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The Influence of State Anxiety and Working Memory Capacity on Attention Control of High-level Athletes

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Abstract

Objective: The current study distinguishes study participants with low and high working memory capacity (WMC) (state anxiety), manipulating state anxiety situations in order to test the interference effect of state anxiety on attention control and the promotion of high WMC on attention control.

Method: This study used a two-factor mixed design. The independent variable within the group is state anxiety (low, high), and the independent variable between the groups is WMC (low, high). The dependent variable is the level of attention control (Incubation period, saccade error rate). The covariate is trait anxiety (T-AI score).

Results: The main effect of state anxiety is significant and the main effect of WMC is significant, but the interaction between the two is not significant.

Conclusion: The benefit of WMC for attention control is cross-situational stability, and the key to attention control ability may, potentially, be working memory.

Keywords: state anxiety; working memory capacity; attention control

Introduction

Anxiety is one of the most common psychological problems (Hong et al., 2022; Meriyati et al., 2018) and a vast majority in a given population is likely to have symptoms of anxiety, encountering anxiety related problems at almost every stage of their childhood and adult life. Anxiety is so widespread and common that individuals are forced totreat it as a key well-being concern. Anxiety is tends to deeply affect our professional and personal life. Some individuals cannot continue to complete their studies due to anxiety, may lose their jobs, lock themselves up, and even cannot get out of their homes for their entire teen or adult lives due to anxiety (Chow & Conway, 2015; Shipstead et al., 2015). This kind of denial and distortion from the inner world is often undetected by surrounding people (Moriya, 2020).

These threats or potential miserable experiences can cause people to have a low degree of suffocation fear at some time in future, which is, in fact, the initial manifestation of anxiety. It may subsequently develop into persistent irritability and a sharper attention to relevant information (Edwards et al., 2015). In the reverse saccade paradigm, antisaccade tasks are considered as effective tools to investigate executive functions such as intentional attention control. In the experiment, the cue will randomly appear to the left or right of the fixation point after the fixation point is presented, and the subjects are required to first suppress the natural saccades towards the cue target and make the reverse saccades in the opposite direction to the cue target as soon as possible. This is done in order to investigate into whether individuals can achieve the suppression of emotional information under the set emotional disorders. Previous studies have shown that not only at the level of conscious processing, but also at the level of subliminal perception, subjects' naming of the color of negative (neutral) information or the color of background blocks is longer than that of normal conditions without emotional disorders. It is found that subjects' attentional inhibition of negative emotions is more difficult than that of positive or neutral emotions. In the emotional simon paradigm, the emotional simon task is associated with the relationship between irrelevant features and responses in the target stimulus task to establish emotional associations. In the experiment, subjects were required to make positive or negative response choices based on non-emotional features, ignoring the emotional titers of the target stimulus. For example, for noun or adjective target stimuli with different emotional titers, the subjects were asked to name the noun target as "incentive" or "bee", and the adjective target as "depression" or "cruelty". It is found that the congruence of stimulus and response on emotional titer affects participants' correct judgment.

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Although anxiety does not make people incompetent, it is still the most common psychological disorder in society (Cénat et al., 2021; Varker et al., 2019). People in their 30-40s may develop an anxiety disorder at some stage of their middle-aged lives. Anxiety disorders cost billions of dollars, which makes it the most expensive mental health problem. They can seriously damage the normal functioning of occupations, society, and families. They can lead to other disorders such as depression and alcoholism. They can also cause physiological disorders, such as heart disease (Rykert et al., 2017). Studies on negative emotions and attention systems have found that negative emotions can produce attentional bias towards negative stimuli, although whether changes in the attention system have an impact on negative emotions has not yet been concluded. Researchers mostly start from emotions, believing that anxiety reduces performance (Diyanto et al., 2018; Schukajlow et al., 2021), the degree of distraction is higher than calm state, and that moderate anxiety can stimulate the individual's level of motivation (Hood et al., 2015).

In any case, previous studies have focused on the impact of anxiety in various aspects (Hellberg et al., 2018; Stephen et al., 2022; Vaccaro et al., 2021), but the impact of attention system on anxiety is rarely mentioned, and even less attention is paid to the impact of changes in attention on anxiety. Most importantly, attention control of high-level athletes is completely ignored by previous studies. Although past studies have examined attention in relation to anxiety, attention control of high-level athletes is not adequately focused by previous studies. Therefore, this is one of the key aspects of the current study thorugh which it makes a contribution to existing literature. As the performance of a team is predominantly based on players' performance which is influenced by anxiety which, in turn, is related to the attention control of high-level athletes. Thus, this study has contributed significantly by investigating attention control of high-level athletes. Kanmogne et al. (2020) and others first put forward the concept of anxiety, believing that anxiety is a kind of human psychological feeling, which is bound to arise when making free choices (Kanmogne et al., 2020). In the stage of theoretical studies on anxiety, various schools of psychology are supported by their own theories. They argue and fight with each other because of different theoretical viewpoints on anxiety generation and treatment, which promotes the growth of anxiety knowledge and the enrichment of anxiety theories. For example, the psychoanalytic school believes that anxiety comes from the squeezing of the ego by the id and superego, which is the tendency of the ego to be distorted. The behaviorist school believes that anxiety is the result of conditioning and is the ability to be sensitive to clues of upcoming events. The cognitive school believes that anxiety stems from wrong pictorial reinforcement. Weicker et al. (2020) make a key contribution to psychology by putting forward the theory of consciousness stratification, which believes that anxiety is the result of libido's (inner energy) inability to release normally. This may be subject to technological development, but it is more of a single direction of the trend (Weicker et al., 2020). Hoshino and Tanno (2016) and others believe that anxiety is not just a single concept but is defined as the duality of state contextuality and trait persistence from the perspective of time span and degree of influence. This is an important contribution to the theory of anxiety. Studies have spearheaded the enthusiasm of the majority of researchers from theoretical study into new study directions and realized the shift from theoretical study to scientific empirical field. The researcher emphasizes in the theory that state anxiety of individuals is temporary and situational, while trait anxiety has been going on for a long time. The key to their difference is that trait individuals are not the same level of healthy as state individuals. State individuals later find out that there is an abnormality in themselves, while trait individuals suffer from it since their childhood or even earlier (Hoshino & Tanno, 2016).

In light of this problem, this paper distinguishes participants with low and high WMC (state anxiety), manipulates state anxiety situations, to examine the interference effect of state anxiety on attention control and the promotion of attention control by high WMC. A two-factor is hybrid designed. The independent variable within the group is state anxiety (low, high), and the independent variable between the groups is WMC (low, high). The dependent variable is the level of attention control (Incubation period, saccade error rate). The covariate is trait anxiety (T-AI score). The results obtained the descriptive statistics of the attention control level of the low and high WMCs in the low and high state anxiety situations as shown in Table 1, and the further unary analysis results are shown in Table 2.

As shown in Figure 1 and Figure 2, the Incubation of high WMC is shorter, but the main effect is not significant in the error rate, which partially supports Hypothesis 2. The interaction between state anxiety and WMC is not significant both in Incubation and error rate, so Hypothesis 3 is not supported. The interference effect of state anxiety on attention control depends on the intensity of state anxiety. People with high WMC have a shorter Incubation, but no difference found in the error rate. The benefits of high WMC for attention control may be reflected in the ability to have more attention resources to deal with various

distracting stimuli while completing tasks. High WMC is beneficial to attention control, and this benefit does not change as a result of changes in state anxiety. This suggests that as long as you have a higher WMC, no matter what degree of state anxiety you face, you can have relatively better attention control ability. The benefit of WMC to attention control is cross-situational stability, and the key to attention control ability may be working memory.

Methodology

Definition of a high-level athlete

High-level athletes refers to players under the age of 22, who have graduated from senior secondary schools, who have obtained the national Second-class athlete certificate (including) or above, and who have won the top six places in team events or the top three places in individual events in provincial (including) or higher competitions in senior high school. They also have the equivalent diploma of senior secondary education graduation, have obtained the national First-class athlete certificate (including) or above, or have won the top eight in the national (or international) team events in the last three years.

Hypothesis 1: State anxiety will interfere with attention control. Specifically, participants with high state anxiety have a longer Incubation and a higher rate of saccade errors.

Hypothesis 2: High WMC is beneficial to attention control. Specifically, participants with high WMC have a shorter Incubation and lower saccade error rate.

Hypothesis 3: WMC is the moderating variable of state anxiety affecting attention control. Specifically, participants with high WMC have less obvious increase in Incubation and saccade error rate under high state anxiety.

Research design

A two-factor is hybrid designed. The independent variable within the group is state anxiety (low, high), and the independent variable between the groups is WMC (low, high). The dependent variable is the level of attention control (Incubation period, saccade error rate). The covariate is trait anxiety (T-AI score).

Research participants

For data collection, 64 college students participate in the study. During the experiment, one person reported that the state anxiety situation does not have any effect. The results of the manipulation test also shows that scores of the participant's heart rate, electroskin, and MRF-3, all show a trend of lower values at high state anxiety situations, so the participant's data is excluded. The data is processed according to the same standard as the pre-experiment. Seven participants have more than 40% invalid reverse saccades, which are also eliminated.

Finally, 56 participants are included in the analysis, 13 males and 43 females, with an average age of 21.339±2.414 years old. Participants read the informed consent form to voluntarily participate before the test, and receive RMB 50 as a reward after the test. The OSPAN task consists of 15 sets of experiments, 60 trials, about 15-20 minutes. In a group of experiments, each word written by the participant is worth 1 point. If all the words are written with correct order, the score of the group of experiments will be counted in the total score. If all the words are written but the order is wrong, half of the score is counted in the total score. In other cases, the experimental scores of this group are not counted in the total score. The maximum total score is 60 points. The higher the score, the higher the WMC. Additionally, before data analysis, the current study examined data to fix the errors. As the errors in the data can change the original results, the role of data screening holds key importance (Won et al., 2017). Therefore, this study carried out data screening to remove the errors related to the missing value (Yang et al., 2020) as well as outlier. Data screening shows that data has no missing value and outlier. Hence, data screening proved that, data is accurate to proceed further.

State anxiety situation setting

Low state anxiety situation:

Same as pre-experiment.

High state anxiety situation:

Control the number of errors: Participants are required to control the error in judging the direction of the arrow within one time, otherwise the experiment will be invalid and must be repeated. Noise penalty: For each error, the participant will receive a 110dB noise penalty last for 500ms.Participants listen to the noise before the experiment. Electric shock penalty: The examiner stands beside the participant with an electric stimulator (24V direct current), and the electric rod is about 10cm away from the skin of the participant's left hand. Once the participant presses the wrong key, he may receive an electric shock at any time, and the examiner decides when to shock (Note: In fact, the examiner does not conduct a real electric shock). Time-limited response: There is only 1 second of button response time. If there is no response for more than 1 second, it will be recorded as an error (Scimeca et al., 2017).

Results and Discussion

The influence of state anxiety and working memory capacity on attention control

First, participants' WMCs are evaluated and sorted according to the OSPAN scores with a view to distinguish the low WMC group from the high WMC group. 54 of the

56 participants have an arithmetic accuracy rate of more than 88% for the OSPAN task, and the other two are 77% and 75% respectively. In this case, the total score multiplied by the correct rate is used for correction. The participants are ranked according to the OSPAN score, with the upper 51% being the high WMC group and the lower 51% being the low WMC group. Overall, the OSPAN score of all participants is M=17.287 and SD=7.189.

Pre-analysis shows that the level of trait anxiety does not meet the prerequisites of covariance analysis (the main effect of the covariate is not significant, which can be considered to be unrelated to the dependent variable: incubation period F(1,52)=0.761, p=.385, error rate F(1,52)=1.713,p=.188), so the covariates are discarded, and state anxiety (low, high) is the independent variable within the group, and WMC (low, high) is the independent variable between the groups. The two indicators of attention control levels (Incubation period, saccade error rate) are the dependent variables, and a multivariate analysis of variance using a two-factor mixed design. The result of the joint homogeneity of variance test indicates the homogeneity of variance, which is in line with the premise of multivariate analysis of variance. The results of descriptive statistics are shown in Table 1.

Table 1

Descriptive statistics of attention control levels of people with low and high WMC in low and high state anxiety situations

Indicators of attention control	WMC grouping	Low state anxiety situations		High state anxiety situations	
		M	SD	M	SD
Incubation period	Low WMC	391.084	43.064	407.444	44.501
	High WMC	354.975	38.807	370.119	43.581
Error rate	Low WMC	.232	.195	.262	.196
	High WMC	.212	.154	.254	.161

The results of multivariate analysis of variance show that: Overall, the main effect of state anxiety is significant (F(2,53)=9.346,p<.001, np^2=.262,power=.971), and the main effect of WMC is significant (F(2,53))=6.113,p=.004, np^2=.188,power=.879), but the interaction effect between the two is not significant (F(2,53)=.103,p=.911, np^2=.004,power=. 064). The results of further unary analysis are shown in Table 2. State anxiety has a main effect on the incubation and error rate: Under high state anxiety, the incubation of participants is prolonged and the error rate rises, which fully supports Hypothesis 1. WMC has a main effect on the incubation, and those with high WMC have a shorter incubation (Figure1), but the main effect on the error rate is not significant (Figure2), which partially supports Hypothesis 2. The interaction effect between state anxiety and WMC is not significant in incubation and error rate, so Hypothesis 3 is not supported.

Table 2

Results of unary analysis of variance of the effects of state anxiety and working memory capacity (WMC) on attention control

Indicators of attention control	Source of variation	SS	MS	F	P	np^2	power
Incubation period	State anxiety	6942.725	6942.725	12.989	.001	.195	.943
	WMC	37777.890	37777.890	12.245	.001	.184	.931
	State anxiety ×WMC	10.159	10.159	0.018	.892	.000	.051
Error rate	State anxiety	0.032	0.032	6.198	.016	.102	.687
	WMC	0.059	0.059	0.102	.748	.002	.062
	State anxiety ×WMC	0.001	0.001	0.193	.662	.0039	.072

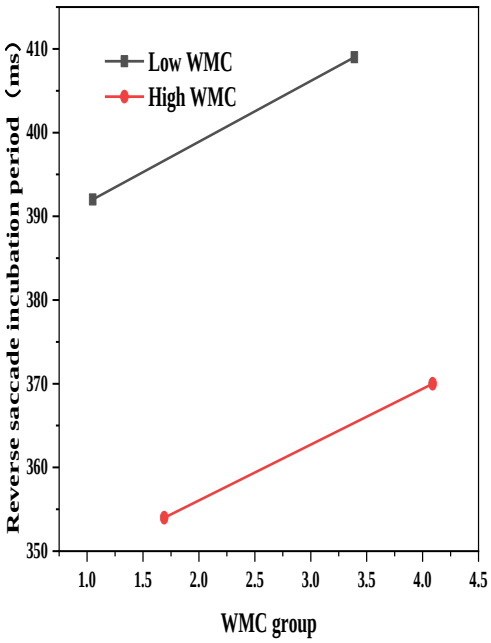

Figure 1 Attention control of people with low and high working memory capacity (WMC) in reverse saccades under low and high state anxiety

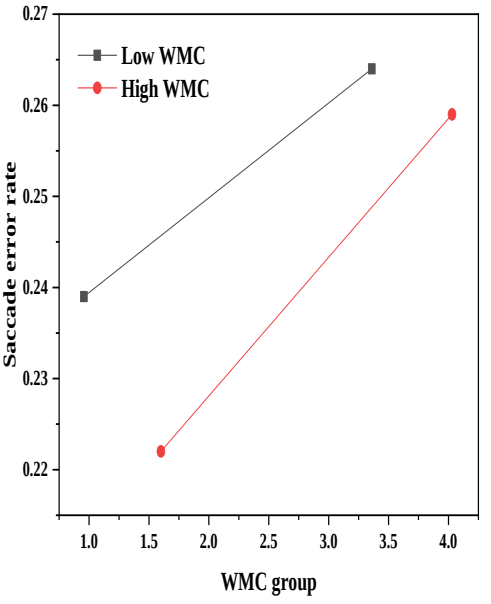

Figure 2 Attention control of people with low saccade error rate and high working memory capacity (WMC) under low and high state anxiety

Result analysis

The results of this study fully support Hypothesis 1, that is, the incubation period of participants under high state anxiety is prolonged and the error rate increases. Combined with the results of the pre-experiment, it is suggested that the influence of state anxiety on attention control may not be entirely an interference effect, which actually depends on the intensity of state anxiety. If the state anxiety is not high, its positive effect of increasing motivation and arousal level may be stronger than its negative effect of interfering with attention control, and the increase of motivation and arousal level may be beneficial to attention control. Only when state anxiety reaches a high level, its adverse effects on attention control will manifest. Previous studies have not obtained consistent results on the issue of state anxiety affecting attention control. This study provides a possible explanation: the interference effect of state anxiety on attention control will only appear at higher levels of anxiety. The state anxiety levels studied before may not be high enough. On the other hand, it also suggests that the influence of state anxiety on attention control may be different from trait anxiety. Trait anxiety is relatively more stable and pure, while the variables involved in state anxiety are more complex (such as the increase in motivation, arousal levels, and interference with attention control), and there may also be mutual influences between variables. It shows that to study the adverse effects of state anxiety in future studies, it may be necessary to induce higher state anxiety to obtain supportive results (Chow & Conway, 2015).

The results of this study partially support Hypothesis 2, that is, the incubation period of people with high WMC is shorter, but there is no difference in error rate. The benefits of high WMC for attention control may be reflected in the ability to have more attention resources to deal with various distracting stimuli while completing tasks. In many cases, distracting stimuli are unavoidable. To concentrate on the current task while facing distracting stimuli. During a dual task, a higher WMC can allocate more resources to two tasks, while when WMC is occupied by one task, the other task will be affected. Dealing with distracting stimuli causes people with low WMC to have fewer resources to deal with the current task. On the other hand, this study did not provide evidenced of the benefit of WMC in terms of error rate. It may be that people with high WMC find it relatively easy to inhibit the attention of distracting stimuli. A faster saccade speed may sacrifice part of the correct rate of the saccade direction, and there may be a speed-accuracy trade-off. It is also possible that the saccade error rate is not as sensitive and stable as the incubation period.

The results of this study do not support Hypothesis 3. The expected moderating effect did not appear, only the main

effects of the two independent variables are found. The interference effect of state anxiety on attention control does not change with the change of WMC, and the benefit of WMC on attention control does not change with the change in state anxiety. From the internal mechanism, perhaps the interference effect of state anxiety on attention control and the promotion effect of WMC on attention control are relatively independent, with the two influencing different components of attention control, which will be discussed in detail in the general discussion. Of course, there is another possibility that the WMC measurement method used in this study does not fully reflect the participants' WMC. There are many ways to measure WMC. Perhaps the part measured by the OSPAN task is not the core part that affects attention control.

In short, the hypothesis of attention control theory is verified, that is, anxiety will interfere with top-down attention control. However, for state anxiety, this interference effect will only appear under high state anxiety, and is not affected by WMC. It suggests that in any case, high state anxiety will interfere with attention control, which does not seem to be good news for athletes facing the test of competition. On the other hand, high WMC is good for attention control, and does not change with the change of state anxiety. It suggests that as long as you have a higher WMC, no matter what degree of state anxiety you face, you can have relatively better attention control ability. The benefit of WMC to attention control is manifested in cross-situational stability, and the key to attention control ability may be working memory. State anxiety is inevitable for athletes on the field, therefore, if some interventions can be used to improve WMC, it may have broader benefits to attention control. Experiment 2 seeks to explore whether working memory training can improve WMC and at the same time also improve attention control ability.

Conclusion

The effects of state anxiety and working memory capacity on the attention control of high-level athletes is explored in the current paper. The WMCs of the participants are evaluated and sorted according to the OSPAN score in order to distinguish the low WMC group from the high WMC group. The results show that the incubation of participants under high state anxiety is prolonged, and the error rate increases. Combined with the results of the pre-experiment, it is suggested that the influence of state anxiety on attention control may not be entirely an interference effect, which depends on the intensity of state anxiety. People with high WMC had a shorter incubation, but no difference is found in the error rate. The benefits of high WMC for attention control may be reflected in the ability to have more attention resources to deal with various distracting stimuli while completing tasks. High WMC is conducive to attention control, and this benefit does not change with changes in state anxiety. It suggests that if you have a higher WMC, no matter what degree of state anxiety you face, you can have relatively better attention control ability. The benefit of WMC to attention control is cross-situational stability, and the key to attention control ability may be working memory. Although there are obvious differences in behavior in this study, it is necessary to further explain the activities of various brain regions for psychological research. At the present stage, psychological research is closely linked with brain neuroscience, and psychological theories and brain neuroscience need to be integrated.

Study Implications

Athlete performance is based on several factors which are highlighted by a number of previous studies. Along with other studies, the current study also identified various factors affecting athletes which is unique in nature and this study investigated the nature of the relationship among variables which is not examined by past researchers. This study has major theoretical implications because this study particularly considered and focused on the attention control of high-level athletes. The attention control of high-level athletes is not considered by previous studies. Furthermore, attention control of high-level athletes is addressed in relation to state anxiety and working memory. In addition, this study offers important insights for practitioners and sport managers/coaches to enhance athlete performance by considering the attention control of high-level athletes, state anxiety and working memory.

Limitations and Future Directions

The current study is limited to some aspects which could potentially become directions for future studies in the filed of attention control of high-level athletes, state anxiety and working memory. Firstly, this study considered state anxiety as an overall construct, however, it has various (sub-)dimensions which include physical concerns, social concerns, and cognitive concerns. Future studies should take stock of these dimensions separately and consider the.ir role in relation to the athletes; alternatively, future studies may consider one or two dimensions provided that these should be clearly defined. Secondly, working memory is also measured as an overall construct. It has three important components such as the phonological loop, visual sketchpad, and the central executive. Future studies should consider these components separately.

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