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A study on the influence of a single bout of moderate-intensity exercise on processing bias towards emotional information of individuals with high psychosocial stress levels

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Abstract
To explore the impact of a single bout of moderate-intensity exercise on cognitive bias of individuals with high psychosocial stress levels. 42 college students with high stress levels were recruited and divided into a exercise group ($N = 21$) and a no-exercise group ($N = 21$). The psychological and behavioral characteristics were studied using word-face stroop task, memory bias task, and interpretion bias task. College students with high psychosocial stress levels have attention bias, memory bias, and Interpretion bias towards negative emotional information, and a single bout of moderate-intensity exercise can increase attention bias towards neutral and positive emotional information, and memory bias towards neutral emotional information, interpretation bias towdrds positive emotional information. A single bout of moderate-intensity exercise can increase the positive cognitive bias towards emotional information, which is beneficial for regulating psychosocial stress levels.

Keywords Psychosocial stress · Word-face Stroop task · Memory bias tasks · Interpretion bias tasks · Physical exercise

Introduction

Studies have confirmed that psychosocial stress can lead to the imbalance of homeostasis and cause mental disorders such as depression, anxiety, addictive behavior, psychosis (Zhao et al., 2021; Phillips et al., 2015; Restrepo & Lemos, 2021; Abdel Wahed & Hassan, 2017; Magalhães et al., 2022; Colizzi et al., 2023; Mansueto & Faravelli, 2022), induce the crime (Liu, 2016), cause eating disorder or increase the suicide tendency (Degortes et al., 2014; Black et al., 2019; Polanco-Roman et al., 2016; Currier et al., 2016; Stack & Bowman, 2023). Researchs also indicated that psychosocial stress can lead to diabetes, asthma, vitiligo, alzheimer's disease, cardiovascular disease and aggravated the illness (Turin & Drobnič Radobuljac, 2021; Priftis & Anthracopoulos, 2008; Krüger et al., 2011; Amaducci et al., 1986; Huang et al., 2023; Khayyam-Nekouei et al., 2013; sun et al., 2017; Lutskyi et al., 2020; Matthews & Li, 2023). Chronic psychosocial stress can also induce malignant tumors, such as ovarian cancer and breast cancer (Lutgendorf et al., 2013; Bower et al., 2014). Psychosocial stress has always been a key factor in many models related to human health or diseases (Slavich, 2016).

With respect to the stress formation mechanism, Folkman and Lazarus & Flokman (1984) put forward the CPT theory, which considered stress as a process, emphasizing that cognition was the key to stress formation and development. This theory can be used to explain the formation of many physical and mental illnesses and strengthen stress management, so it has become a well-recognized classic theory. However, the elucidation of the role of emotions in this theory is insufficient. Researches also verified that the stress level could be mitigated by reducing abnormal emotions due to stress. Consequently, emotion also constitutes a key to stress formation and development. Under such circumstances, understanding the law and mechanism of emotional changes to explore how to adjust emotions and mitigate psychosocial stress levels has become a key concern in psychological research nowadays.

Emotions can affect cognition (Zajonc, 1984). And many studies have also proved that physical exercise can make

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individuals to experience more positive emotions, such as the runner's high and flow experience (Gibson & Bryan, 2023; Bristot et al., 2022; Shang et al., 2023). In the research of sports science, the researchers also found that physical exercise can regulate emotions, and thus reduce psychosocial stress (Puterman et al., 2017; Tanner et al., 2023; Hachenberger et al., 2023; Calpe-López et al., 2022). Basing on the dynamic model of affect (DMA), positive emotions can reduce negative emotions caused by stress (Zautra et al., 2005). Furthermore, according to the broaden-and-build theory (Fredrickson, 2003), increased positive emotions can expand people's thinking and perceptual-behavioural abilities. While in the light of the CPT theory, increased rational cognition leads to more correct evaluations and judgments, and therefore to more positive coping abilities. This leads to more positive coping skills, which buffer stress levels. Therefore, this study suggests that physical exercise may regulate psychosocial stress by improving cognition through the regulation of emotions. So after a single bout of moderate-intensity exercise individuals will show a positive processing bias towards emotional information, such as more reasonable allocation of attention resources, positive memory bias, interpretation bias. The word-face Stroop task, memory bias task, and interpretation bias task were applied to verify this conclusion in this study, and analyze the formation mechanism, in order to reveal the psychological and behavioral characteristics of individual with different levels of psychosocial stress, and the mechanism of mind-body interaction from the perspective of sports science.

Methods

Subject recruitment

The Chinese version of the *Perceived Stress Scale* (CPSS) revised by Yang and Huang (2003) was used to survey college students at Wenzhou Medical University. This scale consists of 14 items and adopt the 5-point Likert scale. The higher the final score is, the greater the psychosocial stress levels is. The questionnaires were distributed at the library and classrooms, distributed and collected on the scene. The high stress level is defined according to the top 10 scores of the *CPSS*. A total of 1200 questionnaires were distributed, and 1099 valid questionnaires were collected, with an effective rate of 90.10%. The average stress perception score was 40.24 ± 5.98. In this study, the α was 0.767.

42 college students from responders with a high stress level were recruited and divided into two groups, one was exercise group, including 5 males and 16 females, average age was 19.24 ± 1.18, the average stress perception score was 49.05 ± 2.73; the other was no-exercise group, including 6 males and 15 females, average age was 19.10 ± 1.30, average stress perception score was 49.00 ± 2.95 (Table 1).

Table 1 Perceived stress and age of the high and low stress groups

Group	N	CPSS score	Age
Exercise group	21	49.05 ± 2.73	19.24 ± 1.18
No-exercise group	21	49.00 ± 2.95	19.10 ± 1.30

The age/CPSS score comparison between groups was carried out using the t-test, and the results showed no significant difference between the two groups ($P > 0.05$) (Table 1). The other demographic data were subject to chi-square tested so that the demographic data of the subjects such as majors and grades matched between two groups. All subjects had normal visual acuity or corrected visual acuity and no cases had color weakness or color blindness. All subjects were right-handed.

This study was approved by the Human Research Protection Committee of East China Normal University (HR 104-2018). The purpose, significance and relevant precautions of this experiment should be informed to the subjects in detail before the experiment, and the subjects should be required to sign informed consent form.

Materials

Word-face stroop task

20 pictures of positive emotion faces and 20 pictures of negative emotion faces were selected, half male and half female, from the *Chinese Facial Affective Picture System* (CFAPS) compiled by Wang and Luo (2005). There was a significant difference in pleasure ($p < 0.001$) and no significant difference in arousal ($p > 0.05$) between the two types of pictures (Table 2). By using image software, the resolution, size, brightness, background and other physical indicators of each picture maintained consistent. By using the relevant software, the emotion word in 40 pt. font size, red song type, was added to both sides of the tip of the nose on the emotional face of each picture. The emotion words were loaded from CFAPS. Finally, four types of pictures were obtained: negative emotion face-emotion word consistency, negative emotion face-emotion word inconsistency, positive emotion

Table 2 Emotional arousal and pleasure of Word-face Stroop task

	Pleasure	Arousal
Negative affective pictures	2.53 ± 0.28	6.90 ± 1.01
Positive affective pictures	6.48 ± 0.46*	6.47 ± 0.83

* significant differences between negative affective pictures and positive affective pictures, $p < 0.001$

face-emotion word consistency, and positive emotion face-emotion word inconsistency. In addition, 4 pictures of positive emotion faces and 4 pictures of negative emotion faces, half male and half female, were used in the practice part, and the pictures used in the practice part were not included in the formal experiment.

Memory bias task

20 pictures of positive emotion faces, 20 pictures of negative emotion faces and 20 pictures of neutral emotion faces were selected, half male and half female, from the *Chinese Facial Affective Picture System* (CFAPS). There was a significant difference in the Pleasure of the three types of pictures between the two. There was no significant difference in arousal between the negative and positive affective pictures, but both differed significantly from the neutral affective pictures (Table 3). By using image software, the resolution, size, brightness, background and other physical indicators of each picture maintained consistent. No picture used in this part of the study appeared in the emotion Stroop task or the interpretation bias task.

Another 6 pictures, including 2 pictures of positive emotion, 2 pictures of negative emotion and 2 pictures of neutral emotion, half male and half female, were used in the practice part, and the pictures used in the practice part were not included in the formal experiment.

Interpretation bias task

16 pictures, including 4 pictures of positive emotion faces, 4 pictures of negative emotion faces and 8 pictures of neutral emotion faces, half male and half female, were selected from the *Chinese Facial Affective Picture System* (CFAPS). There was a significant difference in the Pleasure of the three types of pictures between the two. There was no significant difference in arousal between the negative and positive affective pictures, but both differed significantly from the neutral affective pictures (Table 4). By using image software, the resolution, size, brightness, background and other physical indicators of each picture maintained consistent. No picture used in this part of the study appeared in the emotion Stroop task or the memory bias task.

Morph software was used to fuse negative emotion faces and neutral emotion faces, as well as positive emotion faces and neutral emotion faces, respectively, thus forming blurred pictures (Fig. 1). Each combination formed 9 faces, each fusion ratio was P1 (10% neutral emotion - 90% positive emotion), P2 (20% neutral emotion - 80% positive emotion), P3 (30% neutral emotion - 70% positive emotion), P4 (40% neutral emotion - 60% positive emotion), P5 (50% neutral emotion - 50% positive emotion), P6 (60% neutral emotion - 40% positive emotion), P7 (70% neutral emotion - 30% positive emotion), P8 (80% neutral emotion - 20% positive emotion), P9 (90% neutral emotion - 10% positive emotion) (Fig. 1); N1 (10% neutral emotion - 90% negative emotion), N2 (20% neutral emotion - 80% negative emotion), N3 (30% neutral emotion - 70% negative emotion), N4 (40% neutral emotion - 60% negative emotion), N5 (50% neutral emotion - 50% negative emotion), N6 (60% neutral emotion - 40% negative emotion), N7 (70% neutral emotion - 30% negative emotion), N8 (80% neutral emotion - 20% negative emotion), N9 (90% neutral emotion - 10% negative emotion); There were a total of 72 pictures in 8 groups. Another 4 pictures, including 1 picture of positive emotion, 1 picture of negative emotion and 2 pictures of neutral emotion, were used to fuse into 18 blurred pictures by using the above method and used in the practice part, and the pictures used in the practice part were not included in the formal experiment.

Experimental procedure

Exercise task

Basketball is a quite popular sport and the experimenter also is a university basketball teacher with 12 years of experience. Therefore, the form of exercise in this research is basketball, a one-on-one contest between the experimenters and subjects.

Table 3 Emotional arousal and pleasure of memory bias task

	Pleasure	Arousal
Negative affective pictures	2.61 ± 0.33*#	6.53 ± 0.99*
Neutral affective pictures	4.32 ± 0.36@	4.07 ± 0.85
Positive affective pictures	6.31 ± 0.73	6.08 ± 0.82*

significant differences between negative affective pictures and positive affective pictures, $p < 0.001$; * significant differences between negative affective pictures and neutral affective pictures, $p < 0.001$; @ ignificant differences between positive affective pictures and neutral affective pictures, $p < 0.001$

Table 4 Emotional arousal and pleasure of interpretive bias task

	Pleasure	Arousal
Negative affective pictures	2.90 ± 0.10*#	4.92 ± 1.42&
Neutral affective pictures	4.43 ± 0.37^	3.58 ± 0.24
Positive affective pictures	5.71 ± 0.16	4.75 ± 0.50@

* significant differences between negative affective pictures and positive affective pictures, $p < 0.001$; #significant differences between negative affective pictures and neutral affective pictures, $p < 0.001$; ^significant differences between neutral affective pictures and positive affective pictures, $p < 0.001$; @ignificant differences between positive affective pictures and neutral affective pictures, $p < 0.05$;&significant differences between negative affective pictures and neutral affective pictures, $p < 0.05$

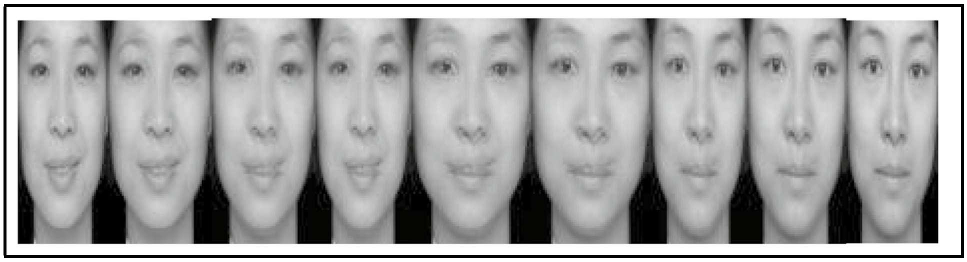


Fig. 1 Ambiguity propensity image

When the subjects arrived at the basketball gym, the experimenters inquired whether they could take exercise, described the purpose and significance of this research if the answer was “Yes”, and explained how to utilize the Ratings of Perceived Exertion (RPE) scale and heart rates to monitor their exercise intensity. The experimenter explained the above because certain exercise intensity must be realized to achieve the research purpose of this experiment and because doing so could avoid exercise injuries. For example, the cardiovascular system is endowed with high compensatory function. The people with poor cardiovascular function are the same as healthy ones seemingly in daily life, but when the exercise intensity increases, the risk will be unveiled and their lives may be endangered. Among others, RPE was proposed by Borg, a Swedish physiologist, in 1970 and Borg argued that physiological and psychological stimulations will be fed back to the brain when people are taking exercise, arousing reactions in the sensory system. The physiologist further classified the self-perception into 6-20 levels to rate exercise intensity. People can quickly judge their own physical function with this approach to ensure their safe during exercise, but this approach is not precise enough.

Maximum oxygen uptake is an objective index for exercise intensity monitoring, but it is difficult to test and hard to be directly applied during exercise. Heart rate is linearly correlated with maximum oxygen uptake and the percentage of maximum heart rate is also linearly correlated with the percentage of maximum oxygen uptake, so heart rate is usually adopted. Furthermore, in normal cases, heart rate is consistent with pulse rate, so pulse rate is usually measured rather than heart rate. The exercise intensity in this research is determined as moderate intensity, i.e., 60-70% of maximum oxygen uptake after the literature review. Next, a formula (maximum heart rate = 220 - age) is adopted to confirm the maximum heart rate of each subject and then the maximum heart rate is multiplied by (60-70%) which is the target heart rate (heart rate range to be achieved and maintained in formal exercise).

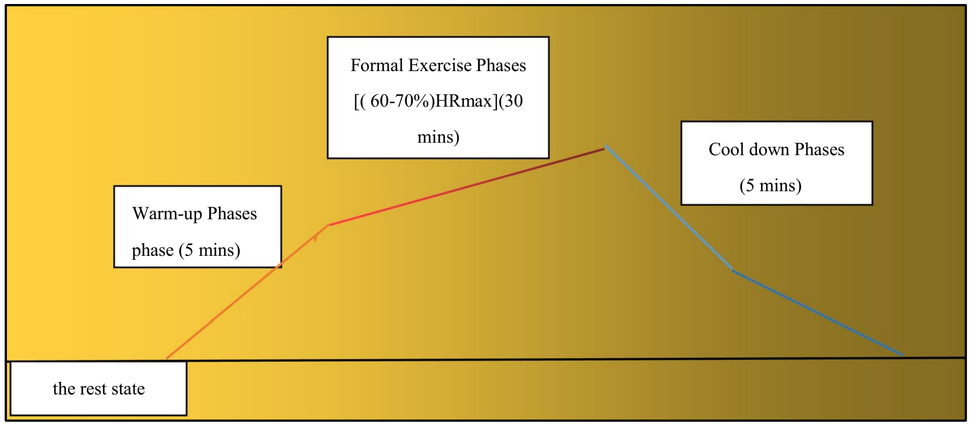
After the subjects comprehended and grasped the experimental procedure, the exercise started. The exercise session consisted of a 5-minute warm-up in the form of jogging and stretching of the limbs. This was followed by 30 minutes of one-on-one basketball (formal exercise), they paused for 10 seconds for every 3 minutes. The subjects were asked to touch their radial artery to measure their pulse rates in 10 seconds and the pulse rates were multiplied by 6 to conclude their heart rates in one minute, which were reported to the experimenter. If the heart rate failed the target heart rate, the exercise intensity was increased and if it did not, the exercise intensity was decreased. Additionally, the experimenter observed the subjects’ breath and complexions and inquired about their RPE, whereby adjusting their exercise intensity and deciding whether to continue the exercise based on their answers, in order to avoid exercise injuries. a 5-minute cool down was performed at the end of the exercise (Fig. 2). After a 15-minute rest, the relevant psychological tasks were performed and completed.

Word-face stroop task

The practice task was initially performed, and should be the same procedure as the formal experiment, with a total of 32 trials. When the correct rate of the subject in the practice task reached more than 90%, they could enter the formal experiment.

The formal experimental task had a total of 2 blocks, namely the “face task” and the “word task”. Each block had a total of 80 trials, of which 40 trials were consistent; 40trials were inconsistent, a total of 160 trials. At the beginning of each trial, a 500 ms blank screen was presented. After the blank screen, a 500 ms “+” fixation point was presented. After the fixation point disappeared, a picture of a face with Chinese characters was presented. In the “face task”, the subjects were required to ignore the meaning of emotion words, focus on facial expressions only, and press the “a” button or “l” button if a positive

Fig. 2 Exercise task



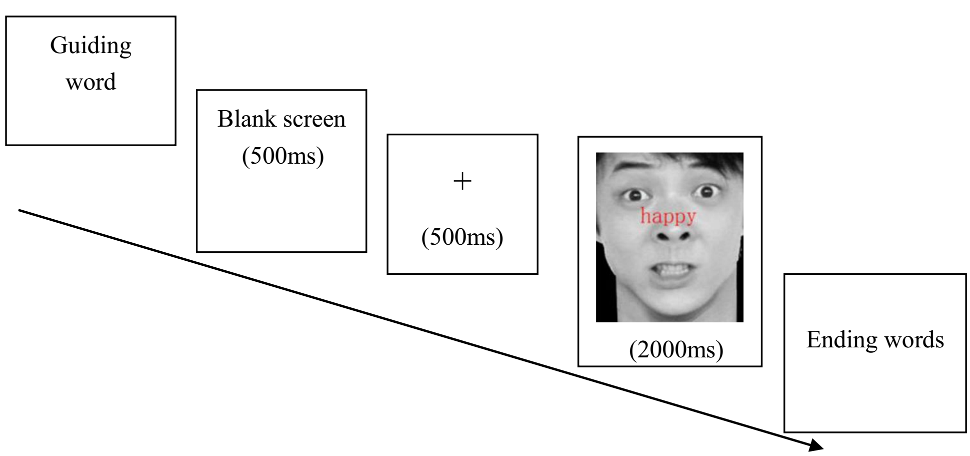
emotion or negative emotion was considered. To avoid memory factor interference, labels were placed on the keyboard to help subjects to make an accurate response on buttons. In the "word task", the subjects were required to ignore facial expressions and focus on the meaning of emotion words only; they should make a response on the keyboard by switching the buttons, that is, pressing the "l" button or "a" button when they considered the word as a positive emotion word or negative emotion word. The presentation time of each picture was 2000 ms, which required the subjects to make an accurate and rapid judgment. If the button reaction time exceeded 2000 ms, it became invalid. After pressing the button, the stimulation disappeared and the next trial proceeded. After the completion of each block, the subjects were allowed to have a 2-minute resting, and then continued to complete the remaining 80 trials. The total time for subjects to complete the task was about 10-15 minutes. The block presentation order was balanced among the subjects. All experimental procedures were compiled and presented using E-prime 2.0 software. The experimental flowchart is shown in Fig. 3.

Memory bias task

After the completion of the word-face stroop task, the subjects were allowed to have a short break, and then continued to complete this part of the study. This part of the study consisted of 2 parts. First, in the practice part, when the correct rate was 100%, the subjects began the formal experiment. The formal experiment consisted of the following three subparts.

Learning task phase: The subjects were required to sit facing the computer, and a guiding word was present on the screen to ask if the subject is ready, and subjects may press the space bar to start the trials if ready. After pressing the space bar, a blank screen was present on computer for 500 ms; Subsequently, the fixation point "+" was present in the center of the screen for 500 ms; After the fixation point disappeared, an emotion picture was present at the fixation point for 2000 ms. Subjects were required to make a rapid button response to judge the valence of emotion pictures, pressing the "a" button for positive emotion pictures, "b" button for neutral emotion pictures, and "l" button for negative emotion pictures. After pressing the button, the picture disappeared, and the next cycle proceeded.

Fig. 3 Word-face stroop task flowchart



Interference phase: The subjects were required to complete oral calculations within 3 digits. For example, 200 minus 3, until no digits could no longer be reduced, and the subjects were asked to report each answer aloud. If the answer was wrong, the trial started again and the duration was 3 minutes. The trial was terminated immediately when the duration exceeded 3 minutes, and another set of oral calculations would be completed when the duration was less than three minutes.

Recognition phase: 60 pictures were randomly presented to the subjects, of which 30 pictures were old pictures that had been shown in the learning task phase; and another 30 pictures were new pictures. Subjects were required to press the "k" button for old pictures and "s" button for new pictures.

E-prime 2.0 software was used to compile and present experimental procedures. The experimental flowchart is shown in Fig. 4.

Interpretation bias task

After the completion of the memory bias task, the subjects were allowed to have a short break, and then continued to complete this part of the study. The whole experiment also consisted of practice task and formal experiment. After the completion of practice task, the subjects began the formal experiment. In formal experiment, a guiding word was present and the subject was required to press the space bar to start the trials if they were ready. A blank screen was present on computer screen for 500 ms; Subsequently, the red fixation point "+" was present in the center of the screen for 500 ms; After the fixation point "+" disappeared, a blurred emotion picture was present at the fixation point for 5000 ms. Subjects were required to judge the valence of pictures, pressing the "6" button for positive emotion, "1" button for neutral emotion, and "0" button for negative emotion. After pressing the button, the picture disappeared. Then the next cycle proceeded. E-prime 2.0 software was used to compile and present experimental procedures. The experimental flowchart is shown in Fig. 5.

Data processing

All data were recorded by using E-prime 2.0. This system automatically recorded the reaction time and error rate of the subjects. As per the criteria of the reaction time within

Fig. 4 Memory bias task flowchart

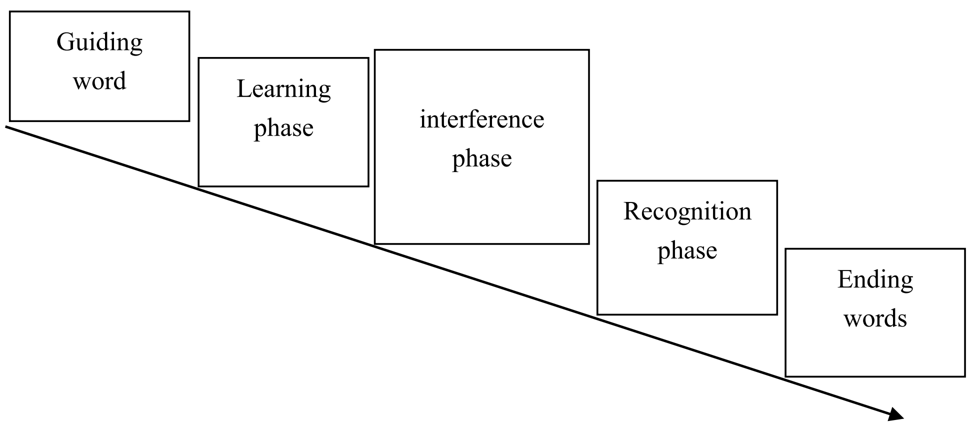
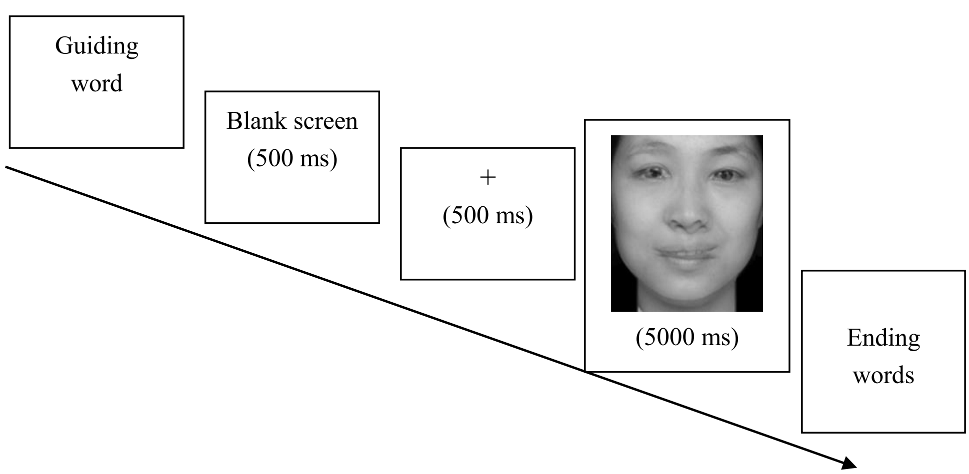


Fig. 5 Interpretation bias task flowchart



3 standard deviations, invalid data and erroneous response trials were excluded from statistics. All measurement data were represented as M ± SD and analyzed using SPSS25.0 statistical software.

Results

Word-face emotion stroop task

Two-factor repeated measure ANOVA of 2 (consistency: consistent vs. inconsistent) × 2 (emotional valence: positive vs. negative) was performed on the reaction time in the non-exercise group. The results showed that the main effect of consistency was significant [F (1,20) = 25.96, $p < 0.001$, η 2 = 0.57]. The interaction between emotional valence and consistency is significant [F (1,20) = 21.69, $p < 0.001$, η 2 = 0.52]. Further simple effect analysis was performed, showing that the reaction time under the condition of positive emotions consistent was significantly lower than that under the condition of positive emotions inconsistent [F (1,20) = 39.03, $p < 0.001$, η 2 = 0.66]. The reaction time under the condition of negative emotions consistent was significantly higher than that under the condition of positive emotions consistent [F (1,20) = 19.31, $p < 0.001$, η 2 = 0.49].

Two-factor repeated measure ANOVA of 2 (consistency: consistent vs. inconsistent) × 2 (emotional valence: positive vs. negative) was performed in the exercise group. The results showed that the main effect of consistency was significant [F (1,20) = 15.72, $p = 0.001$, η 2 = 0.44], the interaction between emotional valence and consistency is significant [F (1,20) = 16.57, $p = 0.001$, η 2 = 0.45]. Further simple effect analysis was performed, showing that the reaction time under the condition of negative emotional consistency was significantly higher than that under the condition of positive emotional consistency [F (1,20) = 6.97, $p = 0.016$, η 2 = 0.26]; the reaction time under the condition of negative emotions inconsistent is significantly lower than that under the condition of positive emotions inconsistent [F (1, 20) = 11.07, $p = 0.003$, η 2 = 0.36]; the reaction time under the condition of positive emotions consistent is significantly lower than that under the condition of positive emotions inconsistent [F (1,20) = 47.39, $p < 0.001$, η 2 = 0.70]. Please refer to Table 5.

Two-factor repeated measure ANOVA of 2 (consistency: consistent vs. inconsistent) × 2 (emotional valence: positive vs. negative) was performed on the error rate in the non-exercise group. The results showed that the main effect of consistency was significant [F(1,20) = 22.89, $p < 0.001$, η2 = 0.53].

Two-factor repeated measure ANOVA of 2 (consistency: consistent vs. inconsistent) × 2 (emotional valence: positive vs. negative) was performed in the exercise group.

Table 5 The reaction time of word-face emotion stroop task

Group	Emotional valence	Reaction time	
		Consistent	Inconsistent
Non-exercise	Negative	615.14 ± 57.21	608.67 ± 54.02
	Positive	580.62 ± 54.39	624.52 ± 55.74
Exercise	Negative	605.57 ± 37.00	602.71 ± 38.59
	Positive	581.48 ± 46.86	623.62 ± 40.36

Table 6 The error rate of word-face emotion stroop task

Group	Emotional valence	Error rate	
		Consistent	Inconsistent
Non-exercise	Negative	0.06 ± 0.04	0.10 ± 0.06
	Positive	0.07 ± 0.05	0.12 ± 0.07
Exercise	Negative	0.04 ± 0.03	0.07 ± 0.04
	Positive	0.05 ± 0.04	0.11 ± 0.07

The remaining data statistical results had no analytical value and were not recorded here due to space constraints

The results showed that the main effect of consistency was significant [F(1,20) = 21.17, $p < 0.001$, η2 = 0.51]. the main effect of emotional valence was significant [F(1,20) = 9.82, $p = 0.005$, η2 = 0.33], so the error rate under the condition of negative emotions (M = 0.06;SD = 0.01) is significantly lower than that under the condition of positive emotions(M = 0.08; SD = 0.01).

Two-factor repeated measure ANOVA of 2 (consistency: consistent vs. inconsistent) × 2 (group: exercise vs. Non-exercise) was performed under the condition of negative emotions, The results showed that the main effect of group was significant [F(1,20) = 4.96, $p = 0.038$, η2 = 0.20]; The error rate of the non exercise group (M = 0.09; SD = 0.01) was significantly higher than that of the exercise group (M = 0.06; SD = 0.01). Please refer to Table 6.

Memory bias task

Learning task phase

For the error rate, two-factor repeated measure analysis of 2 (stress level: high stress vs. low stress) × 3 (emotional valence: positive vs. neutral vs. negative) was performed. When Mauchly's test of sphericity showed $P < 0.05$, Greenhouse-Geisser correction was performed. The results showed that the main effect of group was significant [F(1, 20) = 6.67, P=0.018, η2=0.25], and the interaction of emotional valence and group was marginally significant [F(1.54, 30.74) = 2.92, $p = 0.081$, η2 = 0.13], indicating potential interactions, so a simple effect analysis was performed. The results showed that the main effect of emotional valence was significant in non-exercise group [F(2, 19) = 10.33, p = 0.001, η2 = 0.52], The subsequent pairwise comparison results show that the error rate of negative emotion face pictures was significantly higher than that of positive emotion face pictures (p = 0.001), The error rate of negative emotion face pictures was significantly higher than that of neutral emotion face pictures (p = 0.01). the main effect of emotional valence was significant in exercise group F(2,19) = 4.49, p = 0.03, η2 = 0.32], the error rate of negative emotion face pictures was significantly higher than that of positive emotion face pictures (p = 0.018).

Simple effect analysis also shows that the error rate of negative emotion face pictures is lower in exercis group than that in non-exercise group [F(1,20) = 5.39, p = 0.031, η2 = 0.21], the error rate of positive emotion face pictures is lower in exercis group than that in non-exercise group [F(1,20) = 6.09, p = 0.023, η2 = 0.23]. Please refer to Table 7.

Recognition phase

For the reaction time, two-factor repeated measure analysis of 2 (stress level: high stress vs. low stress) × 3 (emotional valence: positive vs. neutral vs. negative) was performed. When Mauchly's test of sphericity showed $P < 0.05$, Greenhouse-Geisser correction was performed. The results showed that the main effect emotional valence was significant [F(2, 40) = 14. 05, p < 0.001, η2 = 0.41], and the interaction of emotional valence and group was not significant [F(1.54, 30.78) = 0.84, p = 0.44, η2 = 0.04].

For the correct rate, one-factor ANOVA was performed in non-exercise group, the results showed that there were significant differences in it [F(2, 60) = 14.60, *P<0.001, η2=0.33*], The correct rate of negative emotion face pictures was significantly higher than that of neutral emotion face pictures (p < 0.001). The correct rate of negative emotion face pictures was significantly higher than that of positive emotion face pictures (p = 0.002). The correct rate of neutral emotion face pictures was significantly lower than that of positive emotion face pictures (p = 0.031). In exercise group, the results showed that there were significant differences [F(2, 60) = 4.18, p = 0.02, η2 = 0.22], The correct rate of negative emotion face pictures was significantly higher than that of neutral emotion face pictures (p = 0.009). The correct rate of negative emotion face pictures was significantly higher than that of positive emotion face pictures (p = 0.026). (p = 0.031). There was no significant difference in correct rate between neutral emotion face pictures and positive emotion face pictures (p > 0.05). Please refer to Table 8.

Table 7 The error rate in the learning task

Emotional valence	Error rate Negative	Neutral	Positive
Non-exercise	0.20 ± 0.15	0.06 ± 0.10	0.10 ± 0.12
Exercise	0.10 ± 0.07	0.07 ± 0.08	0.03 ± 0.06

The remaining data statistical results had no analytical value and were not recorded here due to space constraints

Interpretation bias task

The correct rate

One-factor ANOVA was performed in the non-exercise group. The results showed that there were no significant differences on the correct rate of fused pictures of negative emotion faces and neutral emotion faces in different proportions [F(7,24) = 0.80, P = 0.59, η2 = 0.19]. there were significant differences on the correct rate of fused pictures of positive emotion faces and neutral emotion faces in different proportions [F(7,31) = 18.58, P < 0.001, η2 = 0.85]. The results of subsequent multiple comparisons showed that the correct rate of P3, P4 was significantly lower than that of P6, P7, P8, P9 (p < 0.05), respectively. Please refer to Table 9.

One-factor ANOVA was performed in the exercise group. The results showed that there were no significant differences on the correct rate of fused pictures of negative emotion faces and neutral emotion faces in different proportions [F(7, 24) = 0.81, P = 0.59, η2 = 0.19]. There were significant differences on the correct rate of fused pictures of positive emotion faces and neutral emotion faces in different proportions [F(7,24) = 23.95, P < 0.001, η2 = 0.87]. The results of subsequent multiple comparisons showed that the correct rate of P1, P2, P3, P4 was significantly lower than that of P6, P7, P8, P9 (p < 0.05), respectively.

T-test for independent samples was carried out between groups. The results showed that the correct rate of P6, P9

Table 8 The correct rate and reaction time in the recognition phase

Emotional valence	Correct rate Negative	Neutral	Positive	Reaction time Negative	Neutral	Positive
Non-exercise	0.73 ± 0.12	0.55 ± 0.10	0.62 ± 0.11	944.33 ± 151.99	992.57 ± 190.48	992.05 ± 162.41
Exercise	0.71 ± 0.12	0.61 ± 0.12	0.62 ± 0.10	945.95 ± 123.81	1035.62 ± 141.94	1013.71 ± 133.04

The remaining data statistical results had no analytical value and were not recorded here due to space constraints

Table 9 The correct rate of interpretation bias task

Group	Emotional valence	10% Neutral affective pictures	20% Neutral affective pictures	30% Neutral affective pictures	40% Neutral affective pictures	60% Neutral affective pictures	70% Neutral affective pictures	80% Neutral affective pictures	90% Neutral affective pictures
Non-exercise	Negative	0.81 ± 0.23	0.80 ± 0.11	0.78 ± 0.26	0.70 ± 0.21	0.58 ± 0.22	0.72 ± 0.10	0.79 ± 0.10	0.82 ± 0.04
	Positive	0.77 ± 0.08	0.79 ± 0.11	0.66 ± 0.14	0.32 ± 0.08	0.76 ± 0.07	0.87 ± 0.03	0.83 ± 0.07	0.89 ± 0.03
Exercise	Negative	0.75 + 0.24	0.74 + 0.18	0.76 + 0.23	0.67 + 0.38	0.70 + 0.15	0.73 ± 0.16	0.90 ± 0.05	0.93 ± 0.10
	Positive	0.70 + 0.10	0.73 + 0.14	0.53 + 0.14	0.35 + 0.08	0.90 + 0.06	0.94 ± 0.08	0.94 ± 0.07	1 ± 0.00

The remaining data statistical results had no analytical value and were not recorded here due to space constraints

in exercise group was significantly higher than that in non-exercise group ($P < 0.05$). Please refer to Table 9.

The reaction time

Within-group one-factor ANOVA was performed on the reaction time of fused pictures of negative emotion faces and neutral emotion faces in different proportions in non-exercise group. The results showed that there were significant differences [$F(7, 24) = 3.23$, $P = 0.015$, $\eta2 = 0.49$]. The results of subsequent multiple comparisons showed that the reaction time of N4 was significantly higher than that of N1, N2, N6, N7, N8, N9 ($p < 0.05$), N3 was significantly higher than that of N7, N8, N9 ($p < 0.05$), respectively. While there were no significant differences in exercise group [$F(7,24) = 1.60$, $P = 0.18$, $\eta2 = 0.18$].

Within-group one-factor ANOVA was performed on the reaction time of fused pictures of positive emotion faces and neutral emotion faces in different proportions in non-exercise group. The results showed that there were significant differences in it [$F(7, 24) = 11.24$, $P < 0.001$, $\eta2 = 0.77$]. The results of subsequent multiple comparisons showed that he reaction time of P1 was significantly lower than that of P4 ($p < 0.05$), and higer than that of p7, p9 ($p < 0.05$); p2, p3 were significantly lower than that of P4, and higer than that of p6, p7, p8, p9 ($p < 0.05$); p4 was significantly higher than that of P6, p7, p8, p9 ($p < 0.05$), respectively.

Within-group one-factor ANOVA was performed on the reaction time of fused pictures of positive emotion faces and neutral emotion faces in different proportions in exercise group. The results showed that there were significant differences [$F(7,24) = 10.05$, $P < 0.001$, $\eta2 = 0.75$]. The results of subsequent multiple comparisons showed that the reaction time of P1 was significantly lower than that of p3, P4 ($p < 0.05$), and higer than that of p6, p8, p9 ($p < 0.05$); p2 was significantly lower than that of p3, P4 ($p < 0.05$), and higer than that of p8 ($p < 0.05$); p3, p4 were significantly higher than that of P6, p7, p8, p9 ($p < 0.05$), respectively.

T-test for independent samples was carried out between groups. The results showed that the reaction time of P7 in exercise group was significantly higher than that in non-exercise group ($P < 0.05$). Please refer to Table 10.

Discussion

Word-face emotion stroop task

For reaction time and error rate, a repeated analysis of variance was conducted in both the non exercise group and exercise group. The results showed that the main effect of consistency was all significant in both groups, indicating a significant stroop effect in both groups of participants. Meanwhile, the results of this study also confirmed that the reaction time of both groups of participants under the condition of negative emotions consistent was significantly higher than that under the condition of positive emotions consistent. Therefore, attention bias towards negative emotional

Table 10 The reaction time of interpretation bias task

Group	Emotional valence	10% Neutral affective pictures	20% Neutral affective pictures	30% Neutral affective pictures	40% Neutral affective pictures	60% Neutral affective pictures	70% Neutral affective pictures	80% Neutral affective pictures	90% Neutral affective pictures
Non-exercise	Negative	1062.00 ± 67.46	1070.50 ± 149.73	1204.75 ± 77.57	1277.50 ± 175.31	1063.50 ± 142.08	982.75 ± 108.50	1008.00 ± 110.38	995.50 ± 31.63
	Positive	1088.75 ± 128.08	1199.50 ± 145.63	1247.50 ± 108.55	1502.50 ± 264.75	945.25 ± 111.47	849.25 ± 50.11	892.75 ± 82.32	889.00 ± 82.60
Exercise	Negative	1132.75 ± 111.34	1122.75 ± 91.02	1193.50 ± 154.22	1072.50 ± 130.82	1060.50 ± 196.51	1013.25 ± 65.95	1005.75 ± 58.00	951.25 ± 128.74
	Positive	1195.00 ± 11.86	1162.50 ± 179.49	1484.00 ± 192.08	1646.50 ± 439.42	911.25 ± 43.71	957.75 ± 30.60	853.50 ± 40.81	901.00 ± 86.68

As the P5 and N5 pictures were the most blurred, they were analyzed separately in this study

The data statistical results had no analytical value and were not recorded here due to space constraints information may be the cause of high psychosocial stress levels in both groups of participants.

The reaction time of participants in the exercise group under the condition of positive emotional inconsistency was significantly higher than that under the condition of negative emotional inconsistency; The error rate under negative emotional conditions is not only significantly lower than that of positive emotions, but also significantly lower than that of the non exercise group, which suggested that a single bout of moderate-intensity exercise has a positive effect on regulating attention bias towards negative emotional information and promoting the formation of attention bias towards positive emotional information, which may be an important reason why physical exercise can regulate psychosocial stress levels. Previous studies results suggested that a single bout of moderate-intensity exercise consistently benefits both emotion and cognition (Giles et al., 2018; Aguirre-Loaiza et al., 2019), which is similar with this study. In addition, the basketball which is a typical collective sports form is prone to forming emotional contagion effects in participants. One recent study used a bias paradigm to assess the emotional valence of the observer to determine whether emotional contagion had occurred. That study showed that emotional contagion is present not only in mammalian but also in avian species (Adriaense et al., 2019). In this study, although the exercise task was two person confrontation in the present study, it is also team sport item which is beneficial to the communication between people. The positive emotional states formed during exercise can have an infectious effect on each other, improve mood and increase rational cognition, which subsequently reduce stress.

Memory bias task

During the learning stage, college students in both the exercise and non exercise groups also had significantly higher error rates towards negative emotional faces than positive emotional faces, indicating that both groups of participants had an attentional bias towards negative emotional information, just the same as the result of the word-face stroop task, demonstrating that attention bias towards negative emotional information may be an important cause for the formation of high stress perception. This study also founded that the exercise group had a significantly lower error rate of negative emotional faces compared to the non exercise group, which similarly indicated that physical exercise improved the attention bias towards negative emotional information among college students with high psychosocial stress levels.

The results showed that the error rate of negative emotional faces in non exercise group was significantly higher than that of neutral emotional faces, while there was no significant difference in the exercise group, so the exercise group increased the error rate of neutral emotional faces, which suggested that a single bout of moderate-intensity exercise increases the attention bias towards neutral emotional information. Researchs have confirmed that cognitive biases towards negative emotional information caused by high psychosocial stress can promote the formation of depression symptoms, which can be reduced by positive processing biases (Beeney & Arnett, 2008). So the attention bias towards neutral emotional information may improve the stress perception of college students with high psychosocial stress levels, which is the positive effect of physical exercise.

There is currently no consensus on the mechanism of memory bias formation in research. The theory of mood-congruent suggests that individuals are more likely to remember information that is consistent with their current emotional state, leading to memory bias. However, there are few reports on the impact of physical exercise on memory bias. The results of the recognition phase showed that the correct rate of negative emotional faces in both the exercise and non exercise groups was significantly higher than that of neutral and positive emotional faces, indicating that both groups of participants had a memory bias towards negative emotions, and which may also be the cause of the high psychosocial stress levels.

The recognition accuracy of neutral emotional faces in the non exercise group was significantly lower than that of positive emotional faces; however, there was no significant difference in the exercise group, indicating that a single bout of moderate-intensity exercise increased memory bias towards neutral emotional information, which may be beneficial for regulating psychosocial stress.

Interpretation bias task

Within-group one-factor ANOVA was performed on the correct rate of fused pictures of negative emotion faces and neutral emotion faces in different proportions in both groups. The results showed that there was significant differences in the non exercise group, while no significant difference in the exercise group. One study has found that the negative interpretation bias is reduced after exercise (Clarke et al., 2018), which is similar to the results of this study. A previous study also founded that individuals with high anxiety had more negative responses and fewer neutral and positive responses (Huppert et al., 2007). Thereby there is a certain interpretation bias towards negative emotional information in the non exercise group, and a single bout of moderate-intensity exercise can reduce it and benefit the regulation of psychosocial stress. The reason may be association with the reducing negative emotions regulated by physical exercise.

In the exercise group, the correct rate of P1 and P2 was significant higher than P6, P7, P8, and P9, respectively. The correct rate of P6 and P9 in the non exercise group was significantly lower than that in the exercise group. That suggested a single bout of moderate-intensity exercise increases a certain interpretation bias of college students with high levels of psychosocial stress towards positive emotional information.

According to lazarus' cognitive phenomenological transactional (CPT) theory, the cognitive appraisal plays a crucial role in the occurrence and development of stress. Studies have confirmed that physical exercise can improve the abnormal psychosomatic symptoms associated with stress perception through regulating cognition (Sailesh & Mukkadan, 2015). Meanwhile, cognition is influenced by emotions. Research suggests that emotional disorders are accompanied by pessimistic judgments, while optimistic judgments are related to emotional stability. Similar to humans, animals often show negative interpretation for ambiguous stimuli after experiencing stress events. In complex environments, maintaining optimism can reduce negative judgment bias and be beneficial to regulating stress (Zidar et al., 2018). One research has also found that cognitive information in negative emotional vocabulary can lead to a "negative cognitive bias" (Espuny et al., 2018); This study found that a single bout of moderate-intensity exercise can regulate the interpretation bias towards negative emotional information and promote an increase in the interpretation bias towards positive emotional information, it is suggested that physical exercise can improve cognitive through the regulation of emotions, and then regulate psychosocial stress levels.

All in all, the observed effects of exercise on cognitive biases from three psychological tasks prove that the viewpoint of this study is correct.

Conclusions

College students with high levels of psychosocial stress have attention bias, memory bias, and interpretation bias towards negative emotional information, which may be the cause of high psychosocial stress levels.

A single bout of moderate-intensity exercise can regulate negative cognitive bias, and increase attention bias and interpretation bias towards positive emotional information, attention bias, memory bias towards neutral emotional information. The findings of this study is benificial for Improvement of intervention methods on psychosocial stress, and finally promoting the quality of life.

As is known to all, the development of negative cognitive biases due to psychosocial stress is a prolonged process, and not all stress stimuli lead to adverse outcomes. The study distinguishes between eustress and distress. Eustress is identified as positively mobilizing psychological and physiological functions for adapting to external environmental demands, contributing to overall health. Only Distress stress has the potential to disrupt the homeostasis of the internal environment, leading to various physical and mental illnesses. The study thus emphasizes the need for more longitudinal research to identify critical points between eustress and distress in different populations and environments. Furthermore, participating in regular physical exercise contributes to overall well-being, promoting both physical and mental health. The various forms of physical activity are widely accessible and suitable for people of all ages and fitness levels. However, public awareness of the positive effects of physical exercise in regulating psychosocial stress and promoting health is lacking. Future efforts should leverage modern media tools, such as social media, smartphone applications, television, and movies, for widespread promotion to increase awareness of and participation in physical exercise, tapping into the positive side thereof. Moreover, drawing on existing evidence, the formation of psychosocial stress is intricately linked to the nervous and endocrine systems. Human psychological behavior is influenced by a multitude of factors, including the environment and culture. Compared to the complex biological networks, there exists an equally complex network in humanities and social sciences. Looking ahead, it is essential for different countries, regions, and ethnicities to engage in proactive collaboration, integrating methods from fields like imaging, physiology, and biochemistry, as well as humanities and social sciences. This comprehensive approach aims to uncover the patterns and mechanisms governing the development of psychosocial stress, providing a systematic understanding of the internal mechanisms by which regular physical exercise regulates stress to promote and protect overall health.

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Author contributions Cui Rongrong contributed to the conceptualization of the study; performed the experiment, supervision, formal analysis, and wrote the manuscript; Yang Jian helped perform formal analysis with constructive discussions.

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Data availability The data used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Competing interests The author declare no conflict of interest at any stage of the project.

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