1.89, $p = 0.183$). In addition, the HTA group also exhibited a marginally significant gender effect (F (1, 22) = 4.11, $p = 0.055$). A one sample t-test was conducted to further confirm the effect of interaction, and revealed that female participants in the HTA group showed a significant attentional bias towards fearful faces (t (11) = 2.66, $p = 0.022$). It is also worth noting that male participants in the HTA group showed a marginally significant attentional avoidance of fearful faces (t (11) = 2.01, $p = 0.069$).

Experiment 2

In Experiment 1, we found a marginally significant attentional effect (avoidance) by fearful faces for HTA male participants in the invisible condition. It might be due to a small sample size (12 participants). Here, we conducted a second experiment employing a similar procedure with more participants. We also included neural face pictures as stimuli to examine if there was any difference between neural faces and emotional (happy or fearful) faces.

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Design. A between-subject independent variable was gender (female vs. male). Within-subject independent variables were emotion (fearful vs. neutral vs. happy) and visibility (visible vs. invisible). Data were analyzed separately for the visible condition and invisible condition.

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Attentional effects by neutral, happy and fearful faces in the HTA group were presented in Figure 5. A 2 (female/male)×3 (happy/neutral/fearful) mixed-design ANOVA was performed for the visible condition and invisible condition separately.

No significant effects were found in the visible condition. In the invisible condition, the interaction of gender and emotion was significant ($F(2, 33) = 5.6$, $p = 0.008$), and the main effect of gender was also significant ($F(1, 34) = 8.62$, $p = 0.006$). A one sample t-test found that, female participants exhibited attentional bias to fearful faces ($t(17) = 2.89$, $p = 0.01$), while male participants exhibited attentional avoidance of fearful faces ($t(17) = -3.75$, $p = 0.002$). This result supported that there was gender difference in HTA population. Additionally, we did not find attentional effects by both neutral and happy faces (see Figure 5).

Discussion

Using binocular suppression to render face images invisible, we

HTA females in our study may be vulnerable to fearful faces, so that they could not direct their attention away from the negative information.

Our study emphasizes two important issues in psychopathological researches. One is consciousness manipulation, the other is gender difference. Previous studies [8,42,43] have tried different

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