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Attentional blink affected by acute stress in women: The role of affective stimuli and attentional resources

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ABSTRACT

The role of attentional resources and affective stimuli on temporal selective attention in the rapid serial visual presentation (RSVP) paradigm under acute stress was explored among women. Seventy-three female undergraduates were randomly assigned to the Trier Social Stress Test (TSST) group or control group. We found that when the first target was negative, stress increased its accuracy. Stress promoted the recognition of neutral target two (T2) only at lag2, and there was no interaction with the emotionality of target one (T1). In addition, the accumulated effect of stress enhanced temporal selective attention, predominately 20–40 min after the TSST task; cortisol concentration during this time period could significantly predict AB task performance. In summary, when attentional resources were severely insufficient, individuals under stress were more able to focus on the current target; that is, stress facilitated selective attention. A novel result was that participants were exempt from the affective influence of previous targets, which may have been caused by activation of the autonomic nervous system and gender differences.

1. Introduction

With rapid social developments and increasing competitive pressures in various fields, people frequently experience stress. In response to stressors, the human body engages in an adaptive response to improve the organism's ability to survive. Activation of the hypothalamus-pituitaryadrenal (HPA) axis and sympathetic nervous system (SNS) can release glucocorticoids and catecholamines, which affect many affective and cognitive functions (Dandolo & Schwabe, 2016; Gärtner, Rohde-Liebenau, Grimm, & Bajbouj, 2014; Hamilton & Brigman, 2015; Jiang et al., 2017).

A series of physiological and psychological reactions caused by stress also affect people's perception and selective attention to their environment (Brüne, Nadolny, Güntürkün, & Wolf, 2013; Macatee, Albanese, Schmidt, & Cougle, 2017; Nelson, Purdon, Quigley, Carriere, & Smilek, 2015). In our daily lives, selective attentional processing is continually performed in response to visual stimuli. The attentional blink (AB) task can utilize a series of visual stimuli; therefore, this task could improve the ecological validity of laboratory-based selective attention research. According to the two-stage model of attentional blink (Chun & Potter, 1995), attentional resources can be effectively regulated by setting the different position of target one (T1) and target two (T2) in a rapid serial visual presentation (RSVP) paradigm. When the stimulus onset asynchrony (SOA) between the two targets is 200–500 ms, the

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attentional resources reserved for T2 are insufficient, which results in a transient impairment in detecting T2 (Raymond, Shapiro, & Arnell, 1992).

The results of studies concerning the effect of acute stress on selective attention are inconsistent. One of the main factors affecting selective attention is available attentional resources (Lavie & Tsal, 1994). Previous studies have shown that acute stress and perceptual load consume the same attentional resources (Sato, Takenaka, & Kawahara, 2012; Tiferet-dweck et al., 2016). Under the dual conditions of high perceptual load and stress, the attentional resources allocated to the current task are severely insufficient. According to the perceptual load theory, limited attentional resources are focused on the current target, which results in unavailability of additional resources to direct toward a distracting stimulus under high cognitive load (Lavie, 1995, 2005). Accordingly, many researchers have found that stress enhances selective attention by reducing the interference of distracting stimuli (Hoskin, Hunter, & Woodruff, 2014; Sato et al., 2012; Tiferet-dweck et al., 2016). To our knowledge, very few researchers have examined the impact of stress on temporal selective attention in RSVP. Schwabe and Wolf (2010) found that acute stress slightly enhanced T2 detection performance in males, both at early lags (SOA $<$ 500 ms) and late lags (SOA $>$ 500 ms). That is, the stress-related promotion of T2 processing in males is not related to available attentional resources. These studies also showed that high cortisol responses to stress enhanced the accuracy of T2 detection at shorter lags. It seems that high concentrations of cortisol promote the processing of targets when available attentional resources are insufficient.

However, some researchers arrived at the opposite conclusion. They found that stress consumes attentional resources and reduce the ability to filter distractions, thereby increasing the interference of irrelevant information and thus damaging selective attention (Bernstein-Bercovitz, 2003; Henckens, van Wingen, Joëls, & Fernández, 2012; Olver, Pinney, Maruff, & Norman, 2014). Researchers who explored the effect of stress on the standard AB (without affective stimuli) found that the accuracy of T2 detection was significantly lower in the stress group than in the control group at shorter lags, but not at longer lags (Kawahara & Sato, 2012, 2013). When the attentional resources reserved for T2 were insufficient, the stress further consumed the attentional resources and impaired the selective attention, thereby reducing the accuracy of T2 detection and increasing the AB. Therefore, it is important to explore the effect of stress load on selective attention.

Numerous researchers have shown that acute stress enhances attention bias toward threatening stimuli (Macatee et al., 2017; Nelson et al., 2015; Quigley, Nelson, Carriere, Smilek, & Purdon, 2012; Sanchez, Vazquez, Gomez, & Joormann, 2014). However, Jiang et al. (2017) found that individuals shift the attention from negative stimuli to more threatening stressors, thus ignoring negative stimuli, and thereby reducing the attentional bias toward threatening stimuli. Tiferet-Dweck and colleagues (2016) found that acute stress can enhance the attentional bias and prolong the reaction times when the target receives adequate attentional resources. In contrast, they found that stress does not differentially effect the recognition of negative and neutral stimuli. Additionally, Schwabe and Wolf (2010) studied the emotional modulation of the AB. They used emotional words as materials and defined T1 and T2 according to four combinations: (a) both targets were neutral, (b) T1 was neutral and T2 aversive, (c) T1 aversive and T2 neutral, or (d) both targets were aversive. Regardless of the combination, the effect of stress on temporal selective attention was not regulated by the emotionality of target and attentional resources. Schwabe et al. (2011) found that the emotional attentional blink (EAB, in which T1 is emotional stimulus) and attentional-blink sparing effects (in which, T2 is emotional stimulus) represent different cognitive processing mechanisms. Therefore, the effect of acute stress on temporal selective attention, which is further influenced by attentional resources and the emotionality of the stimulus, needs separate investigation.

Given the above reviewed, this study explores the mechanism of attentional processing under stress in the RSVP paradigm, which could reflect well the practical significance of selective attention. A prior study showed that when both T1 and T2 were emotional stimuli, the effect of emotional T1 was dominant (Schwabe & Wolf, 2010). Therefore, we further investigated the effect of stress on subsequent targets after processing emotional targets in milliseconds. Emotionality was manipulated only for T1, while the attentional resources available for detection of T2 were manipulated by providing different locations for targets to further explore the effect of attentional resources and affective stimuli on the temporal selective attention under stress. In addition, the only previous study of the effect of stress on attentional blink was conducted with male participants in order to control the influence of female hormones on the acute stress response. Thus, the present study intends to further validate prior results in female subjects. The time course of AB with respect to acute stress was also analyzed. We hypothesized that when the attentional resources were insufficient, stress would promote the recognition of neutral targets, improve temporal selective attention, and remove interference by threatening stimuli.

2. Method

2.1. Participants and design

To avoid the impact of trait anxiety and depression on this experiment (Booij et al., 2015; Fisher, Granger, & Newman, 2010), 350 state-trait anxiety inventory (STAI) and Beck depression inventory (BDI) were randomly distributed through the online recruitment platforms of Shaanxi Normal University. Eighty healthy female undergraduates (age: $M = 19.47$, $SD = 1.82$; trait anxiety scores: $M = 41.93$, $SD = 4.53$; depression scores: $M = 4.18$, $SD = 2.78$) who met the requirements voluntary participated in this experiment and signed informed consent. The body mass index (BMI) values of the subjects ranged from 18 to 27. Subjects also were screened according to the effects of known factors on endogenous cortisol concentrations (Kudielka, Hellhammer, & Wüst, 2009; Kuhlmann, Kirschbaum, & Wolf, 2005). The exclusion criteria as follows: (1) no history of heart disease or hypertension; (2) no medications or caffeine-containing foods during the last three days of the experiment; (3) no symptoms such as bleeding gums and mouth ulcers; (4) there is no strenuous exercise, eating or drinking within 3 h before the experiment; (5) girls avoid menstrual period. To avoid the

effects of cortisol circadian rhythm, all experiments were performed between 2:00 pm and 6:00 pm (Federenko et al., 2004; Izawa, Sugaya, Yamamoto, Ogawa, & Nomura, 2010). The study conformed to the principles of the Declaration of Helsinki (World Medical Association, 2013) and was approved by the Academic Committee of the Ministry of Education of Key Laboratory of Modern Teaching Technology, Shaanxi Normal University in China. This study adopted a three-factor mixed experimental design. Acute stress was the between-subjects variable. T1 emotion and lag were the within-subjects variable. The dependent variables were the accuracy of T1 detection and T2 detection.

2.2. Materials

2.2.1. T1 In RSVP task

Negative pictures and neutral pictures were selected from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2008). Negative pictures were people or animals, which involves violence, disaster and trauma. The number of people and animals in the neutral picture matched the number of people and animals in the negative picture. 19 undergraduates who did not participate in the present experiment were recruited to judge the accuracy of T1 detection (negative or neutral) in the RSVP paradigm in order to ensure that the participants can accurately identify the emotional information of the emotional picture. According to the accuracy of the picture response, 72 images were selected for the study. It included 36 negative and 36 neutral images, and the average accuracy was 93%. Inter-item analysis showed that the difference between negative images ($M = 0.93$, $SD = 0.06$) and neutral images ($M = 0.93$, $SD = 0.06$) was not significant, $t\ (70) = -0.15$, $p = 0.88$. The undergraduates also rated the arousal and the pleasure of the 72 emotional pictures needed for this study. An independent sample *t*-test was performed on the pleasure and arousal of the neutral and negative images, respectively. The results showed that the pleasure of the neutral picture ($M = 5.02$, $SD = 0.47$) was significantly greater than that of the negative picture ($M = 2.11$, $SD = 0.65$), $t\ (70) = 27.22$, $p < 0.001$. The arousal of neutral picture ($M = 4.23$, $SD = 0.47$) was significantly less than the arousal of the negative picture ($M = 7.40$, $SD = 0.80$), $t\ (70) = -25.54$, $p < 0.001$.

2.2.2. T2 in RSVP task

Landscape and architectural images were selected from the copyright-free photo site (https://pixabay.com/). The size of all the color picture stimuli were 420 × 315 pixels (or the viewing angle was 8.6° × 7°, the distance between the subject and the screen was 70 cm). The T2 pictures were evaluated in the RSVP paradigm that the stimuli presentation and related parameters were consistent with formal experiments to ensure the rationality of the picture selection. In this RSVP paradigm, only one target image rotated 90° to the left or right, and the remaining were upright landscape or architectural images. According to the accuracy of the picture response, a total of 84 pictures were selected for the study, including 42 landscape and 42 architectural pictures, with an average correct rate of 98%. Inter-item analysis showed that the difference between the landscape picture ($M = 0.98$, $SD = 0.02$) and the architectural picture ($M = 0.98$, $SD = 0.02$) was not significant, $t\ (82) = 0.11$, $p = 0.91$.

2.3. Measures

2.3.1. Subjective measures

The Positive and Negative Affect Schedule (PANAS) (Watson, Clark, & Tellegen, 1988) and the Chinese version of the trait anxiety portion of Spielberger's State-Trait Anxiety Inventory (STAI) (Shek, 1993; Spielberger, 1983) were used in this experiment to measure the emotional state of subjects at three time points (0 min, 13 min and 53 min).

2.3.2. Heart rate recording

The electrocardiogram (ECG) 100C amplifier module from BIOPAC MP150 (BIOPAC Systems, Inc., CA, USA) was used to measure heart rate. It was measured via three Ag-AgCl disposable electrodes, which were placed on the right upper limb and the right and left lower limbs after the surface was cleaned with alcohol. Heart rate was continuous recording after the practice experiments until the end of the whole experiment and was averaged at each assessment point for each participant.

2.3.3. Saliva sample collection

Enzyme-Linked Immuno Sorbent Assay were used to analyze the saliva samples. Saliva samples were acquired naturally by salivette sampling devices (salivette, Sarstedtstr.1 D-51588. Germany) at 6 time points: 0 min (t1), 13 min (t2), 23 min (t3), 33 min (t4), 43 min (t5), 53 min (t6). All the saliva samples immediately stored frozen at –20 °C until assay. Thawed saliva samples were centrifuged at 2–8 °C for 20 min (3000 rpm), the supernatant was taken for measurement.

2.3.4. Stress induction

In the stress condition, participants were exposed to the Trier Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993). The stress phase lasted 13 min, which consisted of 3 min of preparation time, 5 min of presentation, and 5 min of mental arithmetic. First, the experimenter explained the instructions to the participant. "Now, you need to take an interview and apply for a sales manager position. Later, you need to give a 5 min speech to explain your competitive advantage. The interviewer were professional voice and speech analyst who will rate your speech based on your presentation, logical thinking, and language skills. We will use the camera to record the entire process of your interview for analysis. There will be another task after the speech, the interviewers will personally explain to you. Now give you 3 min to prepare." Next, participants were asked to subtract increments of 17 from 2023 as

quickly and accurately as possible for 5 min. If the calculation was wrong, the interviewer will interrupt and instruct the participant to restart from 2023 (Kudielka, Hellhammer, Kirschbaum, Harmon-Jones, & Winkielman, 2007). During the entire stressful task, all interviewers performed neutrally and indifferently, without any verbal and nonverbal evaluations and feedback.

In the control condition, participants were required to give a free speech for 5 min without limiting the content of the speech. After that, they were asked to count in increments of 15, starting at 0, for 5 min. In order to control the influence of unrelated factors, the entire control task only removed the stressors such as interviewers and camera, other conditions were consistent with the TSST task.

2.3.5. RSVP task

The RSVP task was created with the E-prime2.0 software and presented on a 24-inch computer screen (resolution: 1980 × 1080, refresh rate: 100 Hz). Each trial started with a fixation cross presented for 1000 ms in the center of the display, which was subsequently replaced by a rapid serial presentation of images. Seventeen images, including T1, T2, and 15 upright landscape or architectural images as distractors, were presented on each trial. Each image was presented for 100 ms. T1 was a negative or neutral image presented in stream position 4, 6 or 8, and each position was used equally often for each combination of emotion condition and lag. T2 was a landscape or architectural image that was rotated 90° left or right from its conventional orientation and presented at position 2, 4, 6, or 8 after T1 (with a lag of 2/4/6/8). The first task for the participants was to determine whether T1 was negative (by pressing the "1″ key) or neutral (by pressing the "2" key). Next, the participants searched for a rotated image and determined the direction of rotation by pressing the left arrow key for 90° left and the right arrow key for 90° right. The positions of T1 and T2 were balanced between the conditions. All the stimuli in the sequence were randomly presented. The formal experiment consisted of 288 trials divided into eight blocks. To ensure that the entire attentional blink task was completed under stress or control, the break time between each block was fixed at 1 min and the key response time was fixed at 2 s. The subjects need to carry out 16 trails practice experiment before the formal experiment. No feedback was set in the practice experiment to avoid putting pressure on the subjects. The parameter setting of the exercise task was consistent with the formal experiment, and the materials in the formal experiment were not included in the practice experiment.

2.4. General procedure

Following obtaining informed consent, participants were gargled to ensure that there were no foreign bodies in the oral cavity, and then filled in PANAS and STAI as the pretest of participants' subjective mood. After that, they completed the practice experiments. Heart rate was recorded after subjects fully understood the AB task. They rested for 20 min and provided the first salivary sample. Next, participants were exposed to the TSST or the control condition. Heart rate was continuously measured until the end of the experiment. After the treatment, participants completed the PANAS and STAI again to reflect how they felt about the situation they had experienced. They also provided a second salivary sample. Later, they were allowed to start with the RSVP task. Saliva samples were collected every 10 min after stress or control task. At the end of the experiment, a last saliva sample and PANAS was collected. The recording of heart rate was stopped (see Fig. 1).

2.5. Statistical analysis

Data with T1 accuracy below to 0.72 were excluded. There were also three participants were excluded because the amount of saliva collected was insufficient to analyze biochemical indicators. A total of 73 subjects were involved in the analysis, including 37 stress groups and 36 control groups. We analyzed the subjective assessments using a 2 (group: TSST/control condition) × 3 (time points: t1/t2/t6) repeated measures ANOVA and the heart rate using a 2 (group: TSST/control condition) × 4 (time: −20 to 0 min/0–10 min/10–30 min/30–50 min) (pre/TSST/post 0–20 min/post 20–40 min) repeated measures ANOVA. Changes in saliva cortisol (sC) and saliva alpha amylase (sAA) were compared in a 2 (group: TSST/control condition) × 6 (time points: t1/t2/t3/t4/t5/t6) repeated measures ANOVA. For our analysis of T2 data, only trials with a correct T1 identification were taken into account. Performance in the RSVP task were examined in a 2 (group: TSST/control condition) × 2 (T1 emotion: neutral/negative) × 4 (lag: 2/4/6/8) repeated measures ANOVA. All ANOVA results were corrected by Greenhouse-Geisser, and the comparison between conditions was corrected by Bonferroni. Partial-eta^2 ($\eta 2_p$) was reported as a measurement of effect size for F-test.

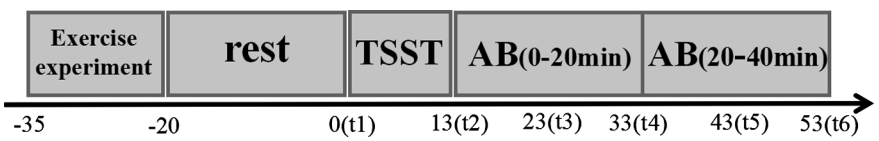

Fig. 1. Salivary samples were collected at six time points (t1-t6). Heart rate was recorded after the exercise experiment and stopped until the end of the whole experiment.

3. Results

3.1. Subjective assessments to stress

The interaction between Time and Group was significant, for PANAS (negative affects), F (1, 71) = 25.089, $p < 0.001$, $\eta^2_p = 0.261$, for state anxiety, F (1, 71) = 50.557, $p < 0.001$, $\eta^2_p = 0.416$. The scores of PANAS and state anxiety within the stress group at t2 were significantly higher than those in the control group ($p < 0.001$), and there was no significant difference between the two groups at other time points. In the stress group, the negative affect and state anxiety at t2 were significantly higher than those at t1 and t3 ($p < 0.001$ for both), and the differences between the three time points in the control group were not significant. Time main effect was significant, for PANAS (negative affects), F (1, 71) = 21.261, $p < 0.001$, $\eta^2_p = 0.230$, for state anxiety, F (1, 71) = 30.108, $p < 0.001$, $\eta^2_p = 0.298$. There was a significant main effect of Group, for PANAS (negative affects), F (1, 71) = 16.266, $p < 0.001$, $\eta^2_p = 0.186$, for state anxiety, F (1, 71) = 39.695, $p < 0.001$, $\eta^2_p = 0.359$. This result indicated that participants experienced negative affect and anxiety state after TSST (see Figs. 2 and 3).

3.2. Physiological responses to stress

3.2.1. Heart rate

The repeated measures ANOVA of the heart rate data results revealed that the interaction between Time and Group was significant, F (1, 71) = 20.824, $p < 0.001$, $\eta^2_p = 0.227$. The heart rate of the stress group was significantly higher than that of the control group during the TSST, $p < 0.001$, but the differences between the groups at other times were not significant. In the stress group, the heart rate during the TSST was significantly higher than at other times. The main effect of Time was significant, F (1, 71) = 107.449, $p < 0.001$, $\eta^2_p = 0.602$. The main effect of Group was significant, F (1, 71) = 4.439, $p = 0.039$, $\eta^2_p = 0.059$. In general, during the stress task, the heart rate of the subjects significantly increased, and after the stress task, the heart rate quickly fell back to the baseline (see Fig. 4).

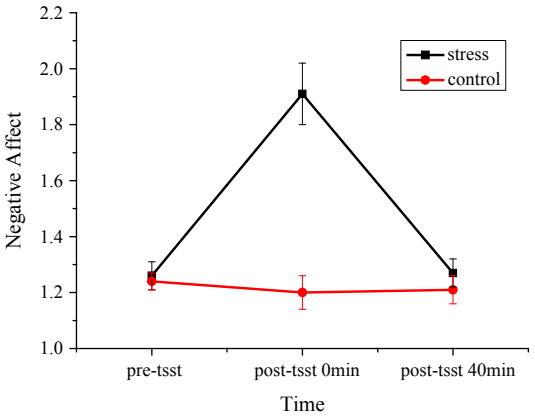

Fig. 2. Means and standard errors of negative affect over time for the stress and control groups. The bars of all the figures in the text are standard error.

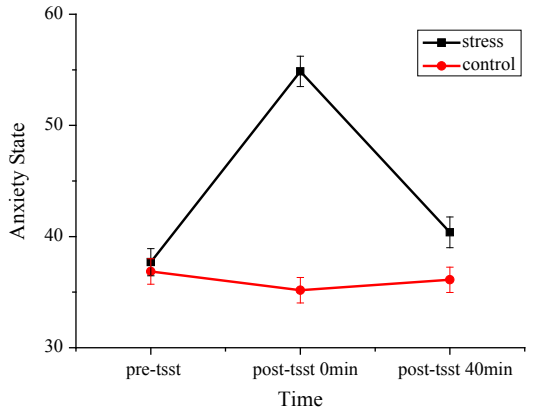

Fig. 3. Means and standard errors of anxiety state over time for the stress and control groups.

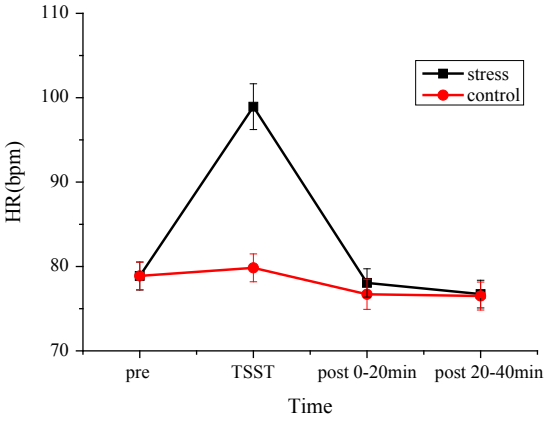

Fig. 4. Means and standard errors of heart rates (HR) over time for the stress and control groups.

3.2.2. Salivary cortisol (sC)

The results showed that the main effect of Time was significant, F (1, 71) = 74.452, $p < 0.001$, $\eta^2_p = 0.512$. The main effect of Group was significant, F (1, 71) = 431.568, $p < 0.001$, $\eta^2_p = 0.859$. There was a Time × Group interaction, F (1, 71) = 46.152, $p < 0.001$, $\eta^2_p = 0.394$. Simple effect analysis show that there was no significant difference between the stress group and the control group in sC concentration at t1 ($p = 0.354$), while stress group significantly higher than control group at t2 to t5 ($p < 0.001$). It indicated that this experiment successfully activated the HPA axis and induced a state of stress in the participants. In control group, sC concentration at t3 time was significantly higher than t1 ($p = 0.006$), t2 ($p = 0.005$), t4 ($p = 0.017$), t6 ($p = 0.036$), and there was no significant difference between t3 and t5 ($p = 0.062$). This result indicated that the RSVP task was also an effective stressor to activate the HPA axis (see Fig. 5).

3.2.3. Saliva alpha amylase (sAA)

The results showed that the main effect of Time was significant, F (1, 71) = 63.139, $p < 0.001$, $\eta^2_p = 0.471$. The main effect of Group was significant, F (1, 71) = 230.801, $p < 0.001$, $\eta^2_p = 0.765$. There was a Time × Group interaction, F (1, 71) = 20.854, $p < 0.001$, $\eta^2_p = 0.227$. Simple effect analysis showed that there was no significant difference between the stress group and the control group in sAA concentration at t1 ($p = 0.384$), while stress group significantly higher than control group at t2 to t5 ($p < 0.001$). That is, this experiment successfully activated the SNS axis and induced a stressed state in subjects. In control group, sAA concentration at t3 time was significantly higher than at t1 ($p < 0.001$), t2 ($p = 0.006$), t5 ($p = 0.017$), and t6 ($p = 0.001$). There was no significant difference between t3 and t4 ($p = 0.240$). This suggested that the RSVP task was also an effective stressor to activate the SNS axis (see Fig. 6).

3.2.4. The combined action of SNS-HPA axis

Ali and Pruessner (2012) found that that the ratios of salivary alpha-amylase over cortisol (AOC) was better than the single sC or sAA in responding to the abnormal regulation of the stress system, which was an effective indicator of stress-related mood disorders and behavioral outcomes. The monitoring of AOC can further explore the effect of the combined action of SNS-HPA axis on various cognitive functions (Alsalman, Denise, & Sven, 2016; Filaire, Ferreira, Oliveira, & Massart, 2013; Nislin et al., 2016).

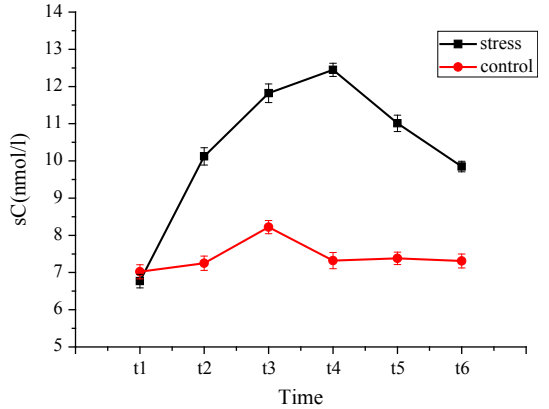

Fig. 5. Means and standard errors for salivary cortisol over time for the stress and control groups.

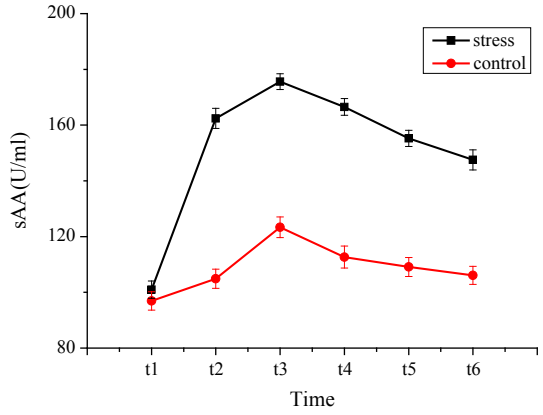

Fig. 6. Means and standard errors for salivary alpha-amylase over time for the stress and control groups.

The specific calculation method was as follows: AUC_g (area under the curve with respect to ground, AUC_g): reflects overall hormone levels; AUC_i (area under the curve with respect to increase, AUC_i): sensitivity of hormone levels over time. $AOC_g = AUC_g$-sAA/AUC_g-sC; $AOC_i = AUC_i$-sAA/AUC_i-sC. Formulas of AUC_g and AUC_i refer to Pruessner, Kirschbaum, Meinlschmid, and Hellhammer (2004). The results of our analysis of AOC are included in Table 1 and Fig. 7.

Prior literature has demonstrated that subclinical individuals (e.g. depressed individuals) present a larger α amylase/cortisol ratio than the healthy individuals (Booij et al., 2015). In our study, no significant difference has been found in AOCg ($p = 0.247$) and AOCi ($p = 0.111$) between the two groups, indicating that the subjects in the stress groups haven't shown the dysregulation of the stress systems. The result has further corroborated that our subject selection has successfully excluded the anxious and depressed individuals, and the subjects in two groups were homogeneous, i.e. the activation rate of the SNS and HPA axis was consistent. We have also found that the AUC_g and AUC_i in stress group were significantly higher than that in control group (all, $p < 0.001$). This also demonstrates the successful activation of the SNS axis and the HPA axis from the perspective of area under the curve with respect to ground as well as to increase.

3.3. Performance in RSVP task

3.3.1. T1

The results revealed a significant main effect of emotion, F (1, 71) = 244.078, $p < 0.001$, $\eta^2_p = 0.775$. Pairwise comparisons showed that the accuracy of T1 detection under negative condition ($M = 0.869$, $SD = 0.043$) was significantly lower than that under neutral condition ($M = 0.976$, $SD = 0.018$; $p < 0.001$). The group main effect was significant, F (1, 71) = 16.709, $p < 0.001$, $\eta^2_p = 0.191$, with larger accuracy observed stress group ($M = 0.939$, $SD = 0.036$) than control group ($M = 0.905$, $SD = 0.036$). The analysis of T1 data revealed an interaction between T1 emotion and group, F (1, 71) = 10.736, $p = 0.002$, $\eta^2_p = 0.131$. Simple effect analysis showed that the T1 detection accuracy of the stress group ($M = 0.897$, $SD = 0.061$) was significantly higher than that of the control group ($M = 0.841$, $SD = 0.061$) in negative conditions, F (1, 71) = 16.669, $p < 0.001$, under neutral conditions, the difference was not significant, F (1, 71) = 2.990, $p = 0.088$. That is, stress promoted the recognition of negative stimuli, given adequate attentional resources, but had no effect on neutral stimuli. In the stress group, the accuracy of T1 detection under neutral condition ($M = 0.981$, $SD = 0.024$) was significantly higher than that of T1 under negative condition ($M = 0.897$, $SD = 0.061$), F (1, 71) = 77.275, $p < 0.001$. In the control group, the accuracy of T1 detection under neutral condition ($M = 0.970$, $SD = 0.030$) was significantly higher than that of T1 detection under negative condition ($M = 0.841$, $SD = 0.061$), F (1, 71) = 176.184, $p < 0.001$. Other main effects and interaction effects were not significant.

3.3.2. T2

The results revealed a significant main effect of emotion, F (1, 71) = 163.014, $p < 0.001$, $\eta^2_p = 0.697$. Pairwise comparisons showed that the accuracy of T1 detection under negative condition ($M = 0.734$, $SD = 0.055$) was significantly lower than that under neutral condition ($M = 0.810$, $SD = 0.055$; $p < 0.001$). The main effect of lag was significant, F (1, 71) = 377.181, $p < 0.001$,

Table 1
SNS-HPA Axis Combined Action Analysis Index ($M \pm SD$).

	Indicators	AUC_G	AOC_G	AUC_I	AOC_I
Stress	sC (nmol/L)	619.75 (45.91)	14.34 (1.30)	235.26 (69.00)	17.69 (12.98)
	sAA (U/mL)	8836.20 (484.80)		3517.03 (696.04)	
Control	sC (nmol/L)	394.83 (27.14)	14.74 (1.83)	73.03 (35.12)	17.54 (14.48)
	sAA (U/mL)	5820.33 (698.07)		1281.03 (560.18)	

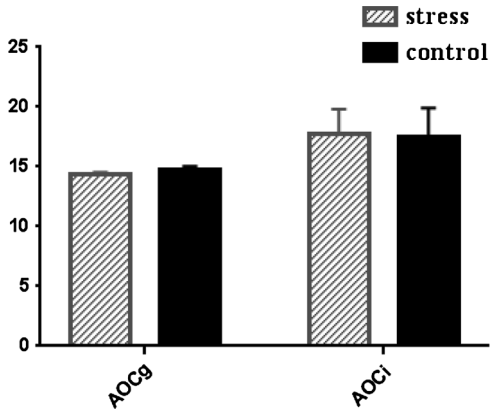

Fig. 7. The results of our analysis of AOCg and AOCi to reflect the combined action of SNS-HPA axis.

$\eta^2_p = 0.842$. The accuracy of T2 detection increases with the lag. The main effect of group was significant, F (1, 71) = 6.203, $p = 0.015$, $\eta^2_p = 0.080$. Pairwise comparisons showed that the T2 detection accuracy in the stress group ($M = 0.794$, $SD = 0.073$) was significantly higher than that in the control group ($M = 0.751$, $SD = 0.073$).

There was a significant interaction between Lag and Group, F (1, 71) = 3.008, $p = 0.031$, $\eta^2_p = 0.041$. At the lag2, the T2 detection accuracy of the stress group was significantly higher than that of the control group, F (1, 71) = 20.511, $p < 0.001$. There were no significant difference between the two groups at lag4 ($p = 0.164$), lag6 ($p = 0.216$) and lag8 ($p = 0.118$). This indicated that stress can promote the recognition of neutral T2 in the case of stronger insufficiency of attention resources. In both groups, the T2 detection accuracy at lag2 was significantly lower than that at lag4, lag6 and lag8. And the accuracy at lag4 was significantly lower than that at lag6 and lag8 ($p < 0.001$), while the difference between lag6 and lag8 was not significant (stress: $p = 0.086$; control: $p = 0.426$).

There was a significant interaction between emotion and lag, F (1, 71) = 14.748, $p < 0.001$, $\eta^2_p = 0.172$. At all lags, the T2 detection accuracy under neutral condition was significantly higher than that under negative condition ($p < 0.001$). The result showed that there was a distinct EAB effect (Mathewson, Arnell, & Mansfield, 2008) (the AB effect can be enhanced when emotionally arousing stimuli are presented as T1 compared with neutral T1) at all lags. In both negative and neutral conditions, the T2 detection accuracy at lag2 was significantly lower than that at lag4, lag6 and lag8. And the accuracy at lag4 was significantly lower than that at lag6 and lag8 ($p < 0.001$), while the difference between lag6 and lag8 was not significant (negative: $p = 0.271$; neutral: $p = 0.085$). The results indicated that negative T1 enhanced the degree of attentional blink, but do not extend the time window. The interaction between emotion × group × lag was not significant, F (1, 71) = 0.344, $p > 0.05$, $\eta^2_p = 0.005$ (see Table 2, Figs. 8 and 9).

3.4. Time course analysis

We divided the AB task into two segments according to the time course of the stress response and conducted a three-factor repeated measures ANOVA for T2 detection accuracy.

3.4.1. 0–20 min after TSST

There was no significant interaction between the group and other independent variables. The interaction between emotion × group × lag was not significant, F (1, 71) = 0.847, $p = 0.496$, $\eta^2_p = 0.012$. While the main effect of the group ($p = 0.007$), emotion ($p < 0.001$) and lag ($p < 0.001$) was significant, the interaction between emotion and lag was significant ($p = 0.017$).

3.4.2. 20–40 min after TSST

The lag and group interactions were found to be significant at this stage, F (1, 71) = 6.521, $p < 0.001$, $\eta^2_p = 0.084$, under the condition of lag2, the accuracy of the stress group was significantly higher than that of the control group. And the main effect of the group ($p = 0.022$), emotion ($p < 0.001$) and lag ($p < 0.001$) was significant, the interaction between emotion and lag was

Table 2
T2 Accuracy of Attentional Blink in Different Conditions ($M \pm SD$).

	Negative				Neutral			
	lag2	lag4	lag6	lag8	lag2	lag4	lag6	lag8
Stress	0.58(0.09)	0.71(0.13)	0.86(0.11)	0.89(0.09)	0.68(0.13)	0.82(0.10)	0.90(0.09)	0.91(0.07)
Control	0.49(0.07)	0.67(0.11)	0.83(0.11)	0.85(0.12)	0.62(0.11)	0.80(0.08)	0.87(0.12)	0.89(0.12)

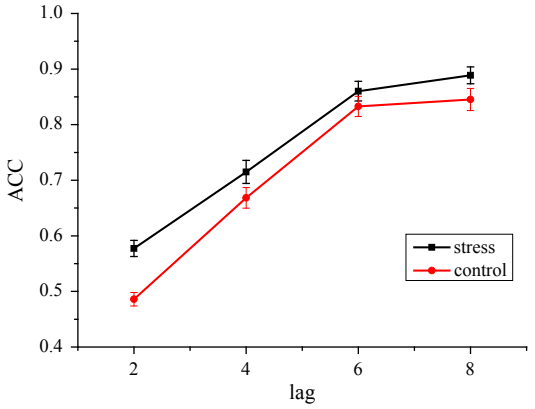

Fig. 8. The accuracy (ACC) of T2 detection over lags for the stress and control groups when T1 was negative. The T2 detection ACC at lag2 of stress group was significantly higher than that of control group.

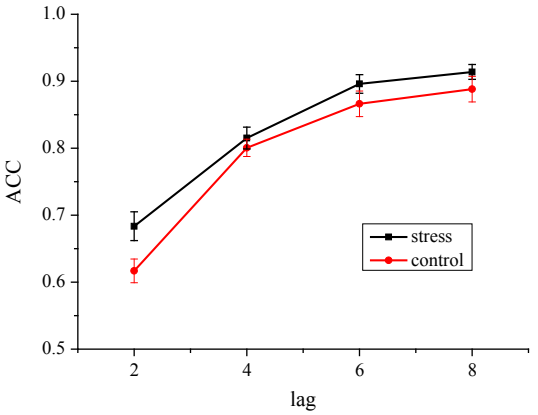

Fig. 9. The ACC of T2 detection over lags for the stress and control groups when T1 as neutral. The T2 detection ACC at lag2 for the stress group was significantly higher than that of the control group.

significant ($p < 0.001$). The interaction between emotion × group × lag was not significant, F (1, 71) = 1.104, $p = 0.349$, $\eta^2_p = 0.015$.

The above results indicated that in the second half of stress, stress promoted T2 detection at lag2 had no interaction with the emotionality of stimuli. Therefore, the cumulative effect of stress on attention, throughout the RSVP task primarily occurred from 20 to 40 min after the TSST task, that is, after the cortisol concentration peaked.

3.5. Regression model

According to the results of the time course analysis, the difference in cortisol concentration between the stress group and the control group from 20 to 40 min after the TSST task was used as the independent variable in a regression analysis, and the difference in performance between the stress group and the control group under the condition of lag2 in the AB task was used as the dependent variable, which were then z-transformed to standardized measurements for regression analysis.

The regression revealed that the cortisol concentration explained 29.7% of the total between-group difference in T2 detection accuracy at lag2 ($R^2 = 0.297$, F (2, 34) = 6.796, $p = 0.003$). That is, cortisol levels from 20 to 40 min after TSST could significantly predict AB performance.

4. Discussion

The present study explored the role of attentional resources and emotional stimuli on the temporal selective attention in RSVP with female participants under stress. The time course of the AB task was also analyzed. A stress response was successfully induced, as shown by the stress group experiencing a more negative affect (anxious state), elevated heart rate, greater sC, sAA, AUC_g and AUC_i levels than the control group. The results of this study indicated that stress promoted the recognition of neutral T2 targets only at lag2, and there was no interaction with the emotionality of the T1. Stress increased the accuracy of T1 detection, when T1 was negative. In addition, cumulative effect of stress on promoting attention primarily appeared 20–40 min after the TSST task. Further,

cortisol concentration during this time period significantly predicted AB task performance. The results of this study are basically consistent with the only prior study of stress-related regulation of AB (Schwabe & Wolf, 2010).

4.1. Stress promotes the processing of negative T1

The results of the current study showed that stress promoted the processing of negative T1. In contrast a previous study found that the accuracy of emotional T1 and T2 was not affected by stress (Schwabe & Wolf, 2010). This discrepancy may be explained by activation of the SNS axis, namely the AB task was performed 20 min after the TSST, at which time the SNS axis played no role. In current study, we found that sAA, an indicator of SNS activation, decreased slowly after reaching its peak. The research of Skoluda et al. (2015) have confirmed that cognitive tasks requiring selective attention can induce stress and specifically activate the SNS axis (Skoluda et al., 2015). The AB task require the subjects to select targets from a number of distractions. Therefore, the AB task is also a stressor and successfully maintained the response of the SNS axis in this study. Previous studies indicated that stress can activate the locus coeruleus in the pons, where the ascending fibers of noradrenergic neurons project to the amygdala to enhance bottom up processing of negative stimuli (Macatee et al., 2017; Sanchez et al., 2014) and release norepinephrine to enhance the attention to threatening stimuli (Aston-Jones, Rajkowski, & Cohen, 1999; van Marle, Hermans, Qin, & Fernández, 2009).

Another reason for the inconsistent results may be related to gender differences. To control for the influence of estrogen, Schwabe and Wolf (2010) investigated the effect of stress on selective attention in a RSVP task only in male subjects. Kreher, Powers, and Granger (2012) showed that high concentrations of norepinephrine combined with cortisol can result in an negative cognitive bias in women. Studies have shown that women who have experienced stress have a greater physiological response and norepinephrine activation compared to men (Back, Waldrop, Saladin, Yeatts, Simpson, & Mcrae, 2008; Mclean & Anderson, 2009; Segal & Cahill, 2009), leading to more obvious attentional bias (Carr, Scully, Webb, & Felmingham, 2016; Gardener, Carr, Macgregor, & Felmingham, 2013).

4.2. Stress promotes the processing of T2

4.2.1. The overall effect of stress

Previous studies have shown that stress slightly enhances overall T2 detection accuracy with no interaction with lag, while the AB is reduced among participants with a high cortisol response, for conditions of early temporal lag (SOA $<$ 500 ms). This indicates that high concentrations of cortisol stimulate temporal attention over periods of the order of milliseconds. In the current study, we did not group the subjects according to their cortisol concentrations, but also concluded that stress promotes the recognition of T2. A series of psychological and physiological responses induced by stress reduced the AB effect, not only the high concentrations of cortisol. Stress promotes the release of norepinephrine, which facilitates selective attention (Aston-Jones & Cohen, 2005) and thus improves the accuracy of T2. Pharmacological studies using the β-adrenergic blocker propranolol and peripheral β-adrenergic antagonist nadolol to manipulate the influence of the adrenergic system on the AB effect have also provided evidence that norepinephrine promotes selective attention (Benedetto, Strange, & Dolan, 2008). Regardless, cortisol plays an important role in this regard. Roelofs, Bakvis, Hermans, Van, and Van (2007) also insisted that sC can effectively regulate the promoting effect of stress on selective attention. The time course analysis showed that the cumulative effect of stress on temporal selective attention primarily occurred 20–40 min after the TSST and cortisol levels during this period significantly predicted AB task performance. This further supports previous conclusions, namely that cortisol plays an important role in promoting the recognition of targets (Schwabe & Wolf, 2010).

4.2.2. The role of attentional resources

Based on previous research, the present study further clarified the role of attentional resources, namely, stress promoted the processing of neutral T2 only when the attentional resources available for T2 were extremely insufficient (at lag2). The present study differed from the previous studies, which divided lags into early and late temporal lags. The outcomes of the current experiment extend the results of previous studies and suggest that more fine-grained discussion is needed, rather than simply dividing the available resources into sufficient and insufficient. The present results support perceptual load theory (Lavie, 1995, 2005). Chajut and Algom (2003) found that attentional mechanisms could predict the promotion of selective attention under stress. That is, along with the high perceptual load, stress further consumes attentional resources, and the remaining attentional resources are focused on the current target. At the same time, in a threatening situation, the individual narrows the scope of consciousness and highly focuses on the target information, thus improving task performance (Huguet, Galvaing, Monteil, & Dumas, 1999). These observations are consistent with the results of previous studies, which showed that stress can increase the selectivity of attention under high perceptual load (Tiferet-dweck et al., 2016). Vytal, Cornwell, Arkin, and Grillon (2012) also confirmed that experiencing a state of anxiety impaired the target detection with a low working memory load (for example: 1-back, 2-back), but not when the working memory load was high (for example: 3-back).

4.2.3. Stress promotes the consolidation of target

The processing of T2 can reflect its consolidation in working memory. At first glance, it seems that stress promotes working memory contrary to previous researchers' results (Gärtner et al., 2014; Terfehr et al., 2011). However, Stauble, Thompson, and Morgan (2013) used a change-detection task to separate the subprocesses of working memory. They concluded that stress promoted encoding and maintenance because the two phases require little cognitive flexibility. As such, these phases are not highly dependent on the prefrontal cortex and thus less sensitive to stress. Stress can also improve the efficiency of information transfer from sensory

perception channels to working memory. That is associated with enhanced updating of working memory, thus promoting the rapid processing of T2 (Fallon & Cools, 2014; Goldfarb, Froböse, Cools, & Phelps, 2017). Gender differences may also be an important factor, with studies showing that women have better information consolidation capabilities than men (Sänger, Schneider, Beste, & Wascher, 2012).

4.3. *The influence of T1 emotion on T2 under stress*

One of the novel results from the current study among women was that stress promoted the processing of negative T1, but did not affect the accuracy of the subsequent T2 detection. Mathewson et al. (2008) used sexual/taboo T1 stimuli in the RSVP paradigm and thereby discovered the EAB effect. The EAB effect is explained by the two-stage model of attentional blink. It has been suggested that emotional stimuli have a stronger initial (first-stage) attentional orienting effect and a greater (second-stage) ability to sustain attentional focus than neutral stimuli (Chun & Potter, 1995). As the capacity of the second stage is limited, emotional T1 stimuli consume more attentional resources than neutral T1 stimuli. Thus, less attentional resources are available for T2, and an emotional T1 stimuli can thereby enhance the AB effect. An fMRI study (Schwabe et al., 2011) manipulated the emotionality of T1 and T2 in the RSVP paradigm, and thereby revealed that the processing of emotional T1 stimuli in the second stage is related to activation of the orbital frontal cortex. However, studies have shown that stress can deactivate the orbito frontal cortex (Dedovic, D'Aguiar, & Pruessner, 2009), leading to decreased processing of emotional T1 in the second stage. Therefore, in a state of stress, emotional T1 are processed to the same extent as neutral T1, thus, processing of T2 is unaffected by emotional T1. Although negative T1 and neutral T1 consume the same attentional resources, the current study also indicated that stress increases the accuracy of detecting negative T1. This further illustrate that stress narrowing attention is achieved by reducing the attentional resources required for negative stimuli, as well as the narrowing of attention caused by stress can facilitate the attention processing of the individual to the target (Chajut & Algom, 2003; Dambacher & Hiibner, 2015).

In general, we essentially verified the results of Schwabe and Wolf (2010) with female participants and further explored the effect of subsequent neutral target after processing an emotional T1 under stress. Stress focuses attention and promotes the processing of neutral target, given insufficient attentional resources. Even with adequate attentional resources, the stress intervention improve detection performance for negative targets. Activation of the SNS and HPA axis plays an important role in the facilitation of selective attention.

5. Limitations and future directions

The current study is the first to explore the temporal selective attention among women under acute stress, using the RSVP paradigm. However, by its nature, our design did not permit us to assess gender differences. Previous studies indicated that female oxytocin levels can regulate stress responses and exert differential effects on cognitive function (Mccarthy, 1995). The accuracy of T2 detection in the RSVP paradigm reflects the consolidation of the target in working memory; there exist gender differences in the working memory processing of individuals affected by acute stress (Zandara et al., 2016). As the subjects in this study were all female, the role of gender in the effect of stress on the AB remains to be verified. Therefore, the large-scale data need to be collected in subsequent research to further compare gender differences in this respect, using the methods employed in this study.

Through this behavioral experiment, we found that stress could promote neutral target processing when available attentional resources were seriously insufficient. However, we still do not know how the limited attentional resources were allocated under stress. That is, it is unknown whether stress improved selective attention by promoting early attentional capture or late working memory consolidation in the RSVP; both the AB and acute stress response were time sensitive. Therefore, event related potential (ERP) technology with high time resolution should be used to explore the time course of stress-affected AB, to verify and expand upon the results of this study.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2019.102796.

References

Ali, N., & Pruessner, J. C. (2012). The salivary alpha amylase over cortisol ratio as a marker to assess dysregulations of the stress systems. *Physiology & Behavior, 106*(1), 65–72. https://doi.org/10.1016/j.physbeh.2011.10.003.

Alsalman, O. A., Denise, T., & Sven, V. (2016). Salivary stress-related responses in tinnitus: A preliminary study in young male subjects with tinnitus. *Frontiers in Neuroscience, 10*. https://doi.org/10.3389/fnins.2016.00338.

Aston-Jones, G., Rajkowski, J., & Cohen, J. (1999). Role of locus coeruleus in attention and behavioural flexibility. *Biological Psychiatry, 46*, 1309–1320. https://doi.org/10.1016/S0006-3223(99)00140-7.
Aston-Jones, G., & Cohen, J. D. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience, 28*(1), 403–450. https://doi.org/10.1146/annurev.neuro.28.061604.135709.
Back, S. E., Waldrop, A. E., Saladin, M. E., Yeatts, S. D., Simpson, A., Mcrae, A. L., et al. (2008). Effects of gender and cigarette smoking on reactivity to psychological and pharmacological stress provocation. *Psychoneuroendocrinology, 33*(5), 560–568. https://doi.org/10.1016/j.psyneuen.2008.01.012.
Benedetto, D. M., Strange, B. A., & Dolan, R. J. (2008). Noradrenergic neuromodulation of human attention for emotional and neutral stimuli. *Psychopharmacology, 197*(1), 127–136. https://doi.org/10.1007/s00213-007-1015-5.
Bernstein-Bercovitz, H. (2003). Does stress enhance or impair selective attention? The effects of stress and perceptual load on negative priming. *Anxiety Stress & Coping, 16*(4), 345–357. https://doi.org/10.1080/10615800310000112560.
Booij, S. H., Bos, E. H., Bouwmans, M. E., Van Faassen, M., Kema, I. P., Oldehinkel, A. J., et al. (2015). Cortisol and α-Amylase secretion patterns between and within depressed and non-depressed individuals. *Plos One, 10*(7), https://doi.org/10.1371/journal.pone.0131002.
Brüne, M., Nadolny, N., Güntürkün, O., & Wolf, O. T. (2013). Stress induces a functional asymmetry in an emotional attention task. *Cognition & Emotion, 27*(3), 558–566. https://doi.org/10.1080/02699931.2012.726211.
Carr, A. R., Scully, A., Webb, M., & Felmingham, K. L. (2016). Gender differences in salivary alpha-amylase and attentional bias towards negative facial expressions following acute stress induction. *Cognition & Emotion, 30*(2), 315–324. https://doi.org/10.1080/02699931.20 14.999748.
Chajut, E., & Algom, D. (2003). Selective attention improves under stress: Implications for theories of social cognition. *Journal of Personality and Social Psychology, 85*(2), 231. https://doi.org/10.1037/0022-3514.85.2.231.
Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance, 21*(1), 109. https://doi.org/10.1037/0096-1523.21.1.109.
Dambacher, M., & Hiibner, R. (2015). Time pressure affects the efficiency of perceptual processing in decisions under conflict. *Psychological Research, 79*(1), 83–94. https://doi.org/10.1007/s00426-014-0542-z.
Dandolo, L. C., & Schwabe, L. (2016). Stress-induced cortisol hampers memory generalization. *Learning & Memory, 23*(12), 679–683. https://doi.org/10.1101/lm.042929.116.
Dedovic, K., D'Aguiar, C., & Pruessner, J. C. (2009). What stress does to your brain: A review of neuroimaging studies. *Canadian Journal of Psychiatry, 54*(1), 6–15. https://doi.org/10.1177/070 674370905400104.
Fallon, S. J., & Cools, R. (2014). Reward acts on the pfc to enhance distractor resistance of working memory representations. *Journal of Cognitive Neuroscience, 26*(12), 2812–2826. https://doi.org/10.1162/jocn_a_00676.
Federenko, I., Wüst, S., Hellhammer, D. H., Dechoux, R., Kumsta, R., & Kirschbaum, C. (2004). Free cortisol awakening responses are influenced by awakening time. *Psychoneuroendocrinology, 29*(2), 174–184. https://doi.org/10.1016/s0306-4530(03)00021-0.
Filaire, E., Ferreira, J. P., Oliveira, M., & Massart, A. (2013). Diurnal patterns of salivary alpha-amylase and cortisol secretion in female adolescent tennis players after 16 weeks of training. *Psychoneuroendocrinology, 38*(7), 1122–1132. https://doi.org/10.1016/j.psyneuen.2012.11.0 01.
Fisher, A. J., Granger, D. A., & Newman, M. G. (2010). Sympathetic arousal moderates self-reported physiological arousal symptoms at baseline and physiological flexibility in response to a stressor in generalized anxiety disorder. *Biological Psychology, 83*(3), 191–200. https://doi.org/10.1016/j.biopsycho.2009.12.007.
Gardener, E. K., Carr, A. R., Macgregor, A., & Felmingham, K. L. (2013). Sex differences and emotion regulation: An event-related potential study. *Plos One, 8*(10), e73475. https://doi.org/10.1371/journal.pone.0073475.
Gärtner, M., Rohde-Liebenau, L., Grimm, S., & Bajbouj, M. (2014). Working memory-related frontal theta activity is decreased under acute stress. *Psychoneuroendocrinology, 43*(5), 105. https://doi.org/10.1016/j.psyneuen.2014.02.009.
Goldfarb, E. V., Froböse, M. I., Cools, R., & Phelps, E. A. (2017). Stress and cognitive flexibility: Cortisol increases are associated with enhanced updating but impaired switching. *Journal of Cognitive Neuroscience, 29*(1), 14–24. https://doi.org/10.1162/jocn_a_01029.
Hamilton, D. A., & Brigman, J. L. (2015). Behavioral flexibility in rats and mice: Contributions of distinct frontocortical regions. *Genes, Brain and Behavior, 14*(1), 4–21. https://doi.org/10.1111/gbb.12191.
Henckens, M. J., van Wingen, G. A., Joëls, M., & Fernández, G. (2012). Time-dependent effects of cortisol on selective attention and emotional interference: A functional MRI study. *Frontiers in Integrative Neuroscience, 6*, 66. https://doi.org/10.3389/fnint.2012.00066.
Hoskin, R., Hunter, M. D., & Woodruff, P. W. (2014). Stress improves selective attention towards emotionally neutral left ear stimuli. *Acta Psychologica, 151*(5), 214–221. https://doi.org/10.1016/j.actpsy.2014.06.010.
Huguet, P., Galvaing, M. P., Monteil, J. M., & Dumas, F. (1999). Social presence effects in the stroop task: Further evidence for an attentional view of social facilitation. *Journal of Personality & Social Psychology, 77*(5), 1011. https://doi.org/10.1037/0022-3514.77.5.1011.
Izawa, S., Sugaya, N., Yamamoto, R., Ogawa, N., & Nomura, S. (2010). The cortisol awakening response and autonomic nervous system activity during nocturnal and early morning periods. *Neuroendocrinology Letters, 31*(5), 685. https://doi.org/10.1159/000287255.
Jiang, C., Buchanan, T. W., Yao, Z., Zhang, K., Wu, J., & Zhang, L. (2017). Acute psychological stress disrupts attentional bias to threat-related stimuli. *Scientific Reports, 7*(1), https://doi.org/10.1038/s41598-017-14138-w.
Kawahara, J., & Sato, H. (2012). Does stress increase or decrease attentional resource? The effect of acute stress on attentional blink. *Journal of Vision, 12*(9), 1338.
Kawahara, J., & Sato, H. (2013). The effect of fatigue on the attentional blink. *Attention, Perception, & Psychophysics, 75*(6), 1096–1102. https://doi.org/10.3758/s13414-013-0507-0.
Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test' - A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*(1-2), 76–81 DOI: 119004.
Kreher, D. A., Powers, S. I., & Granger, D. A. (2012). The relationship between cortisol, salivary alpha-amylase, and cognitive bias in young women. *Behavioral Neuroscience, 126*(1), 157–166. https://doi.org/10.1037/a0026654.
Kudielka, B. M., Hellhammer, D. H., Kirschbaum, C., Harmon-Jones, E., & Winkielman, P. (2007). Ten years of research with the Trier Social Stress Test—revisited. *Social Neuroscience: Integrating Biological and Psychological Explanations of Social Behavior, 56*, 83.
Kudielka, B. M., Hellhammer, D. H., & Wüst, S. (2009). Why do we respond so differently? Reviewing determinants of human salivary cortisol responses to challenge. *Psychoneuroendocrinology, 34*(1), 2–18. https://doi.org/10.1016/j.psyneuen.2008.10.004.
Kuhlmann, S., Kirschbaum, C., & Wolf, O. T. (2005). Effects of oral cortisol treatment in healthy young women on memory retrieval of negative and neutral words. *Neurobiology of Learning and Memory, 83*(2), 158–162. https://doi.org/10.1016/j.nlm.2004.09.001.
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual (Tech. Rep. No. A-8).* Gainesville, FL: University of Florida.
Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Attention Perception & Psychophysics, 56*(2), 183–197. https://doi.org/10.3758/B F03213897.
Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21*(3), 451 doi:10.103/0096-1523.21.3.451.
Lavie, N. (2005). Distracted and confused? Selective attention under load. *Trends in Cognitive Sciences, 9*, 75–82. https://doi.org/10.1016/j.tics.2004.12.004.
Macatee, R. J., Albanese, B. J., Schmidt, N. B., & Cougle, J. R. (2017). Attention bias towards negative emotional information and its relationship with daily worry in the context of acute stress: An eye-tracking study. *Behaviour Research and Therapy, 90*, 96–110. https://doi.org/10.1016/j.brat.2016.12.013.
Mathewson, K. J., Arnell, K. M., & Mansfield, C. A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory & Cognition, 36*(1), 182–200. https://doi.org/10.3758/MC.36.1.182.
Mccarthy, M. M. (1995). Estrogen modulation of oxytocin and its relation to behavior. *Advances in Experimental Medicine & Biology, 395*(395), 235.
Mclean, C. P., & Anderson, E. R. (2009). Brave men and timid women? A review of the gender differences in fear and anxiety. *Clinical Psychology Review, 29*(6), 496–505. https://doi.org/10.1016/j.cpr.2009.05.003.

Nelson, A. L., Purdon, C., Quigley, L., Carriere, J., & Smilek, D. (2015). Distinguishing the roles of trait and state anxiety on the nature of anxiety-related attentional biases to threat using a free viewing eye movement paradigm. *Cognition and Emotion, 29*(3), 504–526. https://doi.org/10.1080/02699931.2014.922460.

Nislin, M., Sajaniemi, N., Sims, M., Suhonen, E., Maldonado, E. F., Hyttinen, S., et al. (2016). Occupational well-being and stress among early childhood professionals: The use of an innovative strategy to measure stress reactivity in the workplace. *Open Review of Educational Research, 3*(1), 1–17. https://doi.org/10.1080/23265507.2015.1128352.

Olver, J. S., Pinney, M., Maruff, P., & Norman, T. R. (2014). Impairments of spatial working memory and attention following acute psychosocial stress. *Stress and Health, 31*(2), 115–123. https://doi.org/10.1002/smi.2533.

Pruessner, J. C., Kirschbaum, C., Meinlschmid, G., & Hellhammer, D. H. (2004). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology, 28*(7), 916–931. https://doi.org/10.1016/S0306-4530(02)00108-7.

Quigley, L., Nelson, A. L., Carriere, J., Smilek, D., & Purdon, C. (2012). The effects of trait and state anxiety on attention to emotional images: An eye-tracking study. *Cognition & Emotion, 26*(8), 1390–1411. https://doi.org/10.1080/02699931.2012.662892.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18*, 849–860. https://doi.org/10.1037/0096-1523.18.3.849.

Roelofs, K., Bakvis, P., Hermans, E. J., Van, P. J., & Van, H. J. (2007). The effects of social stress and cortisol responses on the preconscious selective attention to social threat. *Biological Psychology, 75*(1), 1–7. https://doi.org/10.1016/j.biopsycho.2006.09.002.

Sato, H., Takenaka, I., & Kawahara, J. I. (2012). The effects of acute stress and perceptual load on distractor interference. *Quarterly Journal of Experimental Psychology, 65*(4), 617–623. https://doi.org/10.1080/17470218.2011.648944.

Sanchez, A., Vazquez, C., Gomez, D., & Joormann, J. (2014). Gaze-fixation to happy faces predicts mood repair after a negative mood induction. *Emotion, 14*(1), 85. https://doi.org/10.1037/a 0034500.

Sänger, J., Schneider, D., Beste, C., & Wascher, E. (2012). Sex differences in competition-based attentional selection. *Zeitschrift Für Psychologie, 220*(2), 90–97. https://doi.org/10.1027/2151-2604/a000100.

Schwabe, L., Merz, C. J., Walter, B., Vaitl, D., Wolf, O. T., & Stark, R. (2011). Emotional modulation of the attentional blink: The neural structures involved in capturing and holding attention. *Neuropsychologia, 49*(3), 416–425. https://doi.org/10.1016/j.neurOpsychologia.2010.120.37.

Schwabe, L., & Wolf, O. T. (2010). Emotional modulation of the attentional blink: Is there an effect of stress? *Emotion, 10*(2), 283. https://doi.org/10.1037/a0017751.

Segal, S. K., & Cahill, L. (2009). Endogenous noradrenergic activation and memory for emotional material in men and women. *Psychoneuroendocrinology, 34*, 1263–1271. https://doi.org/10.1016/j.psyneuen.2009.04.020.

Shek, D. T. (1993). The Chinese version of the State-Trait Anxiety Inventory: Its relationship to different measures of psychological well-being. *Journal of Clinical Psychology, 49*, 349–358. https://doi.org/10.1002/1097-4679(199305)49:3<349::Aid-jclp2270490308>3.0.co;2-j.

Skoluda, N., Strahler, J., Schlotz, W., Niederberger, L., Marques, S., Fischer, S., et al. (2015). Intra-individual psychological and physiological responses to acute laboratory stressors of different intensity. *Psychoneuroendocrinology, 51*, 227–236. https://doi.org/10.1016/j.ps yneuen.2014.10.002.

Spielberger, C. D. (1983). *Manual for the State-Trait Anxiety Inventory (STAI)*. Palo Alto, CA: Consulting Psychologists Press.

Stauble, M. R., Thompson, L. A., & Morgan, G. (2013). Increases in cortisol are positively associated with gains in encoding and maintenance working memory performance in young men. *Stress, 16*(4), 402–410. https://doi.org/10.3109/10253890.2013.780236.

Terfehr, K., Wolf, O. T., Schlosser, N., Fernando, S. C., Otte, C., Muhtz, C., et al. (2011). Hydrocortisone impairs working memory in healthy humans, but not in patients with major depressive disorder. *Psychopharmacology, 215*(1), 71–79. https://doi.org/10.1007/s00213-010-2117-z.

Tiferet-dweck, C., Hensel, M., Kirschbaum, C., Tzelgov, J., Friedman, A., & Salti, M. (2016). Acute stress and perceptual load consume the same attentional resources: A behavioral-erp study. *Plos One, 11*(5), e0154622. https://doi.org/10.1371/journal.pone.0154622.

van Marle, H. J., Hermans, E. J., Qin, S., & Fernández, G. (2009). From specificity to sensitivity: How acute stress affects amygdala processing of biologically salient stimuli. *Biological Psychiatry, 66*(7), 649–655. https://doi.org/10.1016/j.biopsych.2009.05.014.

Vytal, K., Cornwell, B., Arkin, N., & Grillon, C. (2012). Describing the interplay between anxiety and cognition: From impaired performance under low cognitive load to reduced anxiety under high load. *Psychophysiology, 49*(6), 842–852. https://doi.org/10.1111/j.1469-8986.201 2.01358.x.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063. https://doi.org/10.1037/0022-3514.54.6.1063.

World Medical Association (WMA) (2013). World Medical Association Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects (www.wma.net/en/30publications/10policies/b3.htm).

Zandara, M., Garcia-Lluch, M., Pulopulos, M. M., Hidalgo, V., Villada, C., & Salvador, A. (2016). Acute stress and working memory: The role of sex and cognitive stress appraisal. *Physiology & Behavior, 164*, 336–344. https://doi.org/10.1016/j.physbeh.2016.06.022.